CAN THE UNITED STATES AFFORD BIOMONITORING?

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Introduction

Water pollution control efforts in the United States historically have been focused on establishing limits on the quantities of pollutants that may be discharged into surface waters by industries and municipalities. Discharge of pollutants is prohibited unless a permit is obtained under the National Pollutant Discharge Elimination System (NPDES)[1], which is administered by the states with U.S. Environmental Protection Agency (EPA) guidance and oversight. The permit specifies the allowable effluent limits and the requirements for monitoring, recording, and reporting. In the past, the allowable effluent limits were based on Best Available Technology Economically Achievable (BAT), on secondary treatment, or on other technology-based criteria.

As the "traditional" pollutants (oxygen demanding and eutrophying materials) generally are being treated sufficiently to protect water quality, attention is being shifted towards pollutants that impact water quality through toxic effects.[2] Regulation of toxic pollutants is difficult because of the great number of toxic chemicals that potentially may be discharged to receiving waters, the need to identify and analyze specific toxic chemicals, the changes in toxic effects of a chemical resulting from its reactions with the matrix of constituents in which it exists, and our inability to predict the effects of exposure to combinations of chemicals.[3] Despite the difficulties, the Federal Water Pollution Control Act Amendments of 1977 (Clean Water Act or CWA) explicitly state that it is the national policy that the discharge of toxic substances in toxic amounts be prohibited.[4] The 1987 Water Quality Act (WQA)[5], a major revision of the CWA, established toxic control as the water quality agendum of the 1990's.[6]

Approaches To Water Quality-Based Toxic Control

Two approaches to water quality toxic control are the whole-effluent, or toxicity-based, approach, which uses biological techniques to assess effluent discharges, and the chemical-specific approach, which uses analytical chemistry techniques.[7] EPA recommends that an integrated approach, including biological and chemical techniques, be used both to assess water quality and to control water quality through permit limitations.[3] Accordingly, EPA has incorporated its "Surface Water Toxic Control Program" into the NPDES.[2]

Key Terms Used In The Water Toxic Control Program

The surface water toxic control program and EPA's Technical Support Document (TSD) for Water Quality-based Toxic control use several key terms. For the reader's convenience and for reference in the remainder of this paper, these terms are defined or described as they were in the references.[2,7]

"Narrative standard" refers to a narrative water quality criterion adopted by a state under section 303(c) of the CWA. All states have adopted a narrative criterion that prohibits the discharge of toxic pollutants in toxic amounts.

"Priority pollutant" refers to the 126 pollutants listed in 40 CFR 423, Appendix A. They are derived from the 65 classes of compounds listed at 40 CFR 401.15.

"Toxic pollutant" means any pollutant listed as toxic under section 307(a)(1) of the CWA. EPA has listed 65 classes of compounds under this section of the CWA -- the 65 referenced above, from which the priority pollutants are derived.

"Toxic" refers to any pollutant or combination of pollutants which causes toxicity to aquatic life or terrestrial life or causes adverse human health impacts.

"Whole effluent toxicity" (WET) means the aggregate toxic effect of an effluent measured directly with a toxicity test. A toxicity test measures the degree of response of an exposed test organism to a specific chemical or effluent. Like biochemical oxygen demand (BOD), which is also a biological measurement, toxicity can be limited in an NPDES permit.

"Ambient toxicity" means toxicity manifested by a sample collected from an aquatic receiving system.

"Bioaccumulation" means the uptake and retention of substances by an organism from its surrounding medium and from food.

"Bioavailability" is the property of a toxicant that governs its effect on exposed organisms. A reduced bioavailability would cause a reduced toxic effect.

"Biomonitoring" is the measurement of the biological effects (such as toxicity) of effluents.

"LC_{50}" is the toxicant concentration killing 50% of the exposed organisms at a specific time of observation. "No Observed Effect Level" (NOEL) is the highest measured continuous concentration of an effluent or a toxicant that causes no observed effect on an organism.

"Toxic unit acute" (TU_a) is the reciprocal of the effluent dilution that causes the acute effect by the end of the exposure period (the reciprocal of the LC_{50}).

"Toxic unit chronic" (TU_c) is the reciprocal of the effluent dilution that provides the NOEL.

"Total maximum daily load" (TMDL) means the total allowable pollutant load to a receiving water such that any additional loading will produce a violation of water quality standards.

"Wasteload allocation" (WLA) means the portion of a receiving water's TMDL that is allocated to one of its existing, or future, point sources of pollution.

"Toxicity reduction evaluation" (TRE) is a study conducted to determine what control options are effective for complying with either toxicity or chemical concentration requirements. The purpose of a TRE is threefold: 1) to isolate causative pollutants or manufacturing processes that produce the chemicals of interest; 2) to identify control options and determine the effectiveness of each option; and 3) to identify a compliance monitoring indicator and demonstrate its effectiveness. Of the three, only the second purpose is essential for developing a control plan for the facility. Toxicity may be used as a control parameter without identifying causative chemicals.

The Chemical-Specific Approach

The chemical-specific approach to toxic control involves the use of laboratory-generated water quality criteria or state standards to limit specific toxicants directly. The toxicity analysis of specific chemicals is done in a comprehensive testing program that attempts to consider a range of toxic endpoints, including human health impact and bioaccumulation. Once a criterion is developed, the number is applied as a permit limit to ensure that the level of that toxicant is not exceeded after discharge.[7]

The principal advantages of chemical-specific techniques are that: (1) chemical analyses generally are less expensive than biological measurements; (2) treatment systems are more easily designed to meet chemical requirements than toxicity requirements; and (3) human health hazards and bioaccumulative pollutants can be addressed best at this time by chemical-specific analysis.[3]

The Toxicity-Based Approach

The toxicity-based approach to toxic control involves the use of toxicity tests (biomonitoring) to measure WET. Simply stated, the biomonitoring protocol includes the following:

* collecting an effluent sample
* diluting the effluent to various concentrations
* placing test organisms into the various dilutions for specified time periods
* evaluating the effect of each effluent concentration on the test organisms.

The effect, or "endpoint" of the test, can be results such as mortality, lower fecundity, reduced growth rates, and terrata. The lowest effluent concentration that causes that endpoint becomes a quantified measure of the concentration that would cause instream impact if exceeded for a particular period of time.[7] Various ways of expressing this concentration are LC_{50} or TU_a for acute tests and NOEL or TU_c for chronic tests. These numerical values express quantitative measures of the parameter "toxicity" and are used by regulatory agencies to quantify narrative state water quality standards such as "no toxics in toxic amounts" and may be used to set discharge permit limitations. The principal advantages of biological techniques are that: (1) the effects of complex discharges of many known and unknown constituents can be measured only by biological analyses; (2) bioavailability of pollutants after discharge is measured best by toxicity testing; and (3) pollutants for which there are inadequate chemical analytical methods or criteria can be addressed.[3]

Toxicity Testing Protocols

Toxicity testing protocols for measuring the acute and chronic toxicity of effluents to freshwater and marine

organisms have been developed and published by EPA.[8,9,10] Other available methodologies may be used if the state can show they are "scientifically defensible and protective of aquatic life".[2] Since living organisms are being evaluated in all procedures, there are factors inherent in any procedure which can introduce variability. Some of these factors are:

* the species chosen for the test
* the age and health of the organisms
* the test conditions
* the nature of the dilution water

The test species to be used depends on the objectives of the test and the requirements of the regulatory agency. Species that have been used in toxicity tests and are acceptable test organisms are listed in the test methods.[8,9,10] Although it might seem desirable to use test organisms residing in the receiving water, it is not recommended unless it is required by state statute or some other binding factor.[7] Use of resident biota is not considered practical because: 1) sensitive organisms may not be present in the receiving water because of previous exposure to the effluent or other pollutants; 2) often it is difficult to collect organisms of the desired age and condition from the receiving water; 3) organisms used must be identified to species, which might require their examination by a taxonomic expert.[7] Different species exhibit different sensitivities to toxicants. Often several orders of magnitude of difference exist between the least sensitive and the most sensitive species when they are exposed to a particular toxicant.[7] The primary goal in establishing a toxicity testing requirement is to find a sensitive test species.[7] Since the measured toxicity of an effluent may be caused by unknown toxic constituents, the relative sensitivities of the test species will also be unknown. Therefore, proper effluent toxicity analysis requires an assessment of a range of sensitivities of different test species to that effluent. In determining how many species to test, cost must be balanced against decreased scientific uncertainty. Analysis of species sensitivity ranges found in the national water quality criteria documents indicates that if tests are conducted on three particular species (*Daphnia magna, Pimephales promelas, and Lepomis macrochirus*), the most sensitive of the three will have an LC_{50} within one order of magnitude of the most sensitive of all species tested.[7] This was found to be true for 71 of the 73 priority pollutants tested with four or more species.[7] To eliminate a sufficient portion of the uncertainty for this factor, EPA recommends that three species be tested.[7] The permitting authority is required to account for species sensitivity when using toxicity tests.[2]

The age and health of test organisms can affect test results. The use of early life stages is recommended for all tests. To enhance the value and comparability of data, the same species in the same life stages should be used throughout a monitoring program for a given facility.[7] The health of test organisms is determined by observing them for at least 48 hours before testing. Maintaining the organisms in a healthy state requires close attention to details such as clean, disinfected holding tanks supplied with a water of good quality (proper pH, temperature, dissolved oxygen (DO) content, hardness, alkalinity, and salinity for the species); the feeding regime; and handling as gently, quickly, carefully, and minimally as possible.

Test conditions must be selected with due consideration being given to factors such as vessel size, loading limit (the weight of organisms per liter of test solution to minimize DO depletion), light intensity, feeding regime, temperature, and DO concentration. Water temperature ranges for the test organisms must be maintained within the recommended limits. DO concentrations must be checked at the beginning of the test and regularly throughout the test. Aeration is employed, if necessary, to ensure that the DO does not fall below 40% saturation for warm water species and 60% saturation for cold water species. (Aeration can introduce other variables.)[8] These test conditions must be maintained for each vessel. Thus, for five dilutions, with only one replicate test vessel per concentration, and one control vessel, eleven vessels must be monitored. Considering all this, one may be amused by the test condition that states: "Minimize stress on test organisms by avoiding unnecessary disturbances."[8] Recommended test conditions for test species are included in the testing protocols.

Several factors influence the choice of dilution water. Receiving water collected upstream from the discharge point should be used as dilution water wherever possible.[8,9,10] If the presence of contaminants in the receiving water make it undesirable (if the objective of the test is to determine the effect of multiple point sources, contaminated receiving water may be desirable), or if it is not economically feasible to supply receiving water to a remote laboratory, other surface waters or ground waters or synthetic waters may be used. When the receiving water is an estuary, dilution water collected from such a source may require salinity adjustment. Similarly, since effluents are freshwater, the salinity of each effluent dilution used for the test might require adjustment. The testing protocols provide directions for preparation of synthetic seawater and for making salinity adjustments.[8,9,10] Dilution water is acceptable

if healthy organisms survive in it without signs of stress and mortality does not exceed 5% during the acclimation period.[8]

Quality assurance for effluent toxicity tests includes the use of reference toxicants to establish the validity of the data generated by laboratories.[8] Three reference toxicants, with instructions for their use and the expected LC_{50} values, are available. Laboratories must evaluate the sensitivity of each batch of organisms with a reference toxicant within the seven days preceding a toxicity test or concurrently with the test.[8]

The preceding focus on toxicity testing protocol, which was general, and descriptive primarily of the acute, static, test, should illustrate that a toxicity test is an involved, time-intensive procedure. A toxicity test has been described as a "relatively simple procedure."[7] (One might be wary of any laboratory procedure described as "relatively simple.") Even the mechanics of the test dictate the need for a well-trained, knowledgeable technologist because "judgment calls" need to be made at various stages. Since personnel costs are a significant part of a laboratory's operating expense, this probably will be reflected in the costs for toxicity tests. Cost ranges provided by one user of toxicity testing services[11] are $60 to $135 for a static screening test (an acute test for detecting the presence of toxicity), $180 to $405 for a static definitive test (an acute test for detecting the dilution of effluent that produces the toxicity), $1,000 for a 7-day chronic test, and as much as $5,000 for special testing. EPA comments that costs of toxicity tests typically range from a few hundred dollars for simple screening tests to as much as one or two thousand dollars for chronic toxicity tests.[2]

Exceeding the permit limits for WET or for a specific toxicant may require the implementation of a toxicity reduction evaluation (TRE). The purposes of a TRE were stated with the definition given previously. The steps or phases of a TRE are those designed to achieve the purposes.[7] EPA recently has published documents for TRE procedures guidance.[12]

Statutory and Regulatory Basis for Biomonitoring

The statutory basis for biomonitoring is the Clean Water Act, 33 U.S.C. 1251 et seq, as amended by the Water Quality Act (WQA) of 1987.[2] The WQA requires states to identify and list those waters that are adversely affected by toxic, conventional, and nonconventional pollutants and to prepare individual control strategies (ICS) that will control point source discharges of toxic pollutants. If EPA disapproves a state's plan with respect to a list or an ICS, then EPA must implement these requirements in cooperation with the state. The statute further requires implementation of the ICS to bring such waters into compliance within three years. The statutory deadlines are aggressive and ambitious; meeting them will be a very difficult task for EPA and the states.[6] A number of provisions in the WQA lay the foundation for the use of whole effluent testing in order to meet the goals of the legislation. Biological monitoring and whole effluent testing are mentioned specifically as part of data gathering efforts.[5] Section 303(c)(2)(B) of the WQA says that where numerical criteria are not available and the state reviews standards or adopts standards during triennial review, the state is to adopt "criteria based on biological monitoring and assessment methods."[5]

Regulations to implement the CWA provisions described above were published as a final rule on June 2, 1989.[2] (Prior to these regulations, EPA had attempted to implement biomonitoring through policy and guidance[3].) Several changes were made to 40 CFR 122.44, which covers the establishment of limitations, standards, and other permit conditions in NPDES permits. The regulations make it clear that controlling WET is necessary where controls on individual pollutants do not adequately protect water quality; that an NPDES permit must limit any pollutant or pollutant parameter (whether conventional, nonconventional, or toxic) including WET, that "is or may be discharged at a level that causes, has the reasonable ability to cause, or contributes to an excursion above any water quality criterion, including state narrative water quality criteria"; and that WET limitations are enforceable in the same way as any other effluent limitation in an NPDES permit. In the analysis of the rulemaking, EPA stated that it expects that "with few exceptions, all major POTWs and major industrial discharges will need to be evaluated to determine whether they have a reasonable potential to cause excursions."[2] Water quality-based effluent limits shall be developed from the state's water quality standards and be consistent with WLAs derived from TMDLs for water quality-limited segments. A new paragraph added to 40 FR 123.63 clarifies EPA's authority to withdraw a state's NPDES program if a state fails to develop an adequate program for developing water quality-based effluent limits in NPDES permits.[2]

Perspectives of Federal Regulators

The WQA calls for control of toxic discharges by 1993. EPA's surface water toxics control program, designed to meet this goal, includes both biological

and chemical procedures for characterizing effluents and developing effluent limits. These limits are to be incorporated into NPDES permits. Federal and state controls over discharges of toxic pollutants have been strengthened by federal regulations.

Reactions of the Regulated Community To Biomonitoring

Commenters to the proposed rulemaking which was published as a final rule on June 2, 1989, argued that the state narrative water quality criterion "no toxics in toxic amounts" could not be used as a basis for requiring WET limits. EPA cited a case in which the court concluded that although toxicity appears to be an attribute of pollutants rather than a pollutant itself, the CWA authorizes the use of toxicity as a measure to regulate effluents.[2] Commenters also questioned whether biomonitoring can be used to predict biological impact to receiving waters. To address this issue, EPA conducted the "Complex Effluent Toxicity Testing Program" which produced eight site-specific studies showing that where exposure is adequately assessed, effluent toxicity correlates directly to instream impact.[2]

There are questions about the toxicity testing methods. Some think that accuracy should be defined as the ability of toxicity tests to predict the potential for environmental degradation if test results are to be used as a measure of permit limit compliance.[13] They comment about artificially induced stresses inherent in the test procedures and test conditions which do not reasonably reflect the receiving environment. For example, procedures allow DO concentrations to drop to 40% saturation which would be a violation of water quality standards in many states.[13] Thus effluents found to be toxic in the presence of artificial DO stress might not be toxic upon removal of that stress. They also think that salinity adjustments add significant artificial stresses and do not simulate adequately the receiving environment for reasons detailed in the reference.[13] Others think that EPA should publish guidelines and toxicity testing procedures before using biomonitoring and WET limits in NPDES permits.[2] They question whether the testing protocols are appropriate for enforcement-based programs where standardized protocols and interlaboratory reproducibility are required for legal action.[14] EPA's position on this issue is that the permitting authorities must use their judgment in determining which testing methods are appropriate for the NPDES permits; that until EPA publishes guidelines, the permitting authority must specify in the permit which analytical methodology must be used.[2] This illustrates another concern of the regulated community: "Which form of biomonitoring will states require?".

Several states have biomonitoring regulations in effect already. Some require chronic toxicity testing; some require acute; and some require both. The TRE procedures that EPA has published solely employ acute toxicity testing for TRE evaluation, stating that "Phases I and II depend on acute toxicity and can not be used for effluents that do not have it", and that "much work needs to be done before chronic toxicity methods are developed and proven."[12] In a situation where chronic toxicity is observed and implementation of a TRE is required, the permittee could enter into an expensive chronic-based TRE for which there is no protocol; or he could ask for relief from the permit requirement in which case the problem could compound greatly should a concerned third party take legal action against the continuous violation of chronically toxic effluent.[12] Thus the form of biomonitoring that will be required for a specific situation is an important question.

State Regulatory Perspectives

Each state permitting authority "must use reliable and consistent procedures to determine whether a discharge causes, has a reasonable potential to cause, or contributes to an excursion above a water quality criterion" and thus requires a WET limit.[2] The permitting authority then must derive the limits to be included in the permit, specifying the testing protocol and the test species that are to be used. Although EPA has published guidance documents to assist the states in most facets of the water quality-based toxics control program, each state agency must use its judgment in developing an adequate program. Obviously, this will require expenditures of a state's financial and personnel resources.

Perspectives of Industrial Dischargers

An industry's existing hazardous waste management system, designed to meet chemical-specific permit limitations effectively, might not be effective for toxicity limitations. Investigations of the possible causes of toxicity and changes that might be required to control toxicity can be extensive and expensive. Mr. Niall O'Shaughnessy, engineer with CH_2M Hill Southeast, says (personal communication, Feb. 1990) that the range of costs for industrial TREs is $50,000 to $100,000 for the studies only. Two case studies are presented.

Industry A[15] produces specialty organic chemicals. It utilizes batch processes and 400-450 raw materials to produce 200-250 products. Its existing wastewater

treatment included equalization, biological oxidation, secondary clarification, effluent filtration, and belt filter press sludge dewatering. Initial screening of the effluent showed that the presence of toxicity varied, and that there was a positive correlation between toxicity and total organic carbon. Performance evaluation of the wastewater treatment plant (WTP) revealed inadequate equalization and a deficiency of oxygen and nutrients. Testing to evaluate the control of effluent toxicity with powdered activated carbon showed it was effective but required high addition rates, making it expensive to implement. Also, large spills in the plant could overcome its effectiveness. The use of granulated activated carbon (GAC) reduced effluent toxicity but there was poor utilization of the GAC, and there was toxicity breakthrough before chemical oxygen demand breakthrough. The use of GAC was prohibitively expensive. Conclusions and recommendations from this industry's toxicity investigation were to add nutrients at the WTP, to improve equalization, to reduce in-plant spills, and to evaluate in-plant treatment.

Industry B[15] is a manufacturer of resin, producing numerous products on a campaign basis, using batch processes. Its existing wastewater treatment included equalization, biological oxidation, secondary clarification, and a polishing pond. The industry's permit was to be upgraded in the future, and it faced stringent acute toxicity limits since it received no credit for instream dilution. Its effluent displayed a highly variable toxicity (LC_{50} ranging from 10% to 75%) which showed no correlation to product campaigns. The industry's TRE approach was to consider an outfall line to a larger receiving stream nearby and to design a BAT diffuser to optimize regulatory-defined instream waste concentration (IWC). The conclusions from industry B's toxicity investigation were the following:

* existing treatment can sometimes be improved to meet toxicity limits
* source control is not always cost-effective or feasible
* alternate effluent disposal sometimes is feasible, and
* toxicity reduction programs must be "custom designed" to each situation

An engineering consulting firm, CH_2M Hill Southeast, which has worked with several industries engaged in TREs offers the following suggestions for the first steps:[15]

* understand your draft permit
* understand EPA and state biomonitoring policies and regulations
* realize that the following permit items may be negotiable:
  - hydrologic event to define limits
  - mixing zone issues
  - acute vs. chronic toxicity testing
  - definition of noncompliance
  - TRE implementation requirements

The firm offers the following suggestions as guidance for a practical approach to TREs:[15]

(1) do baseline monitoring
(2) develop a long-range plan
(3) use a phased approach, continuously examining costs and uncertainties
(4) optimize existing treatment
(5) examine effluent disposal alternatives such as increasing diffusion, reducing effluent flow, and discharging to a POTW or to an alternative receiving stream
(6) do toxicity treatability studies early
(7) use robust toxicity reduction technologies
(8) coordinate with the regulators; be diligent and technically sound

Perspectives of Municipal Dischargers

Biomonitoring is expected to have a large impact upon POTWs. If EPA is correct in its assessment that many POTWs presently in compliance with existing permits will fail the proposed biomonitoring tests, there will be a large number of POTWs facing enforcement actions.[14] Unlike industry, the POTW does not have direct control of processes and materials or the option to discontinue discharge. POTWs are subject to a continuing variability of influent, the impacts of synergism and antagonism, and the potential impact of raw water supply quality.[16] While incidental removal does occur in the treatment process, POTWs are not designed to remove causes of toxicity.[18] Illegal discharges and domestic discharges can contribute toxicity which POTWs cannot control. Two municipal TRE case studies provided by Larry Ausley, supervisor of the aquatic toxicology unit, North Carolina Department of Environmental Health and Natural Resources, are presented.[17]

Municipality A utilized a "causative agent" approach to its TRE. Because a large portion of its waste stream was contributed by several textile-producing firms, the POTW suspected that toxicity was being caused by this dominant portion of the waste stream. With chemical-specific evaluation of the effluent, a consulting laboratory identified several effluent

constituents specific to textile operations at levels which could be implicated in the POTW's observed effluent toxicity. Alkylphenol ethoxylate surfactants were identified as the most probable cause of toxicity in the waste stream. Negotiations between the city and its industrial users resulted in the substitution of surfactants which were more biodegradable. Immediately following this substitution by all of the textile facilities, acute toxicity in the municipal effluent decreased dramatically. When a municipal wastewater is dominated by a particular contributor or class of contribution, this chemical-intensive method of toxicity reduction can be effective *if* causative agents are identified quickly *and* removed or reduced at the source. In the converse, continued trial and error quickly overcomes the cost/benefit balance of this method.

Municipality B, with significant contributions from industrial users, tracked sources of toxicity by performing acute toxicity tests on influent samples taken from various points in the collection system. They ranked the relative toxicity of major contributing streams and then applied relative flow volumes to identify sources suspected of contributing to final effluent toxicity. When an industrial discharge appeared to contribute to WET, bench scale treatment of the discharged waste was performed using activated sludge from the POTW. As a result of this work, the city developed a sewer use ordinance which provided that industrial users either: 1) pass acute toxicity tests at an LC_{50} equal to, or greater than, their relative contribution to the municipal system, or 2) pass a chronic toxicity test of their discharge after treatability testing using the POTW's activated sludge. Municipality B still has not met WET limitations but has realized a decrease in toxicity. This TRE approach is called the "toxicity treatability" approach.

It should be noted that in neither case was the problem of WET solved. The problem was detected and investigated, and various approaches toward a solution were implemented. This process is costly. Charles Logue, process control manager of Jacksonville, Florida's, department of public utilities, wastewater division, reports that Jacksonville has spent $600,000 over the past four years but has not solved its WET problem yet.[11] North Carolina's report[17] (which includes no information on costs) is more encouraging; it reports that approximately 75% of its POTWs and its industrial dischargers are in compliance with the toxicity limits in their permits.

Municipal studies from North Carolina[17] indicate that POTWs which have taken active steps toward identification and reduction of toxic contributions to their systems frequently realize dramatic decreases in toxicity and additional benefits. One city reported virtual elimination of the discharge of organic solvents and a 50% reduction of the concentrations of conventional and metallic pollutants from city-permitted industrial users.

The influence of industrial discharge on POTW effluent toxicity has been emphasized, but when one is designing a toxicity identification plan one should not overlooked that the domestic wastewater contribution can contain significant amounts of toxicants. While the problem of domestic waste toxicity may be difficult or impossible to regulate directly, it is not unreasonable for municipalities to instigate public awareness programs to inform users of the problem that exists and to ask for voluntary waste minimization and proper hazardous waste disposal techniques.[17]

As municipal systems deal with WET, they also should realize the potential contribution of toxic substances from small businesses such as hospitals, garages, laboratories, and exterminators. A pervasive cause of WET in municipal treatment systems is chlorine. Approximately one third of the 1,600 North Carolina dischargers that currently report effluent chlorine levels average residuals of between 0.3 mg/l and 1.0 mg/l levels which would be expected to cause significant impact upon sensitive aquatic species, thus affecting these facilities' ability to comply with WET limits.[17] North Carolina recently adopted a water quality action level of 17 micrograms per liter for chlorine.[17]

Conclusions

From the industrial and municipal case studies, and from the suggestions offered for investigating and controlling WET, it is apparent that absolute and final answers do not exist. The field of effluent toxicity identification and reduction is a young one. Nearly every effort made at reduction will be breaking some new ground and making some new discoveries.[17]

The following opinion, expressed by James T. Egan,[18] seems appropriate. "Toxics control is the current issue commanding everyone's attention. It is no longer a simply technical, economic, or even environmental issue; it is an emotional issue regardless of one's perspective. It is also pushing the limits of current technology. The capacity of our society to produce toxic wastes in pursuit of a higher standard of living far outstrips our ability to detect and treat such wastes. We must realize that effective control of toxic discharges is likely to entail significant changes in the American lifestyle."

Can the United States afford biomonitoring? Yes. We can, and we must. However, to do so will challenge the commitment and the creativity of our industries, our municipalities, our regulators, our engineers, our scientists, and our nation's people. We must consciously periodically reresolve that we are willing to pay the cost for the protection that biomonitoring can afford our nation.

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