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Technical Support Document For Water Quality-based Toxics Control

United States
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Office of Water
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TECHNICAL SUPPORT DOCUMENT FOR WATER QUALITY-BASED TOXICS CONTROL

This copy represents the second printing of this document.

Changes made to this document reflect corrections of typographical errors and the following update of the interim guidance on criteria for metals: The Agency has issued "Interim Guidance Interpretation and Implementation Aquatic Life Criteria for Metals." The interim guidance supersedes criteria document statements expressing criteria in terms of a acid soluble analytical method and also the metals discussion of Section 5.7.3. The availability of this document appeared in the June 5, 1992 Federal Register (Vol. 57, No. 109, pg. 24401).

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the receiving water. Recommended methodologies for conducting biosurveys are included in References 56 through 62.

1.5 INTEGRATION OF THE WHOLE EFFLUENT, CHEMICAL-SPECIFIC, AND BIOASSESSMENT APPROACHES

Section 101(a) of the CWA states: "The objective of this Act is to restore and maintain the chemical, physical and biological integrity of the Nation's waters." Taken together, chemical, physical, and biological integrity define the overall ecological integrity of an aquatic ecosystem. Regulatory agencies should strive to fully integrate all three approaches since each has its respective capabilities and limitations. Table 1-10 shows EPA guidance, State implementation, and State application of each approach [55]. The information summarized in Box 1-6, and discussed in detail below, explains how each approach complements the other and why no one of the approaches should be used alone.

A more detailed discussion of the capabilities and limitations of the three approaches is provided below.

1.5.1 Capabilities and Limitations of the Chemical-specific Approach

The principal capabilities of the chemical-specific approach are:

- At present, protection of human health only can be achieved by control of specific chemicals.
- A more complete understanding is available on the toxicology of specific chemicals. EPA acute ambient water quality criteria are based on protecting up to a minimum of eight different organisms including fish, invertebrates, and plants; a minimum of three organisms are used to develop chronic criteria. Considerable information is available in the scientific literature on toxicity caused by specific chemicals.
- Treatment systems are more easily designed to meet chemical requirements because more treatability data are available.
- More information is available on the fate of a pollutant in receiving waters so that the pollutant fate can be conveniently predicted through modeling. Persistence and degradation can be factored into the evaluation.
- Chemical analyses are sometimes less expensive than toxicity testing and biological surveys, if there are only a few toxicants present. This is more pertinent if only chlorine and ammonia are present in an effluent or ambient water.
- This approach allows prediction of ecological impacts before they occur. NPDES permit limits can therefore be developed before an actual ecological impact occurs.

The principal limitations of the chemical-specific approach are:

- All toxicants in complex wastewaters are not known and, therefore, control requirements for all toxicants cannot be set. Toxicological information on these unknown pollutants is often unavailable.
- The bioavailability of the toxicants at the discharge site are typically not assessed, and the interactions between toxicants (e.g., additivity, antagonism) are not measured or accounted for. As a result, the controls may be either under protective or overly protective.
- Direct biological receiving water impact and impairment is not typically measured. There is no way to ascertain directly if the chemical controls adequately are protecting aquatic life.
- Complete measurement of all individual toxicants, particularly where many are present in the mixture, can be expensive. Organic chemicals, in particular, can be costly to measure.

Table 1-10. Process for Implementation of Water Quality Standards

Criteria	EPA Guidance	State Implementation	State Application
Chemical-Specific	Pollutant-specific numeric criteria	State Standards -use designation -numeric criteria -antidegradation	Permit limits monitoring Best management practices Wasteload allocations
Narrative "Free Froms"	Whole effluent toxicity guidance	Water Quality Narrative -no toxic amounts translator	Permit limits monitoring Wasteload allocation Best management practices
Biological	Biosurvey minimum requirement guidance	State Standards -refined use -narrative/numeric criteria -antidegradation	Permit conditions monitoring Best management practices Wasteload allocation

Box 1-6. Components of an Integrated Approach to Water Quality-based Toxics Control

Control Approach	Capabilities	Limitations
Chemical-Specific	-Human health protection -Complete toxicology -Straightforward treatability -Fate understood -Less expensive testing if only a few toxicants are present -Prevents impacts	-Does not consider all toxics present -Bioavailability not measured -Interactions of mixtures (e.g., additivity) unaccounted for -Complete testing can be expensive -Direct biological impairment not measured
Whole effluent toxicity	-Aggregate toxicity -Unknown toxicants addressed -Bioavailability measured -Accurate toxicology -Prevents impacts	-No direct human health protection -Incomplete toxicology (few species may be tested) -No direct treatment -No persistency or sediment coverage -Conditions in ambient may be different -Incomplete knowledge of causative toxicant
Bioassessments	-Measures actual receiving water effects -Historical trend analysis -Assesses quality above standards -Total effect of all sources, including unknown sources	-Critical flow effects not always assessed -Difficult to interpret impacts -Cause of impact not identified -No differentiation of sources -Impact has already occurred -No direct human health protection

1.5.2 Capabilities and Limitations of the Whole Effluent Approach

The principal capabilities of whole effluent techniques are:

- The aggregate toxicity of all constituents in a complex effluent is measured, and toxic effect can be limited by limiting one parameter—whole effluent toxicity.
- Toxicity caused by compounds commonly not analyzed for in chemical tests is detected. Control of the toxicant(s) is not dependent upon established toxicological information that may not yet be available for some pollutants.
- The bioavailability of the toxic constituents is assessed, and the effects of interactions of constituents are measured. Additivity, synergism, and antagonism between compounds in an effluent are addressed implicitly by whole effluent toxicity.
- The toxicity of the effluent or ambient water is measured directly for the species tested.
- This approach allows prediction of ecological impacts before they occur. NPDES permit limits can therefore be developed before an actual ecological impact occurs.

The principal limitations of whole effluent techniques are:

- The approach only measures and controls toxicity to aquatic organisms. It does not protect human health from exposures through ingestion of fish. This is particularly important for carcinogens.
- EPA's water quality criteria are based on a minimum of eight different species for the acute criteria and three different species for the chronic criteria. Effluent aquatic toxicity commonly is measured with only one, two, or three species. For some toxicants a wider sensitivity range (more species) must be tested; particularly where the mode of toxicity action is specific (such as diazinon or some other pesticides).
- There is less knowledge on designing or manipulating treatment systems to treat the parameter toxicity. Investigate tools for identifying causative toxicants only have been recently developed and may not easily identify all causative toxicants. As a result, identification and proper control may be difficult and expensive.
- The whole effluent toxicity test directly measures only the immediate bioavailability of a toxicant; it cannot measure the persistence "downstream" and long-term cumulative toxicity of a compound. Thus, bioaccumulative chemicals necessarily are not assessed or limited. Toxicants can accumulate in sediment to toxic concentrations over a period of time.
- Where there are chemical/physical conditions present (pH changes, hardness changes, solids changes, salinity changes, photolysis, etc.) that act on toxicants in such a way as to

(which could include probabilistic modeling) to determine if simplifications in dilution calculations projected higher concentrations than would be expected using the detailed model. The authority also would need to examine concurrently the sampling approach and analysis of the biosurvey data to determine if it appropriately characterized the water. If there was still a difference, then the regulatory authority will need to use the more protective approach as the basis to determine necessary regulatory controls.

1.6 OTHER FACTORS INFLUENCING WATER QUALITY-BASED TOXICS CONTROL

An understanding of the fate and behavior of both single toxicants and whole effluent toxicity after discharge can be important in the application of water quality-based toxics controls. Evaluating the combined effects of interacting toxic discharges also may be important in multiple discharge situations. When evaluating the receiving water behavior of toxicants and toxicity, factors such as toxicity degradation or persistence, and toxicant additivity, antagonism, and synergism are important. Ambient toxicity tests can give some indication of the importance of each of these factors:

- **Toxicity Persistence**—How long and to what extent (in terms of area), does effluent toxicity or the toxicity of a single toxicant persist after discharge? It is not reasonable to assume that in all cases the persistence of both individual toxic chemicals and effluent toxicity is conservative. For two effluents of equal initial toxicity, the aquatic effects of an effluent whose toxicity degrades rapidly will be different from an effluent whose toxicity persists.

- **Additivity, Antagonism, and Synergism**—When toxicants or effluents with toxic properties mix in the receiving water, what is their combined fate and toxic effects?

- **Test Interferences**—This includes pH, temperature, salinity, hardness, and metals.

Each of these factors is discussed below.

1.6.1 Persistence

As soon as an effluent mixes with receiving water its properties begin to change. The rate of change of toxicity in that effluent is a measure of its toxicity persistence or degradation. After mixing, the level of toxicity in the receiving water may either remain relatively constant (until further diluted), increase in toxicity due to transformation, or degrade due to fate processes (photodecomposition, microbial degradation) or compartmentalization processes (particulate adsorption and sediment deposition, volatilization).

One disadvantage of the chemical-specific approach is that the bioavailability of the toxicant after discharge is not measured. Onsite toxicity testing has indicated that the individual toxicants causing toxicity measured at discharge sites tend relatively to be persistent near the point of discharge [23, 31-38]. However, persistence of individual chemicals can be modeled and the persistence of specific toxicants also can be accounted for in making impact predictions and setting controls. A procedure to determine whether or not an effluent's toxicity is persistent has been developed by EPA [63]. The procedure describes the steps required to conduct a laboratory evaluation of the degradation of toxicity in complex effluents that are released to receiving waters by simplistically simulating a water body and discharge. **EPA recommends this procedure be conducted where the interaction of sources of toxicants is critical to establishing controls.**

This simple procedure is performed in a refrigerator-sized environmental chamber in the laboratory using commonly available glassware and shipped effluent samples. Toxicity is measured using conventional acute or short-term chronic toxicity tests. The results are used to generate a toxicity degradation rate for the effluent under representative environmental conditions. The procedure has several applications, including measuring the decay of effluent toxicity in a stream or lake, and identifying the most important fate processes responsible for toxicity decay (which also may be useful in treatability or toxicity identification studies).

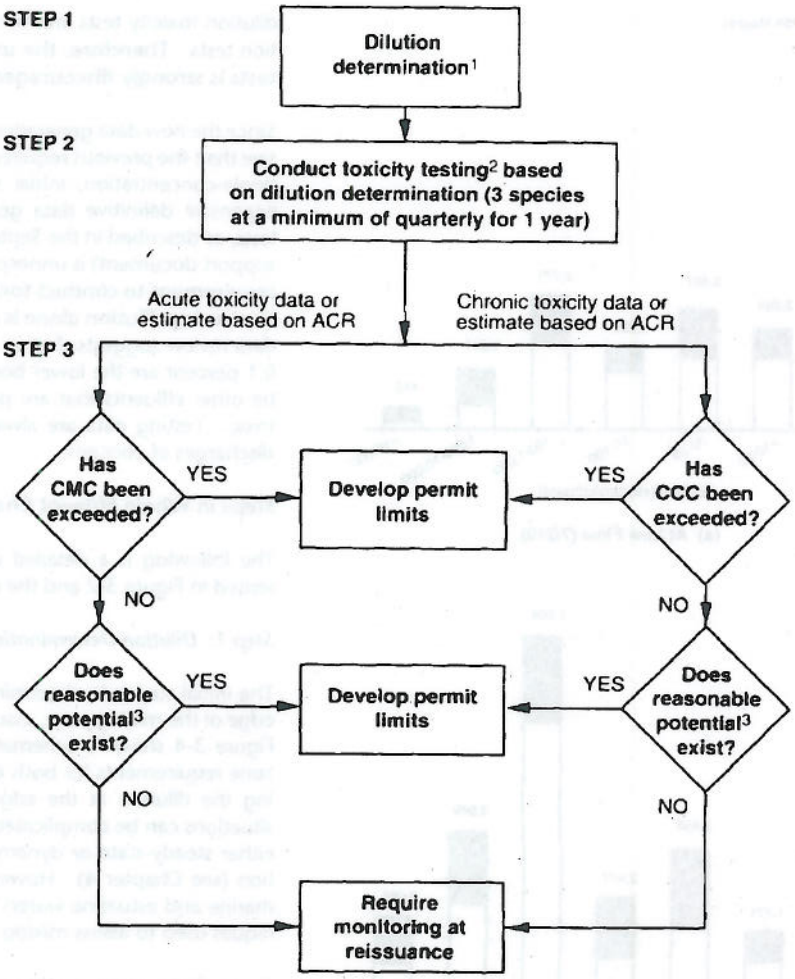
Mixing zones designated by State water quality standards, or developed on a case-by-case basis, are typically small enough that toxicity evaluations need only consider near field situations. Continuous discharges continually can introduce toxic pollutants into a receiving water. Although these pollutants can decay over time, this decay will occur downstream or away from the discharge. The receiving water concentrations at the point of discharge continually are being refreshed. In these instances, toxicity can be considered conservative and persistent (nondecaying) in the near field.

However, effluent toxicity can exhibit far field decay. Typical patterns of progressively decreasing downstream toxicity (similar to biochemical oxygen demand decay) have been observed in a number of freshwater situations [23, 31-38]. This is of concern when evaluating the combined toxicity of sources located far apart. If there is reason to suspect that an effluent's toxicity is not persistent, several techniques can be employed to measure changes of toxicity after discharge:

- Testing should be performed during various seasons of the year corresponding to various receiving water flow regimes. The toxicity test itself, when performed with dilution water immediately upstream or from an uncontaminated area nearby, is an analogue of the mixing and fate processes taking place in the receiving water. The types of rapid chemical reactions found in the mixing zone also can be expected to take place to a large extent when effluents and receiving waters are mixed for toxicity tests. The effects on toxicity persistence of varying physical/chemical conditions in the receiving water or in the effluent cannot, however, be accurately predicted from these results.

- Ambient toxicity testing, as detailed in Appendix C, measures the ambient interactions of effluent and receiving water and can be used to assess toxicity persistence.

Toxicity persistence may present a more serious problem in estuarine or lake receiving waters where the toxicity is not flushed away rapidly. In one study, on a POTW effluent being discharged into a small cove off of Narragansett Bay, the decay rate of the effluent was temperature-dependent and was reduced markedly during



Notes:

[1]Dilution determinations should be performed for critical flows and any applicable mixing zones.

[2]Toxicity testing recommendations

a. Dilution > 1000:1: acute testing, check CMC only.

b. 100:1 < Dilution < 1000:1: acute or chronic testing, check CMC and CCC with data or ACR.

c. Dilution < 100:1: conduct chronic testing, check CCC with data and CMC using acute data or ACR.

[3]Reasonable potential: Use procedures in Box 3-3.

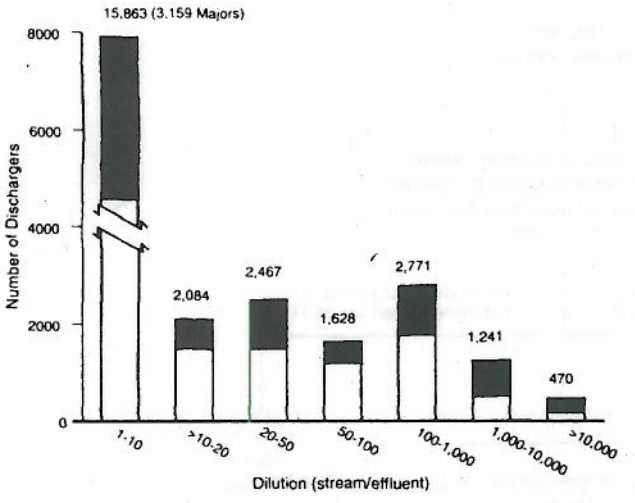
Figure 3-2. Effluent Characterization for Whole Effluent Toxicity

1) The effluent causes or contributes to an excursion of a numeric or narrative water quality criterion and the permit requires a limit on toxicity.

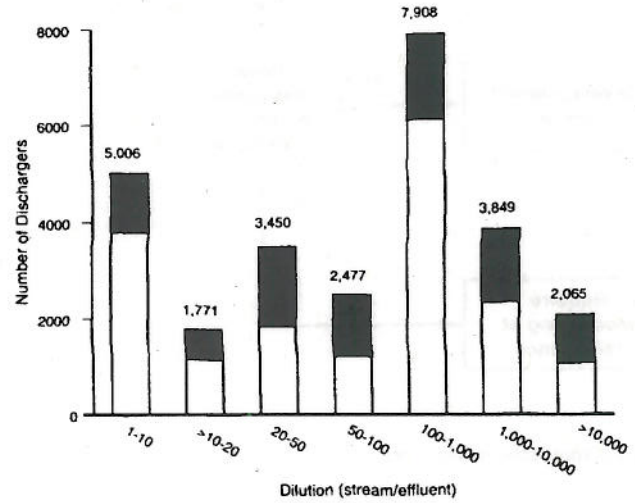
2) The effluent has a reasonable potential of causing or contributing to an excursion of a numeric or narrative water quality criterion and a limit is required.

3) The effluent has a very low probability of causing or contributing to an excursion of a water quality standard and no limit is required.

This categorization is accomplished by using dilution estimates in the first step and the results of the toxicity tests in the next steps. In addition, all these impact estimates assume discharge at critical conditions and imposition of any applicable mixing zone requirements. Therefore, a conservative assumption is used to determine whether or not an impact is projected to occur. Estimates of possible toxic impact are made assuming that the effluent is most toxic to the most sensitive species or lifestage at the time of lowest available dilution.



(a) At Low Flow (7Q10)



(b) At Annual Mean Flow

Figure 3-3. National Distribution of NPDES Dilution Conditions at 7Q10 and at Annual Mean Flow

The changes to the EPA's data generation recommendations eliminate the application of multiple sets of safety margins that was proposed in the 1985 version of this document. Rather, general observations on effluent toxicity described above now allow regulatory authorities to tighten the bounds of the initial dilution categorization, eliminate the species sensitivity uncertainty factor and target LC_{50}s of 1 percent and NOECs of 0.1 percent as the most extreme toxicity measurements that can normally be expected for the vast majority of effluents discharged by NPDES permittees for acute and chronic toxicity, respectively. The observation of toxicity was based on multiple dilution tests. The same observation may not hold for toxicity measured with single dilution tests (pass/fail). As reflected in Chapter 1, single dilution toxicity tests are much more variable than multiple dilution tests. **Therefore, the use of single concentration toxicity tests is strongly discouraged for this data generation process.**

Since the new data generation requirements are much less expensive than the previous requirements, tiered testing (less expensive, single-concentration, initial screening followed by increasingly expensive definitive data generation, using multiconcentration tests, as described in the September 1985 version of the technical support document) is unnecessary. However, **elimination of the requirement to conduct toxicity testing on the basis of projections using dilution alone is not recommended.** Although EPA's data review suggests that an LC_{50} of 1 percent and an NOEC of 0.1 percent are the lower bounds on effluent toxicity, there may be other effluents that are presently unmeasured that are more toxic. Testing data are always desirable for fully characterizing discharges of concern.

Steps in Whole Effluent Characterization Process

The following is a detailed description of the major steps presented in Figure 3-2 and the rationale behind each.

Step 1: Dilution Determination

The initial step is to determine the dilution of the effluent at the edge of the mixing zone, assuming the State allows mixing zones. Figure 3-4 shows a schematic representation of typical mixing zone requirements for both acute and chronic toxicity. Calculating the dilution at the edges of mixing zones for site-specific situations can be complicated. Modeling can be employed using either steady-state or dynamic approaches to calculate the dilution (see Chapter 4). However, for complex situations, such as marine and estuarine waters or lakes, dye studies (or other techniques used to assess mixing zones) may still be required.

Some State water quality standards do not allow the use of mixing in the control of acute toxicity. For these States, acute toxicity is often limited at the end of the pipe. Permit limits derived to enforce such requirements would be considered "water quality-based" because they would be based upon an ambient criterion (as opposed to an arbitrary test endpoint). Regardless, both chronic and acute toxicity must be assessed in these situations.

Step 2: Toxicity Testing Procedures

Where toxicity tests are required in order to make decisions regarding appropriate next steps in a screening protocol, **EPA recommends as a minimum that three species (for example, a vertebrate, an invertebrate, and a plant) be tested quarterly for a minimum of 1 year.** As discussed in Chapter 1, the use of three species is strongly recommended. Experience indicates that marine algae can be a highly sensitive test species for some effluents. Using a surrogate species of the plant kingdom adds another trophic level to the testing regimen. For both freshwater and marine situations, the use of three species is more protective than two species since a wider range of species sensitivity can be measured. EPA is continuing to develop toxicity test methods using additional organisms including plants. In addition, EPA has revised the test for *Selenastrum*, which has improved the test precision.