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ABSTRACT

Since the passage of the Water Quality Act of 1987, biomonitoring has been incorporated into the National Pollutant Discharge Elimination System permits for wastewater treatment plants. A Toxicity Reduction Evaluation (TRE) is required when the toxicity limits of the permit are repeatedly violated to determine the cause of the toxicity and to identify a corrective action. Many municipal wastewater treatment plants have been required to conduct TREs and have found them to be expensive and time-consuming.

A protocol was issued by the U.S. Environmental Protection Agency (EPA) in 1988 to provide guidance to municipalities in conducting TRE assessments. While several studies have focused on the details of how to perform a TRE, none has addressed the effectiveness of the TRE in resolving toxicity problems. This study attempted to do this by directly contacting 37 municipalities in EPA Region IV that had or are presently conducting TREs and questioning them on their use of the EPA protocol. They were asked via a questionnaire to assess the benefits of the protocol in identifying the toxicant and corrective action and to identify any problems or concerns they had with the TRE process and the EPA protocol.

Twenty-six completed questionnaires were received. The survey indicated that the protocol has been successful in resolving acute toxicity problems but has had limited success and more difficulties when dealing with chronic toxicity. The protocol is also less successful when toxicity is intermittent or appears to result from multiple toxicants. Major complaints about the TRE process concern the cost and time required especially when tests are inconclusive. While biomonitoring was noted as a useful indicator of effluent toxicity, several respondents believed the protocol is not sufficiently developed to be used as an enforcement tool.

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I. INTRODUCTION

A. BACKGROUND

In 1984, the U.S. Environmental Protection Agency (EPA) issued a new directive[1] which called for the assessment of the toxicity of a wastewater treatment plant effluent based on its effect on the biological life in the receiving stream. This policy became law with the passage of the Water Quality Act of 1987[2] which stated that where numerical criteria were not available, states could use biological monitoring or assessment methods and was implemented with the incorporation of biological testing into the National Pollutant Discharge Elimination System (NPDES).

Specific permit requirements for biomonitoring vary from state to state but principally require examining the acute and chronic exposure of an aquatic species to various concentrations of the treatment plant effluent. A permit is violated when there are repeated failures to meet the water quality limits set in the NPDES permit. More frequent testing of the effluent may be required to confirm the toxicity, followed by an order for a toxicity identification evaluation (TIE) and/or a toxicity reduction evaluation (TRE).

Simply stated, the TRE is a plan to determine the cause for the failure to meet water quality standards and to identify corrective actions to control the effluent at acceptable levels. In 1988, EPA issued a support document, "Toxicity Reduction Evaluation Protocol for Municipal Wastewater Treatment Plants" to provide guidance to publicly owned treatment works (POTWs) in conducting TRE assessments. The document presents a detailed guide to aid in preparing TRE plans, evaluating the information generated during the TREs, and developing a technical basis for the selection and implementation of toxicity control methods. Because each facility has different features, there is no single plan for a TRE. Instead the protocol serves to identify the principal objectives needed based on an overall flowsheet of the TRE process.

A TIE can be performed as a stand-alone evaluation or as integral component of a TRE. The TIE specifically addresses aquatic toxicity by combining toxicity testing with tests to characterize the physical and chemical nature of the constituents which cause toxicity (Phase I - Toxicity Characterization), with tests to specifically identify the toxicants (Phase II - Causative Toxicant Identification), and with tests to confirm the presence of the suspected toxicants (Phase III - Causative Toxicant Confirmation). EPA issued protocols in 1988 that individually address each of these phases.

Since the inclusion of the water quality-based limits in NPDES permits, many municipalities have been required to conduct TREs. They have found that conducting a TRE can be an expensive and time-consuming process. A single round of biological tests can cost in the neighborhood of $2500 and a TRE can require years to complete. Many municipalities have questioned the cost and effectiveness of the process especially when dealing with chronic toxicity. The studies performed to date by the EPA laboratories have focused on the details of how to perform a TIE or TRE but have not addressed the effectiveness of the evaluations in resolving toxicity problems.

In 1988 the Permits Division of the Office of Water contacted all of the States and EPA Regions in an attempt to consolidate TRE information to assist permit writers in evaluating their TRE plans and results. The report entitled "Abstracts of Toxicity Reduction Evaluations" outlined twenty-three cases from eight states. Only seven municipal facilities were included in the report and because it was issued at approximately the same time as the municipal protocol, it did not address the effectiveness of the protocol. Efforts to update this information have been suspended due to the cost and time required to identify and contact all facilities that have completed a TRE.

Additional results of TREs have been noted in the EPA protocols, in wastewater industry publications, and at professional organization meetings. However, the information is generally brief in nature without the detail needed to address the effectiveness of the TRE. Complete reports of the EPA case studies provide extensive information, but there are only a limited number of these studies. Consultants who are hired to conduct TREs for municipalities have reported on TREs, but mainly report their experience in a summarized format or only as an oral presentation because they do not have the incentive or possibly the permission of the municipalities to provide extensive reports. As a result, sufficient information either from EPA or the open literature is not available to address how effective the protocols have been in identifying toxicants and corrective actions or to identify if there are common problems or concerns that should be addressed in future EPA studies and protocols.

B. OBJECTIVES

The objectives of conducting this research were:

1. To develop a questionnaire to examine the use of the EPA "Toxicity Reduction Evaluation Protocol for Municipal Wastewater Treatment Plants" and assess how beneficial the protocol has been in identifying the toxicant and corrective action; and

2. To identify any common problems or concerns expressed by municipalities concerning the TRE process and the EPA protocol.

II. LITERATURE REVIEW

The water quality-based national policy issued by the EPA in 1984 called for a TRE "where there was significant likelihood of toxic effects to biota in the receiving water". A protocol[3] for TREs at municipal treatment plants was developed to provide methods and procedures for (1) the design of a TRE, (2) the development and review of a TRE plan, (3) the evaluation of the results and data generated during the TRE, and (4) the development of a sound scientific and engineering basis for the selection and implementation of a toxicity control method. Because each facility has different features, the protocol provides a flowchart (Figure 2.1) for a TRE program and allows the POTW to identify the principal components needed in their program.

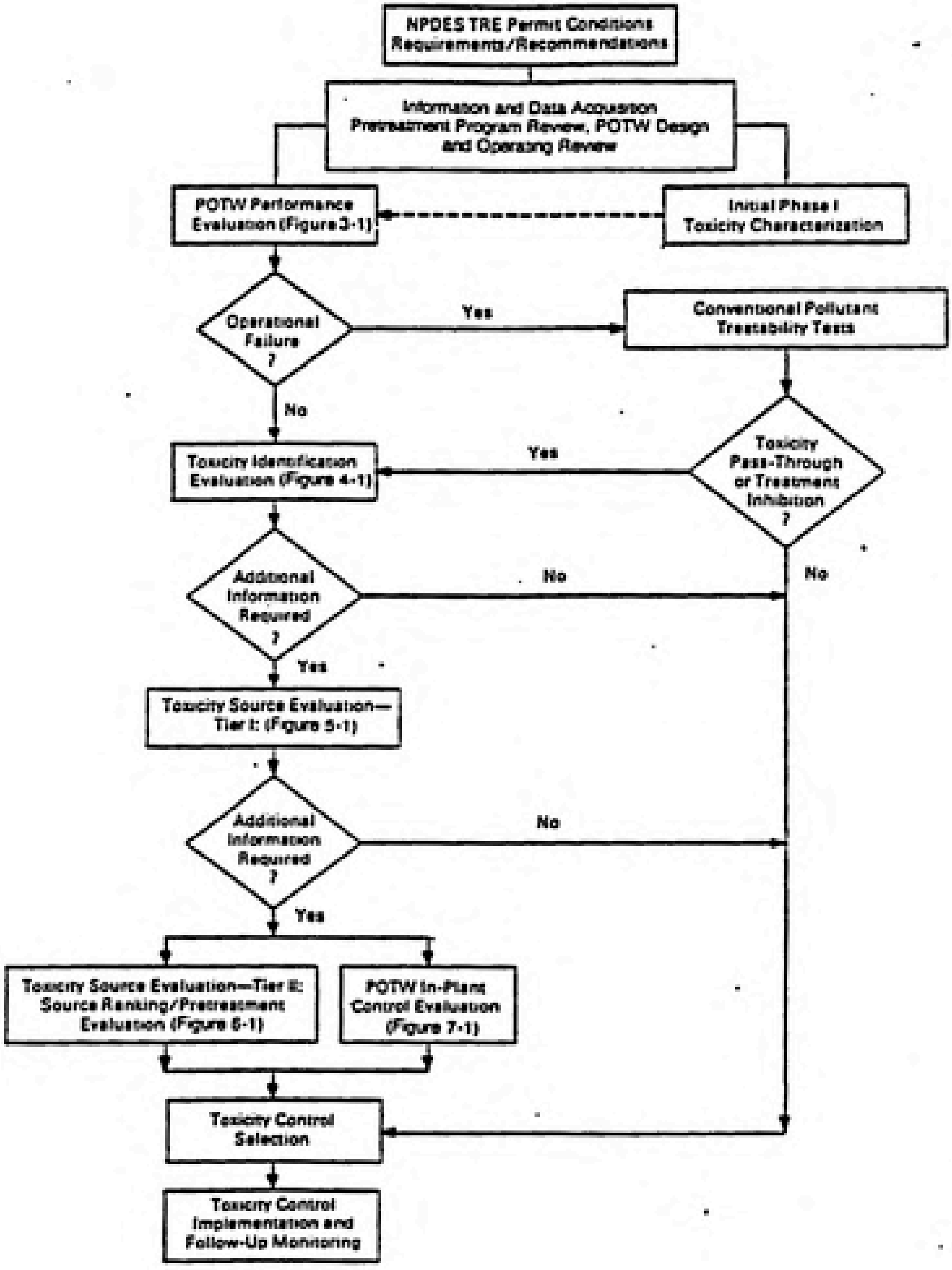
The first step in a TRE is Information and Data Acquisition. Its purpose is to obtain information about the operation and performance of the wastewater treatment plant (WWTP) and its pretreatment program. Specific information collected includes the treatment plant's design capabilities, treatment performance, operation and maintenance practices, industrial waste surveys, and pretreatment monitoring and compliance reports.

Next a POTW Performance Evaluation (PPE) is conducted in an attempt to identify and correct treatment deficiencies that may be responsible for all or part of the effluent toxicity. The PFE involves a review of the major treatment units using wastewater characterization data and process operations information. When performed in conjunction with a TIE Phase I analysis, it may identify options for improving conventional pollutant treatment and for reducing effluent toxicity.

If the first two steps do not identify methods to reduce effluent toxicity to acceptable

FIGURE 2.1

TRE FLOW DIAGRAM FOR MUNICIPAL WASTEWATER TREATMENT PLANTS[1]



levels, the TRE proceeds to the TIE stage. The TIE is divided into three phases designed to track toxicity by combining analytical tests with toxicity tests. Phase I (Toxicity Characterization)[4] consists of tests to characterize the physical and chemical nature of the constituents which cause toxicity. Phase I tests are relatively simple tests that involve systematically removing or rendering inert groups of toxicants with similar physical/chemical characteristics (eg. metals, nonpolar organics, ammonia, chlorine). By comparing the treated sample toxicity to the untreated sample toxicity, types of compounds causing toxicity may be identified. Specific tests include toxicity degradation, aeration, filtration, C_{18} solid phase extraction, pH adjustment, oxidant reduction, EDTA chelation, and graduated pH treatments. Phase I results are intended as a first step in a specific identification of a toxicants but can be used to develop treatability studies if the tests adequately characterize the toxicants.

TIE Phase II (Causative Toxicant Identification) includes specific test methods to further identify specific causative agents such as non-polar organic compounds (NPO), ammonia, cationic metals, and chlorine. Phase II may require the use of high pressure liquid chromatography (HPLC) columns to separate the toxicants into fractions if non-polar organic compounds are suspected. The fractions are then subjected to gas chromatography/mass spectrometry (GC/MS) procedures to identify specific toxicants. Other toxic specific separation and identification methods may also be required depending on the results from Phase I.

Confirmation of the suspected toxicants is then attempted in TIE Phase III (Causative Toxicant Confirmation). This phase includes observation of test organisms symptoms, additional species toxicity testing, and correlation of toxicity and toxicant concentration from multiple samples.

The original TIE protocols developed in the 1980s addressed only acute toxicity. Revised TIE protocols specifically addressing chronic toxicity were issued in September of 1992.[5] The documents were prepared based on experience with *Ceriodaphnia dubia* and *Pimephales promelas* (fathead minnows) as the test organisms. The new protocols also attempt to reduce toxicity testing time, provide more detail on the identification of toxicants, and provide more guidance on the confirmation of hidden toxicants which are non-additive or partially additive.

Following toxicant identification in the TIE, the facility can choose to conduct either a Toxicity Source Evaluation (TSE), a POTW In-Plant Control Evaluation or both. The choice depends on whether the toxicant is expected to be found at a single source or distributed throughout the sewer system. A TSE would be used when a single source is suspected to confirm toxicity which could be reduced through a pretreatment program. An In-Plant Control Evaluation is used when the toxicant is suspected to be distributed throughout the sewer system which would more likely require toxicity reduction at the treatment plant.

The TSE is performed in a two-tiered approach.[1] In Tier I, wastewater at various points in the sewer system is sampled and analyzed for toxics and/or toxicity. In Tier II, additional testing is performed to confirm suspected sources of toxicity identified in the Tier I evaluation. Both tiers of the TSE use a refractory toxicity assessment (RTA) which involves treating the sewer samples in aerobic batch bioreactors and testing the resulting effluents for toxicity. After confirmation of the identity of a toxic discharger, pretreatment program options can be considered.

An In-Plant Control Evaluation has the objective of selecting and evaluating feasible treatment options for the reduction of toxicity at the plant. Treatment options are selected based on the data gathered in the PPE and TIE and on the knowledge of treatment process operations. The treatment options can be enhancement of the existing plant processes or the addition of new treatment processes to the plant. Bench-scale or pilot-scale treatability studies are then conducted simulating the treatment options selected and are combined with toxicity testing and possibly TIE Phase I testing to evaluate the removal of the toxicants.

To complete the TRE process, the data collected from all the prior TRE steps are summarized and reviewed. The toxicity control methods and technologies are then selected for implementation using the criteria recommended in the protocol.

Few examples of the use of municipal TREs in solving toxicity problems are found in the literature. Most of those that are available were conducted before the EPA protocol was issued, and, therefore, do not reflect the effectiveness of the protocol in solving toxicity problems.

Neiheisel[6] studied influents and effluents at six Ohio municipal wastewater treatment plants to evaluate the importance of wastewater sources on influent toxicity and on the toxicity reduction produced by the municipal wastewater treatments. The plants selected received wastewater from domestic/commercial sources and from domestic/commercial plus industrial sources. The survey revealed that chronic toxicity as measured by *Ceriodaphnia* and sub-chronic toxicity as measured by fathead minnow occurred in all raw wastewater and that the toxicity of the raw wastewater from the domestic/commercial sources and from the domestic/commercial plus industrial sources was substantially similar. BOD and solids removal was efficient in all plants but toxicity reduction by conventional primary-activated sludge treatment was highly variable. The level of toxicity reduction and toxic pass-through at the municipal plants did not correlate strongly with the presence or absence of industrial wastewater sources.

Of the six WWTPs, the City of Akron Botzum WWTP received the most toxic influent wastewater. Although it achieved significant toxicity reduction, a biological impact assessment of the Cuyahoga River revealed a severe impact on the aquatic communities downstream of the plant. On the basis of this assessment, it was selected for a toxicity reduction evaluation that was summarized by Botts[7]. A TIE was conducted and indicated the toxicity was caused by a non-polar organic compound or a combination of non-polar organic compounds. Metals were also identified as possible toxicants. Monitoring of the effluent was continued, but no correction action was taken because the acute effluent toxicity abruptly ended in the summer of 1986. Several reasons for the elimination of the toxicity were proposed including the termination of discharge by a large chemical manufacturer.

Logue[8] conducted a 15-month study to identify sources of toxicity in a Jacksonville, Florida collection system. Bioassays performed on the Buckman WWTP between 1979 and 1984 had shown the effluent to be consistently toxic. The approach chosen for the TRE was a generic, toxicity treatability procedure to trace toxicity through the collection system. This method was believed to be attractive since it would lead to modifications in the sewer ordinance code or pretreatment permits, thus placing the burden for reducing toxicity directly on dischargers.

Samples from ten stations in the collection system were obtained and treated in batch activated sludge reactors using return activated sludge from the Buckman plant. Toxicity was determined on samples before and after treatment based on *Daphnia pulex* mortality after 48-hours. Both residential and industrial wastewaters exhibited toxicity, but biological treatment completely detoxified the residential wastewater while only partially reducing the toxicity of industrial wastewaters. The authors believed this study supported the use of toxicity screening as a useful tool in the identification of contributors of toxicants, but did not indicate if or how the results has been used to reduce toxicity at the Buckman plant.

EPA's Office of Water[9] surveyed all states and EPA Regions to find examples of successful TREs from both industries and municipalities. The survey revealed that most states had not progressed in the implementation of the whole effluent toxicity limits to the point at which TREs had been completed. State files were obtained from California (San Francisco Bay Region), Delaware, Maryland, New Jersey, North Carolina, and Virginia. In addition, the EPA Environmental Research Laboratory in Duluth, Minnesota, provided reports of the TIEs they had conducted while developing the TIE protocol. A summary of the information provided from the municipal wastewater treatment plant TREs is shown in Table 2.1.

TABLE 2.1

MUNICIPALITIES THAT CONDUCTED A TRE IN EPA STUDY

* Hollywood, FL
  Toxicity - Acute
  Year Conducted - 1986
  TIE conducted by EPA Duluth. Solid phase extraction column suggested non-polar organics. GC-MS revealed diazinon. Tests conducted in 1987 and 1988 gave similar results.

* Las Vegas, NV
  Toxicity - Acute
  Year Conducted - 1986, 1987
  TIE conducted by EPA Duluth. Solid phase extraction column suggested non-polar organics. GC-MS revealed dichlorvos and diazinon.

* Columbus, NC
  Toxicity - Acute and Chronic
  Year Conducted - 1987
  TIE conducted by Burlington Research, Incorporated. Solid phase extraction column suggested non-polar organics. 90% of influent was from a textile mill. Alkyl phenyl ethoxylates and benzyl trimethyl ammonium chloride used as process chemicals by the textile mill were suspected. Further work was needed.

* Fayetteville, NC (Cross Creek)
  Toxicity - Chronic
  Year Conducted - 1988
  Failure was attributed to continuous dosing of cationic polymers to secondary clarifiers.

* High Point, NC (Eastside)
  Toxicity - Acute and Chronic
  Year Conducted - 1987
  Burlington Research, Incorporated used EPA Toxicity Characterization Bioassay Procedure but could not identify toxicant. City banned industrial user discharge of chlorinated hydrocarbons and alkyl phenols which were identified by BRI as a major contributor of toxicity. Toxicity tests were passed after the ban.

* Jefferson, NC
  Toxicity - Acute
  Year Conducted - 1987
  Burlington Research, Incorporated conducted a toxicity reduction evaluation. BRI recommended the reduction of alkyl phenol ethoxylates along with modifications to new WWTP.

TABLE 2.1 (CONTINUED)

* Mt. Airy, NC

  Toxicity - Acute

  Year Conducted - 1986

  Plant serves town and 14 textile plants. Extensive chemical analysis provided a list of suspect chemicals. City issued a ban on chlorinated hydrocarbons, phthalate compounds, and alkyl phenol compounds and adopted local limits on copper and zinc for non domestic users. Toxicity was reduced but not eliminated.

The most extensive data available on municipal TREs are from the EPA case studies at the Patapsco WWTP in Baltimore, Maryland, at the Linden Roselle Sewerage Authority WWTP in Linden, New Jersey, and at the Cross Creek WWTP in Fayetteville, North Carolina.

One of the first case histories of a toxics management program at a municipal wastewater treatment plant was the Patapsco WWTP study summarized by Botts[10]. The study was initiated as a cooperative agreement between the City of Baltimore and the EPA in April of 1986 and completed in September of 1987. Patapsco was selected based on the wide range of industrial contributions to its influent, which would provide an opportunity to evaluate the TRE procedures under conditions where identification of a single toxicity source was unlikely, and because of the evidence of toxic inhibition and toxic pass-through at the plant. The plant was also considered a good location because the personnel were experienced with toxicity monitoring.

The study included a conventional evaluation (suspended solids, BOD, COD, and nutrients) of the two influent wastestreams, a conventional evaluation of the primary and secondary effluents, a review of plant operating data, in-plant acute and chronic toxicity measurements, and a TIE based on the Anderson-Carnahan and Mount[11] procedure available at that time. *Ceriodaphnia dubia*, *mysidopsis bahia*, and Microtox™ were used to assess acute toxicity while only *Ceriodaphnia dubia* was used for chronic toxicity testing.

The study indicated that the Patapsco WWTP performance as measured by conventional analyses was good during the period the TRE was conducted. Evaluation of the wastewater indicated that the influent was toxic and that although secondary treatment resulted in a major reduction of acute and chronic toxicity, substantial acute and chronic toxicity remained following secondary treatment. The TIE found the primary components of toxicity to be non-polar organics, but the GC/MS analysis of the NPO fractions was unable to confirm the presence of the specific organic compounds causing the toxicity. Compounds removed by volatilization and ammonia were also found to contribute lesser amounts of toxicity.

During the study, a toxicity treatability method was developed to screen the potential sources of wastewater toxicity entering the treatment plant using batch tests of selected source wastewaters with Patapsco WWTP activated sludge. The procedure was found to be an effective tool for identifying and ranking possible toxicity contributors and for identifying industrial dischargers that interfere with biological treatment at the treatment plant. No changes to the treatment plant were recommended pending a further investigation to characterize the effects of the effluent toxicity on the Patapsco River estuary.

Morris[12] provides a summary of the TRE activities at the Linden Roselle Sewerage Authority (LRSA) WWTP in Linden, NJ. The plant had provided good treatment performance for conventional pollutants but the effluent was acutely toxic to *Mysidopsis bahia*. *Mysidopsis bahia* was used because in biomonitoring because the treatment plant discharges to the Atlantic Ocean. However, the TRE was conducted using *Ceriodaphnia dubia* as a surrogate freshwater test species because mysids are considered too costly and complex to use in the TIE analyses.

TIE Phase I results suggested that toxicity to *Ceriodaphnia* was associated with ammonia-type compounds and non-polar organic compounds. Phase II results indicated ammonia could account for a significant portion of the whole effluent toxicity. The TIE NPO analyses indicated a variety of NPOs including organophosphate and benzene compounds. Surfactants were also suggested in one sample. Results also indicated that acute toxicity in the LRSA effluent is variable and that ammonia can mask the effect of other toxicants. Neither ammonia treatments nor NPO treatments alone consistently eliminated effluent toxicity.

For the EPA case study, one of the primary objectives of was an evaluation of the Refractory Toxicity Assessment (RTA) approach for tracing sources of effluent toxicity. A RTA simulates the biological treatment provided by the treatment plant using bench-scale, batch reactors and then uses toxicity tests on the effluent to evaluate whether the WWTP will adequately reduce toxicity. Samples taken from selected manholes and industrial discharges in the sewer system were evaluated and potential sources of pass-through toxicity were found. Chemical-specific analyses were used to identify and confirm the presence of ammonia from the industrial sources. Process chemical lists from possible industrial contributors were compared with the TIE NPO analyses to identify sources of NPO toxicity.

Information on the causes, sources, and treatments of the LRSA effluent toxicity is currently under evaluation. Source controls may involve pretreatment limits on ammonia or toxicity-based pretreatment limits for NPOs. In-plant treatment controls such as biological nitrification, air stripping, and selective ion exchange are also being considered.

Botts[13] documented the EPA case study at the Cross Creek WWTP in Fayetteville, NC. The treatment plant effluent met NPDES requirements for conventional pollution treatment but was acutely toxic to *Ceriodaphnia dubia*. The goal of the study was to evaluate the EPA Municipal Protocol and to refine the protocol based on the experience. The TRE at Cross Creek included all of the primary steps recommended for a municipal TRE: a plant performance evaluation, a pretreatment program review, a toxicity identification evaluation, and a toxicity source evaluation.

The plant performance evaluation found the plant to be generally operating within design specifications and not contributing to the acute effluent toxicity. Review of the pretreatment program did not reveal any major toxicity sources based on conventional or priority pollutants. Useful information was obtained about the dischargers to the collection system and helped identify sampling points for the toxicity source evaluation.

From the TIE, Phase I indicated that non-polar organic compounds were causing the majority of the acute effluent toxicity to *Ceriodaphnia*. Phase II further identified the pesticide diazinon as the primary cause of effluent toxicity with other non-polar organics also contributing to toxicity.

The TSE conducted during the case study used a two-tier approach. The first tier included an assessment of the techniques for tracing sources of refractory toxicity while the second tier looked for specific chemicals. As part of the Tier I TSE, a calibration study was first conducted to determine the operating conditions for the refractory toxicity assessment test. Sections of the wastewater collection system were evaluated for potential sources of refractory toxicity using bench-scale bioreactors with Cross Creek WWTP activated sludge. The RTA test results indicated none of the locations stood out as consistent sources of acute refractory toxicity.

The chemical specific source evaluation (CSSE) surveyed diazinon throughout the collection system. Diazinon was found to be distributed widely throughout the collection system with higher concentrations in residential areas. However, the diazinon did not consistently account for all the observed acute toxicity during the CSSE.

Toxic control options were investigated and indicated that control of diazinon would be difficult because of its wide-spread use and low concentrations. Treatments for diazinon were found to be limited to several untested, experimental methods. The most practical method for control of diazinon was believed to be to reduce the usage of diazinon by educating the public of the problem and requesting their assistance.

The case study concluded that all the initial elements of a TRE are important and provide clues to the causes and sources of toxicity. Each component evaluation should be used in conjunction with other test results in order to obtain an accurate assessment of the variability, nature and sources of the substances causing acute whole effluent toxicity.

Case studies were conducted in North Carolina st High Point and Fayetteville using the TIE and TSE protocols.[14] The objectives of the studies were to apply the TIE and TSE protocols to cases where pass-through toxicity was highly variable, and to investigate the potential for return activated sludge to desorb compounds that may cause acute toxicity.

The studies at High Point Westside WWTP pointed out the difficulty in identifying sources or the nature of toxicity when events are sporadic. During the course of research from October 1987 to April 1988, the acute toxicity events lessened in frequency thus making it impossible to anticipate when to collect whole effluent samples. One significant, acute toxic sample was collected. The TIE Phase I and II tests identified nickel as the cause of toxicity. This was confirmed by reviewing plant data which indicated high nickel levels when the sample was taken.

Four TIEs were conducted on effluent from the Fayetteville Cross Creek WWTP. In all cases toxicity was completely removed using the C_{18} SPE columns. Two RTAs were conducted using acute toxicity as the end point and testing five important industrial contributors to the Fayetteville plant in an attempt to track the source of toxicity. Three of the industries were identified as contributing to pass-through toxicity but attempts to isolate the effect of each in a synthetic wastewater failed because of interference from biomass toxicity.

The work concluded with the study of biomass toxicity at three wastewater treatment plants. Return activated sludge was centrifuged and toxicity measured on the centrate. In two of the three cases, the centrate was found to be greater than the toxicity of the whole effluent.

III. METHODS

The objectives of this project centered on obtaining information about the TRE process directly from municipal treatment plants. The first step was to develop a questionnaire that would adequately survey all areas necessary to evaluate the TRE process. Table 3.1 outlines the information considered to be important.

Plant operation information was requested to characterize the type of plants experiencing toxicity problems. Information on biomonitoring was desired to provide data on the nature of the toxicity experienced. The majority of the survey was designed to deal with the plant's TRE experience as defined by the components of a TRE listed in the EPA protocol. Each component was defined to help focus on the outcome of the task and to help the respondents, who in many cases do not personally perform the TRE, identify whether the activity was completed and if it was beneficial. Finally, the goals of a TRE, the identification of toxicant and a correction action, were addressed. The questionnaire developed is shown in Appendix A.

After developing the questionnaire, the next step was to identify POTWs that had conducted TREs. The scope of this project was limited to an EPA Region rather than to the entire country because of funding and time limitations. Region IV was chosen because it has been a leader in the implementation of the TRE and therefore would provide a larger database than the other regions. Moreover, a better response was expected because we were located in this region.

In Region IV, all states except Florida administer the NPDES program. The states of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee and the EPA Region IV office in Atlanta, Georgia were contacted to provide a list of municipalities that

TABLE 3.1

INFORMATION TO OBTAIN FROM TOXICITY REDUCTION SURVEY

General Information:
- POTW Plant Location
- POTW Plant Name
- Contact person at POTW

Plant Operation Information:
- Plant flow rate
- Estimate of influent sources
  - (industrial vs municipal)
- Type of treatment system before TRE

Biomonitoring Test Information:
- Whole effluent toxicity limits
- Type of tests required (acute or chronic)
- Species used
- Frequency of testing
- Who performs biomonitoring tests
- Report of results (how detailed)

TRE/TIE Information:
- Condition that mandated TRE
- Start and end dates of TRE
- Who performed TRE
- Results of TRE municipal protocol components and how useful in correcting problem:
  - Information and Data Acquisition
  - Performance Evaluation
  - TIE Phase I - Toxic Characterization
  - TIE Phase II - Toxic Identification
  - TIE Phase III - Toxic Confirmation
  - Toxicity Source Evaluation
  - POTW In-Plant Control Evaluation

Corrective Action:
- Toxicant identified
- How toxicity was reduced using information from TRE/TIE

had conducted TREs. Several states did not provide sources. The State of Mississippi indicated that they have only recently begun biomonitoring of municipal treatment plants and that the biomonitoring is only performed at facilities that have industrial input. The state of South Carolina did not have any facilities that had proceeded to the latter stages of the TRE. The state of Georgia also did not have any facilities in the latter stages of the TRE. The result of these contacts with state and EPA Region IV personnel was a list of 37 municipal wastewater treatment organizations that were under orders to conduct TREs.

After identifying the WWTPs, attempts were made to contract the POTW by telephone to express the purpose of the project, to request their participation, and to ensure the questionnaire would be sent to the proper person. This personal contact was important to encourage the participation in the survey. A copy of the questionnaire along with a cover letter reiterating its purpose was then sent to each facilities.

In addition, the state of North Carolina identified several facilities that had experienced a reduction in toxicity after construction projects even though the projects had not been designed specifically to address toxicity. While not specifically related to the TRE protocol, the experience of these WWTPs could still be important in addressing corrective actions to toxicity problems. Thus, information was obtained from these facilities by telephone but the questionnaire on conducting a TRE was not relevant.

IV. RESULTS

A. NORTH CAROLINA TELEPHONE SURVEY

In discussions with the North Carolina Department of Environmental Management, four municipal treatment plants were identified that had not undergone a TRE but had seen a reduction in toxicity after construction projects were completed. These facilities were at Ashboro, Benson, and High Point (Eastside and Westside). Each was contacted during the summer of 1992 and asked what processes or capabilities the construction project had added to the treatment plant.

In Ashboro, the plant treats an influent that is 75% industrial and includes flow from battery manufacturing, metal finishing, and textile manufacturing at an average flow of 4.7 MGD. The plant effluent was found to exhibit toxicity prior to the start of a major construction project. Because the project was already planned, the state agreed to allow the facility to conduct bench-scale tests based on their new treatment plant train rather than requiring a complete TRE. The existing plant consisted of bar screens, grit chambers, a trickling filter, secondary clarification, chlorination, and final aeration. The construction project was aimed primarily at increasing the capacity of the plant from 4 to 6 MGD but also added nitrification capability to the plant using an extended aeration process that the plant personnel referred to as the Schreibel process. Dechlorination is not included in the plant.

Testing after construction confirmed the reduction in toxicity shown in the bench-scale studies. The source of toxicity could be speculated to have been ammonia which is more effectively converted to nitrate in an extended aeration nitrification process than with a trickling filter process. Toxicity due to inadequate biological treatment capacity might also be indicated because the capacity increase also increased the biodegradation capacity of the plant.

In Benson, the utility was aware that their effluent was toxic and had attempted to identify the toxicant but their TIE tests were inconclusive. The construction project was initiated to increase capacity of the plant from 0.83 MGD to 1.5 MGD. Toxicity reduction was not considered in the project. The processes in the plant consists of bar screens, grit chambers, and oxidation ditch, secondary clarifiers, multi-media filters, chlorination, dechlorination, and reaeration. No new treatment processes were added in the construction. Testing after construction showed a reduction in toxicity. Inadequate biological treatment capacity would be indicated as the cause of toxicity because only capacity was increased and no new processes were added to the plant.

The Eastside and Westside plants in High Point were upgraded primarily to increase capacity. These plants had previously experienced problems with surfactants from the textile industries in the area and had requested the industries to change the type of surfactants used. Both plants employ the activated sludge process for biological treatment. The construction projects increased capacity of the existing processes and added sand filters after the secondary clarifiers. The Westside plant which is smaller and receives most of the chemical manufacture discharge but has passed all biomonitoring tests since the construction. The larger Eastside plant initially passed biomonitoring tests but has recently failed these tests. The toxicity problem is being investigated, but they have not been required to conduct a TRE. It is suspected that the return in toxicity may be due to industries using the banned surfactants. In addition to the known toxic surfactants which were banned by the city, toxicity prior to construction may have been caused by inadequate biological treatment because capacity was increased in the project or by suspended solids which are being more effectively removed with the addition of sand filters to the treatment train.

B. TOXICITY REDUCTION SURVEY

A questionnaire was sent to 37 POTWs in EPA Region IV in June of 1992. Of these 37 facilities, 18 were successfully contacted by telephone to request their participation. Replies were received from 23 of the 37 contacts for a response rate of 62%. Two of the municipalities indicated that they no longer exhibited toxicity problems. In one of these cases, it was believed that the initial biomonitoring test results had been inaccurate because subsequent biomonitoring by a more experienced laboratory indicated the plant effluent passed the NPDES permit limits. In the case of the second municipality, effluent toxicity was reduced due to a recent plant upgrade. Four of the municipalities had more than one facility with toxicity problems and completed more than one questionnaire. A total of 26 questionnaires were received. Table 4.1 summarizes the response rate to the survey.

The distribution of responses from the individual states in Region IV is shown in Figure 4.1. The largest participation was from Kentucky (38%), which also had the most POTWs contacted, followed by Florida (31%), North Carolina (15%), Alabama (12%), and Tennessee (4%). As was previously noted, questionnaires were not sent to Georgia, Mississippi, or South Carolina.

The first section of the questionnaire requested general information about the treatment plant in order to characterize the respondents. The distribution of treatment plant size is shown in Figure 4.2. While most of the respondents (69%) fell in the medium size plant range of 1-10 MGD, toxicity was found to be experienced at all plant sizes.

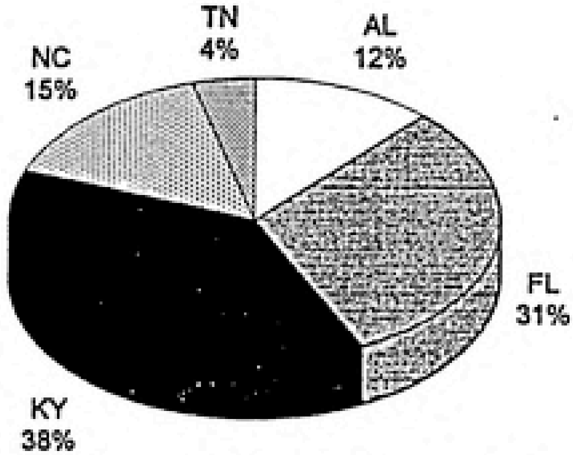
An estimate of industrial input to the plant was also requested (Figure 4.3). For the purpose of this study a plant was considered to receive a "major" industrial input if the industrial flow contribution was greater than 10% and a "minor" industrial input if the industrial flow contribution was less than 10%. The majority of the respondents received industrial discharges

TABLE 4.1

RESPONSE TO POTW TOXICITY REDUCTION SURVEY

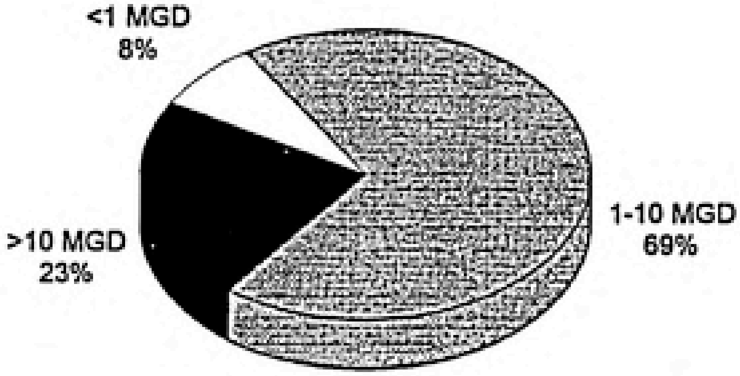
Total Number of Surveys Sent	37
POTWs Contacted by Phone	18
POTWs Contacted by Phone that Replied	16
Total Number of Replies	23
Percentage of POTWs that Replied	62%
POTWs No Longer Conducting TRE	2
POTWs Completing >1 Survey	4
Total Number of Completed Surveys	26

FIGURE 4.1
States Represented in TRE Survey



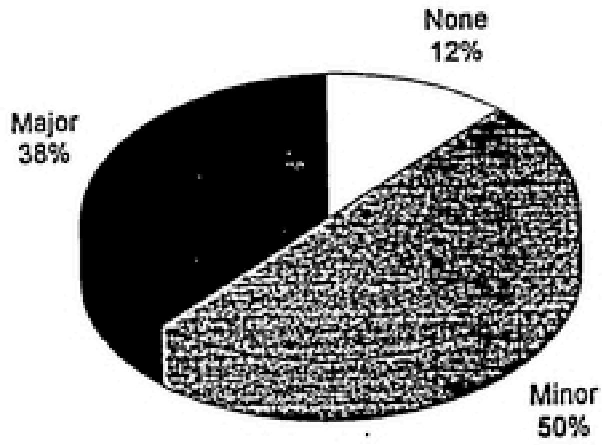
No questionnaires were sent to GA, MS, or SC.

FIGURE 4.2
Plant Size of Survey Respondents



Small - <1 MGD   Medium - 1-10 MGD   Large - >10 MGD

FIGURE 4.3
Industrial Wastewater Sources



Minor - 0-10% of Flow, Major - >10% of Flow

TABLE 4.2

SOURCES OF INDUSTRIAL INPUT

Textiles	Metal Finishing or Plating
Printing	Chemical Manufacture
Industrial Laundry	Food Processing
Pulp and Paper	Lead Battery Manufacture
Paint Manufacture	Groundwater Remediation
Dairy Products	Photo Processing
Electrical and Electronic Component Manufacture	

(88%) with 50% having minor (0-10% of the flow) industrial input and 38% having major (>10%of the flow) industrial input. Some of the sources of industrial discharges are shown in Table 4.2. A variety of sources were identified. Several of the sources were common to a number of the plants but seemed more to reflect the industrial base of the state (such as textiles in North Carolina) rather than one industry as causing more toxicity problems.

The second section of the questionnaire addressed the quality of the pre-TRE treatment systems. Figure 4.4 shows a breakdown of the secondary biological treatment systems used by the respondents. Most of the treatment plants (72.3%) had suspended growth systems. The suspended growth systems identified were activated sludge with mechanical aeration (31.0%), activated sludge with diffused aeration (20.7%), activated sludge using pure oxygen (10.3%), and oxidation ditch (10.3%). Attached growth systems were also represented and consisted of rotating biological contactors (RBC) (20.7%) and trickling filters (6.9%). While the type of biological treatment varied, the survey indicated that all the plants had what would be considered conventional secondary treatment and that toxicity problems were seen in several types of biological treatment systems.

Advanced treatment was also found at some of the treatment plants at noted in Figure 4.5. Nitrification processes were present at 46% of the plants, denitrification at 8%, and phosphorous removal at 27%. Nineteen percent of the plants had sand filters and 8% had dual media filters. A majority of the plants (77%) also dechlorinated the effluent prior to discharge. These results indicated that the addition of an advanced treatment processes to a conventional plant does not ensure the elimination of toxicity.

FIGURE 4.4
Biological Treatment Systems at Surveyed Plants

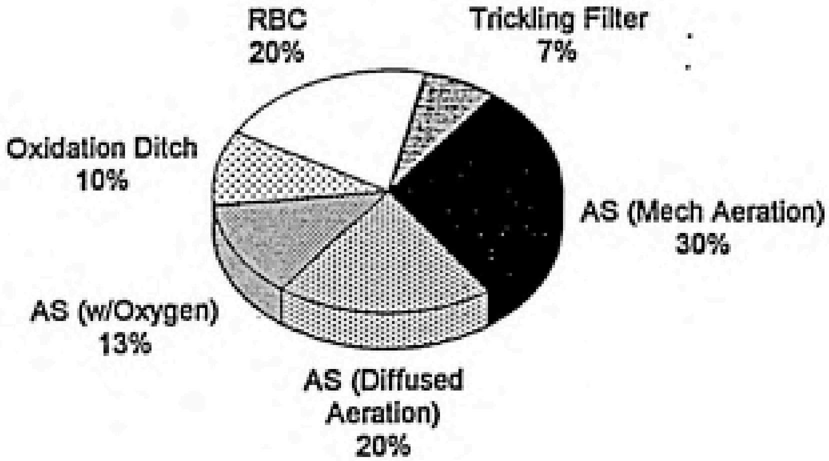
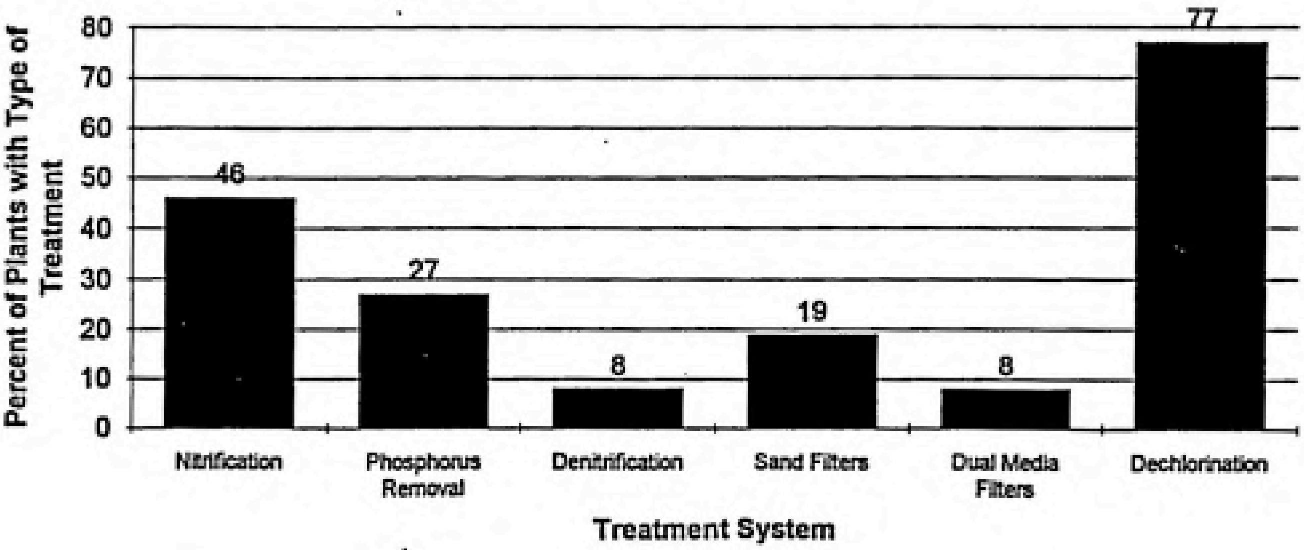


FIGURE 4.5
Advanced Treatment Sytems at Surveyed Plants



Next the questionnaire requested information about routine biomonitoring. Figure 4.6 shows a breakdown of the species used to monitor toxicity. The predominant species used was *Ceriodaphnia* (48%) followed by the fathead minnow (26%). Mysid shrimp (11%) was used in areas of Florida where the plant effluent discharges into brackish water. Other species included *Daphnia pulex* and *Menidia beryllina* (inland silverside). Most of the respondents (81%) do not have laboratory facilities for biomonitoring and instead contract this work to commercial laboratories.

The EPA Permit Writer's Guide[15] states there is generally no reason to mix two types of monitoring for the same outfall and that the permit limits should be derived from the test, acute or chronic, which provides the most restrictive performance level. Many of the respondents, however, have both acute and chronic limits in their permits. Table 4.3 lists the specific acute and chronic limits reported by the respondents. The types of toxicity exhibited at the POTWs is shown in Figure 4.7 with 39% experiencing only acute toxicity, 37% experiencing only chronic toxicity, and 24% experiencing both acute and chronic toxicity.

The remainder of the questionnaire dealt with the TRE experience. Time devoted to the TRE process by the respondents varied from four months to over four years. Eighty-nine percent of respondents had hired consultants to perform the TRE. Because revised TIE protocols specifically addressing chronic toxicity were issued after the questionnaire, the responses on experience with the TIE reflect the original protocol which only addresses acute toxicity.

The objective of each TRE component as identified in the EPA protocol was defined and then followed by questions pertaining to whether the step had been completed and whether a toxicant or corrective action had been identified by performing that step. Table 4.4 summarizes the results of the TRE protocol section of the survey.

The final questions dealt with the most important objectives of a TRE: that is, whether

FIGURE 4.6
Species Used to Monitor Toxicity

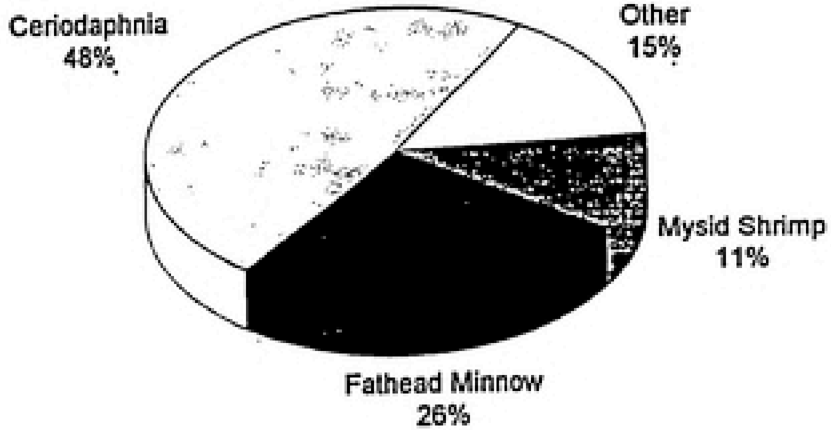


FIGURE 4.7
Type of Toxicity Exhibited

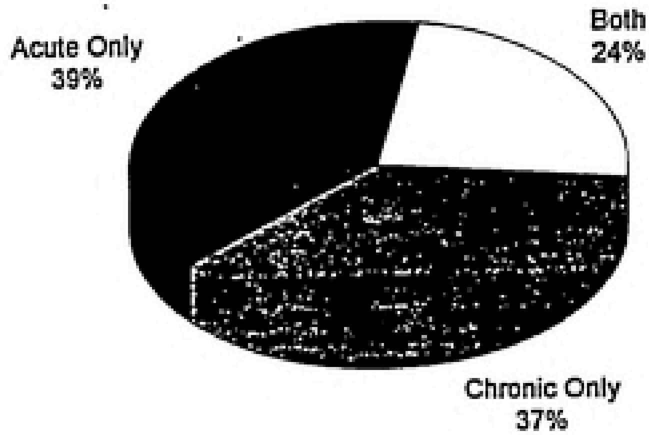


TABLE 4.3
REPORTED ACUTE AND CHRONIC TOXICITY LIMITS

<u>Acute Limits</u>:	LC_{50}	50% in 96 hours
		100% in 96 hours (2 POTWs)
		100% in 48 hours
		50% in 48 hours (2 POTWs)
		50% in 24 hours
<u>Chronic Limits</u>:	TU_c	1.0
		1.1
	NOEL	100% in 7 days (5 POTWs)
		91% in 7 days
		89% in 7 days
		99% Pass/Fail Mini-Chronic (2 POTWs)
		72% Pass/Fail Mini-Chronic
		4% Pass/Fail Mini-Chronic
	NOEC	8% in 7 days
		100% in 7 days (2 POTWs)
		83% in 7 days

TABLE 4.4

SUMMARY OF EXPERIENCE WITH TRE COMPONENTS

TRE Component	Number of Plants that Completed Step	Number of Plants that Identified Toxicant In step	Number of Plants that Identified Action In step
Information and Data Acquisition	16	1	4
Performance Evaluation	12	3	0
TIE - Toxicant Characterization	16	8	1
TIE - Toxicant Identification	10	8	0
TIE - Toxicant Confirmation	6	6	0
Toxicity Source Evaluation	9	3	2
In-Plant Control Evaluation	7	0	4

the toxicants were successfully identified and whether corrective actions were identified by the process. A toxicant had been identified in 13 of the 26 surveys. The toxicants identified are shown in Figure 4.8. The most common toxicant identified by the TRE was diazinon, a commonly used organophosphate insecticide, which was found in 54% of the cases. It should be noted that in half of these cases diazinon was suspected by the environmental officials and the WWTPs weredirected to proceed to the TIE phase and look specifically for diazinon. Thus in these instances, the TIE was biased toward an *a priori* assumption that diazinon was the cause of toxicity.

Corrective actions were identified in 14 of the 26 completed surveys. Figure 4.9 shows a summary of these actions. Most of the corrective actions (52%) are plant upgrades to increase plant capacity or changes in the biological treatment used. The selection of an alternative form of biological treatment was in most cases based on comparisons made with other treatment plants in their state. For example in Kentucky, a study by the Department of Water had indicated that RBC plants do not perform as well as an activated sludge plant in reducing effluent toxicity. Several RBC processes in Kentucky are being replaced with activated sludge processes.

Restrictions on industrial dischargers (33%) into the treatment systems are also being used as corrective actions. In some cases the restrictions were proposed based on the Information and Data Acquisition step of the TRE. In most cases, restrictions were not used exclusively but were used in combination with a plant upgrade or process improvement to the existing plant.

The importance of the biomonitoring species was also revealed. In 5% of the responses it was noted that the effluent passed the toxicity test after switching to a test species that was more indigenous to their receiving stream. These POTWs were located in coastal areas of Florida and discharged into ocean or brackish coastal waters. The change in species was from *ceriodaphnia* to *mysidopis bahia.*

FIGURE 4.8
Toxicants Identified in TRE

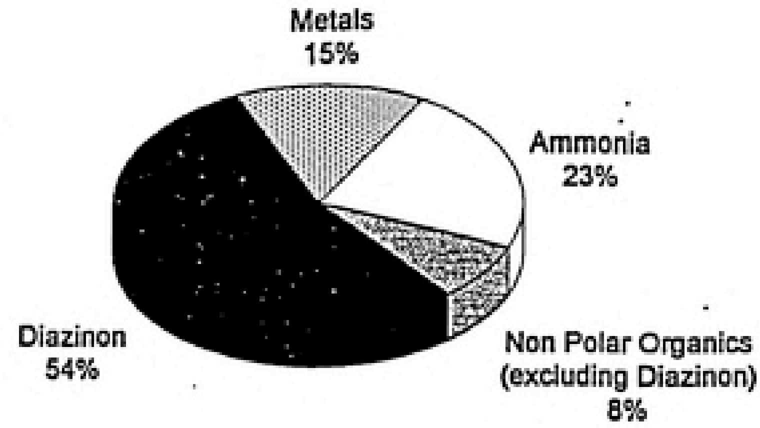
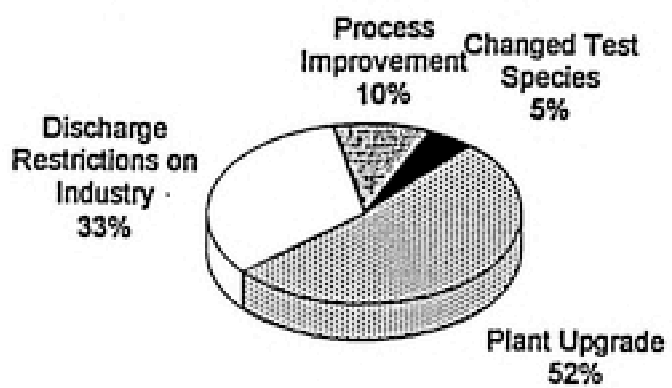


FIGURE 4.9
Corrective Actions Taken By POTWs



Throughout the questionnaire the respondents were given the opportunity to provide any comments or concerns about the TRE process. A summary of some comments addressing specific components of the protocol is listed in Table 4.5 and a summary of comments of a general nature on the TRE process is listed in Table 4.6. Several respondents stated that the information and data acquisition and POTW performance evaluation steps provided useful information that helped them assess the efficiency of their plant operation and rule out some possible toxicants. The in-plant control evaluation and source toxicity evaluation steps were also considered valuable because they helped compare possible corrective actions and evaluate whether plant process upgrades or changes in the type of biological treatment would eliminate toxicity. However, it was also noted that the information collected in these steps is based on short term evaluations and may not be representative of long term operation of the plant.

In cases where a specific toxicant was suspected, the TIE was very useful in confirming the toxicant. However, in a few responses where a specific toxicant was not suspected, the TIE was inconclusive, with all TIE manipulations eliminating toxicity. In some cases involving chronic toxicity, the toxicity did not seem to be strong enough or persistent enough for easy identification of a toxicant. It was also noted that the TIE protocol was developed for acute toxicity, and its usefulness in cases of chronic toxicity was questioned.

TABLE 4.5

SUMMARY OF COMMENTS ON TRE COMPONENTS

Information and Data Acquisition:

* The data we collected has been very useful but did not give us a conclusive answer to our toxicity problem.
* Collection of basic data allowed us to rule out some possible toxicants.
* We were able to get a general idea of what the toxicants were by viewing the information and data acquired by this protocol. It at least gave us some possibilities to look at.
* It is my understanding that this section establishes a data base for comparing possible corrective actions that may be required in later phases of the TIE. It is helpful to analyze data from a broad standpoint initially, but it is hard to discern short-term "trends" at a POTW.
* The city is on the 304L list for cadmium, zinc, and high chloride in the effluent. All three were eliminated as possible causes of toxicity.
* Treatment plant has failed biomonitoring on an inconsistent basis. No consistent pattern for follow-up to confirm and identify sources.

Performance Evaluation:

* The plants operate efficiently, but were not designed to remove the suspected toxicant (ammonia). All other possible sources of toxicity caused by any of the plant processes were eliminated.
* I am currently in the process of doing an in-depth PPE (POTW Performance Evaluation) especially as it pertains to secondary treatment. I think that this phase was not given enough emphasis in the original work that was done by our consultant.
* Division of Water study on Kentucky POTWs to correlate RBC versus oxidation ditch (sic) process and percent industrial flow versus commercial and residential shows that RBC POTW will not pass biomonitoring and that percent industrial flow is not a factor.

TIE Phase I (Toxicant Characterization):

* Some significant results were obtained from certain bench top treatment only to be negated with further testing .
* Most of the characterization steps were performed. The better results came from the pH adjustment. We seemed to have better survival rates at lower pHs. This correlates with the theory that there is less unionized ammonia at lower pH levels. (Facility that identified ammonia as toxicant.)
* Specific toxicants could not be identified by TIE. City attempted to find the source of toxicity. Simulation of oxidation ditch process on raw influent produces an effluent that passes test. Division of Water has given permission to stop TRE/TIE work until oxidation ditches are complete and tested.
* On the TIEs performed, some had several indications of possible treatments and the next group had different results.
* Toxicity not strong enough or persistent enough for easy identification.

TABLE 4.5 (CONTINUED)

* All manipulations reduced and/or eliminated toxicity.
* Any and every manipulation proved effective!
* We are having trouble with this test due to the fact that only a third of our samples show toxicity.

TIE Phase II (Toxicant Identification):

* A zeolite column was used to strip ammonia from the test aliquots. This gave us greatly improved survival rates. (POTW that had ammonia toxicity.) A number of the 126 priority pollutant scans were performed on effluent samples from both plants but data indicated an absence of any of these toxicants.
* On the TIEs performed some had several indications of possible treatments and the next group had different results.
* Toxicity not strong enough or persistent enough for easy identification.
* All tests were inconclusive.

TIE Phase III (Toxicant Confirmation):

* Side-by-side tests using zeolite-treated aliquots and normal aliquots proved beneficial to our theory. We also did the same procedure using freshwater test organisms side-by-side with saltwater organisms.
* EPA Region IV put the city under an administrative order to test for diazinon, malathion, and CVP (chlorofenvinphos). Upon finding significant amount of diazinon, the city was told to do a TIE Phase II confirmation rather than do Phase I and Phase II Investigation. Phase III did confirm that diazinon is the primary toxicant.

Toxicity Source Evaluation:

* The toxicant diazinon was already known. In an attempt to track where the source was, the city collected samples from major lift stations, and investigated other possible sources (i.e. pet groomers, health departments for head lice control, etc.).
* Samples from industrial dischargers are analyzed bimonthly for various toxicants. Discharge violators are reprimanded accordingly. Samples are analyzed for toxicants such as metals, phenol, oil and grease, and cyanide. Pesticide analysis is not performed on a regular basis.
* While no toxicity testing has been done on any of our indirect dischargers, we monitor parameters that could contribute to toxicity, i.e. metals, chlorides, TTO, etc.
* Industrial section proved non-toxic. Commercial areas were somewhat toxic. A strictly residential area proved to be the most toxic by far. (Treatment plant that had diazinon indicated in TIE.)

TABLE 4.5 (CONTINUED)

POTW In-Plant Control Evaluation:

* Through comparison studies between our two plants, one in which little or no toxicity occurred and the other in which high toxicity occurred, possible corrective actions were determined.
* Very helpful in planning the needed upgrade.
* Breakpoint chlorination was used by the consulting lab to remove ammonia from our effluent samples. This procedure did not work well in the lab environment. It was tried at one plant but proper chlorine dosage could not be attained.

Corrective Action:

* It is believed that once the plant is upgraded to AWT using the A^2/O technology (a biological phosphorous removal process with nitrification) and as long as the plant is operated well, the toxicity will be controlled. Evidence of this has been collected using another city's A^2/O plant for comparison. Further investigation is taking place to determine the control parameters to insure that the diazinon is removed through this process.
* Diazinon is believed to come from non-point source, thus no corrective action was taken.
* Existing RBC units were not considered as effective for toxicity reduction as activated sludge process. Therefore, completed an oxidation ditch expansion.

An interesting observation was made by examining the cases (excluding the change in species) where correction actions had been identified. Figure 4.10 shows a breakdown of the types of toxicity in those cases. On the surface, the figure would indicate that the TRE is successful in identifying solutions to acute and chronic toxicities. However, when the specific cases were reviewed it was found that in the acute only cases, specific toxicants were identified in all while in the chronic only and both acute and chronic cases, no specific toxicants were identified. This tends to confirm the comments that the present TRE does not work well in identifying toxicants when chronic toxicity is exhibited.

In September 1992, a new protocol, "Toxicity Identification Evaluation: Characterization of Chronically Toxic Effluents, Phase I", EPA/600/6-91/005F, was issued along with the revised documents, "Methods for Aquatic Toxicity Identification Evaluation: Phase II Toxicity Identification Procedures", EPA/600/R-92/080, and "Methods for Aquatic Toxicity Identification Evaluations: Phase III Toxicity Confirmation Procedures for Acutely and Chronically Toxic Samples", EPA/600/R-92/082, to provide guidance specifically for chronic TIEs.[5] The documents were prepared based on experience with *Ceriodaphnia dubia* and *Pimephales promelas* (fathead minnows) as the test organisms. The Phase I procedure has been modified for chronic toxicity and uses a two-tiered approach which in the effluents examined has considerably reduced the toxicity testing time. Phase II protocol was revised to provide procedures for the identification of non-polar organics, metals, and ammonia and to provide guidance for the identification of surfactants. The revised Phase III document provides more detail on each confirmation approach and contains a chapter on hidden toxicants, i.e., toxicants which are non-additive or partially additive and toxicants which are present at dramatically different toxic unit ratios. The new documents should improve the success to toxic identification in chronic cases.

FIGURE 4.10

Type Toxicity for Which Corrective Action Was Identified

Another concern was that the protocol is too complicated for the average wastewater operator to follow. This limits practical input that an operator could provide to the study that a consultant cannot provide.

The suitability of biomonitoring as an enforcement tool, particularly with chronic toxicity, was also questioned. Several facilities have experienced inconsistencies in the results between certified laboratories with blind samples showing significantly different toxicity. In fact two facilities that indicated they were no longer conducting a TRE said that toxicity was eliminated by changing laboratories. One case was also noted where the control was more toxic in chronic tests than the effluent sample.

Comments also enforced the belief that the TRE can be a time-consuming and expensive process. This was particularly frustrating in cases where the TRE has been completed and a toxicant or corrective action had not been identified. One facility listed the cost of the TIE at $2500 per test. Another that had been conducting a TRE for approximately three years listed a total cost of $100,000. A follow up contact made to a small facility which contracts their TRE testing, and which has been in the process for less than a year, indicated they are budgeting $9600 for testing next year and anticipate that they may require testing costing up to $20,000 per year if they cannot resolve their toxicity problems. A larger municipality which does their testing in-house spends approximately $25,000 per year on labor and materials. All POTWs that commented indicated that this cost is significant in their budget.

Finally, when mandated to conduct a TRE each facility seems to have sincerely done their best to resolve the toxicity problem. However, the ability of each facility to achieve toxicity reduction differs. To make full use of the information provided by the TRE, the process and the deliverables from each stage must be understood by both the consultant, if one is hired, and the personnel at the municipality. Some of the municipalities, particularly the smaller ones, commented that they do not have adequate staff or technical background to devote to the process. This problem was indicated by some of the responses in the questionnaire. After the objective of TRE component was defined in the questionnaire, the respondents were asked to indicate whether the step had been completed. In many cases the respondents didn't know whether the objective defined had been completed either by following the protocol or by using some similar procedure. In several cases where a second consultant had been hired it was noted that they now realized that the first consultant had not followed the TRE protocol.

Few respondents indicated that they received help from either their state or the EPA other than a copy of the protocol. In cases where there had been assistance, it was indicated to be very helpful. Improved assistance with the TRE process from states and the EPA to the municipalities may be one way to help municipalities ensure they are proceeding correctly and logically through the process.

TABLE 4.6

SUMMARY OF GENERAL COMMENTS ON THE TRE PROCESS

* The U.S. E.P.A. Region IV personnel have been both helpful and patient in allowing the city to resolve this toxicity problem.

* The whole process is subject to influences that we believe are beyond the control of the laboratory and the treatment plant. The fresh water species are very sensitive to the slightest change in their environment. Our toxicity has been intermittent which only exacerbates the problem.

* Made very little progress in TRE with identifying toxicant before we had our species changed to salt water species.

* State provide assistance in conducting TRE but only after the TRE had been in progress for almost a year. Only "assistance" from EPA was handbooks.

* I don't like biomonitoring. It is costly, unbelievably time-consuming, and in many cases, inconclusive. I think the protocol is too complicated for the average wastewater operator to follow. I have a degree in biology and experience in basic research studies, and I find it a real challenge to try to figure out what I'm supposed to do next. I'm afraid that valuable local input for the TRE from wastewater operators who know their facilities is being wasted, because the protocol is intimidating. This may be part of the reason that TIE studies are often inconclusive - they lack local input (that a consultant generally cannot give).

* "Toxicity Reduction Evaluation Protocol for Municipal Wastewater Treatment Plants" not a good tool for identify chronic toxicity - great for acute toxicity.

* Still conducting TIE. All Phase II tests have been inconclusive. We have not identified toxicant as of yet and feel like money is being thrown down the drain ($2500 per test) in a fruitless search for such a low-level toxicity. After almost 2 years of chronic toxicity testing and a diligent effort to attain compliance, we have begun to feel frustrated. The problems with the TIEs and TREs, in my opinion, are due to the potential of any single event occurring during a seven day period with a duration of less than 1 hour ... with the permittee generally unaware of the event's occurrence. It could even be a rainfall causing run off of metals from the road, or pesticides/insecticides from yard applications, etc..

V. CONCLUSIONS AND RECOMMENDATIONS

Many municipalities have been required to conduct TREs when the toxicity limits of the permit were repeatedly violated, and have found them to be expensive and time-consuming. This study gave municipalities in EPA Region IV that had conducted TREs the opportunity to assess the benefits of the EPA municipal TRE protocol in identifying the toxicant and corrective action, and to identify any problems or concerns they had with the TRE process.

Treatment plants required to conduct a TRE varied in size, industrial input, type of biological treatment, level of advanced treatment, biomonitoring species used, and type of toxicity experienced. Responses were received from 23 of the 37 municipal WWTPs contacted and represented 5 of the 7 states in EPA Region IV. A majority of the facilities that replied could be classified as medium flow rate (1-10 MGD) plants with minor (0-10% of flow) industrial input. Most plants employed what would be considered conventional secondary treatment and some also used advanced treatment process.

In cases of acute toxicity, the protocol appeared to be useful in identifying both the toxicant and corrective action. For cases of chronic toxicity or both acute and chronic toxicity, the protocol was not very successful in identifying the toxicant but was helpful in identifying a corrective action. The process can be extremely frustrating when multiple toxicants appear to be present (i.e. all sample manipulations eliminate toxicity) or when the toxicity is intermittent. EPA has revised the TIE protocols to address these issues.[10] The improvement provided by these new protocols should be assessed after municipalities have some experience with them.

It would also be valuable to study the entire sampling process.[16] The comments expressed concerning chronic testing suggest variability errors. The variability due to preparation error has been examined.[17] A statistical evaluation should be used to define the sources of error and to determine whether the sampling procedure provides a representative sample.

The major complaint about the TRE process was the cost of testing. A single test can cost $2500 and municipalities have had to budget approximately $10,000 to $25,000 extra per year for this special testing. These costs are significant in their budgets. Comments about the TRE process were particularly negative in cases where the tests were inconclusive, had to be repeated several times, or differed between laboratories. As stated above, the protocols have been revised to address some of these issues. However, based on the concerns of the survey respondents there still appears to be a need for a cheaper method to assess toxicity rather than a modification of an existing one.

Another major complaint was the time, or probably more appropriately the staff, required to conduct the TRE. The POTW staff may not have sufficient number or expertise to conduct the TRE in-house. Hiring a consultant adds additional costs to their budgets. However even with a consultant, the municipality needs to understand the TRE process and the purpose of each step to ensure their money is being well spent. This issue could be addressed by either simplification of the TRE protocol, more detailed information on the deliverables to be expected from each step of the TRE, or more assistance from the state agencies or the EPA. Draft documents that provide detailed guidance for conducting the POTW Performance Evaluation[18] and the TSE - In-Plant Control Evaluation[19] have been prepared by EPA and should aid in these steps after the documents are issued.

A specific technology development need that might be indicated from the survey is for an accepted treatment process to remove diazinon. Corrective actions identified by the respondents were not consistent. Some indicated nothing could be done while others are pursuing expensive treatment plant upgrades.

In general, the municipalities believed biomonitoring is a useful tool for assessing the toxicity of their effluent. They also indicated that useful information about their plant operation and possible improvements could be obtained from the TRE. However, many were frustrated with the TRE process and believed it should not be used as an enforcement tool until the problems they have experienced are resolved.

Due to funding and time limitations, this study was limited to a written survey in format and EPA Region IV in scope. Comments concerning biomonitoring and the TRE process were consistent with views that have appeared in the literature[20,21,22,23] and with personal contacts with consultants that have performed TREs. Repeating this survey to encompass more EPA Regions might be valuable to confirm that the concerns are similar in other parts of the country. It is suggested that more time be invested at the beginning to investigate the availability of databases to identify POTWs conducting a TRE, rather than having to contact each state individually as was done in the study (a very time-consuming step). The questionnaire developed was quite lengthy (6 pages) but did not provide comprehensive details of the problems. Future surveys might be more productive if they focused more on one component of the TRE protocol and were directed to the person actually doing the work (another time-consuming identification step).

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APPENDIX

COVER LETTER SENT TO POTW CONTACTS

Dear :

Thank you for agreeing to participate in our survey on the experience of POTWs using EPA protocols for toxicity reduction evaluation (TRE) and toxicity identification evaluation (TIE). This study is being conducted as part of a Cooperative Agreement between the U. S. EPA and the University of North Carolina. I am the principal investigator of the project. Pat Backus, a Master's degree candidate in Environmental Engineering, is conducting this survey as part of her Master's Report. The information you provide will help us assess the usefulness of the current TRE and TIE protocols in identifying toxic agents at POTWs. It will also be used to direct our research on developing bench-scale treatability tests that may be incorporated into the TIE protocol at a later date. Our goal is to provide POTWs with a more practical tool for solving effluent toxicity problems.

The survey is divided into several sections to request information on your treatment plant operation, NPDES permit, biomonitoring requirements, TRE/TIE experience, and corrective action taken as a result of the TRE/TIE. You are welcome to provide any additional comments you have on your experience with the TRE.

We understand that many POTWs have hired consultants to perform TREs. If this is the case at your POTW, we would greatly appreciate you permitting us to contact your consultant if we have additional questions on what was done in the TRE.

Please send the completed survey back in the enclosed stamped and addressed envelope. If you have any questions about filling out the survey form or about the disposition of the data, please call me at (919) 966-2480. Thank you again for your participation.

Sincerely,

Francis A. DiGiano, Professor
Water Resources Engineering

POTW Toxicity Reduction Survey

General Information:

POTW Name: ______________________________

Contact Person: ______________________________

Address: ______________________________

____

____

Phone: ______________________________

Plant Operation Information:

Wastewater Sources: Industrial (%) ________ Municipal (%) ________

Types of Industries:

- ☐ Textiles
- ☐ Food Processing
- ☐ Metal Finishing or Plating
- ☐ Pulp and Paper
- ☐ Petroleum Refining
- ☐ Chemical Manufacture
- ☐ Electrical and Electronic Components

☐ Other ______________________________

____

Permitted Plant Capacity: ________ mgd

Components of Treatment System Before TRE(If there is more than one treatment train please enter a number in the boxes to identify each train.):

- ☐ Bar screens
- ☐ Comminutors
- ☐ Grit chambers
- ☐ Primary clarifiers
- ☐ Trickling filters
- ☐ Oxidation ditch
- ☐ Activated sludge with diffused aeration
- ☐ Activated sludge with mechanical aeration
- ☐ Rotating biological contactor
- ☐ Sequencing batch reactors
- ☐ Phosphorus removal
- ☐ Nitrification
- ☐ Denitrification
- ☐ Secondary clarifiers
- ☐ Dual-media filters
- ☐ Multi-media filters
- ☐ Sand filters
- ☐ Granular activated carbon (GAC)
- ☐ Powdered activated carbon (PACT)

☐ Disinfection by ______________________________

☐ Dechlorination by ______________________________

☐ Diffuser on plant discharge

☐ Other ______________________________

____

____

Biomonitoring Permit Information:

Whole effluent toxicity limits: LC_{50} _______% in ____ hours

NOEL _______% in ____ days

Species used for tests:

☐ Ceriodaphnia ☐ Fathead minnow ☐ Mysid shrimp ☐ Other ____________

Frequency of biomonitoring:
☐ Monthly ☐ Bimonthly ☐ Quarterly ☐ Biannually ☐ Other ____________

Who performs biomonitoring tests?
☐ POTW ☐ State ☐ Contract lab ☐ Other ____________

Is biomonitoring information reported to the state or EPA using either EPA/600/4-85/014, Section 10, Report Preparation or EPA/600/4-89/001, Section 9, Report Preparation? ☐ Yes ☐ No

If no, how is information reported? ____________

____

TRE/TIE Information:

Toxicity is ☐ Acute and/or ☐ Chronic.

Approximate dates when you conducted TRE (month/year)?

Start ________ End ________

Did you hire a consultant to conduct TRE? ☐ Yes ☐ No

If we have questions on what steps were taking in conducting the TRE may we contact the consultant? If yes, please provide the following information.

Consulting Firm ____________

Office Location (city,state) ____________

Contact Person ____________

Phone ____________

Did your state provide assistance in conducting TRE?
☐ Yes ☐ No ☐ Not sure, ask consultant

Did EPA provide assistance in conducting TRE?
☐ Yes ☐ No ☐ Not sure, ask consultant

Was the EPA document "Toxicity Reduction Evaluation Protocol for Municipal Wastewater Treatment Plants" used in conduction the TRE?
☐ Yes ☐ No ☐ Not sure, ask consultant

TRE - Information and Data Acquisition:

This is the collection of data on the operation and performance of the POTW and data from the POTW's pretreatment program such as industrial waste survey applications and local limits compliance reports.

Did you use the EPA protocol recommended for this step?
☐ Yes ☐ No ☐ Not sure, ask consultant

If not, did you collect similar data but not using EPA protocol?
☐ Yes ☐ No ☐ Not sure, ask consultant

Were you able to identify the toxicant using the information gathered in this step? ☐ Yes ☐ No

Were you able to identify a corrective action using the information gathered in this step? ☐ Yes ☐ No

Comments on the use of "Information and Data Acquisition":

TRE - POTW Performance Evaluation:

This is the evaluation of POTW operating and performance data to indicate possible in-plant sources of toxicity of operation deficiencies that may be allowing toxicity pass-through.

Did you use the EPA protocol recommended for this step?
☐ Yes ☐ No ☐ Not sure, ask consultant

If not, did you collect similar data but not using EPA protocol?
☐ Yes ☐ No ☐ Not sure, ask consultant

Were you able to identify the toxicant using the information gathered in this step? ☐ Yes ☐ No

Were you able to identify a corrective action using the information gathered in this step? ☐ Yes ☐ No

Comments on the use of "POTW Performance Evaluation":

TRE - TIE Phase I (Toxicant Characterization):

Bench-top characterization steps that consist of toxicity degradation, aeration, filtration, C_{18} solid phase extraction, pH adjustment, oxidation-reduction, ETD chelation, and graduated pH treatments.

Did you use the EPA protocol recommended for this step?
☐ Yes ☐ No ☐ Not sure, ask consultant

If not, did you collect similar data but not using EPA protocol?
☐ Yes ☐ No ☐ Not sure, ask consultant

Were you able to identify the toxicant using the information gathered in this step? ☐ Yes ☐ No

Were you able to identify a corrective action using the information gathered in this step? ☐ Yes ☐ No

Comments on the use of "TIE Phase I":

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TRE - TIE Phase II (Toxicant Identification):
Specific test methods that can be used to further identify specific causative agents such as non-polar organic compounds, ammonia, cationic metals, or chlorine.

Did you use the EPA protocol recommended for this step?
☐ Yes ☐ No ☐ Not sure, ask consultant

If not, did you collect similar data but not using EPA protocol?
☐ Yes ☐ No ☐ Not sure, ask consultant

Were you able to identify the toxicant using the information gathered in this step? ☐ Yes ☐ No

Were you able to identify a corrective action using the information gathered in this step? ☐ Yes ☐ No

Comments on the use of "TIE Phase II":

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TRE - TIE Phase III (Toxicant Confirmation):

. of toxicant by a series of test steps including observation of test organism symptoms; additional species toxicity testing; and correlation of toxicity and toxicant concentration for multiple samples.

Did you use the EPA protocol recommended for this step?
☐ Yes ☐ No ☐ Not sure, ask consultant

If not, did you collect similar data but not using EPA protocol?
☐ Yes ☐ No ☐ Not sure, ask consultant

Were you able to identify the toxicant using the information gathered in this step? ☐ Yes ☐ No

Were you able to identify a corrective action using the information gathered in this step? ☐ Yes ☐ No

Comments on the use of "TIE Phase III:

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RE - Toxicity Source Evaluation:

Involves sampling the effluent of sewer dischargers or sewer lines for the toxics or toxicity and identifying the source.

Did you use the EPA protocol recommended for this step?
☐ Yes ☐ No ☐ Not sure, ask consultant

If not, did you collect similar data but not using EPA protocol?
☐ Yes ☐ No ☐ Not sure, ask consultant

Were you able to identify the toxicant using the information gathered in this step? ☐ Yes ☐ No

Were you able to identify a corrective action using the information gathered in this step? ☐ Yes ☐ No

Comments on the use of "Toxicity Source Evaluation":

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TRE - POTW In-Plant Control Evaluation:

Treatability testing is used to evaluate methods for optimizing existing treatment processes and to assess options for additional treatment to reduce effluent toxicity.

Did you use the EPA protocol recommended for this step?
☐ Yes ☐ No ☐ Not sure, ask consultant

If not, did you collect similar data but not using EPA protocol?
☐ Yes ☐ No ☐ Not sure, ask consultant

Were you able to identify the toxicant using the information gathered in this step? ☐ Yes ☐ No

Were you able to identify a corrective action using the information gathered in this step? ☐ Yes ☐ No

Comments on the use of "In-Plant Control Evaluation":

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____

____

Corrective Action:

Was toxicant identified? ☐ Yes ☐ No

If yes, what was toxicant(s)? _______________________

____

What corrective action was taken to reduce toxicity (such as improved existing plant operation, added more capacity, added or changed treatment train, improved monitoring of sewer dischargers, placed restrictions or industrial dischargers, repaired existing equipment, etc.)?

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(If you have any additional comments about toxicity problems, biomonitoring, or using the TRE/TIE EPA protocols, please attach them to the survey. Thank you.)