

WASTE REDUCTION



HANDBOOK FOR USING
A WASTE-REDUCTION APPROACH
TO MEET AQUATIC TOXICITY LIMITS

POLLUTION PREVENTION PROGRAM

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT, HEALTH, AND NATURAL RESOURCES

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for Using a Waste-Reduction Approach
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I Introduction to Aquatic Toxicity Testing and Control

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A. Introduction

Historically, the regulation of surface water quality and discharges to surface water has been accomplished through the use of chemical specific analyses of individual parameters. Limitations established using these methods are based on the effects that the individually measured chemical constituents are predicted to have on the receiving stream, its resident populations of organisms, and its designated uses. These effects are based on past observation and laboratory and field studies of effects of various levels of the chemicals.

One of the drawbacks of this method of controlling water quality is that the combined effects of every constituent of a wastewater discharge are impossible to determine, even where the identity and concentration of every constituent are known, which in itself is not generally feasible. Most wastewaters are a complex matrix of chemical substances which interact with each other and have varying effects on their surroundings, as compared to their singular presence in another solution. The U.S. Environmental Protection Agency has estimated that even GC/MS, one of the most heavily relied upon analytical tools for organic compounds, can detect only about 20 percent of the synthetic organics known to exist (Mount and Anderson-Carnahan, 1988). It quickly becomes obvious that the assessment of effects of a complex wastewater on aquatic organisms must be made using that whole wastewater and that the most efficient means of determining effects is by direct measurement.

A. 1. Biomonitoring: Instream Population Assessment: Direct measurement of the effects of whole wastewater is the strength of biological monitoring activities. Biomonitoring generally takes one of two forms. The first is instream population assessment. This technique requires collection of representative resident aquatic species, identification of these species, and a comparison of this population to a control population or a natural undisturbed population. This method has the benefit of showing population "memory" of ecological events, such as short term

discharges of toxicants. Disadvantages include the facts that the method does not indicate either the causative agent or the source of impact, and that it is not effective in determining effects during worst-case flow events unless the analysis is made during these events.

A. 2. Biomonitoring: Whole Effluent Toxicity Testing: Whole effluent toxicity testing is the other form of biomonitoring employed to control the impact of wastewater discharges. Whole effluent toxicity tests essentially expose sensitive aquatic species, representative of those organisms in the receiving stream, to the wastewater for a specified period and derive endpoints based on some response of the test organism.

Aquatic toxicity tests generally are designed as either acute tests, which measure an effect over a time span that is short relative to the life cycle of the organism, or as chronic tests, which are longer relative to the life cycle of the organism or span a very sensitive life stage of the organism. Both types of analyses compare the response of a "control" population of organisms to the response of a "treated" population of organisms in order to test whether the treated population shows some adverse effect.

Endpoints of these analyses are frequently measured as either lethality or as some non-lethal response such as suppression of growth or reproductive success. Lethal endpoints are most often reported as an "LC₅₀" or the concentration of effluent or toxicant that is predicted to kill 50 percent of the test population. Sublethal endpoints are frequently reported using values defined as NOEC or No Observed Effect Concentration, LOEC or Lowest Observed Effect Concentration, and ChV or Chronic value, the geometric mean of the NOEC and LOEC. The NOEC and LOEC are determined by statistical analyses of treatment response compared to control response for a particular test.

Since whole effluent toxicity testing is utilized by regulators as a method of predicting effects of the discharge on sensitive aquatic species, it is important that the test be shown to have predictive ability. Work by Mount et al. (1984 and 1985), Mount and Norberg-King (1986), Norberg-King and Mount (1986), and Eagleson et al. (1990) have shown the predictive

ability of *Ceriodaphnia dubia* chronic testing to provide a fair estimate of instream effects of a discharge.

A. 3. Test Reliability and Laboratory Competency: In the past, a great deal of discussion has been generated about the reliability of aquatic toxicity testing. While it is true that the methodologies being used are by no means simple or easy to perform, the inherent precision of these methods, when practiced by competent, experienced, and conscientious laboratories, is no less than that of most other analytical procedures used in water quality monitoring today. Specific inter-laboratory and intra-laboratory precision citations are given by the three basic testing protocol manuals published by EPA (U.S. Environmental Protection Agency 1985c, 1989a, 1988b). Aquatic toxicity analyses and interpretation of results of these analyses should be made by experienced professionals. Persons seeking assistance from commercial firms offering aquatic toxicity testing should confirm—by examining references, a list of past clientele and projects, and documentation of strict quality control practices, that the commercial firm has the necessary expertise and a commitment to quality.

B. Aquatic Toxicity - State and Federal Regulations

B. 1. The Clean Water Act: In 1972 the Congress of the United States passed the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (PL 92-500 amended by PL 100-4, 1987). The goals of this law are: (1) elimination of the discharge of pollutants to navigable waters, (2) provision of interim guidelines for the protection of aquatic life and aquatic recreational uses, (3) prohibition of the discharge of toxic pollutants in toxic amounts, (4) provision of federal financial assistance for construction of publicly owned wastewater treatment works (POTWs), (5) development of waste treatment management processes to control the sources of pollutants in each state, (6) provision for research to develop technology for eliminating the discharge of pollutants to navigable waters, and (7) expeditious development and implementation of programs to control both point and non-point source pollution.

B. 2. N.C. Water Quality Standards: North Carolina water quality standards adopted to meet the goals of federal regulations are found under N.C. Administrative Code § 15 NCAC 2B. 0200 *Classifications and Water Quality Standards applicable to surface waters of North Carolina*. Section .0208 of these standards, revised effective October 1, 1989, provides standards for toxic substances as:

.0208 STANDARDS FOR TOXIC SUBSTANCES AND TEMPERATURE

(a) Toxic Substances. The combination of toxic substances, either alone or in combination with other wastes, in surface waters will not render waters injurious to aquatic life or wildlife, recreational activities, public health, or impair the waters for any designated uses. Specific standards for toxic substances to protect freshwater and tidal saltwater uses are listed in Rules .0211 and .0212 of this Section, respectively. Procedures for interpreting the narrative standards applicable to all waters are as follows:

(1) Aquatic life standards. The concentration of toxic substances will not result in chronic toxicity. Any levels in excess of the chronic value will be considered to result in chronic toxicity. In the absence of direct measurements of chronic toxicity, the concentration of toxic substances will not exceed the concentration specified by the fraction of the lowest LC_{50} value which predicts a no effect chronic level (as determined by the use of acceptable acute/chronic ratios). If an acceptable acute/chronic ratio is not available, then that toxic substance will not exceed one-one hundredth (0.01) of the lowest LC_{50} or if it is affirmatively demonstrated that a toxic substance has a half-life of less than 96 hours, the maximum concentration will not exceed one-twentieth (0.05) of the lowest LC_{50} .

B. 3. NPDES Toxicity Limitations: As a result of these regulations and national policy guidance, the N.C. Division of Environmental Management (N.C. DEM) instituted the policy of

including whole effluent toxicity limitations in the NPDES discharge permits of all new or renewed major and complex minor dischargers effective February 1987 (N.C. Division of Environmental Management, 1987). These limitations are developed on the basis of protecting aquatic populations at a given site from the discharge of pollutants at chronically toxic levels. Exposure of the organisms is allocated under flow descriptions prescribed by water quality standards (NCAC § 15 2B.0206), specifically the permitted monthly average flow of the treatment facility diluted by the 7Q10 flow of the receiving stream. The 7Q10 value represents the lowest flow for a seven day period that should occur once every ten years, as provided by the U.S. Geological Survey for that stream segment. With this information, an expected dilution percentage can be calculated for each discharge to each stream segment as:

$$\text{Allowable Toxicity (Chronic Value)} > \frac{\text{PF}}{\text{PF} + 7\text{Q10}} \cdot 100 \text{ (Instream Waste Concentration)}$$

Where PF equals the permitted maximum average monthly wastewater discharge of the facility and 7Q10 as described. For example, a treatment facility with a permitted discharge of 0.6 million gallons per day (MGD) to a stream with a 7Q10 flow of 0.3 cubic feet per second (cfs) would have a calculated instream waste concentration (IWC) of 75.6 percent.

The particular toxicity limitation applied to a discharge will be based on that facility's IWC with the intent of protecting the organisms in the receiving stream from chronic exposure to toxicants at all times, based on dilutions occurring during low stream flow periods. Where the IWC of a discharge is calculated at less than 1 percent, the toxicity limit can usually be applied as an LC_{50} (that concentration of waste which causes 50 percent mortality in the test organisms) which is 100 times greater than the IWC. This provides the one-one hundredth times the lowest LC_{50} application factor discussed by the regulations cited above for protection against chronic toxicity where an acute/chronic ratio is not known. This allows the discharger to perform the often less expensive and less time-consuming acute toxicity test yet still provides protection from chronic toxicity as required by regulation. As an example, a discharge with an IWC of 0.6

percent would be required consistently to meet a whole effluent toxicity limit of an LC_{50} greater than 60 percent (0.6 X 100). These acute toxicity tests are most often required to use the water fleas *Ceriodaphnia dubia* or *Daphnia pulex*, which are sensitive aquatic invertebrates found throughout the world in clean surface waters and frequently used as laboratory indicators of toxic impacts of wastewaters.

B. 4. The Chronic Toxicity Test: Where an instream waste concentration exceeds 1 percent, the 100 times the LC_{50} factor cannot be used because the wastewater cannot be tested at greater than 100 percent. In this situation, the chronic toxicity of the waste must be tested directly. This is done by requiring that a sensitive test organism is exposed to the wastewater to determine whether it will affect the organism's ability to live, grow and reproduce in a manner statistically equivalent to a control population. The test that is receiving more and more use across the United States for this purpose is the *Ceriodaphnia dubia* survival and reproduction test. The organism is exposed to test concentrations for a six- or seven-day period to determine whether its survivability or reproductive success is impaired by the wastewater. A North Carolina modification of this EPA analysis exposes the organism to a single effluent concentration equal to the IWC of the facility.

C. North Carolina Program History

The N.C. Division of Environmental Management is responsible for regulation of surface water quality in the State of North Carolina. The U.S. Environmental Protection Agency (EPA) has delegated to N.C. DEM's Water Quality Section the authority to administer the National Pollutant Discharge Elimination System (NPDES) permitting and enforcement process in the state. The N.C. Water Quality Section began to measure responses of aquatic organisms to environmental stresses in the late 1970s in response to the national trend to balance technology-based effluent limitations with water quality-based regulations.

In the 1970s the aquatic biology staff engaged in broad based assessments of populations of benthic macroinvertebrates, planktonic and periphytic algae, and fish as well as investigations

of the feasibility of the state's use of newly developing strategies of monitoring whole effluent acute toxicity as described by the U.S. EPA in 1975 and later in 1978. When it became evident that whole effluent toxicity monitoring and control would be a national focus for EPA, the N.C. Water Quality Section established a permanent and separate work group of scientists to develop capabilities in this field. The Aquatic Toxicology Group (now Unit) was formed in January 1983. Since that time, the Unit has become one of several programs used by the Division to assess the biological integrity of North Carolina's surface waters.

During 1983, the Group conducted its first *Ceriodaphnia dubia* and fathead minnow sub-lethal toxicity tests in joint studies with EPA Region IV biologists. The 1985 publication of short term, sub-lethal toxicity test methodologies (U.S. Environmental Protection Agency, 1985a) and subsequent publication of a technical support document by EPA (U.S. Environmental Protection Agency, 1985d) formed the basis for implementing aquatic toxicity testing. The importance of sub-lethal toxicity assessment for a regulatory agency was discussed by Eagleson et al. in 1986. This report pointed out that approximately 49 percent of the acute aquatic toxicity testing accomplished to that date did not sufficiently address sub-lethal impacts of wastewaters due to the limited sensitivity of acute lethal analyses.

From 1985 to 1987 aquatic toxicity testing and monitoring of whole effluent toxicity became increasingly important in the day-to-day work of the Water Quality Section. Results were used as weighted evidence in judgments on permitting issues of conventional and individual toxic pollutants. Intensive on-site toxicity evaluations conducted with the Division's mobile toxicity laboratory provided information to both the state and discharger on what effluent constituents or characteristics might cause observed toxicity.

C. 1. The Monitoring Requirement: The monitoring requirement now in effect grew directly out of procedures established in the implementation phase of the toxicity testing and control program. Any discharger whose effluent is found to be toxic through state testing is required to do appropriate effluent toxicity testing. This requirement is issued through

administrative letter, as part of the NPDES permitting process. This letter states that whole effluent toxicity is likely to become a limited parameter upon permit re-issuance and that monitoring should be used as an information-gathering process to determine the source of and to reduce observed toxicity to levels that will likely be imposed by the new permit. Where this monitoring information demonstrates that a facility is not able to substantially reduce effluent toxicity under the administrative letter requirement, the subject permit may be reopened and permit limitations may be established before scheduled renewal takes place.

C. 2. Definition of Non-Compliance and the SOC: Monitoring frequency applied to discharges is a factor of how much data is available already on effluent toxicity, how much potential for variability of effluent toxicity exists, frequency and volume of discharge, and special situations such as discharge above particularly sensitive watersheds. Non-compliance with whole effluent toxicity limitations has been defined by North Carolina as a failure to meet required standards on two consecutive required monitoring events. The facility is issued a notice of violation or non-compliance, and is asked to provide information to the state describing what activities the facility will undertake to investigate and correct the non-compliant situation. Where non-compliance remains a problem over time, the facility may wish to enter into a Special Order by Consent (SOC) with the N.C. DEM. The SOC gives a facility relief from possible penalty a specified period during which the facility agrees to perform remedial activities. Should the activities not solve the problem within the specified period, DEM may grant the facility an extension or may proceed to civil enforcement. Should the facility not wish to enter into an SOC, enforcement activities would begin as the result of recurring non-compliance.

C. 3. Monitoring Costs and the N.C. Mini-Chronic Analysis: One concern many dischargers have expressed about toxicity monitoring requirements is that of the cost of performing the analyses, particularly the chronic test. The multiple concentration EPA analysis is being offered by a few commercial laboratories at costs of between \$1000 and \$2000 each. For many smaller municipalities and industrial firms this cost would be prohibitive where monthly monitoring is required. Thus DEM has established that in cases where compliance

means causing no observable effects at the defined instream waste concentration, a single concentration test will be appropriate to demonstrate compliance. Methods for performing such a test were developed by staff biologists and approved by the Director of the Division as the North Carolina *Ceriodaphnia* Chronic Effluent Bioassay Procedure, December, 1985 (Rev. 6/88, 9/89).

This analysis varies from the full range EPA *C. dubia* chronic analysis. It is performed using two samples collected during the test, which are used in set up, and two renewals. The significance of the difference between reproductive results from the treatment population and reproductive results from the control population is determined at the 99 percent confidence level. While the analysis is designed to be performed using a single effluent concentration to determine compliance, an appendix of the methodology describes procedures for performing a multiple concentration test to determine actual effect level.

When performed using the single effluent concentration, this method reduced the fee for the analysis to the range of \$250 to \$400 and made it an effective tool for showing compliance. Where non-compliant situations were indicated, many dischargers opted for a multiple concentration test to determine severity of toxicity. However, using the N.C. modified test procedure, even this test can be done at a reduced cost because only two samples are needed and the laboratory effort is reduced. For instances where the issue of acute toxicity within a mixing zone applies, a similar acute "pass/fail" test has been established which exposes a population of at least 40 (4 replicates X 10 organisms) sensitive aquatic organisms to a high effluent concentration to determine significant lethal effects compared to a control population.

D. Program Objectives and Strategy

Throughout the history of the Division's toxicity control efforts, it has been the operational strategy to work with whole effluent toxicity in a fair manner. Where indications of effluent toxicity have occurred, the indications have proven significant at a high degree of certainty. The abbreviated testing procedures developed by the Division are examples where the

statistical significance levels have been increased to 99 percent, so that in the absence of a dose/response curve (which remains available at the discretion of the permittee), the reliability of the data is greater yet. In December 1988 it became the stated policy of the Water Quality Section that two consecutive failures of permit limitations of toxicity would be required before a discharger would be considered significantly non-compliant with limitations (N.C. Division of Environmental Management, 1988). While the requirement of two consecutive failures does not imply a retest or confirmation of the first event, it does help to provide weight of evidence that a problem situation exists on a recurrent basis.

D. 1. Test Results Requirements and Laboratory Certification: All facilities submitting results of aquatic toxicity analyses for NPDES requirements in North Carolina are required to have these analyses performed by a laboratory certified by the state (N.C. Administrative Code Section: 15 NCAC 2H.1100 Biological Laboratory Certification). The state's laboratory certification program, initiated in October 1988, is intended to provide dischargers access to laboratories with demonstrated competence in methodologies offered and to provide a means to control testing methods used.

As toxicity testing results are submitted to DEM by dischargers, each results sheet is reviewed for compliance with certain minimal quality assurance criteria and data propriety. These reviews are conducted by staff of the Aquatic Toxicology Unit which designed the reporting forms to assure the inclusion of sufficient information to make judgments on each test. Included in this information are test species, test date, sampling dates, initial and terminal dissolved oxygen, pH, and temperature of each appropriate test concentration, hardness, specific conductance, total residual chlorine, sample temperature on receipt by laboratory, replicate reproduction and/or mortality, statistics applied, and the signature of the responsible official certifying accuracy of data supplied. Should any of this information not be supplied or certain quality parameters not be met, a letter will be written to the discharger and/or the performing laboratory asking that a correction be made, where appropriate, or informing the facility that the data supplied is unacceptable and the testing effort should be repeated. As data is determined to be acceptable, it is entered into a database of self-monitoring toxicity

information. This database is updated and made available to the Division's seven regional offices on a monthly basis.

D. 2. Failure-to-Report Notices: Facilities which fail to satisfy reporting requirements are issued failure-to-report notices and may subsequently be fined by the state. When a facility has reported two consecutive tests results which indicate exceedances of effluent toxicity limitations, a Notice of Violation (NOV) is issued. The NOV indicates that the facility is in a significant non-compliant condition and requires that a report be submitted indicating what actions will be taken within a defined time period to correct the non-compliant condition. Once the facility has submitted requested plans of action and is able to pass the next monitoring event, this non-compliant situation will be considered resolved. When continued non-compliance is evident at a facility, two options are available to the state for resolution. The first is to continue directly to an enforcement action, which could lead to civil penalty or permit revocation. The second option and the one deemed most desirable in most cases is for the state to enter into an SOC as discussed earlier.

E. Consideration of Methods of Toxicity Reduction

The actions taken by a facility non-compliant with whole effluent toxicity limitations are, by default, a toxicity reduction evaluation. Because of the potentially complex nature of whole effluent toxicity and the likelihood that the causes of this toxicity vary at each facility, the state of North Carolina does not specify testing procedures for an acceptable toxicity reduction plan. Rather, plans are evaluated on the likelihood that they will bring the facility into compliance. There is no requirement that the facility identify particular causative toxicants as long as the whole effluent limitations can be met consistently.

E. 1. Published Resources for Toxicity Reduction: Several documents provide logical sequences for the evaluation of effluent toxicity. EPA's "Methods for Aquatic Toxicity Identification Evaluations" series (Mount and Anderson-Carnahan, 1988; U.S. Environmental Protection Agency, 1989c, 1989d) provides a strong basis for characterization, identification, and

confirmation of suspected toxicants. EPA has expanded on this methodology and identified problems and solutions specific to industrial facilities (U.S. Environmental Protection Agency, 1989e) and municipal wastewater treatment plants (U.S. Environmental Protection Agency, 1989f). Both of these documents provide a basis on which to formulate a facility-specific plan of action. In both documents, the importance of initial information-gathering phases is discussed. Wherever possible, information already in hand should be utilized to gain knowledge on potential toxicants in the waste stream. Chemical inventories, facility plumbing diagrams, compliance monitoring data, process or operating schedules, housekeeping practices, etc. can all provide useful information in the toxicity identification/reduction process, particularly where certain events can be correlated with increases or decreases in observed toxicity. The use of these existing resources should be considered among the most cost effective steps taken toward toxicity reduction.

E. 2. Initial Steps: Concurrent with information gathering, a review of existing housekeeping practices should be undertaken. This review should address all sources of waste including floor drains, cooling towers, air washers, boilers, washdown areas, cleaning areas, laboratories, etc. Any point at which wastewater can enter the collection system should be considered a possible source of observed toxicity.

The operational efficiency of the wastewater treatment system should be evaluated, including records that indicate variability in treatment efficiency. An efficient treatment system will decrease operationally affected toxicity variability, which will simplify identification of compounds causing toxicity.

An investigation of effluent toxicity variability, both short term and long term, can help identify toxicant additions. If variability can be correlated with events such as batch dumps, shift changes, or other operational activities, it may indicate which waste streams contribute to final effluent toxicity.

Further toxicity tests may also help identify sources of whole effluent toxicity. However, it is important to realize that what may be toxic in influent streams may not be causing effluent toxicity. Therefore, some credit for wastewater treatment is usually afforded separate influent streams, often by bench scale treatment in order to narrow in on problem areas. Toxicity that passes through the waste treatment system, or "refractory" toxicity can be addressed by bench scale treatment models that are frequently utilized by wastewater engineering firms for chemical/physical treatments and/or by biological bench scale treatments.

E. 3. Adapting Protocols: N.C. DEM does not view EPA toxicity evaluation documents as end-all solutions to toxicity reduction plan development. DEM encourages facilities to tailor methodologies to their own situations. This recommendation extends to the incorporation of chronic toxicity reduction by adaptation of these protocols. An argument against use of chronic toxicity reduction evaluations is that methodologies have not been published. Experienced aquatic toxicologists should be able to modify existing protocols to address deficiencies of the methods and design experimentation to address the variables present in chronic work. A few of these variables include: (1) the use of multiple samples (i.e. is the toxicity expressed by one sample indicative of the causative agents of another sample) versus the use of a single sample, which may degrade in toxicity over time and not be reflective of the results of a compliance test and (2) the fact that test species may be harmed as much by some chronic test procedures as by toxic compounds in test effluent. EPA is, in fact, currently developing protocols for working with chronic toxicity identification procedures that will provide some additional technical guidance.

When controlled experimentation is used to reduce whole effluent toxicity, an absolute methodology may not be necessary because one is seeking relative difference between test populations rather than an absolute measure of environmental impact. Once toxicity reduction is indicated, the defined standard testing methods can be utilized for compliance needs.

E. 4. Common Causes of Toxicity: Several common wastewater constituents have time and again, been implicated as causative or contributory agents of whole effluent toxicity: chlorine, ammonia, chloride, copper, zinc, biocidal compounds (as either process chemicals or as cooling tower/air washer treatments), pesticides, and disinfectants. If these compounds are in an effluent, their effects should be evaluated.

In many instances, these chemicals/compounds may appear in a wastewater without having been added during the manufacturing processes. Chlorine, copper, and zinc are frequently constituents of a municipally supplied water source. Adjustment of wastewater pH usually results in creation of chloride or sulfate salts, which can contribute to whole effluent toxicity. Cleansers, disinfectants and pesticides used in housekeeping can enter collection systems.

Generally, the term "toxic chemicals" brings to mind compounds like DDT, dioxin, and PCB's. One has to keep in mind that toxic effects can be produced by apparently innocuous constituents, if they are present at concentrations intolerable to aquatic species. Organisms killed by table salt are just as dead as organisms killed by priority pollutants. Reducing whole effluent toxicity is not a great problem if we don't preconceive the cause but follow a logical path toward identification of the source(s).

F. Bibliography

- Ahmad, N. et al. 1984. Aquatic Toxicity Tests to Characterize the Hazard of Volatile Organic Chemicals in Water: A Toxicity Data Summary. EPA 600/S3-84-009.
- Aquatic Invertebrate Bioassays. 1980. A.L. Buikema, Jr. and John Cairn, Jr., Eds. American Society for Testing and Materials. Philadelphia, Pa.
- Benoit, D.A. and G.W. Holcombe. 1978. "Toxic effects of zinc on fathead minnows (*Pimephales promelas*) in soft water." *Jour. of Fish Biol.* 13: 701.
- Bills, Terry D., Leif L. Marking, and Jack H. Chandler. 1977. Formalin: Its Toxicity to Nontarget Aquatic Organisms, Persistence, and Counteraction. In: *Investigations in Fish Control*. U.S. Dept. of the Interior, Fish and Wildlife Service, National Fishery Research Laboratory, La Crosse, Wisconsin.
- Birge, W.J., J.A. Black, A.G. Westerman, T.M. Short, S.B. Taylor, D.M. Bruser, and E.D. Wallingford. 1985. Recommendations on numerical values for regulating iron and chloride concentrations for the purpose of protecting warm water species of aquatic life in the commonwealth of Kentucky. Memorandum of Agreement No. 5429. Kentucky Natural Resources and Environmental Protection Cabinet.
- Bringmann, G., and R. Kuhn. 1977. "The toxicity of waterborne contaminants towards *Daphnia magna*." *Z. Wasser Abwasser Forsch.* 10(5):161-166.
- Brungs, William A. 1973. "Effects of residual chlorine on aquatic life." *Jour. WPCF* 45: 2180-2193.
- Chapman, G. A. et al. Effects of water hardness on the toxicity of metals to *Daphnia magna*. United States Environmental Protection Agency, Corvallis, Oregon. (Manuscript)
- Curtis, M.W., T.L. Copeland, and C.H. Ward. 1978. "Acute toxicity of 12 industrial chemicals to freshwater and saltwater organisms." *Water Research* 13:137-141.
- Dawson, G.W. et al. 1977. "The acute toxicity of 47 industrial chemicals to fresh and saltwater fishes." *Jour. Hazardous Materials* 1(4):303-318.
- Dowden, Bobby F., and H.J. Bennett. 1965. "Toxicity of selected chemicals to certain animals." *Jour. WPCF* 37(9):1308-1316.
- Eagleson, K.W., D. L. Lenat, L. W. Ausley, and F. B. Winborne. 1990. "Comparison of measured instream biological responses with responses predicted using the Ceriodaphnia chronic toxicity test." *Env. Toxicol. and Chem.* 9(8):1019-1029.
- Eagleson, K. W., S. W. Tedder, and L. W. Ausley. 1986. Strategy for whole effluent toxicity evaluations in North Carolina. *Aquatic Toxicology and Environmental Fate: Ninth volume*. ASTM STP 921, T. M. Poston and R. Purdy, eds. Philadelphia: American Society for Testing and Materials.
- Foster, L. Mayer, and M.R. Ellersieck. 1986. Manual of Acute Toxicity: Interpretation and Data Base for 410 Chemicals and 66 Species of Freshwater Animals. U.S. Fish & Wildlife Service Res. Pub. no. 160.
- Hashimoto, Y., and Y. Nishiuchi. 1981. "Establishment of bioassay methods for the evaluation of acute toxicity of pesticides to aquatic organisms." *Jour. Pest. Sci.* 6(2):257- 264.
- Johnson, Waynon W., and M.T. Finley. 1980. *Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates*. U.S. Dept. of the Interior, Fish and Wildlife Service, Washington, D.C.

Introduction to Aquatic Toxicity Testing and Control

- Leblanc, G.A. 1980. Acute Toxicity of Priority Pollutants to Water Flea (*Daphnia magna*). *Bull. Environ. Contam. Toxicol.* 24(5):684-691.
- Lewis, M.A. 1983. "Effect of loading density on the acute toxicities of surfactants, copper, and phenol to *Daphnia magna* Strauss." *Arch. Environ. Contam. Toxicol.* 12:51.
- Mattson, Vincent R., J.W. Arthur, and C.T. Walbridge. 1976. Acute toxicity of selected organic compounds to fathead minnows. U.S. Environmental Protection Agency. EPA-600/3-76-097.
- Mount, D. I., Alexis E. Steen, and Teresa Norberg-King. 1985. Validity of Effluent and Ambient Toxicity Testing for Predicting Biological Impact on Five Mile Creek, Birmingham, Alabama. EPA/600/8-85/015. Duluth, MN: Environmental Research Laboratory.
- Mount, Donald I., and C.E. Stephan. 1969. "Chronic toxicity of copper to the fathead minnow (*Pimephales promelas*) in soft water. *Jour. Fish. Res. Board Can.* 26: 2449-2457.
- Mount, D.I., N.A. Thomas, T.J. Norberg, M.T. Barbour, T. H. Roush, and W.F. Brandes. 1984. Effluent and Ambient Toxicity Testing and instream Community Response on the Ottawa River, Lima, Ohio. EPA-600/3-84-080. Environmental Research Laboratory, Duluth, MN.
- Mount, D.I. and L. Anderson-Carnaham. 1988. Methods for Aquatic Toxicity Identification Evaluations: Phase I. Toxicity Characterization Procedures. EPA/600/3-88/034. Duluth, MN: Environmental Research Laboratory.
- Mount, D. I. and Teresa Norberg-King. 1986. Validity of Ambient Toxicity Testing for Predicting Biological Impact, Ohio River, Near Wheeling, West Virginia. EPA/600/385/071. Duluth, MN: Environmental Research Laboratory.
- Norberg-King, Teresa J. and Donald I. Mount. 1986. Validity of Effluent and Ambient Toxicity Tests for Predicting Biological Impact, Skeleton Creek, Enid Oklahoma. EPA/600/8-86/002. Duluth, MN: Environmental Research Laboratory.
- N. C. Division of Environmental Management. 1987. Internal Memo Re: Water Quality Toxics Program. Jan. 22, 1987.
- N.C. Division of Environmental Management. 1988. Internal Memo Re: Whole Effluent Toxicity Testing compliance Evaluations. Dec. 6, 1988.
- Sanders, H.O., and O.B. Cope. 1966. "Toxicities of several pesticides to two species of cladocerans." *Trans. Am. Fish. Soc.* 95(2):165-169.
- Sloof, W., J.H. Canton and J.L.M. Hermens. 1983. "Comparison of the Susceptibility of 22 Freshwater Species to 15 Chemical Compounds. I. (sub) Acute Toxicity Tests. *Aquatic Toxicology* 4: 113-128.
- United States Environmental Protection Agency. 1980. Ambient Water Quality Criteria for Zinc. EPA/440/5-80/079.
- United States Environmental Protection Agency. 1984a. Ambient Water Quality Criteria for Ammonia. EPA/440/5-85/001.
- United States Environmental Protection Agency. 1984b. Ambient Water Quality Criteria for Cadmium. EPA/440/5-84/032.
- United States Environmental Protection Agency. 1984c. Ambient Water Quality Criteria for Copper. EPA/440/5-84/031.
- United States Environmental Protection Agency. 1984d. Ambient Water Quality Criteria for Cyanide. EPA/440/5-84/032.

- United States Environmental Protection Agency. 1985a. Short Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. EPA/600/4-85/014.
- United States Environmental Protection Agency. 1985b. Ambient Water Quality Criteria for Chlorine. EPA/440/5-84/030.
- United States Environmental Protection Agency. 1985c. Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms. Third Edition. EPA/600/4-85/013.
- United States Environmental Protection Agency. 1985d. Technical Support Document for Water Quality Based Toxics Control. EPA 440/4-85-032.
- United States Environmental Protection Agency. 1988a. NPDES Compliance Inspection Manual. Office of Water Enforcement and Permits (EN-338)
- United States Environmental Protection Agency. 1988b. Short Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms. EPA/600/4-87/028.
- United States Environmental Protection Agency. 1989a. Short Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. Second Edition. EPA/600/4-89/001.
- United States Environmental Protection Agency. 1989b. Protocols for Short Term Toxicity Screening of Hazardous Waste Sites. EPA/600/3-88/029.
- United States Environmental Protection Agency. 1989c. Methods for Aquatic Toxicity Identification Evaluations-Phase II Toxicity Identification Procedures. EPA/600/3-88/035. Duluth, MN: Environmental Research Laboratory.
- United States Environmental Protection Agency. 1989d. Methods for Aquatic Toxicity Identification Evaluations-Phase III Toxicity Confirmation Procedures. EPA/600/3-88/036. Duluth, MN: Environmental Research Laboratory.
- United States Environmental Protection Agency. 1989e. Generalized Methodology for Conducting Industrial Toxicity Reduction Evaluations (TREs). EPA/600/2-88/070. Cincinnati, OH: EPA Risk Reduction Engineering Laboratory.
- United States Environmental Protection Agency. 1989f. Toxicity Reduction Evaluation Protocol for Municipal Wastewater Treatment Plants. EPA/600/2-88/062. Cincinnati, OH: EPA Risk Reduction Engineering Laboratory.
- Verschuere, Karel. 1983. *Handbook of Environmental Data on Organic Chemicals, 2nd Edition*. Van Nostrand Reinhold Co., New York.
- Ward, Ronald W., and G. Michael DeGraeve. 1978. "Acute Residual Toxicity of Several Wastewater Disinfectants to Aquatic Life." *Water Resources Bulletin* 14(3): 696-709.
- Weed Science Society of America. 1983. *Herbicide Handbook of the Weed Science Society of America*. Fifth Edition. Champaign, Illinois.
- Winner, Robert W., and Michael P. Farrell. 1976. "Acute and Chronic Toxicity of Copper to Four Species of *Daphnia*." *Jour. Fish. Res. Board Can.* 33: 1685-1691 (1976).



II Waste Reduction as an Alternative for Meeting Toxicity Limits

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Pollution Prevention Program

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A. Introduction to Pollution Prevention Philosophy

Pollution prevention is not new to American industry: it is simply a way to increase process efficiency and profitability. Waste residuals represent inefficiencies in the production process, and the costs associated with these residuals represent unnecessary overhead. A more efficient production process will result in lower toxics emissions if fewer residuals are produced at a constant production rate. If technical expertise on pollution prevention alternatives were made available, manufacturers would quickly implement pollution prevention techniques because of the economic incentives.

However, implementing a program to reduce the generation of toxic waste is seldom that simple. In order to realize the benefits of pollution prevention, most firms must overcome three major barriers. Figure 1. provides a useful reference of terms and points out one of the most important barriers to prevention strategies: the lack of federal commitment to pollution prevention initiatives. The terms included in the figure have different meanings to industry, the EPA, the Office of Technical Assessment (OTA), and the public. The continuum of waste minimization practices, ranging from simple toxics concentration to input substitution, obscures the value of waste reduction programs. The economic benefits of pollution prevention are not obvious because regulatory compliance is confused with long-term solutions. As a result, the mixed signals sent out by the EPA and Congress tend to reinforce a tentative approach by industry toward pollution prevention. Indeed, the vast body of environmental regulations emphasizes compliance with emissions standards through specific control technologies.

Prevailing corporate attitudes toward waste management represent a second major barrier to pollution prevention. These attitudes were succinctly captured by R. A. Day and R.

Figure 1. Differences in Waste Management Terminology

DIFFERENCES IN WASTE MANAGEMENT TERMINOLOGY

POLLUTION PREVENTION: Any activity which reduces the need to treat, store, or dispose of hazardous waste in any environmental media. Shifting the ultimate disposition of waste across media (i.e. incineration of organic solvents) is not considered a form of pollution prevention even if the total volume of hazardous waste is reduced. While source reduction is the preferred alternative, recycling, regeneration and reuse of raw materials are all acceptable forms of pollution prevention.

WASTE REDUCTION: In-plant practices that reduce, avoid, or eliminate the generation of hazardous waste so as to reduce risks to health and the environment. Actions taken away from the waste generating activity, including waste recycling or treatment, are not considered waste reduction.

WASTE MINIMIZATION: The reduction, to the extent feasible, of hazardous waste that is generated or subsequently treated, stored, or disposed of. It includes source reduction or recycling activity undertaken by a generator that results in 1) the reduction of total volume or quantity of hazardous waste, or 2) the reduction of toxicity of hazardous waste, or both, so long as the reduction is consistent with the goal of minimizing present and future threats to human health and the environment.

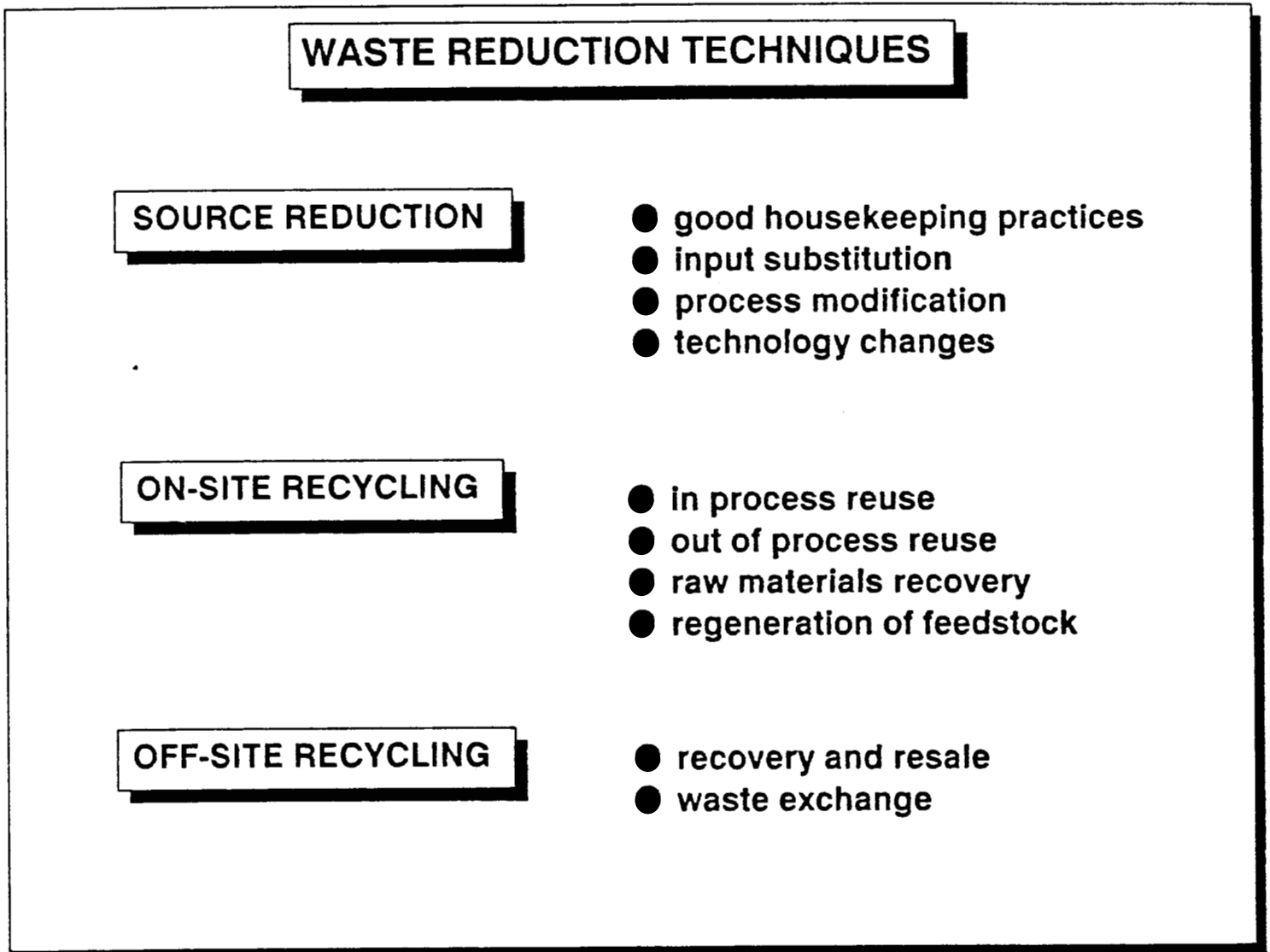
L. Price in a passage from the 1990 HazTech International Conference. "For many years we have thought of waste management as an unfortunate cost of doing business. We grudgingly hired engineers to handle our waste control problems and sank a great percentage of our revenues into maintaining environmental compliance. We are finding, however, that this is not a road which leads to a sustainable future. Industry cannot afford the costs and liabilities. The old attitudes must be replaced by the new attitude that waste reduction is a sound investment both ecologically and economically" (Day and Price 1990). Thus, the adversarial relationship between industry and environmental regulators has often blinded industry to the economic advantages of waste reduction.

And lastly, the design and implementation of pollution prevention programs requires a multidisciplinary approach to problem solving. The unique nature of industrial processes makes it impossible to develop generic solutions to waste reduction. Even among manufacturing facilities of the same company, operating parameters, quality control, and physical characteristics of the line may all be different. As a result, independent facilities may be reluctant to accept suggestions which change an already successful operation. Moreover, the organizational dynamics of industrial operations should not be underestimated. Organizations as well as individuals tend to resist change and rely on familiar procedures and established protocols. Innovative waste reduction solutions, therefore, are not likely to come from a water resources engineer or a production manager. The synthesis of disciplines, including the experience of line personnel, offers the only practical means of generating lasting waste management solutions.

The message here is simple but powerful; the successful implementation of a waste reduction program requires a fundamental, philosophical change in waste management attitudes across the entire organization. From the executive level to the level of the line employee, it must be clearly understood that pollution prevention is everybody's responsibility!

Considering that any change involves some element of risk, why should a company divert resources from existing treatment technologies into the relatively new waste reduction

Figure 2. Waste Reduction Techniques



methodology? What has motivated those companies that have implemented successful waste reduction programs? What incentive provided the impetus to change waste management philosophies? Worker safety? Liability? Economics? Despite competition for capital funds, how have some firms overcome the inherent resistance to pollution prevention programs? Finding the answers to these questions is a critical step in understanding how a pollution prevention program can be successfully implemented.

This chapter will demonstrate how waste reduction principles may be applied to reduce effluent toxicity. But more importantly, we will try to bring out the decision-making process used in identifying and ranking options and marshalling support for their implementation. For the sake of simplicity, we will include recycling and reuse under the heading of waste reduction. While the umbrella of pollution prevention technically includes this broader range of waste management tools, waste reduction techniques generally offer a more direct approach to reducing whole effluent toxicity. Examples provided in the workbook may not lead to specific technological choices, but they will suggest a commonality among successful programs. The process of change is, to some extent, as important as the actual selection of a waste reduction option. If the key players are not convinced of the economic and technical merits of a waste reduction option, it stands little chance of being accepted.

B. Waste Reduction as an Alternative for Meeting Aquatic Toxicity Limits

Developing waste reduction options designed to meet aquatic toxicity limits presents an especially difficult problem. Integrating the aquatic toxicity of the components of a waste stream with other screening criteria such as cost and technical feasibility greatly complicates the decision-making process. In addition, tracking the source of toxicity is often the rate limiting step in generating appropriate waste reduction measures. Typically, a waste audit is performed in order to characterize waste streams and unit processes. Applied to the problem of aquatic toxicity, the audit would target compounds having relatively high toxicity values. Unfortunately, this type of investigative work seldom predicts a specific cause of aquatic toxicity. Any of a

Figure 3. Facility Practices and Waste Generation

FACILITY PRACTICES AND WASTE GENERATION	
FACILITY PRACTICE	IMPACT ON WASTE GENERATION
Production schedule	improper scheduling can: <input checked="" type="checkbox"/> increase frequency of cleanup <input checked="" type="checkbox"/> increase raw materials wasted <input checked="" type="checkbox"/> increase toxic loading of the effluent
Chemical inventory	improper screening procedure can: <input checked="" type="checkbox"/> result in expired stock <input checked="" type="checkbox"/> ignore less toxic input alternatives
Chemical usage	improper addition of chemicals can: <input checked="" type="checkbox"/> decrease process efficiency <input checked="" type="checkbox"/> escalate addition of "offsetting" chemicals such as defoamers
Stoichiometry	imprecise chemical measurement can: <input checked="" type="checkbox"/> increase off-spec batch dumps <input checked="" type="checkbox"/> generate off-spec product <input checked="" type="checkbox"/> increase raw materials usage

number of confounding variables of the waste stream can obscure the identity of the toxic actor:

- Bioavailability of metals to biota
- Additive effects of compounds
- Proprietary nature of process compounds
- Relative treatability of compounds
- Tradeoffs between toxicity and BOD

Therefore, it is critical that every effort is made to reduce effluent toxicity by preventing or minimizing the addition of toxic input materials. In response to specific violations of toxicity standards, the waste audit functionally becomes identical to a Toxicity Reduction Evaluation (TRE). However, the objective of the TRE is to achieve compliance with regulations governing whole effluent toxicity using any means available. In contrast, the goal of the waste audit is to achieve compliance through waste reduction techniques and, wherever possible, identify additional opportunities to reduce toxic discharges regardless of compliance status. Nonetheless, the waste audit would place particular emphasis on those waste streams suspected of causing the toxicity problems. The range of options afforded by waste reduction strategy, from housekeeping improvements to process modifications, provides the means to reduce aquatic toxicity at a fundamental level. While whole effluent standards have become increasingly stringent, treatment technologies have become increasingly expensive. Clearly, the best way to avoid more costly treatment technologies is not to generate the waste in the first place.

C Waste Reduction Options and Effluent Discharge

In the context of toxicity reduction of whole effluents, waste reduction techniques fall into two broad categories: 1) source reduction and 2) recycling and reuse. Waste reduction options suggested for each of these techniques are outlined in Figure 2. The following sections will present a brief explanation of each option and practical applications of the principles in the reduction of effluent toxicity. It is important to note that these applications only scratch the surface of possible variations of waste reduction strategies. The reader is encouraged to think

creatively about the principles outlined in this section and how they might be applied to the operations in his/her own facility.

D. Source Reduction through Good Housekeeping Practices

The potential for simple, cost effective waste reduction found in good housekeeping practices is frequently overlooked. Standard facility practices such as chemical handling and production scheduling can have a profound impact on waste generation. Examples of housekeeping protocols potentially responsible for toxicity increases are presented in Figure 3. In most cases, simple corrective action can substantially reduce toxic loading of the effluent before treatment. Employee incentive programs, whether financial, award based, or both, can encourage a number of waste reduction ideas from almost every area of housekeeping.

D. 1. Production Scheduling. Over 80% of waste rinse water from paint manufacturers comes from equipment cleaning. The rinse water often consists of waste solvents and paint sludges containing metals. If production scheduling can be optimized so that runs progress from light to dark, the frequency of equipment cleaning can be greatly reduced. This "simple" scheduling change can result in lower water consumption, conservation of valuable paint materials, and reduced wastewater discharge (Lorton 1988). Textile dyeing and printing, and many types of ink printing can also benefit from scheduling optimization.

D. 2. Prescreening of Chemical Inventories. In 1975, Westpoint Pepperell established a toxic chemicals committee to review the existing input chemicals and to evaluate any chemical under consideration. The analysis was based on a wide range of criteria from health effects to environmental impact:

- hazardous waste characteristics
- biodegradability
- heavy metal content
- availability of safer alternatives

- personnel safety
- potential for release to the environment
- ultimate fate of the chemical

Based on these criteria, the committee recommended inventory changes from input substitution to the standardization of certain solvents (Schecter and Hunt 1989). Similarly, in 1980, Consolidated Diesel Company instituted a material approval procedure which performs the same screening function and encourages all employees to become active participants in the business. Any material listed in a purchase requisition must be approved prior to ordering. The company has implemented an approval protocol accessible to any employee with a minimum of procedural red tape (Kohl et al. 1984). For both companies, the prescreening has reduced lost input materials, lowered treatment costs, and decreased the toxic load of effluent discharges.

Understanding the toxic potential of chemicals becomes even more important when considering input changes to reduce effluent toxicity. For example, the metal plating industry has concentrated on the removal of cyanides and metals from their effluent discharge. However, the presence of additional pollutants such as phosphates, phenols, trace metals, oil and pH fluctuations can effectively destroy the biological floc of a municipal treatment plant. Relatively small quantities are sufficient to wipe out aquatic life in a large stream, and, quantities as small as 1 ppm have resulted in fish kills (Barefoot 1983).

D. 3. Conservation of Chemical Input. The tendency to practice "more is better" is evident from the line operation of many textile mills. Overuse of defoamers, retarders and levelers can result in the escalation of these assistants. For example, retarders and levelers are often added to insure level dye exhaustion onto the substrate. However, the need for these specialties can be greatly reduced or eliminated through proper control of the operating temperature. Since retarders and levelers typically contain large amounts of surfactants, effluent toxicity will increase in relation to their respective amounts. Similarly, excessive amounts of foam producing chemical specialties require a corresponding increase in defoamer to offset the

side effects. Although the foamer/defoamer ratio may stay the same, the gross amounts may greatly exceed the levels necessary for efficient processing. Conservation of chemicals will almost always reduce toxic loading of the effluent (Smith 1986).

D. 4. Precise Measurement of Chemical Input. Another source of toxic loading is the result of human error in the stoichiometric formulation of process batches. In dye formulations, the component ratios are critical to the quality and reproducibility of shades. If these ratios are not carefully followed, an entire batch can end up in the effluent. Moreover, studies suggest that the cost of handling, storage, and transport of dyes and chemicals may account for up to 10% of the total materials cost (Smith 1988). The introduction of more accurate delivery systems, especially in the area of automated dye dispensers, can result in a substantial decrease in waste generation. Automation also promises to improve product quality and reproducibility.

E. Source Reduction through Input Substitution

One of the major benefits of instituting a chemical screening mechanism is the identification of chemicals amenable to change. For example, chlorofluorocarbons (CFC's) are typically selected for metal degreasing operations. Their solubility properties and high volatility make them ideal for cleaning most metal parts; most common soils dissolve readily in CFC's and they leave virtually no residue on the part. Quality cleaning is especially important for subsequent plating or painting operations. However, CFC's can substantially increase whole effluent toxicity and are known to be ozone depleters. A number of aqueous based solvents have begun to surface in response to these problems. Simple Green, an alkaline based detergent, has been successfully used in a variety of degreasing operations. Not only is it classified as non-toxic, it is rapidly biodegradable. Since Simple Green may not be appropriate for all applications, other less toxic substitutes should be used whenever possible.

Other examples of input substitution involve more complex decisions. Obviously, quality control should be the primary focus of any decision to change the product formula in a substantive way. To illustrate this point, consider the case of a Massachusetts label

manufacturer. In order to reduce the costs associated with the treatment and disposal of hazardous organic solvents, the company retrofitted an entire product line with aqueous based adhesives. Approximately one month later, the company was forced to recall thousands of tons of product due to adhesion problems. The lack of an appropriate pilot study resulted in a substantial financial loss and considerable embarrassment over customer complaints (Massachusetts label manufacturer, personal communication 1991). There are no magic formulas to assess the impacts on quality associated with different inputs. Trade literature, vendor information, and engineering expertise should all be a part of the decision-making process. If the decision maker is satisfied that the data supports input substitution, then a pilot study can be performed to verify the quality predictions. By integrating quality control at each step, product failure can be effectively eliminated.

F. Source Reduction through Process Modification

Process modification generally signifies a more mature waste reduction program since the engineering techniques tend to be process specific. Often, this type of change requires a capital expenditure which most companies are unwilling to provide without a previous record of achievement in waste reduction efforts. The metal finishing industry provides a dramatic example of effluent toxicity reduction through process modification. Metal plating is characterized by some amount of metals discharge (primarily nickel, copper, zinc, and silver) in the wastewater effluent. These metals, usually complexed with cyanides, can greatly increase whole effluent toxicity. Although treatment technologies are well established for cyanide destruction and metal recovery, water consumption is generally high and metals continue to escape into the effluent. The profound impact of metals on whole effluent toxicity underscores the need to eliminate their discharge completely. Many companies have done just that. By closing the loop of metal plating operations, metal platers have achieved zero or near zero discharge. The Robbins Company of Attleboro, Massachusetts, installed a new wastewater treatment and recovery system in 1988 which forms a closed loop. The company, a medium sized jewelry manufacturer, now discharges nothing but domestic waste and non-contact cooling water from the annealing furnaces. The small quantity of hazardous waste it generates, containing mostly semi-precious metals, is sent off-site to a recovery facility (Greiner 1990).

G. Source Reduction through Technology Changes

Technology changes also tend to be characteristic of mature waste reduction programs and have relatively high capital costs. However, unlike process modifications, technology changes sometimes involve radical departures from the existing operating procedures. For this reason, technology changes seem to play a minor role in waste reduction strategies. One of the more striking examples involves treatment of cooling tower wastewater. To prevent bacterial growth in the cooling tower, facilities must include a biocidal agent in the cooling water. Since the agent is often aldehyde based, the cooling water can make a significant contribution to whole effluent toxicity. Although other biocides are available, most will increase the overall toxic loading of the effluent. The J.P. Stevens Company of Boger City, NC, has performed a pilot study investigating the use of an ultraviolet (UV) light disinfection unit to control microbial growth in cooling water from a textile air washer. The preliminary results indicate that the UV unit can successfully control microbial populations without the addition of any chemical biocides. Although UV technology is not a new technology, this innovative application can potentially eliminate a common source of whole effluent toxicity (Adkins et al. 1988).

Another example of a technology change comes from an ink printing company in Eastern Massachusetts. Through an informal waste minimization opportunity assessment, Tadco, Inc. identified a major source of waste in the inks leftover from previous jobs. The inks were solvent based, containing small amounts of metal based pigments and were discharged in the effluent or disposed of as hazardous waste. The company installed computer software capable of formulating new colors from existing inks and completely eliminated the disposal of leftover inks (Tadco ink manufacturer, personal communication 1991).

H. Recycling as a Means of Reducing Effluent Toxicity: Recovery and Reuse of Raw Materials

Although recycling is an effective means of waste reduction, its application to meeting whole effluent toxicity standards is somewhat limited. By definition, recycling assumes that the waste has already been produced and the only management decision remaining is whether to

incorporate it into the effluent stream or dispose of it as hazardous waste. However, in some cases recycling does afford a cost effective way to reduce toxic loading of the effluent. For the purposes of this discussion, we will consider only raw materials recovery and reuse as a technique which can pay immediate dividends in reducing toxic waste loading. The authors do not intend to discourage other recycling options as viable means toward waste reduction. Nevertheless, this handbook focuses on waste reduction methodology that can be used to lower whole effluent toxicity. Thus, our intent is to provide the reader with some basis for comparing waste reduction alternatives to the expansion of treatment capacity.

A substantial body of literature exists describing raw materials recovery. From the recovery of precious metals in a plating operation to the reuse of textile dyes, three fundamental principles must be followed. First, the material to be recovered must have an implicit economic value. In other words, the cost of recovered material should not exceed the cost of virgin material. Second, the process must be amenable to wastestream segregation and raw material collection. For example, it is very difficult to salvage valuable dyes from textile wastewaters given their complex array of specialty chemicals. Third, the recovery process must compare favorably to the treatment process on the basis of efficiency and operating costs. The plating process provides an excellent example of how these factors affect the decision to recycle. If we compare the number of plating operations that engage in silver recovery with those engaged in copper and zinc recovery the contrast becomes apparent. Very few operations recover semi-precious metals because the implicit value of copper and zinc is low compared to the cost of recovery; or the cost of recovered copper and zinc is high compared to virgin materials. Moreover, treatment technologies are very effective in minimizing the effluent loading of semi-precious metals.

I. Constructing a Pollution Prevention Program

Now that we have reviewed the fundamentals of waste reduction methodology, it is time to turn our attention to how a pollution prevention program is built. It is important to note that designing and implementing a pollution prevention program is an iterative process; as the

staff acquires more experience, program goals will become more clearly defined and the waste reduction "philosophy" will gain momentum. Small, initial successes will lead to larger, more comprehensive waste reduction measures as the program matures.

However, the program's ultimate success depends upon the level of commitment from the corporate office. The allocation of resources to pollution prevention activities, while necessary, is not a sufficient guarantee of the program's success. The highest level of management should issue a policy statement which defines the objectives of the pollution prevention program, establishes goals for waste reduction, and welcomes the contributions of all employees in realizing the program's objectives. A statement of this nature not only encourages all employees to assume the responsibility for pollution prevention, but also convinces middle managers of the importance of the program's success. Like production incentive plans, pollution prevention incentive plans provide positive feedback for employees, managers, or divisions for achievements in waste reduction. Having established a mandate for pollution prevention, the process begins with the selection of the pollution prevention team.

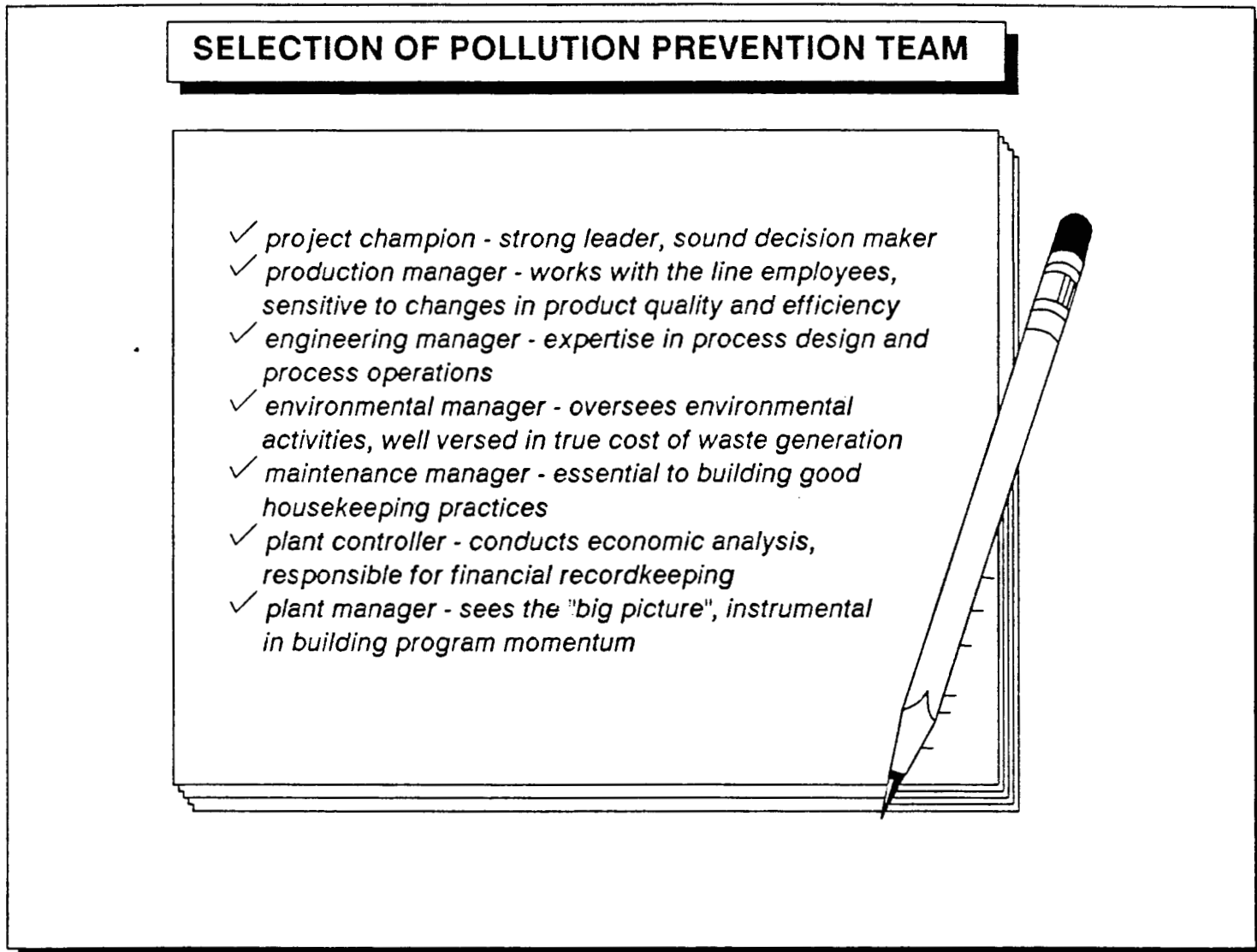
J. Selecting the Pollution Prevention Team

Selection of the task force is a critical step in building the foundation for the pollution prevention program. Although the size and composition of the team will differ depending on the size and nature of the company, the essential elements remain constant. Not surprisingly, the team suggested by Figure 4 includes a mix of technical experts from engineering and production as well as financial and environmental managers. But perhaps the most critical component of the team is the presence of a pollution prevention champion. Bringing change to an organization requires a champion; a person regarded as a sound decision maker who will be responsible for "setting the table" so that a change can occur. In this context, the champion acts as the agent for change. His function will be very similar to that of a project manager; the champion will create the change indirectly through other people. Like the project manager, the champion will take primary responsibility for the success or failure of the change. The

champion will not only evaluate the technical and economic merit of waste reduction options but also assess the organizational forces likely to impact the success or failure of the change.

The organizational structure within a company will shape many of the parameters of the decision-making process. Interactions between functional managers and line personnel, availability of capital funds, peer group dynamics, and management communications are all variables that will determine the final outcome of a proposal for change. Careful analysis of organizational forces is instrumental in bringing about change. For example, if the production foreman tends to be territorial about changes affecting "her" line process, the champion must solicit her support very early in the process. The exclusion of "non-team" managers or employees from the process will invariably lead to a confrontational relationship between the team and other plant personnel. If outside consultants are brought in to build a program, attention must be given to this type of confrontation. Admittedly, the consultant brings certain expertise in pollution prevention, but in-house staff are not always receptive to outside help. In some instances, functional managers may infer criticism from proposed changes in the production process. As communications break down, the team is liable to meet with explanations of why certain changes cannot be done. The project champion, whether an in-house manager or an outside consultant, should encourage the team to spend time "on the line" to ensure an open line of communication with plant personnel. By creating an atmosphere of give and take, the team benefits from the experience of managers and line personnel and greatly increases the chances for successful implementation of waste reduction initiatives. Again, the emphasis of the program should be on the team concept of responsibility for pollution prevention. Our approach advocates developing an appreciation of the skills and abilities of the players in order to include them in the change process in a meaningful way.

Figure 4. Selection of Pollution Prevention Team



Information for original art from Waste Advantage, Inc. 1991.

K. Assessing the Opportunities for Pollution Prevention

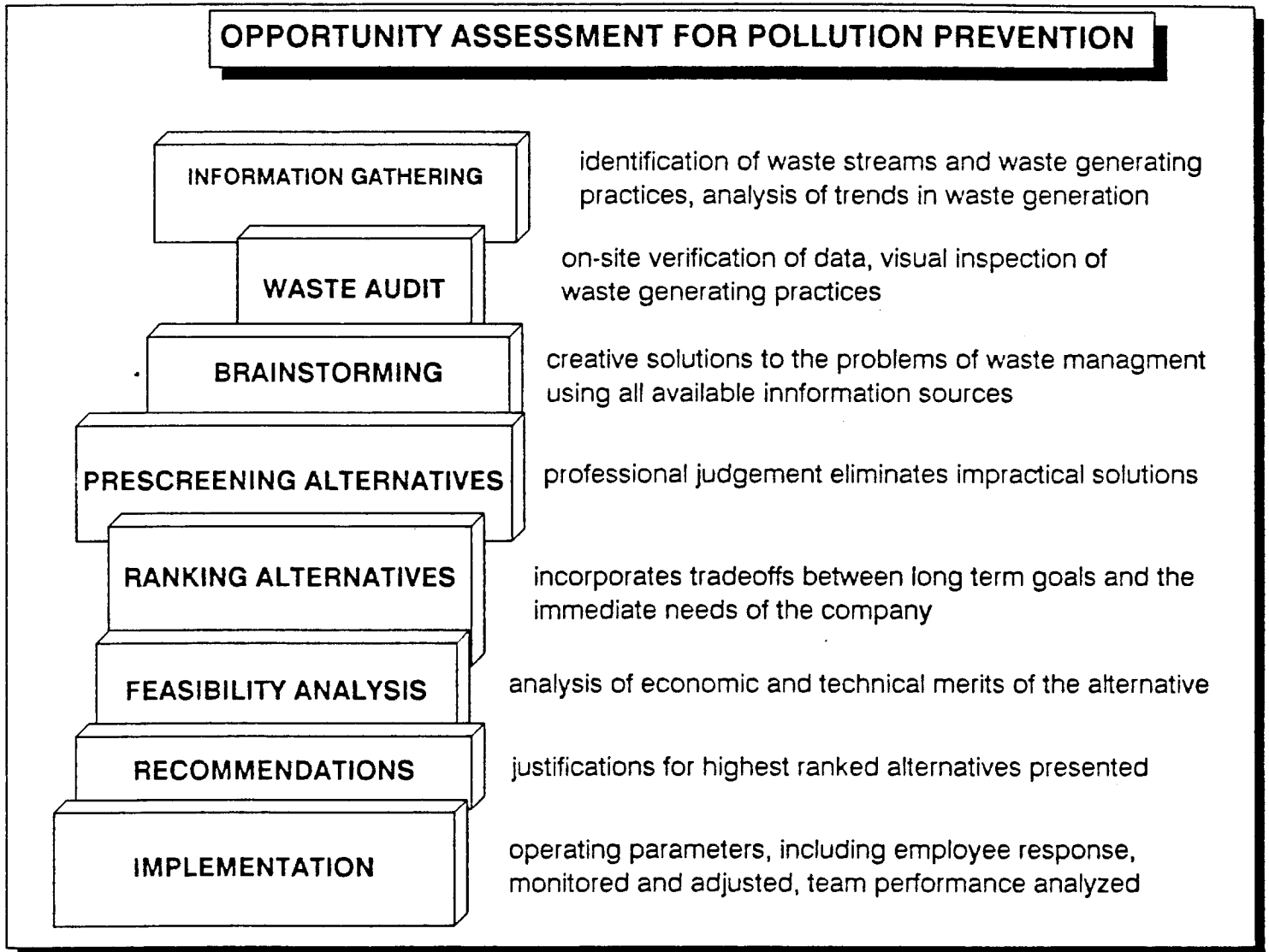
The cornerstone of a pollution prevention program is often called the waste minimization opportunity assessment. Functionally equivalent to the environmental or waste audit, the object of the opportunity assessment is to collect information on waste generating processes and to identify waste reduction alternatives. Organizing the elements as in Figure 5 can provide a useful framework for designing a pollution prevention program. However, the process is iterative by nature and the steps frequently overlap and play off one another. For example, the information gathering step can reveal immediate options to reduce waste generation. Similarly, the on-site inspection may uncover operation parameters that can be substituted and removed from the manufacturing process. In any event, the assessment should be regarded as a dynamic process, with experience and information creating new opportunities for waste reduction.

The following discussion of the pollution prevention opportunity assessment is not intended as a detailed, step-by-step analysis of the procedure. Such an analysis is beyond the scope of this workbook and would only serve to distract the reader from our ultimate goal; to reduce effluent toxicity. Instead, we have attempted to present principles which will assist the reader in designing a flexible program to generate and analyze waste reduction alternatives for the control of whole effluent toxicity.

K. 1. Information gathering. The information gathering step provides a detailed description of waste generating processes, identifies waste streams and standard operating conditions, and analyzes trends in waste generation. The primary sources of information include:

- whole effluent toxicity test results
- hazardous waste manifests
- biennial reports
- emission inventories (SARA TITLE III, SECTION 313)
- permits and/or permit applications

Figure 5. Opportunity Assessment for Pollution Prevention



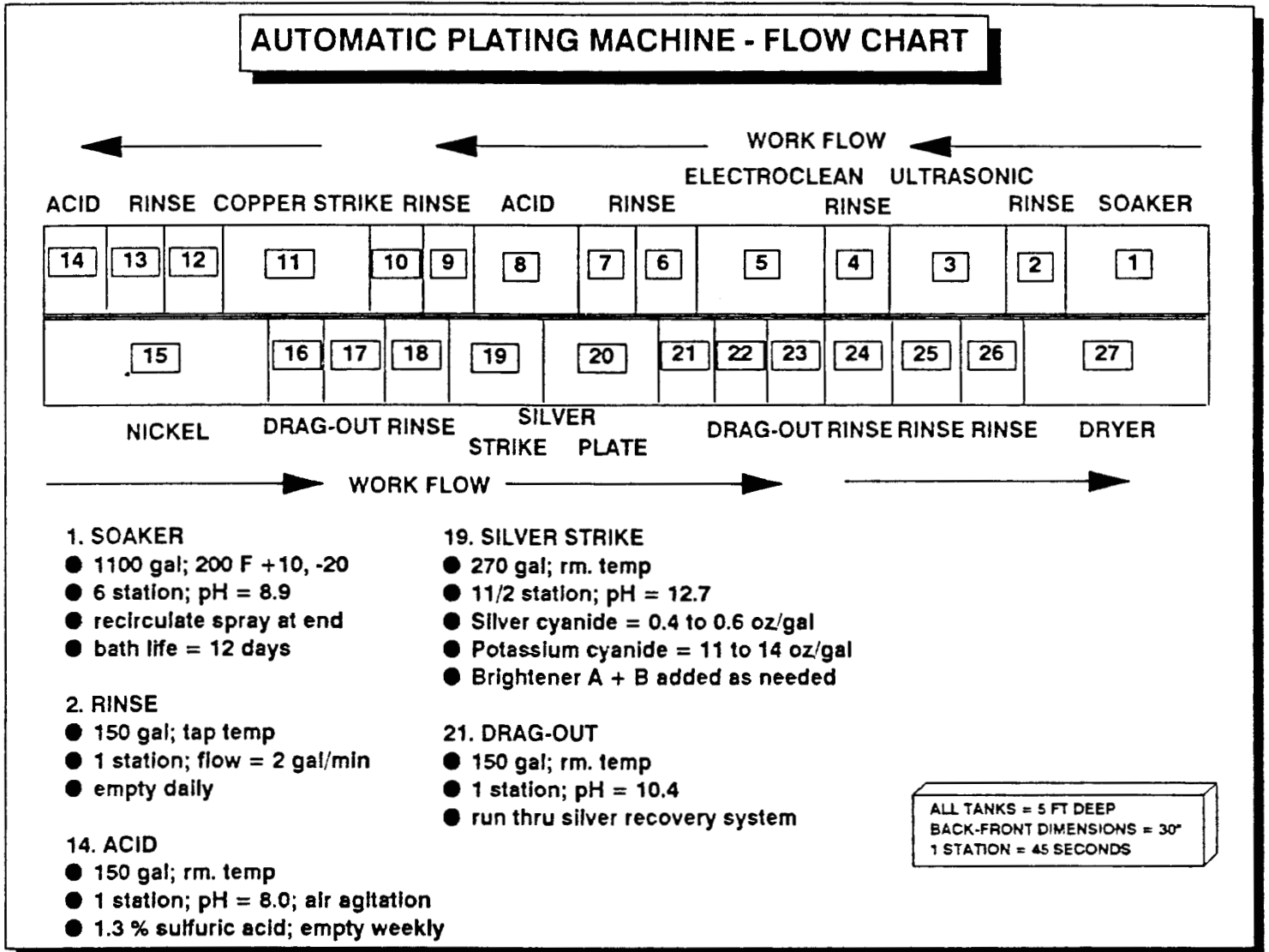
- operation manuals, process descriptions
- production schedules, operator logs
- design flow diagrams

Typically, this information is supplemented by line personnel and translated into a process flow diagram as shown in Figure 6. Our example of actual waste audit data from a metal plating line includes only the parameters for several tanks. Nevertheless, an enormous amount of information is contained in the process diagram. Operating parameters, mass balances, and production rates can all be evaluated using this one flow diagram.

The information gathering step also provides the raw data to analyze trends in waste generation. Matching toxicity spikes with production schedules can provide a powerful investigative tool for isolating toxic processes; the effect of waste stream variability on effluent toxicity cannot be overemphasized. This waste generation analysis can often suggest immediate actions to reduce toxic loading of the effluent. For example, analysis of toxicity spikes may correlate with certain personnel shifts or batch runs. The toxicity databases outlined in appendices A and B are useful in coordinating the aquatic toxicity with certain types of waste streams. Comparing the trends in waste generation with the toxicity databases contained in the AQUIRE, IRIS, and WERL databases can help prioritize and target processes for special attention during the next phase: the on-site waste audit. Refer to Section VII for more details concerning these databases.

K. 2. On-site waste audit. The waste audit begins with a thorough on-site inspection to determine if any additional information is needed to verify the accuracy of the flow diagrams and waste stream analysis obtained in step 1. Inspections should coincide with operations involving input materials associated with high aquatic toxicity characteristics or toxicity spikes. The Generator's Checklist in Figure 7 illustrates the types of questions that the pollution prevention team should ask during its on-site inspection. As the team completes the waste generation profile, waste reduction options will begin to emerge. Remember, it is critical that

Figure 6. Automatic Plating Machine Flow Chart



Source: Greiner 1990.

the team establish a rapport with line personnel before the actual audit. A group of "strangers" that descends on the floor with a battery of questions will probably not be received well. Moreover, the inspection presents a useful opportunity to solicit input from the line on waste reduction ideas. By laying the groundwork for the waste audit, the team can inspire a positive attitude toward pollution prevention activities. Indeed, with the help of line personnel, the team can generate a substantial number of waste reduction options from the inspection alone.

K. 3. Brainstorming. This step requires particular skill on the part of the project champion. The brainstorming session should be a creative "free-for-all" to generate as many waste reduction options as possible. At this meeting, the champion should allow all team members, as well as any interested employees, to propose reduction alternatives without any criticism. This management technique is designed to eliminate the stage fright which most people associate with group meetings. By emphasizing creative solutions, a healthy competition among participants often develops which brings out more innovative thinking. Only after the group has exhausted all possible solutions should the alternatives be evaluated on more conventional criteria such as economic or technical feasibility.

K. 4. Preliminary screening of alternatives. In this step, the team critically evaluates the alternatives on minimum criteria which fulfill the priorities of the facility's pollution prevention program. For example:

- Can the alternative reduce effluent toxicity?
- Is the alternative technically reasonable?
- Does the alternative address immediate regulatory concerns?

This step should not necessarily incorporate in-depth economic analysis. The purpose of the preliminary screen is to use professional judgement to weed out alternatives that fail to meet minimum criteria. In this case, the minimum criteria were chosen to focus on a particular need: to reduce whole effluent toxicity. However, the criteria should be tailored to meet

Figure 7. A Generator's Checklist for Waste Reduction

A GENERATOR'S CHECKLIST FOR WASTE REDUCTION	
Water use/reuse	<ul style="list-style-type: none"><input type="checkbox"/> using multiple rinse tanks?<input checked="" type="checkbox"/> using countercurrent rinsing?<input checked="" type="checkbox"/> installing drainboards and drip tanks?<input type="checkbox"/> installing racks above plating tanks to reduce dragout?<input type="checkbox"/> using fog nozzles and spray units?<input checked="" type="checkbox"/> agitating rinse bath (air or solution agitation)?<input type="checkbox"/> recycling and reusing spent rinse water through such metal recovery techniques as ion exchange or electrochemical recovery?<input type="checkbox"/> segregating all waste streams?<input type="checkbox"/> using an evaporator for material recovery from rinse tanks?
Rinse water	<ul style="list-style-type: none"><input type="checkbox"/> flow control valves?<input type="checkbox"/> identifying water inflow and outflow from each unit process?<input type="checkbox"/> evaluating reuse of clean or contaminated water?<input checked="" type="checkbox"/> using timers or foot pedals to control water usage?<input checked="" type="checkbox"/> using conductivity cells in plating rinse systems?<input type="checkbox"/> reactive rinsing?
Maintenance	<ul style="list-style-type: none"><input checked="" type="checkbox"/> using seal-less pumps?<input type="checkbox"/> installing spill basins on dikes?<input checked="" type="checkbox"/> installing splash guards and drip boards?<input type="checkbox"/> installing overflow control devices?<input type="checkbox"/> maximizing use of welded pipe joints?

Information for original art from Hazardous Waste Reduction Program of Oregon 1988.

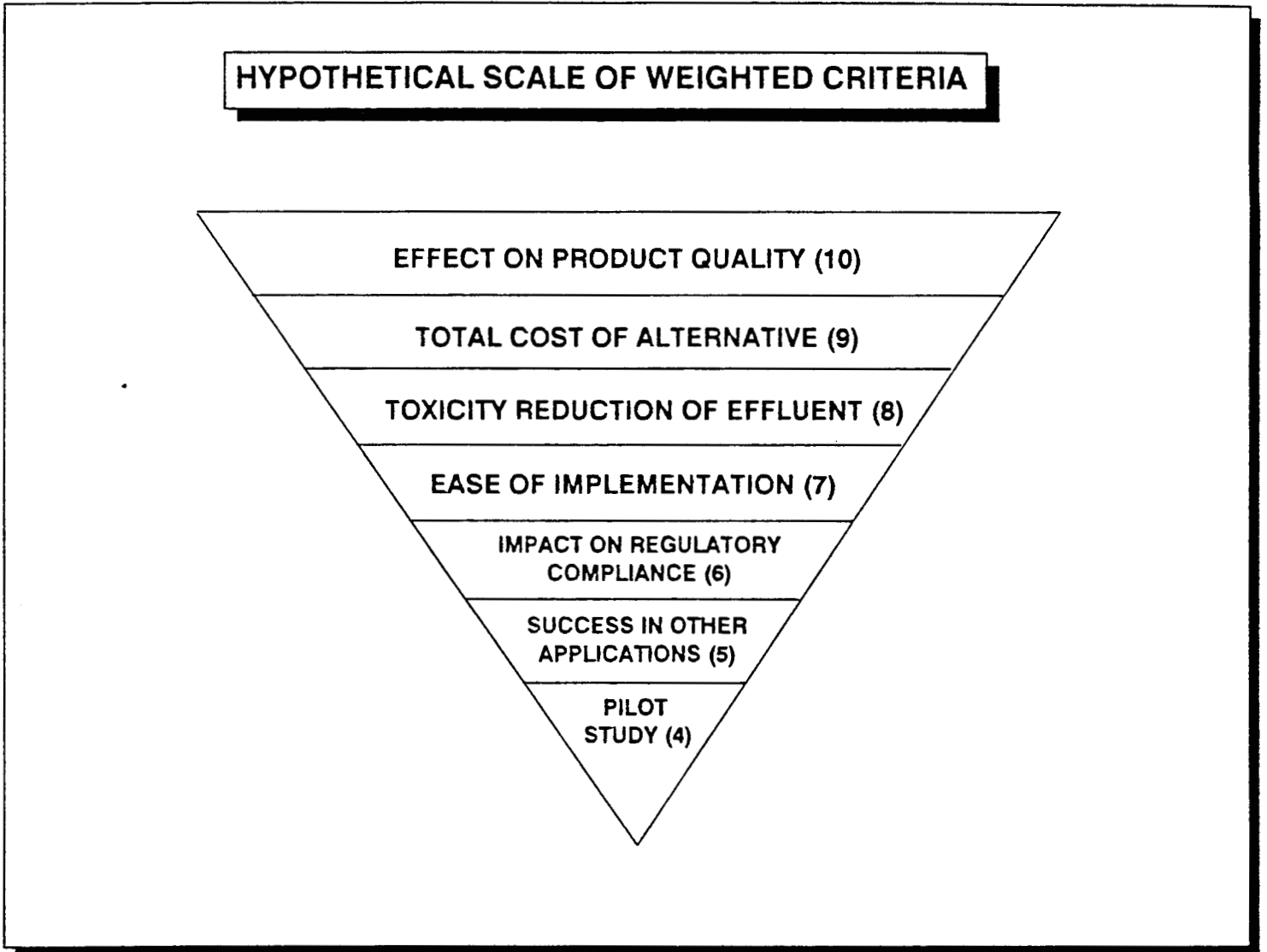
whatever needs the company deems appropriate. Lowering treatment and disposal costs, reducing raw materials or toxics usage, or staying within a strict operating budget are all legitimate starting points for minimum screening criteria. But regardless of the criteria chosen, this step will separate alternatives relevant to the company's immediate priorities from alternatives that deserve future consideration.

K. 5. Ranking waste reduction alternatives. This step is analogous to building a record of decision. The evaluation must include not only how the alternatives were ranked but also how important each criterion was to the decision. The inverted pyramid shown in Figure 8 illustrates how a typical weighting scheme might be developed. The most important criterion, effect on product quality, is shown at the top of the pyramid and receives the maximum weight of 10. By assigning a weight of "10" to the effect on product quality, the team implies that this factor is crucial to the decision-making process. However, many criteria are difficult to judge, so the team must set an arbitrary scoring scale and assign explicit definitions to each score. The arbitrary nature of the scale will not affect the rankings as long as the scale is applied consistently by all team members. In our hypothetical example, the team decides that a scoring scale from 1 to 10 will be applied to each criterion and defines the scores for "effects on product quality" as follows:

SCORE	MEANING
10	product quality is known to improve
8	product quality should improve
6	product quality suspected to improve
5	product quality will be unaffected
4	product quality suspected to diminish
2	product quality should diminish
1	product quality will diminish

For this example, let's assume that the production manager of a metal finishing operation is evaluating a process change involving the use of a deionized water system to replace organic solvents as the final rinse for plated products. Based on vendor information

Figure 8. Hypothetical Scale of Weighted Criteria



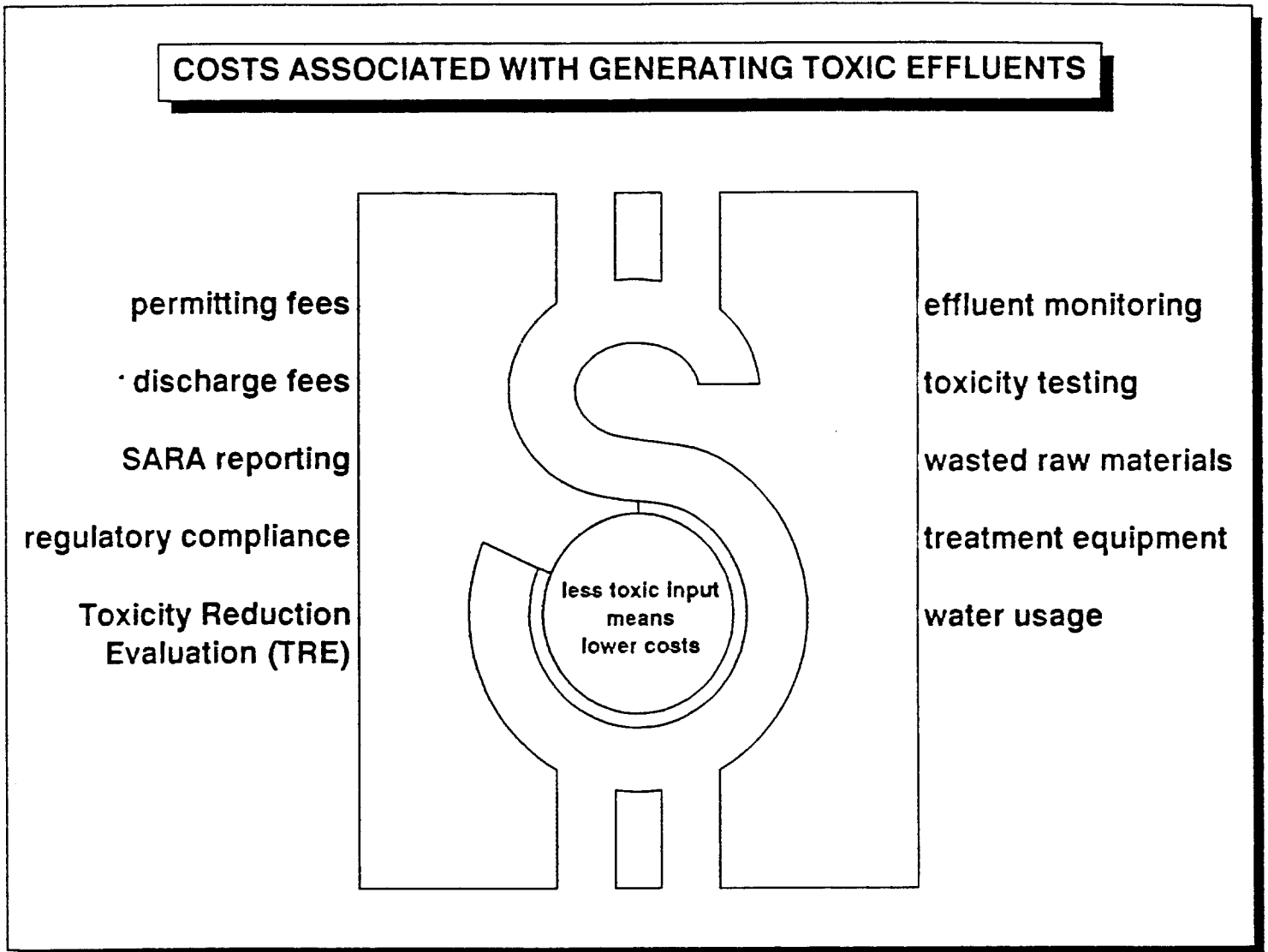
from similar applications, she gives a score of "5" to the alternative. The alternative score would then be multiplied by the weighting factor of 10 to produce a total weighted score of "50" for effects on product quality.

Cost is the second most important criterion in our example and receives a weight of 9. It should be pointed out that the weights as well as the criteria should be consistent with corporate policy. If the criteria do not reflect corporate attitudes, the recommendations for waste reduction alternatives will not stand up to executive scrutiny. This axiom is particularly valid for cost evaluation since cost is frequently used to reject waste reduction alternatives.

The team must perform a thorough economic analysis to justify its selection of waste reduction alternatives. Costing out an alternative requires more complicated scoring definitions than those presented for "product quality". Typically, the payback period is compared to the perceived costs of waste generation. When the waste reduction alternative involves large capital expenditures, net present value and the internal rate of return are also projected against the costs of waste generation. The costs associated with the generation of toxic effluents is given by Figure 9, however, most pollution prevention programs extend this list to include long term liability under Superfund as well as the transportation, treatment, storage, and disposal costs of hazardous waste. For our example of the deionized water system, we will assume that the team focused on direct costs of whole effluent toxicity such as a Toxicity Reduction Evaluation, non-compliance fines, or comparative investments in treatment technology. The scaling scheme might look like the following:

SCORE	MEANING
10	payback period less than 6 mo.
8	payback period less than 1 yr.
6	payback period less than 2 yrs.
2	payback period less than 3 yrs.
1	payback period greater than 3 yrs.

Figure 9. Costs Associated with Generating Toxic Effluents



The production manager has priced out the deionized water system at just under \$10,000 with utility costs averaging about \$1,900 per year. Vendor information indicates that filters must be changed at least once every three months for a total of \$1,100 annually. Maintenance can be purchased under contract for an additional \$400 per year for a total cost of \$13,400. From the analysis of waste streams conducted in step #1, the team estimates that use of the organic solvent costs the company in excess of \$9,000 annually. In its analysis, the team included the annual cost attributes listed below:

Raw materials cost	\$5,200
Treatment and disposal costs	\$1,200
- transportation	
- tipping fees	
Labor costs	\$500
- handling raw material	
- handling waste	
- cleanup of spills	
Reporting requirements	\$400
- permitting requirements	
- RCRA manifesting	
- SARA reporting	
Operating costs for pretreatment	\$700
- utilities; maintenance	
Toxicity monitoring	\$1,400
<hr/>	
TOTAL	\$9,400

Since the payback period would be within 2 years, the production manager gave the cost criterion a score of 6, multiplied by the weight of 9, for a total score of 54. Although the actual numbers are fictitious, they illustrate the importance of including **all** costs associated with waste generation. Hopefully the methodological framework presented in the first two examples will provide the reader with a basis for developing a ranking system tailored to the individual needs of the company. Remember, the ranking system is useful only if it reflects the priorities established by corporate policy and simplifies the complex matrix of tradeoffs. Deciding which waste reduction alternative(s) is appropriate at any given time is not a trivial matter; it requires an explicit ranking system in order to set up the common ground for discussion.

K. 6. Analysis of technical and economic feasibility. This step initiates a review process for upper management and functional managers to comment on the team's waste reduction alternatives. At this point, more sophisticated economic analyses may be performed, assumptions regarding data interpretation may be questioned, and technical aspects of installing equipment or programs may be considered in greater detail. If the team has continued to solicit input from the appropriate players throughout the process, this step should amount to a "proof reading" of the team's recommendations.

The feasibility analysis provides a safeguard against presenting options to corporate management that are not widely supported on their economic and technical merits. Referring back to the deionized system example, the plant manager may have noticed that installation of the system will require the relocation of other equipment, and may want those costs included in the evaluation. Similarly, a financial manager may point out a conflict in capital expenditure for the deionized system with a proposed project to upgrade existing piping with new PVC pipes. The team may want to address this conflict in their recommendations or they may re-evaluate their alternative selection. However, if the appropriate players are not included throughout the process, the feasibility analysis may paralyze the pollution prevention program. This paralysis represents a serious threat to the success of the program; costly delays may result in a loss of faith in pollution prevention as a primary strategy in waste management. A corporate shift in policy may severely undermine the team's ability to function and may even result in termination of the program.

K. 7. Recommendations. Finally, the team presents its recommendations for waste reduction alternatives to corporate management. The recommendation should include the economic and technical justifications, a concise description of the ranking process, and an executive summary of how this alternative compares with the other promising alternatives identified in the ranking step. By including this summary along with the recommendation, the team opens the door to future pollution prevention initiatives and demonstrates the variety of alternatives open to management to reduce waste generation. Moreover, the summary gives the decision maker the opportunity to adjust waste management priorities according to the broader

needs of the company. For example, assume that the waste audit revealed that the installation of a resistivity meter in the copper strike tank could reduce the addition of cyanide by 40% with a 2 month payback period. Although the projected reductions in effluent toxicity may be lower than the projections for the deionized system, the decision maker may opt for the more immediate alternative in order to build momentum for the program. As the momentum grows, more attention will be given to pollution prevention initiatives and a larger allocation of resources may follow.

K. 8. Implementation. The final step in the process is to implement the waste reduction alternative selected by corporate management. The team should not assume that its responsibilities toward the project end here. Through functional managers, the team must ensure that the equipment (or procedure) is operating maximally and that line personnel are fully acquainted with its operation. In addition, the changes in waste generation and effluent toxicity should be monitored and analyzed to determine the effectiveness of the alternative in achieving its projected goals. The follow-up serves two critical functions. First, it allows the team to make adjustments—employee training, resetting operating conditions—to optimize waste reduction. And, second, it allows the team to critically evaluate their performance and to avoid the same mistakes in the future. The team's motto should be simple: "Repeat what worked, improve what didn't."

L Case Study

Pollution Prevention in Practice: Eastside Plating's Success Story

The following text was taken from a success story of the Eastside Plating Works of Portland, Oregon (Hazardous Waste Reduction Program of Oregon, 1989). The piece describes the evolution of a pollution prevention program and illustrates many of the principles discussed in the preceding sections. We have included a brief commentary at the end of each section to bring out the pollution prevention principles at work.

Eastside Plating has made money complying with new environmental regulations. Under the direction of Tom Loos, Maintenance and Water Treatment Manager, the electroplating firm implemented operational changes that save more than \$300,000 annually.

But Loos recommends a cautious approach when it comes to upgrading plant operations. He warns against hurried contracts with anyone promising 'bulletproof' systems at 'bulletproof' prices. Turning down one such offer with a price tag of \$250,000, Loos instead brought Eastside into compliance for \$75,000 by upgrading existing equipment and purchasing used, as well as new, equipment.

He credits classes offered by the American Electroplating Society, Conventional Waste Treatment Technology for Heavy Metals, and Department of Environmental Quality for helping him find affordable yet effective solutions.

Comments: Loos is the ideal project champion. He has the technical understanding and economic savvy, and is obviously determined to make pollution prevention work for his company.

Eastside's 'first generation' upgrade improves efficiency

Eastside Plating management made the commitment to implement a hazardous waste reduction program in 1982. By changing rinsing techniques, substituting materials and segregating wastes for treatment, the firm has become a more cost-effective operation. The changes were possible using available technology, according to Loos.

Comments: The corporate management at Eastside Plating clearly made a policy commitment to waste reduction.

Compliance one step at a time

Eastside Plating began modifying its operation to comply with environmental regulations. By setting priorities and upgrading in phases, the firm was able to work toward compliance yet meet increased demand for services during a period of rapid growth.

The first operational modifications addressed counterflow and cascade rinsing systems. The changes decreased water used for rinsing, a process that accounts for 90 per cent of all water used in electroplating.

In counterflow rinsing, water is used a number of times, dramatically reducing volume required. Fresh water is introduced in the last tank of a multiple tank system, and flows toward the source of contamination.

Cascade rinsing requires only one tank with a center divider which allows water to spill into the other side. The filling/draining process is continuous and very slow.

Both systems cut water bills and wastewater treatment costs and greatly reduce the risk of violating anti-pollution laws.

Comments: The initial phases of their pollution prevention program focused on regulatory compliance. At some point, there was a definitive statement of priorities which allowed Loos to proceed with waste reduction initiatives without undermining the company's growth.

Substitute materials decrease wastes by 50 per cent

Loos next searched for waste treatment chemicals that decreased, rather than increased, the production of sludge. Total chromium and cyanide wastes were cut in half simply by changing reducing agents.

Chromic acid wastes are now oxidized by using sodium bisulfite and sulfuric acid instead of ferrous sulfate, while cyanide reduction is now accomplished more efficiently with gaseous, instead of liquid, chlorine.

Comments: Loos targeted waste treatment chemicals that produced sludge to reduce waste disposal costs and long term liability. Thus, his selection of input substitution was predicated on that goal.

Automation cuts chemical use

Eastside Plating then upgraded its three major waste treatment components: the cyanide oxidation tank, the chromium reduction tank, and the acid/alkali neutralizing tank. The goal was to separate tank flow, eliminate contamination of the acid/alkali neutralizing tank and increase efficiency.

Automated metering equipment reduced the quantity of costly caustic chemicals needed to treat acid wastes by 50 per cent. To eliminate the risks associated with pump failure and to equalize flow rate, cyanide and chromic acid oxidation and reduction tanks were redesigned as gravity flow systems. Finally, plumbing was segregated to prevent cross-contamination.

These simple solutions have saved Eastside Plating hundreds of thousands of dollars. The company has also reduced its 'cradle to grave' liability for hazardous wastes.

Comments: Using source segregation and technology change, Eastside reduced the quantity of toxic input chemicals and minimized the risk of spills and/or overflows.

Suppliers are cost-effective problem solvers

Loos consulted with suppliers when he modified Eastside Plating's mixing sump (sometimes called a reaction tank) and a flocculent mix tank (sometimes called a neutralization tank). Treated chromic and cyanide water rinses flow into the sump, where the pH is increased by mixing it with strong caustics before it is pumped to the flocculent mix tank.

"We prefer to have any pH or flow fluctuations in the sump, not the neutralization tank," says Loos. Inadequate mixing and fluctuations in pressure and flow had caused engineering nightmares in the past, he adds.

But Loos no longer has nightmares about 'indigestion' in the mixing sump interfering with the neutralization process. Redesign resulted in three pumps handling ongoing operations—as well as emergencies. His suppliers/consultants helped resolve the problem of inadequate mixing by baffling the neutralization tank. To find the best coagulant, he worked with five companies, doing extensive jar testing and comparison studies, before selecting a dry anionic polymer.

"Engineering assistance is readily available," Loos says. "Companies want to make a sale and we gave them the opportunity to demonstrate their products."

Comments: This is an excellent example of utilizing information sources such as vendors to generate waste reduction alternatives. Moreover, Loos conducted extensive pilot studies before choosing the best coagulant.

Regulators can help, too

"The non-compliance gap can close like a bear trap," warns Loos. To ease the pain, he recommends working with regulators instead of trying to avoid them. "The City of Portland and the Department of Environmental Quality were more interested in helping us solve our problems than in blaming us."

He credits the city's industrial sewage specialists and DEQ waste minimization classes for helping him find an effective yet affordable clarifying and drying system.

This upgrade uses a new clarifier, a new dryer, and a used sludge press to separate liquid and solid wastes. The system met Loos' specified requirements: it is easy to maintain; it shortens the final de-watering process; and it decreases the flow rate to an average of 125

gallons/minute, with fluctuations of not less than 70, nor more than 180, gal/min. The clarifier's slanting 60 degree lamella plate design allows the sludge to slide to the bottom where it's raked at the rate of one revolution every ten minutes.

His bosses love to hear Loos tell the story of how he saved \$19,000 by purchasing a used press rather than a new one. This final modification resulted in a 4-1 reduction in sludge volume and annual net savings of \$16,000.

Comments: Several principles are in evidence here. First, the company's positive attitude toward regulators has given them access to expertise which, otherwise, they would not have had. Eastside's commitment to environmental responsibility probably resulted in a more flexible approach by the regulators as well. Second, an apparent source of toxicity spikes was the system "upchuck" that Loos refers to. Although Oregon did not have toxicity testing at that time, the principle of identifying toxic events was still used to target a particular waste stream. And third, the fact that Loos purchased a used press indicates that his economic analysis was sensitive to constraints on capital expenditures.

Employee education and participatory management makes Eastside Plating Works---WORK

Employees can make or break the best anti-pollution plan. Eastside Plating has an extensive employee education program. "It's a matter of changing how we do business," says Loos. Storage and movement of chemicals and sludge is planned to be "stupid-proof". Eastside's Safety Committee helps all employees work together more safely.

Eastside Plating's philosophy is that the buck stops with each employee. In keeping with that philosophy, each employee has line manager responsibility.

Comments: This is the essence of the pollution prevention message: it is every employee's responsibility to change the way the company conducts the business of waste management!

'Second generation' improvements planned for the future

According to Loos, successful electroplating companies of the future will recycle the precious metals used in plating operations. Gold, silver, cadmium and copper will be salvaged through the use of plate-out recovery units and distillation and smelting operations for repeated use.

Electroplaters need only look at California to see that additional restrictions are likely in the future. Nickel hydroxide sludge soon may be declared a carcinogen. While sludge and wastewater are now the only regulated wastes in the industry, clean air standards for chromic and nitric acid emissions may require costly scrubbers. Proper handling of filter paper and cartridges used in sludge treatment will be important in limiting long-term liability.

Waste Reduction as an Alternative for Meeting Toxicity Limits

Loos says he's happy that Eastside hasn't been a player in the 'cradle to grave' liability associated with dumping sludge in landfills. "Dilution is no longer the solution to pollution. Metal finishing and plating companies must become responsible, environmentally aware professionals if our companies are going to survive."

Comments: Again, Loos has brought out the reason why pollution prevention should be given primacy as a waste management strategy: It is the only path that leads to a sustainable environmental and economic future.

M. BIBLIOGRAPHY

- Adkins, Dave, Roger Schecter, and Gary Hunt. 1988. Pollution Prevention Challenge Grants: Project Summaries. North Carolina Pollution Prevention Program, Department of Natural Resources and Community Resources and Community Development. Raleigh, NC.
- Barefoot, Quint, M. 1983. Pollution Prevention Alternatives in the Electroplating and Metal Finishing Industries. North Carolina State University, Raleigh, NC.
- Benforado, David M., and John S. Hunter. 1987. "Life Cycle Approach to Effective Waste Minimization." *The Journal of the Air Pollution Control Association* 37 (10): 1206-1210.
- California Department of Health Services, Toxic Substances Control Division. 1988. Economic Implications of Waste Reduction, Recycling, Treatment and Disposal of Hazardous Wastes: Fourth Biennial Report. CA.
- Campbell, Monica E. and William M. Glenn. 1982. Profit from Pollution Prevention: A Guide to Industrial Waste Reduction & Recycling. Pollution Probe Foundation. Toronto, Ontario, Canada.
- Day, Robin A., and Roger L. Price. 1990. Waste Reduction Technical Assistance Programs: Supporting Business and Industry in Ensuring a Sustainable Future. Proceedings from the HazTech International Conference, October 2-4, Pittsburgh, PA.
- Drabkin, Marvin. 1988. "The Waste Minimization Assessment: A Useful Tool for the Reduction of Industrial Hazardous Wastes." *The Journal of the Air Pollution Control Association* 38 (12): 1530-1541.
- Drabkin, Marvin. 1989. "The Waste Minimization Audit Process - Methodology and Case Studies." *Toxic Substances Journal* 9: 55-110.
- Greiner, Timothy J. 1990. Closed-looped Metal Finishing Processes. Office of Safe Waste Management, Department of Environmental Management. Boston, MA.
- Hahn, Robert W. and Eric H. Males. 1990. "Can Regulatory Institutions Cope with Cross Media Pollution?" *Journal of Air and Waste Management Association* 40 (1): 24-31.
- Hazardous Waste Reduction Program of Oregon. 1988. A Generator's Checklist. The Department of Environmental Quality, Portland, OR.
- Hazardous Waste Reduction Program of Oregon. 1989. Guidelines for Waste Reduction and Recycling: Metal Finishing, Electroplating, and Printed Circuit Board Manufacturing. The Department of Environmental Quality, Portland OR.
- Hazardous Waste Reduction Program of Oregon. 1989. Guidelines for Waste Reduction and Recycling: Solvents. The Department of Environmental Quality, Portland OR.
- Hemstreet, Russell, A. 1987. How to Conduct your Waste Minimization Audit. Chemcycle Corporation, Government Institutes Conference on Hazardous and Solid Waste, February 19-20. Boston, MA.
- Hunt, Gary, and Roger Schecter. 1987. Accomplishments of North Carolina Industries: Case Summaries. North Carolina Pollution Prevention Program, Department of Natural Resources and Community Resources and Community Development. Raleigh, NC.
- Hunt, Gary. 1988. "Waste Reduction in the Metal Finishing Industry." *The Journal of the Air Pollution Control Association* 38 (5): 672-680.

Waste Reduction as an Alternative for Meeting Toxicity Limits

- Jacobs Engineering Group, Inc. 1986. Case Studies of Minimization of Cyanide Waste from Electroplating Operations. Hazardous and Toxic Materials Division. Pasadena, CA.
- Kahane, Stephen W. 1986. Waste Minimization Audits. ICF Technology, Inc., Solvent Waste Reduction Alternatives Symposium. Los Angeles, CA.
- Kohl, Jerome, Phillip Moses, and Brooke Triplett. 1984. Managing and Recycling Solvents: North Carolina Practices, Facilities, and Regulations. North Carolina State University. Raleigh, North Carolina.
- Lorton, Gregory A. 1988. "Waste Minimization in the Paint and Allied Products Industry." *Journal of the Air Pollution Control Association* 38 (4):422-427.
- New Jersey Department of Environmental Protection & US Environmental Protection Agency. 1987. Proceedings of the Hazardous Waste Reduction Audit Workshop. Trenton, NJ.
- Newton, Jim. 1990. "Setting Up a Waste Minimization Program." *Pollution Engineering: Water/Hazardous Wastes/Air* XXII (4): 75-81.
- Oldenburger, Kirsten U. and Joel S. Hirschhorn. 1987. "Waste Reduction: From Policy to Commitment." *Hazardous Waste and Hazardous Materials* 4 (1).
- Pojasek, Robert B. 1987. Practical Considerations in Implementing your Waste Minimization Program. Chemcycle Corporation, Government Institutes Conference on Hazardous and Solid Waste, February 19-20. Boston, MA.
- Pollution Prevention Program. 1988. Developing and Implementing a Waste Reduction Program. North Carolina Pollution Prevention Program, Department of Environment, Health, and Natural Resources. Raleigh, NC.
- Price, Roger L. 1990. "Stopping Waste at the Source." *Civil Engineering* April, 1988: 67-69.
- Resch, Michael E. 1988. "Hazardous Waste Minimization Audits Using a Two-Tiered Approach." *Environmental Progress* 7 (3): 162-166.
- Richardson, Stephanie S. 1990. Waste Audit--The First Step to Waste Reduction. North Carolina Pollution Prevention Program, Department of Natural Resources and Community Resources and Community Development. Raleigh, NC.
- Savage, Mary, David Peck, David Naleid, and Sana Hamady. 1990. An Integrated Hazardous Waste Minimization Approach. Proceedings from the HazTech International Conference, October 2-4. Pittsburgh, PA.
- Schechter, Roger N. 1987. Reduction of Hazardous Wastes: Innovative Opportunities for Industry and Government. North Carolina Pollution Prevention Program, Department of Natural Resources and Community Resources and Community Development. Raleigh, NC.
- Schechter, Roger N. and Gary Hunt. 1989. Case Summaries of Waste Reduction by Industries in the Southeast. North Carolina Pollution Prevention Program, Department of Natural Resources and Community Development. Raleigh, NC.
- Smith, Brent. 1986. Identification and Reduction of Pollution Sources in Textile Wet Processing. North Carolina Pollution Prevention Program. Department of Natural Resources and Community Development, Raleigh, NC.
- Smith, Brent. 1988. A Workbook for Pollution Prevention by Source Reduction in Textile Wet Processing. North Carolina Pollution Prevention Program. Department of Natural Resources and Community Development, Raleigh, NC.

- Smith, Brent, 1989. Identification and Reduction of Toxic Pollutants in Textile Mill Effluents. North Carolina State University. Department of Polymer and Textile Chemistry, Raleigh, NC.
- Tsai, Eric Chai-Ei and Roy Nixon. 1989. "Simple Techniques for Source Reduction of Wastes from Metal Plating Operations." *Hazardous Waste and Hazardous Materials* 6 (1): 67-78.
- United States Environmental Protection Agency. Waste Minimization Issues and Options. EPA/530-SW-86-042. Office of Solid Waste and Emergency Response, Washington, DC.
- United States Environmental Protection Agency. 1988. Waste Minimization Opportunity Assessment Manual. EPA/625/7-88/003. Hazardous Waste Engineering Research Laboratory, Cincinnati, OH.
- United States Environmental Protection Agency. 1989. Generalized Methodology for Conducting Industrial Toxicity Reduction Evaluations (TREs). EPA/600/2-88/070. Risk Reduction Engineering Laboratory, Cincinnati, OH.
- United States Environmental Protection Agency. 1988. Methods for Aquatic Toxicity Identification Evaluations: Phase I Toxicity Characterization Procedures. EPA/600/3-88/034. National Effluent Toxicity Assessment Center, Environmental Research Laboratory, Duluth, MN.
- United States Environmental Protection Agency. 1988. Methods for Aquatic Toxicity Identification Evaluations: Phase II Toxicity Identification Procedures. EPA/600/3-88/035. National Effluent Toxicity Assessment Center, Environmental Research Laboratory, Duluth, MN.
- United States Environmental Protection Agency. 1988. Methods for Aquatic Toxicity Identification Evaluations: Phase III Toxicity Confirmation Procedures. EPA/600/3-88/035. National Effluent Toxicity Assessment Center, Environmental Research Laboratory, Duluth, MN.
- United States Environmental Protection Agency. 1989. Waste Minimization in Metal Parts Cleaning. EPA/530-SW-89-049. Office of Solid Waste and Emergency Response, Washington, DC.
- United States Environmental Protection Agency. 1989. Pollution Prevention in Metal Manufacturing. EPA/530-SW-89-056. Office of Solid Waste and Emergency Response, Washington, DC.
- United States Environmental Protection Agency. 1989. Case Studies from the Pollution Prevention Information Clearinghouse (PPIC). Draft. Office of Environmental Engineering and Technology Demonstration and the Office of Pollution Prevention. Washington, DC.
- United States Environmental Protection Agency. 1985. Project Summary. Textile Dyes and Dyeing Equipment: Classification, Properties, and Environmental Aspects. EPA/600/S2-85/010. Hazardous Waste Engineering Research Laboratory, Research Triangle Park, NC.
- United States Environmental Protection Agency. 1983. Project Summary. Closed-Cycle Textile Dyeing: Full-Scale Hyperfiltration Demonstration. EPA/600/S2-83/027. Industrial Environmental Research Laboratory, Research Triangle Park, NC.
- Waste Advantage, Inc.. 1991. Industrial Waste Prevention: Guide to Developing An Effective Waste Minimization Program. In press. Southfield, Michigan.



III Opportunities for Waste Reduction within Specific Processes in the Textile Industry*

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A. Introduction

North Carolina textile operations produce large volumes of wastewater. The preparation, coloring, and finishing processes that produce a single pound of fabric may require the use of 10 to 35 gallons of water. In addition, because of the many production steps involved and the great variety of products manufactured, the nature of textiles wastewaters varies widely. These factors make treatment of textile wastewaters difficult and costly at best. Moreover, many toxic constituents of textile wastewaters, such as toxic organic chemicals, are not degraded or converted by the typical activated sludge wastewater treatment process.

The difficulty of treating textile wastewaters and the large volumes of wastewaters produced warrant consideration of source reduction as a waste management approach in the textile industry. Source reduction strategies are especially important for wastes which are not amenable to treatment. One obvious example is color: there is no general technology for color removal. Dyes are formulated to be stable and resistant to light and chlorine and are therefore more resistant to treatment and decolorization. Metals, which are major contributors to aquatic toxicity, present a nearly intractable treatment problem which may best be solved by preventing their entry into the wastestream. BOD presents textile operations a treatability dilemma. BOD typically ranges from 300 ppm upwards in textile wastewaters—significantly exceeding even POTW pretreatment limits. However, options for reducing BOD may increase toxicity. For instance, substitution of less degradable surfactants—branched alcohol ethoxylates—may help lower five-day BOD, but these materials will pass through the treatment system and increase effluent toxicity.

*Adapted from Smith, Brent. 1989. *Identification and Reduction of Toxic Pollutants in Textile Mill Effluents*. N.C. Pollution Prevention Program.

Reducing waste at the source can conserve energy and water; decrease waste liability; reduce waste collection and treatment costs; and boost utilization of raw materials through waste recovery and recycling. Waste reduction may also be the key to NPDES permit compliance for textile manufacturers who are direct dischargers.

In a project sponsored by the N.C. Pollution Prevention Program, North Carolina textile manufacturing operations typical of three common industry types were studied to characterize their effluents, identify precursors or sources of toxic material in the effluent, and suggest ways of reducing or eliminating toxic materials from wastewater effluent. Facilities studied were printing plants, dyeing and finishing plants, and yarn dye/knitting operations. The study yielded

- ○ principles which should be used broadly by the industry as a whole to guide research efforts and product and process design, and
- source reduction strategies for toxics which can be implemented within a single facility (unilaterally).

Both approaches are important if toxics are to be minimized. Following are a brief discussion of the results of the project along with the broad and unilateral strategies for reducing toxicity in textile mill effluent using waste reduction approaches.

B. General Characteristics of Textile Dischargers

B. 1. Printing Plants. The printing plant studied produces printed textile fabrics for consumer items such as apparel, curtains, and home furnishings. Fabric styles, widths, and weights vary widely. Most of the fabrics are cotton and cotton blends with polyester. The majority of printing is done with water insoluble pigment dispersions. Other operations which support the printing process are fabric preparation, dyeing, and finishing. Foam back coating is also done, with and without flame retarding additives.

In this typical facility, total water use is about 11 million gallons per month, or 5 gallons per pound of fabric processed. Testing of wastewater for conventional pollutants gave the data for Table I.

Table I. Pollutants found in the wastewater of a typical textile printing plant

<u>Parameter</u>	<u>Range Observed</u>
BOD	206-857 ppm
pH	5.7 - 10.4 standard pH units
TSS	100 - 380 ppm
COD	1734 - 2151 ppm
NH ₃ as N	0.56 - 4.59 ppm
Oil and Grease	6 - 28 ppm
Phenolics	0.04 - 0.20 ppm
Metals	
Copper	.10 - 1.56 ppm
Iron	.23 - .31 ppm
Zinc	.18 - .57 ppm
Lead	.11 ppm

B. 2. Dyeing and finishing plant. The typical dyeing and finishing plants studied contain wet processing (preparation, dyeing, finishing) operations using 10 to 30 gallons of water per pound of fabric. Total monthly effluent ranges from about 2 million gallons to over 50 million gallons per month. These facilities process a wide variety of fabrics, both knit and woven, made from all types of fibers, including polyester, cotton, acrylic and nylon as well as blends. Conventional pollutants in the wastewaters of these operations are similar to those for printing operations (Table 1).

In aquatic toxicity testing of effluent from dyeing and finishing facilities studied, four aquatic species were used in short and long-term tests, both static and flow through. These organisms included *Daphnia pulex*, *Pimephales promelas*, *Ceriodaphnia sp.* and *Lepomis macrochirus*. Toxicity levels varied widely in each mill effluent from day to day. The lowest toxicity was "none," meaning that the species tested could survive during the test period in the effluent being tested. The highest toxicity was typically 50% to 70%, meaning that a 50% to

70% solution of effluent in distilled water was lethal to 50% of the test subjects. More dilute solutions were not toxic to that number of test subjects.

2. C. Yarn Dye/Knitting Operations. The yarn dye/knitting operation studied produces about 350,000 to 400,000 pounds per week of dyed cotton and polyester/cotton blended yarn. The total effluent is about 1.5 to 2.0 million gallons per day, or 20-30 gallons per pound of fabric. Due to this high water usage per pound of product, the concentration of pollutants is substantially less than at other sites. For example, BOD levels of 100 to 150 ppm are observed in this facility, compared to 200 to 500 ppm in other facilities. The site prepares knitting yarn by bleaching and scouring. Then the yarn is dyed with either fiber reactive, vat, direct, and/or disperse dyes on 1200 pound package dye machines at 10:1 liquor ratio. Finally, the yarn is wound through a wax and oil emulsion for lubrication prior to knitting. The dyeing equipment is conventional high temperature package dye machines which hold 1200 pounds per load on stainless steel tubes. A wide variety of chemical specialties and commodities is used.

The effluents of all three textile manufacturing facilities were sampled for the presence of volatile/nonvolatile organics and inorganic materials. The samples were collected after treatment at the point where effluent was discharged to a POTW or water body. Table 2 indicates the results of the analyses.

Table 2: Organics and inorganics detected in typical textile mill effluent

<u>Facility Type</u>	<u>Volatile Organic</u>	<u>Nonvolatile Organic (ppm)</u>	<u>Inorganics (ppm)</u>
Printing Plants	Present	121	405
Dyeing and Finishing Plants	Present/absent	245	1483
Yarn Dye/Knitting Operations	present	131	2252

C. Causes of Effluent Toxicity

Even with the variability in textile effluent, some generalities can be made about the sources of toxicity in textile plants. The two main sources are raw materials and processing operations. Three categories of materials used in textile processing (or incidental to materials used) can be expected to cause effluent toxicity: metals, surfactants, and organic solvents.

Actual wet processing operations have the greatest potential for aquatic toxicity. Two suspect areas are dyeing/printing and desizing operations. Within the dyeing/printing area, operating conditions, dye/print selection, and material composition may all contribute to toxicity.

In addition to dyeing/printing and desizing operations, an investigation of toxicity potential in a textile plant should focus on bleaching, scouring, fulling, and mercerizing processes.

D. Industry Strategies for Waste Reduction

D. 1. Chemical Use Reduction. Chemical use in textile processing may range from a low of 10% to more than 100% of the weight of the finished goods depending on the specific process. It stands to reason, then, that a great potential for waste and toxicity reduction resides in chemical selection and use. Unfortunately, the basic roles of chemicals in many processes are not fully understood, making it difficult or impossible to select more environmentally compatible substitutes or modify processes to reduce chemical use.

Considerable work was done in our project related to the contamination of wastestreams by "specialty" chemicals, or chemical processing assistants—in particular, dye carriers. One important part of the study was aimed at quantifying individual carrier components left in the dyebath after a single dyeing with the ultimate objective of assessing the potential for reusing dyebaths and assessing the environmental impact of expended baths that become part of the wastestream. Results of this study of twelve different carriers used on woven polyester fabric

indicated near total absorption of carrier active (solvent) components by the polyester fiber. On the other hand, almost none of the surfactant emulsifier, a significant contributor to toxicity, was absorbed. (For specific conclusions of this study see E. 3. and E. 8.) Additional similar research is needed.

D. 2. Process modification. In addition to chemical specialties, chemical commodities contribute to pollutant loads in textile wastewaters. These chemicals rarely exhaust onto a fabric during processing and thus are almost always totally discharged in wastewater. Unlike chemical specialties, whose composition is unknown, the chemical identity of chemical commodities is known. Chemical commodities used in large quantities in textile wet processing include electrolyte, alkali, acid, oxidizing and reducing agents, size, enzymes, and sequestrants. The greatest obstacle to reducing chemical commodity use and toxicity related to chemical commodities is lack of complete understanding of processes. Certain processes are inherently inefficient in their use of chemicals. For example, fiber reactive batch dyeing requires an amount of salt almost equal to the weight of the goods—thousands of pounds per day for a typical dye house. Alternatively, pad batch dyeing uses no salt at all for the same fiber reactive dyes and the same shade on the same fabric. Clearly, the application of chemicals to substrate is a process within which there are substantial opportunities for reducing waste and toxicity, if the processes are well understood. This is another area in which the industry and individual facilities should focus research.

D. 3. Equipment and Process Design. Finally, waste management throughout the textile industry could be enhanced by making waste reduction a focus in the design of manufacturing equipment and processes. For instance, if containers such as printing screens, storage drums, and mix tanks were designed for easier emptying and cleaning, untreatable wastes would be easier to segregate and keep out of the general wastestream. Similarly, equipment which can minimize solvent loss, drag out, and impurity build-up in the dyeing and finishing processes supports waste reduction.

These are issues on which the industry and its suppliers should have a continuing dialogue.

E. Specific Strategies for Unilateral Waste/Toxicity Reduction

Twelve specific measures are recommended for reducing the contribution of toxic materials to textile wastewaters.

E. 1. Prescreen all chemicals for toxic materials prior to use. The first general recommendation is to carefully prescreen and quality control all incoming chemicals at each site. Chemicals should be evaluated according to a wide range of performance, health, and environmental impact criteria. These include cost and performance, hazardous waste characteristic (ignitability, toxicity, corrosivity, reactivity, flammability), priority pollutant status (EPA's list of 126), availability of safer alternatives, biodegradability, heavy-metal content, potential for accumulation in the facility, hazard potential when mixed with other chemicals, proposed manner of use, ultimate fate of the chemical, hazard potential to the customer, who will handle the chemical, how will it be used (mixed with, concentrations), does the user have the proper safety equipment, what are the spill procedures, incompatibilities, etc.

Screening chemicals prior to use keeps costs lower by controlling chemicals at the point of use and avoiding waste management costs. Also, nominal values for routine quality control checks of incoming shipments can be established. Safety and cost information can also be assembled and distributed at this time.

E. 2. Test all shipments of chemical specialties when received. Because of the complex and proprietary nature of chemical specialties, it is not possible to use specific analytical methods for each component. But, quality control of all incoming shipments of chemicals can be done using minimal equipment according to the following protocol. Before beginning, obtain a physical standard for each chemical product from the vendor, as well as a technical product data sheet. (This is part of E. 1. above.)

First retain an appropriately sized sample (100 ml) for future reference. Then, permanently mark the date that the drum was opened, as a visual verification that the test was done, and as an aid in detecting aged chemicals. Actual testing procedures include check pH with meter or paper and record, check viscosity with Zahn cup and record, check density with hydrometer and record, note color and clarity visually and record, note odor and record, check index of refraction with hand-held refractometer (for clear liquids) and record, compare data to previous history and vendors' standard values, enter the data on a control chart for display, keep records for each chemical on a long-term basis, retest drums which have been opened for a long time. The final and most important step is to review results with the vendor often, even when the tests show no apparent problems.

By using these simple tests, a manufacturer can detect significant variations in products which are supplied to him for production use and develop a rapport with vendors which is invaluable in case of problems.

E. 3. Review and evaluate all chemical handling practices at each location. In the previously mentioned study of dye carriers, it was evident that since active components of dye carriers are absorbed by the fabric, their contribution to wastewater toxicity should be minimal. When these materials are found to be significant constituents of wastewater, it can be assumed that they come primarily from casual sources, such as spills and cleanup. Actual mill audits conducted during the study showed that at some facilities, nonprocess sources contributed up to half of the active dye carrier components in wastewater. These contributions can be eliminated easily by simple waste reduction practices: (a) use a separate dipper for each chemical in the drug room or mix kitchen; (b) take time to drain each drum thoroughly after it is "empty;" (3) do not wash materials down the laboratory drain but use proper waste disposal cans—separate ones for each type of waste.

E. 4. Evaluate processes and materials used in terms of the kind of waste that will be produced. The study of dye carriers revealed that the amount of exhaustion of a number of

components depended on process factors. The exhaustion of components such as trichlorobenzene, perchloroethylene, methylbenzoate, chlorotoluene, methyl p-toluate (methyl cresotinate), and diphenyl ether was influenced by time, temperature, pH, electrolyte content, liquor ratio, and surfactants and emulsifiers in the bath. Process modifications to reduce waste and toxicity can be made only if it is known how process parameters affect the wastestream.

E. 5. Use shop, laboratory, and cleaning chemicals judiciously. Many materials identified as toxic residues in textile wastewater probably do not originate from production processes at all but rather are cleaning, maintenance and shop chemicals. Examples are hydrocarbons (most commonly kerosene, varsol, stoddard solvent or mineral spirits), methylene chloride (paint stripper, metal cleaning and degreasing, laboratory extraction solvent), acetone and alcohols. These materials resist biodegradation and are detrimental to treatment systems, so the key to reduced toxicity of wastewater is again source reduction. Valid techniques for this include segregation, capture and incineration, recycle, recovery and reuse, and restriction of use.

For cleaning uses, chlorinated and/or aromatic solvents can frequently be replaced with biodegradable surfactants such as linear alcohol ethoxylates, or with abrasive powders, which are not water soluble.

E. 6. Conserve chemicals. It is not unusual to find excessive and unnecessary use of specialty chemicals in dyeing and other textile wet processes. Sometimes chemicals are used to counteract the harmful side-effects of other chemicals. But it appears that often there is no investigation of the conditions that make the use of a specialty chemical necessary or of the amount actually needed. For example, defoamer is frequently added to reduce foaming caused by other chemicals specialties, but at one facility, we found defoamer being used at 100 to 1000 times the normal rate, at great cost to the facility.

The need for each specialty should be documented and the quantity used should be carefully controlled. In addition, the performance of all specialties used should be evaluated. In

many cases, it is more judicious to adjust, substitute, or to remove offending chemicals from a process than to add more chemicals to offset undesired side effects. Such conservative use of chemicals can significantly reduce waste loads and processing costs.

It is also necessary to conserve commodity chemicals, especially electrolytes. The chemical usually detected in the greatest quantity in textile effluent is common salt. The toxicity of this material is low (TLm96 > 1000 ppm), but in substantial concentrations it is toxic to aquatic life. Its extremely high volume use in textile dyeing makes it worthwhile to consider as a candidate in a mill's overall toxicity reduction program.

In general, minimizing liquor ratios in dyeing machines will help reduce salt use, since the amount of this chemical to be used is based on the bath, not the cloth. Also there are dyeing methods which use little or no salt. One method is pad/batch dyeing. Pad batch (cold) dyeing of cellulose is a proven method and has been used quite successfully in a wide variety of applications. Benefits include eliminating the use of salt and chemical specialties, with associated cost savings and waste reduction. In many ways, it is one of the most reliable and easiest-to-control methods available today for dyeing cellulose.

E. 7. Locate sources of all toxic metals and substitute less toxic alternatives whenever possible. The following metals have been detected in textile mill effluents: aluminum, antimony, arsenic, chromium, cobalt, copper, iron, manganese, mercury, rubidium, scandium, silver, titanium, and zinc. Metals come from several sources in textile processing: fiber, incoming water supply, metal parts of equipment (e.g. pumps, pipes, valves), oxidizing and reducing agents, electrolyte, acid and alkali, dyes and pigments, certain finishes, herbicides and pesticides, and maintenance chemicals. Metals in wastewaters can be eliminated or reduced by substituting chemicals and dyes that do not contain metals; eliminating metals from the raw water supply and from raw materials; retaining leftover mixes; allowing maximum exhaustion of dye; eliminating the contribution of metals by maintenance chemicals, and reviewing usage of biocides and herbicides.

E. 8. Reuse dye and bleach baths, if possible. A number of studies have shown dyebath renovation and reuse to be feasible. Our study of dyebath carriers revealed that dyebath reuse can reduce the concentration of surfactant emulsifiers in the wastestream. In refurbishing dyebaths for reuse, essentially all the carrier active materials need to be replaced. However, a minimum amount of emulsifier is needed. A "dyebath reuse carrier" in which emulsifier is minimized would give maximum source reduction of toxics and BOD.

E. 9. Segregate wastes whenever possible. A major waste reduction strategy is to produce more treatable, less dispersible, or less persistent wastes. Keeping untreatable wastes out of the general wastestream by segregation can help accomplish this goal. For example, removing impurities from raw materials (such as removing metals from fabric) before putting the materials into the process stream and segregating the waste from the materials preparation process could go a long way toward solving metals toxicity in textile mill effluent. Similarly, segregating waste from print paste cleanup areas can help reduce metals and color in the general wastewater stream. Automation can greatly facilitate wastestream segregation.

E. 10. Maintain equipment and modify when needed. In many cases, modifying equipment can provide source reduction such as reducing "drag out" or reducing liquor-to-goods ratio. Reduced liquor-to-goods ratio results in less water use and thus less alkali or acid required for pH adjustments, less stabilizer, lubricants, etc. Recycling wastestreams within a process can also be effective. Examples such as reusing once-through non-contact cooling water and counter current washing are broadly applicable.

Equipment maintenance is also important in several ways. First, properly maintained equipment produces good work, less reworks, and less off-quality materials. Second, spillage, leaks, and other processing bath losses can contribute significantly to waste loads. In addition, the methods and chemicals used for maintenance including machine cleaners, solvents, degreasers, cutting oils and lubricating oils (especially knitting oils) can contribute greatly to wastewater toxicity.

E. 11. Use automated chemical handling systems wherever possible. Automated chemical and dye dispensing systems are one of the biggest innovations currently impacting the textile dyeing industry in the United States. Chemical handling by human workers is hazardous, inaccurate, non-reproducible, wasteful, and expensive. Dye house and drug room automation can directly impact each of these areas. For example, dye ranges can be automated so that either liquid or powder dyes can be fed directly to the machine. This control means fewer error and batch dumps, fewer safety problems from handling, and better repeatability for lab to dye house correlation. Dye house automation can also interface nicely with quality control of raw materials. For example, if a dye is found to be too strong or too weak, an automated system can simply be programmed to compensate by dispensing adjusted amounts to get the correct shade. The same advantage exists for chemicals.

E. 12. Practice good housekeeping. Although it seems trivial, housekeeping is an important factor in the overall safety and waste management program in a mill. Sloppy and untidy conditions lead to waste, and housekeeping is a good general indicator of the attitude of the workers.

F. Bibliography

- ADMI-EPA. 1979. The Effect of Textile Dyeing Effluents on the Environment.
- Knox, J. E., ed. 1977. *High Performance Liquid Chromatography*. Edinburgh: Edinburgh University Press.
- Kulube, Herbert. 1987. Residual Carrier Components in Exhausted Textile Dyebaths. Master's thesis, North Carolina State University, Raleigh, NC.
- Schlesinger, H.A., E. F. Dul, and T. A. Friday, Jr. *Pollution Control in Textile Mills*. Chapter 15, pp 15.1-30.
- Smith, Brent. 1986. Identification and Reduction of Pollution Sources in Textile Wet Processing. Raleigh: N.C. Division of Environmental Management.
- Smith, Brent and James Rucker. 1987. "Water and Textile Wet Processing." *American Dyestuff Reporter* July 1987: 15.
- Tedder, Steve. 1986. Aquatic Bioassay Toxicological Summary. Unpublished document of the N.C. Division of Environmental Management.
- U.S. Environmental Protection Agency. 1979. Development Document for Effluent Limitations Guidelines and Standards for the Textile Mills, EPA 440/1-79/0226.

G. Case Studies

A Case Study of a Dyeing and Finishing Plant

Richard Diehl and Sam Moore
Burlington Research, Inc.

The City of Concord, NC, operates a 24 MGD pure oxygen treatment plant which discharges treated industrial and domestic wastewaters into Rocky River. Effluent from the treatment facility is monitored for chronic toxicity at a 73% concentration, the projected instream waste concentration (IWC) under low-flow conditions, according to the North Carolina *Ceriodaphnia* Chronic Effluent Bioassay Procedure. Results of the first chronic bioassay conducted in July 1987 indicated that effluent was chronically toxic. Because of excessive foaming and clarifier settling problems regularly evident at the WWTP, surfactants were suspected as a probable source of toxins in effluents used for the July bioassay. However, it was uncertain whether inadequate treatment of surfactants due to WWTP design/operation or an external source of surfactants contributed to the foaming and poor solids settling.

The City of Concord indicated that it wanted to address the use of alkyl phenol ethoxylate (APE) compounds by its three industrial dischargers—all textile businesses. Although Rocky River WWTP effluent had passed two chronic bioassays subsequent to the July test, WWTP personnel were concerned that effluent toxicity would reappear during cold weather months when activated sludge WWTPs do not operate at peak efficiency. They also wished to eliminate the frequent foaming and settling problems. Both of these goals could be accomplished by the optimization of surfactant usage by the three textile dischargers. Together, these firms produce approximately 50% of the incoming flow to the treatment facility, with Mill #1 contributing an estimated 37.5% of the flow.

Focus on Mill #1 was warranted for two other reasons. First, the periodic foaming problems at the Rocky River WWTP had been closely related to the operational status of Mill #1's biological trickling filter. Secondly, Mill #1 and the city wanted to investigate the possibility of receiving untreated process wastes.

Wastestream Monitoring: A program of influent and effluent sample collections at the Rocky River WWTP and Mill #1 was conducted from October 1988 through December 1989. Chronic bioassays were also conducted with the Rocky River effluent composites. Additional tests included analysis of foam samples collected from the Rocky River WWTP and laboratory foam tests conducted with solutions of nonionic NP-10 (nonyl phenol) prepared to represent Rocky River and Mill #1 effluent nonionic CTAS surfactant concentrations. CTAS nonionic surfactants were extracted and analyzed for intact and metabolic nonionic surfactant compounds.

Chemical Optimization: Review of Mill #1 chemical usage indicated that nonyl phenol ethoxylates were extensively used in process chemicals. In early 1989, Mill #1 began to reformulate its major scouring products to replace aromatic APE compounds, which require

longer periods for biological treatment, with linear alcohol ethoxylates, compounds more amenable to degradation. The other textile dischargers were similarly directed to optimize their surfactant usage.

Rocky River WWTP Operations: Rocky River WWTP personnel were directed to monitor the solids and foaming of Mill #1 discharge. When these parameters rose to higher than normal levels during seasonal temperature changes, the flow was to be redirected to an aerated holding basin where it could then be directed to the main aeration basin in a slower, more controlled manner. This practice was implemented to stop slug loadings of inadequately treated wastewater.

Discussion: Surface active properties of surfactant and detergent compounds make them indispensable to the textile industry for cleaning, wetting, and enhancing processes. However, many of these same properties cause problems in waste treatment and are a source of post-treatment aquatic toxicity. In order to enhance rapid waste treatment and consequent removal of surface active properties, many suppliers of detergent compounds to the textile industry have devised structures that offer good surfactant properties with very rapid biodegradation. It has been BRI's experience that the rapidity of biodegradation to a non-surface active state is a critical property for an "environmentally friendly" detergent product for textile use. When a surfactant degrades, its hydrophilic portion is removed by bacterial metabolic processes. This forces the surfactant to assume an oil-like nature. The surfactant, in its more hydrophobic partially degraded state, is easily absorbed by the biomass (dead and alive) that exists in the waste treatment facility. The partially degraded surfactant is thus concentrated in the biomass, remaining there until it degrades further, ultimately into H₂O and CO₂; or until the sludge is degraded further. Consequently, surfactants are eliminated from the biomass. The most toxic nonionic surfactants are those that border on oil solubility but remain dispersible in water. This is especially true when the base hydrophobe exhibits toxicity to microorganisms, which occurs at very low concentrations (<1 mg/L). When a surfactant degrades it actually may start as a highly water soluble product, only to be degraded into a more oil soluble product as intermediate biodegradation takes place. In other words a surfactant can be rendered more toxic by partial biodegradation than it was in its fully intact form.

Study findings minimized the significance of nonionic surfactants as probable sources of effluent chronic toxicity.

Case Study of a Dyeing and Finishing Plant

Summary

Industry: Sheeting and Toweling, Dyeing and Finishing Operation

Company Name /Contacts: City of Concord, Rocky River WWTP

Rationale: To eliminate alkyl phenol ethoxylates (APEs) from product formulations.

Waste Reduction Option: Chemical Optimization

Technical Summary: APE compounds were eliminated/minimized in process chemicals and replaced with linear alcohol ethoxylate compounds (LAEs). This substitution enhanced biological treatment of process wastes at Mill #1's trickling filter WWTP and eliminated foaming and solids settling problems at the City of Concord Rocky River WWTP which received this pretreated wastestream.

Information Sources: Surfactant literature regarding biological treatment and aquatic toxicity impact.

Costs: Minimal increase in cost of process chemicals (undocumented).

Performance: Elimination of Rocky River WWTP operational problems and minimization of potential source of aquatic toxicity.

Impact on Product Quality: None

Case Study of Hosiery Mill Dischargers

Richard Diehl and Sam Moore
Burlington Research, Inc.

The Town of Star, NC, operates a wastewater treatment plant which receives approximately 0.340 MGD from domestic and industrial sources. Effluent is discharged into Cotton Creek, where it composes 100% of the stream flow during periods of low-flow. Star's NPDES Permit requires that effluent is to be monitored for chronic toxicity to *Ceriodaphnia* at a 100% concentration. The four industrial dischargers, all hosiery manufacturers, account for an estimated 80% of the incoming wastestream. The town's treatment facility has had a history of non-compliance with several effluent parameters, including acute and chronic toxicity, and frequent POTW operational problems. A meeting was held November 1988 so that representatives of discharging industries, the town, and Burlington Research, Inc. (BRI) could set a course for correcting WWTP problems. It was agreed that a Waste Minimization effort by the four industrial dischargers would be the first step in the program. It was also agreed that WWTP operations would be reviewed during this period of chemical optimization/waste minimization. While the urgency of correcting the effluent toxicity problem was recognized, it was understood that the makeup of WWTP effluent would likely change after waste minimization and WWTP operation corrections were completed. The consensus was that only a minimal program of toxicant identification and reduction would be conducted until other efforts were completed.

Waste Minimization Program Summaries for each mill are as follows:

Mill #1: Mill #1 dyes and bleaches hosiery made of cotton and synthetic yarns. Its discharge accounts for 38% of the flow to the WWTP. A site visit revealed that wastewater was bypassing the mill's pretreatment equalization basin and that the basin was in poor condition. It was recommended that the equalization basin be reconditioned and some type of aeration system installed and that the equalization system be used consistently. Because of the proximity to the Star WWTP and its significant flow, Mill #1's impact by slug loading to the WWTP was a primary concern. Based on the hypochlorite/bisulfite bleaching system being used, aeration of the equalization basin was recommended, a practice which would help to minimize chlorine slugs and pH fluctuations seen in the influent to the WWTP. Implementation of these practices and use of optimally degradable surfactant compounds would minimize post-treatment toxicity in WWTP effluent.

Mill #2: Mill #2 operates a knitting, bleaching/dyeing and finishing facility and contributes 34% of the flow to the WWTP. Mill #2 has excellent equalization (approximately 24 hours) and aerates waste before discharge. Staff measure or weigh all chemicals, and amounts were minimized during a waste minimization effort undertaken several years ago. Most of Mill #2's volume work is in the bleaching area. In lieu of bisulfite, a peroxide and hypochlorite bleaching system is used. With respect to surfactant usage, wetting agents are linear alcohol based and the softening system is stearic acid amide based. One product was

found that contained APE at the beginning of the study, but this product has been eliminated. Mill #2 is now APE free and all chemicals have been optimized for structure and handling.

Mill #3: Mill #3 dyes and bleaches hosiery of cellulosic and synthetic origin. It contributes approximately 3% of the flow to the WWTP. Mill #3 has one man in charge of its chemical operations and is able to maintain strict controls on usage. It has installed a system which provides 2-3 hours of wastestream equalization. There is no aeration but with its small flow, impact to the WWTP should be minimal. Mill #3 has completed a chemical structure and application optimization and is not discharging any extraordinary amounts of dyehouse chemicals per 100# of socks processed.

Mill #4: Mill #4 knits, bleaches, dyes, and packages men's, women's and children's hosiery. Flow contribution to the Star POTW is approximately 5%. Mill #4 has no equalization capability but it does neutralize chlorine and bisulfite batch waste prior to discharge. Several chemicals containing APE have been identified and eliminated from inventory. BRI recommended that Mill #4 consider an equalization system as a way to address its non-compliance levels of wastewater parameters.

WWTP Operation Review: Inadequacy of the WWTP aeration system was cited as an operational deficiency early in the study and was corrected in December 1988. BRI has expressed concern about the location of the oxidation basin discharge weir approximately 250 feet downstream from the influent port and about untreated wastewater that exits at this location. BRI believes that the portion of untreated organic chemicals being discharged may contribute to the chronic toxicity evident in WWTP effluent. While the N.C. Division of Environmental Management and WWTP design engineers disagree with BRI regarding the discharge location, additional Toxicity Identification chemical and bio-monitoring could substantiate toxicity cause and effect.

Conclusions: With 80% of incoming flow attributable to textile businesses, the Town of Star's WWTP is in reality an industrial waste treatment facility. Due to the batch nature of hosiery dyeing, it may be shown after a complete engineering study that additional pretreatment could be obtained by utilizing existing, but unused, basins at the WWTP. Many of the mills do not have land or funds for such facilities. In other words, BRI believes that if optimal WWTP operations cannot be achieved after engineering and industrial pretreatment requirements have been met, it may be prudent for the town to build suitable pretreatment and surcharge industries for the expansion.

BRI remains concerned about the possible impact of salt and other inorganics on chronic toxicity. Alternative technology to the use of salt in dyeing or bleaching cellulose needs to be pursued. Though only preliminary data is available, the salt content of POTW effluent is an issue requiring future attention.

Case Study of Hosiery Mills

Summary

Industry:	Hosiery Mills including knitting, bleaching, dyeing and finishing operations
Company Names/ Contacts:	Town of Star
Rationale:	To eliminate alkyl phenol ethoxylates (APEs) from product formulations; and to optimize all process chemical usage
Waste Reduction Option:	Chemical Optimization/Minimization
Technical Summary:	APE compounds were eliminated/minimized in process chemicals and replaced with linear alcohol ethoxylate compounds (LAEs); usage and application of process chemicals adjusted where possible to eliminate overuse.
Information Sources:	Surfactant literature regarding biological treatment and aquatic toxicity impact; BRI experience in textile chemical use minimization
Costs:	Minimal increase in cost of process chemicals with APE substitution
Return on Investment:	Estimated savings per industry of \$2,000 - \$5,000 per month in chemical purchase
Performance:	Waste loading to the Star WWTP has been reduced. Effluent chronic toxicity still evident.
Impact on Product Quality:	None

A Case Study of Textile Pretreatment and Toxicity

Ivan A. Cooper
The Avendt Group, Inc.

A North Carolina cotton and polyester dye/finisher was identified as the source of ammonia nitrogen causing a POTW to exceed its effluent limits. The Avendt Group provided environmental consulting service to the textile processor to find a cost effective approach to reduce ammonia nitrogen before the effluent was discharged to the municipal sewer system.

The textile processor had a pretreatment discharge of 500,000 gpd and ammonia nitrogen levels ranging from 170 to 400 mg/l. The high nitrogen levels were traced to the general area of dyeing and washing operations. Procedures to address the problem included the following:

- First, an ammonia nitrogen concentration limit for the processor's wastewater had to be determined.
- Next, an evaluation was needed to determine the precise source of ammonia nitrogen. Specific steps in this evaluation involved the purchase of an ammonia nitrogen probe for testing points within the plant; sampling various waste streams to determine flows, ammonia, and pH; contacting the urea supplier and other vendors to evaluate possible process modifications; investigating pretreatment process modification for removal of ammonia; and evaluating the possibility of enhanced ammonia nitrogen reduction in the POTW.
- Finally, a plan acceptable to the City POTW had to be developed and implemented to meet the ammonia nitrogen effluent requirement.

The investigation produced the following results. Negotiations with the POTW established a daily maximum limit of 50 mg/l of ammonia nitrogen. The source of the ammonia nitrogen was traced to the urea content of print paste and temperature of the process. Under high temperature, urea was degraded to ammonia. The recovery options for urea were explored but eliminated due to high process cost. Waste minimization and pretreatment options along with process changes were explored.

The evaluation determined that controlled wetting of the fabric prior to printing reduces the amount of urea used. Criteria for the development of pretreatment options included cost, ease of operation and maintenance, time needed to modify or add pretreatment, and regulatory aspects. Based on the criteria, pretreatment options considered were air stripping, breakpoint chlorination, biological degradation and ion exchange.

Final recommendations were that the discharge limits could be met without the pretreatment options by waste minimization through fabric pre-wetting, separating dye drum wash water and processing it off-site, and increasing aeration in the pretreatment facility.

A Case Study of Textile Pretreatment and Toxicity

Summary

- Plant Type:** Textile Processing Industry
500,000 gpd pretreatment plant discharge
- Problem:** Exceeded effluent limitations from pretreatment plant to City POTW. POTW fined by state for stream quality violations. Consent agreement signed, fines to be levied.
- Source:** Ammonia nitrogen generated from conversion of urea during dyeing and washing operations.
- Solution:** Develop cost effective approach for reducing ammonia nitrogen in the effluent of the pretreatment facility to a prearranged standard of 50 mg/l.
- Procedure:**
- 1) Determine effluent limitations acceptable to the POTW.
 - 2) Evaluate process to determine source of ammonia nitrogen and site reduction.
 - 3) Develop and implement an acceptable plan to meet effluent requirements.
- Results:**
- 1) Urea recovery options were identified but eliminated from consideration because of cost.
 - 2) Waste minimization evaluation established that controlled wetting of the fabric prior to printing reduces the amount of urea needed.
 - 3) Final recommendations were that by implementing waste minimization by pre-wetting fabric, separating dye drum wash water and processing it off-site, and increasing aeration in the pretreatment facility, the processor could meet its discharge limits.

Case Study of a Hosiery Mill

Ivan Cooper
The Avendt Group, Inc.

When the toxicity of its effluent was confirmed in early 1985, a North Carolina hosiery mill was required by the N.C. Division of Environmental Management (DEM) to implement a monthly aquatic toxicity monitoring program. A 48-hour acute static *Daphnia pulex* LC₅₀ of >90.0 percent was established as the toxicity reduction goal.

The hosiery mill dyes panty hose with acid and disperse dyes in rotary dyeing machines. Major process chemicals used in addition to dyestuffs include surfactants, chelating agents, and fabric softeners. A review of composite effluent measurements prior to the initiation of the toxicity reduction evaluation (TRE), characterized the effluent as having high COD pass-through and potentially toxic concentrations of total metals. A review of monthly acute toxicity tests revealed that the effluent had a history of dramatic LC₅₀ fluctuation, ranging from a low of 38.1 percent to a high of >90.0 percent.

The mill screened its chemical usage to eliminate or minimize compounds with known toxicities and minimal biodegradability, including alkyl phenol ethoxylates (APE), biocides, quaternary ammonium compounds and organic solvents. In spite of chemical optimization, effluent toxicity continued to fluctuate well below the goal. A concurrent review of wastewater treatment plant (WWTP) operations revealed frequent influent overload. It was suggested that the mill consider additional equalization to supplement WWTP capacity and consider utilizing dyeing machines which lower the liquor ratio from the original 30:1 to 10:1 in order to lower the volume of wastewater entering the WWTP.

Since the feasibility of increased equalization and low-liquor dyeing was undecided, an effort was made to further characterize effluent, with the focus on metal and surfactant measurements. Analyses indicated the presence of high concentrations of copper, nickel, and zinc and a toxic concentration of a CTAS (nonionic surfactant). Because APE surfactants had been eliminated during the chemical optimization, it was apparent that the linear alcohol ethoxylate (LAE) compounds being used were not being adequately biodegraded in the WWTP to nontoxic levels. Metal content was analyzed for both free and complex state; however, the textile process water may contain metal complexed with chelating agents. Therefore, the effluent may not be as toxic as if all the metals were in the free state. It was surmised that incompletely degraded LAEs were the cause of effluent toxicity. A biological treatment experiment indicated that toxicity in the effluent could be reduced to the acute static LC₅₀ goal of 90 percent with extended biological treatment.

The most logical and least expensive approach to toxicity reduction was to increase waste equalization to allow for slower addition of influent to the WWTP, thereby providing time for adequate treatment. The incorporation of additional WWTP sludge contact time and the substitution of LAEs for APEs as process chemicals were both critical to the success of the TRE. The toxicity reduction goal was accomplished and the NPDES permit was modified by DEM to require only quarterly toxicity testing. The mill effluent has continued to test nontoxic.

A Case Study of a Hosiery Mill

Summary

- Plant Type:** Nylon hosiery dyeing mill, direct discharger
- Problem:** Effluent toxicity confirmed. Monthly aquatic toxicity monitoring program required; toxicity reduction goal of 48-hour acute static Daphnia pulex LC₅₀ of >90 percent established.
- Source:** Incompletely degraded linear alcohol ethoxylate surfactants
- Solution:** Equalize flow to wastewater treatment plant and extend treatment period.
- Procedure:**
- 1) Optimize chemical use, eliminate alkyl phenol ethoxylate surfactants
 - 2) Analyze sludge to determine removal of metals and surfactants
 - 3) Review wastewater treatment plant operations
 - 4) Suggest options for improving treatment of surfactants in WWTP
- Results:** Water minimization was achieved through lowering the liquor ratio from 30:1 to 10:1 in the dyeing machines. WWTP began operation on a continuous basis so influent flow to the plant was slowed and retention time of process wastes in the activated sludge contact chamber was increased. Toxicity reduction goal was accomplished and maintained and permit was modified to allow quarterly testing.



IV Opportunities for Waste Reduction within Specific Processes in the Metal Finishing Industry

Roger Dhonau
Pace, Inc.

A. Introduction

There are over 30,000 metal finishing facilities in the United States involved in manufacture of products as diverse as pins and components of the space shuttles. These facilities range in size from one-person operations to corporations employing well over a thousand people. Metal finishing encompasses 45 unit operations (Table 1) involved in the machining, fabrication and finishing of products. Standard industrial categories utilizing metal finishing operations include primarily those in groups 34 through 39.

Table 1: Metal Finishing Unit Operations

1. Electroplating	16. Thermal Cutting	29. Sintering
2. Electroless Plating	17. Welding	30. Laminating
3. Anodizing	18. Brazing	31. Hot Dip Coating
4. Conversion Coating	19. Soldering	32. Sputtering
5. Etching	20. Flame Spraying	33. Vapor Plating
(Chemical milling)	21. Sand Blasting	34. Thermal Infusion
6. Cleaning	22. Other Abrasive Jet Machining	35. Salt Bath Descaling
7. Machining	23. Electric Discharge Machining	36. Solvent Degreasing
8. Grinding	24. Electrochemical Machining	37. Paint Stripping
9. Polishing	25. Electron Beam Machining	38. Painting
10. Tumbling (Barrel finishing)	26. Laser Beam Machining	39. Electrostatic Painting
11. Burnishing	27. Plasma Arc Machining	40. Electropainting
12. Impact Deformation	28. Ultrasonic Machining	41. Vacuum Metalizing
13. Pressure Deformation		42. Assembly
14. Shearing		43. Calibration
15. Heat Treating		44. Testing
		45. Mechanical Plating

One of the largest segments in this broad industrial category is the electroplating industry. This industry performs a number of the metal finishing industrial unit operations, generating diverse wastestreams. For this reason, the electroplating industry has been selected for discussion as representative of the broader metal finishing industry.

Electroplating is defined for the purposes of standard industrial classification (SIC) as applying metallic coatings on surfaces by electrodeposition. The industry is assigned SIC Code 3471 and includes both independent (job shop) platers and captive operations associated with fabrication and assembly. About 50 percent of the companies engaged in electroplating are concentrated in Illinois, Michigan, Ohio, Pennsylvania, New Jersey, New York and Connecticut.

Historically, electroplaters discharged the following wastes to either their local sewer systems or nearby streams:

- Electroplating Rinse Waters
- Spent Plating Baths
- Spent Cleaning Solutions
- Waste Oils

Most of these wastes are highly toxic and have, therefore, fallen under considerable environmental regulation. With the enactment of various environmental legislation during the 1970s and 1980s and a general increase in environmental awareness, there has been a dramatic decrease in the type and quantity of discharges to stream and sewer made by electroplaters. Discharges now consist primarily of pretreated electroplating rinse water and cleaning wastewaters. The other two primary wastestreams, waste oils and spent plating baths, are now routinely managed so as to avoid their introduction into the facility's wastewater management system. For the most part, discharges from electroplating facilities are now in full compliance with the federal limitations under regulations promulgated under 40 CFR 433 and 413.

While compliance with federal pretreatment requirements has significantly improved the quality of discharges from electroplating operations, these discharges seldom meet recently

enacted whole effluent toxicity limitations. Consequently, electroplaters are being forced to take another major step in the improvement of their effluent quality.

Although equipment is readily available that will allow an electroplater to treat effluent to these new levels, it is often prohibitively expensive and/or impractical. A more logical approach is to incorporate aspects of the electroplater's overall waste minimization program into the company's effluent toxicity reduction efforts. Under this approach, toxic materials are prevented from entering the wastewater in toxic amounts, thereby eliminating or minimizing the need for expensive additional treatment equipment. This is generally far more cost effective and reliable. In addition, the added benefit of a reduction in raw material requirements is often realized.

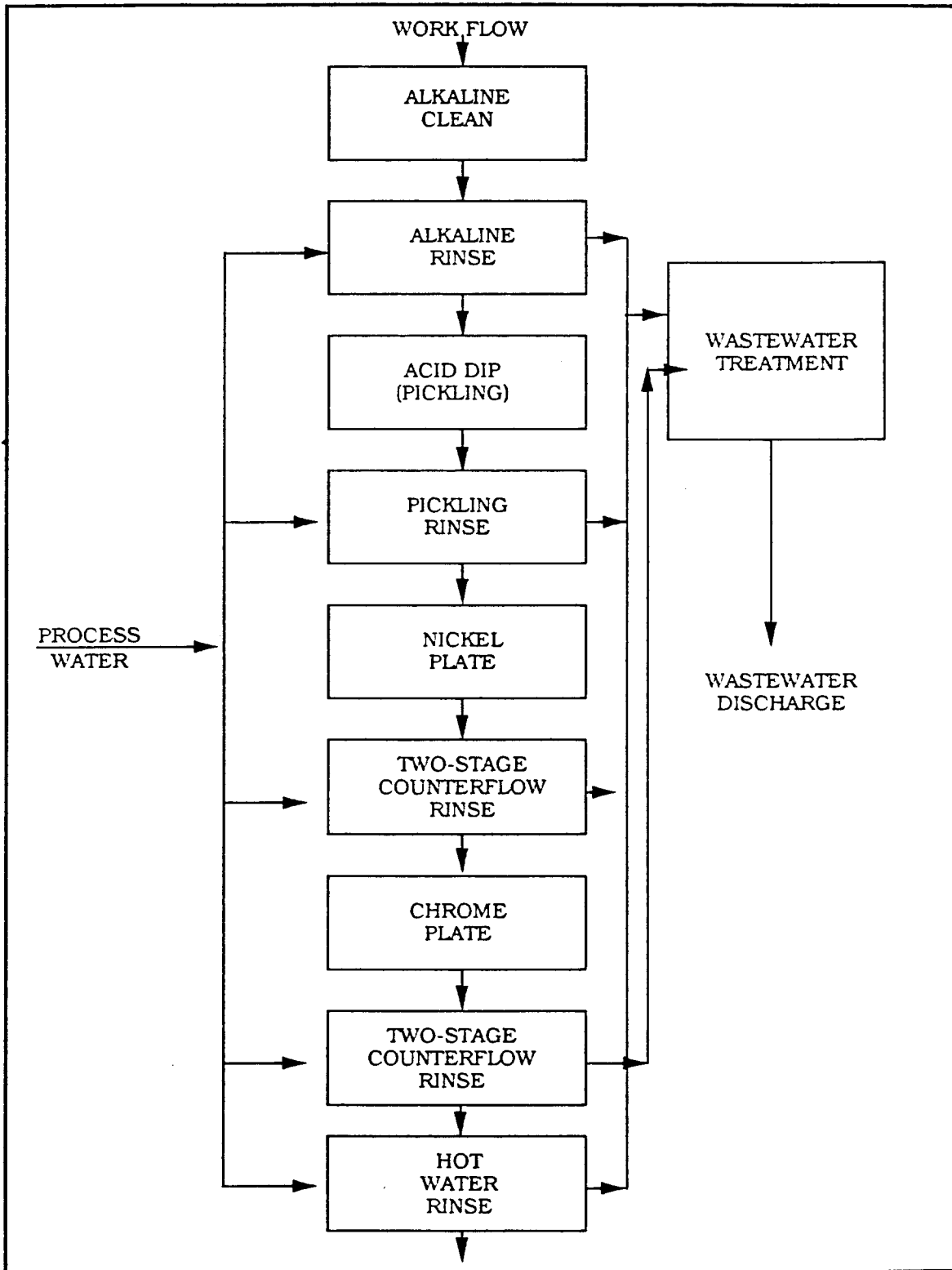
B. General Characteristics of Electroplating Discharges

B. 1. Electroplating Rinse Water. As depicted in the example electroplating process flow diagram (Figure 1), rinses generally occur after every process step. This is necessary both to prevent cross contamination of the various baths and to prepare the work piece for the next treatment. Although many exceptions exist, these various rinse waters are usually combined and routed to a centralized treatment system. Obviously, this pretreated wastewater is expected to contain dilute concentrations of the various plating baths and in-line cleaner constituents. In addition, chemicals found in the supply water and components of the substrate metal are also expected to be present. Thus, for the example shown in Figure 1, untreated wastewater would be expected to contain the following ions, assuming use of certain popular baths:

Bicarbonate	Nickel	Nitrates
Calcium	Chloride	Phosphates
Chromium	Fluoride	Sulfates
Carbonate	Magnesium	Borate

Various oils, surfactants, and proprietary organic additives are also expected to be present. Concentrations of each of these constituents is, of course, dependent upon numerous variables including rinse water flow rates, bath composition, drag out rate and so on.

Figure 1: Example Electroplating Process Flow Diagram



**Table 2: Federal Categorical Discharge Standards
Affecting Electroplating Operations**

**Electroplating Category 40CFR 413
(Existing Job Shops)**

Facilities discharging <38,000 liters (10,000 gals.) per day to sewer

<u>POLLUTANT</u>	<u>DAILY MAXIMUM (mg/L)</u>	<u>MAXIMUM 4-DAY AVERAGE (mg/L)</u>
Cadmium (T)	1.2	0.7
Lead (T)	0.6	0.4
Cyanide, Amenable	5.0	2.7
Total Toxic Organics (TTO)	4.57	--

Facilities discharging >38,000 liters (10,000 gallons) per day to sewer

<u>POLLUTANT</u>	<u>DAILY MAXIMUM (mg/L)</u>	<u>MAXIMUM 4-DAY AVERAGE (mg/L)</u>
Cadmium (T)	1.2	0.7
Chromium (T)	7.0	4.0
Copper (T)	4.5	2.7
Lead (T)	0.6	0.4
Nickel (T)	4.1	2.6
Zinc (T)	4.2	2.6
Total Metals ¹	10.5	6.8
Cyanide, Total	1.9	1.0
Total Toxic Organics (TTO)	2.13	--

METAL FINISHING CATEGORY 40CFR PART 433

Pretreatment standards for existing sources (PSES) discharging to sewer

<u>POLLUTANT</u>	<u>DAILY MAXIMUM (mg/L)</u>	<u>MAXIMUM MONTHLY AVERAGE (mg/L)</u>
Cadmium (T)	0.69	0.26
Chromium (T)	2.77	1.71
Copper (T)	3.38	2.07
Lead (T)	0.60	0.43
Nickel (T)	3.98	2.38
Silver (T)	0.43	0.24
Zinc (T)	2.61	1.48
Cyanide, Total	1.20	0.65
Total Toxic Organics	2.13	--
Alternative to Total Cyanide: Cyanide, Amenable	0.86	0.32

Treatment standards for new sources (NSNS) discharging to stream

<u>POLLUTANT</u>	<u>DAILY MAXIMUM (mg/L)</u>	<u>MAXIMUM MONTHLY AVERAGE (mg/L)</u>
Cadmium (T)	0.11	0.07
Chromium (T)	2.77	1.71
Copper (T)	3.38	2.07
Lead (T)	0.69	0.43
Nickel (T)	3.98	2.38
Silver (T)	0.43	0.24
Zinc (T)	2.61	1.48
Cyanide, Total	1.20	0.65
Total Toxic Organics	2.13	--
Alternative to Total Cyanide: Cyanide, Amenable	0.86	0.32
Oil & Grease	52	26
Total Suspended Solids	60	31

¹ Total metals is the sum of copper, nickel, total chromium and zinc.

Typical treatment of spent rinse waters is based upon pH adjustment to form and precipitate relatively insoluble metal hydroxides. Solids formed in this process are then segregated from the effluent, and the effluent is discharged. This technology has been generally found adequate for meeting the requirements of Federal Categorical Treatment Standards of 40CFR 413 and 433 (Table 2). It is supplemented by special steps for destruction of cyanides and reduction of hexavalent chromium when appropriate.

Table 3: Examples of Treated Effluent Composition
(All values are in mg/l unless otherwise noted)

Parameter	Company A (copper/nickel plate on steel)	Company B (brass/nickel & chrome plate)	Company C (aluminum anodizing black oxide)	Company D (nickel/electro- forms on almn)
pH (S.U.)	9.1	9.2	7.6	9.1
TSS	3.1	4.0	14	7.2
Sulfate	133	165	•	1600
Nitrate-Nitrite	2.4	2.4	*	40
Aluminum	0.2	0.12	0.08	0.07
Boron	0.5	14	•	21
Chromium	0.1	0.12	0.08	0.07
Copper	0.48	0.34	1.3	0.43
Iron	0.76	0.39	1.1	0.04
Magnesium	1.7	2.1	*	0.05
Nickel	1.1	0.32	0.46	0.21
Phosphorus	1.5	1.8	1.0	0.13
Zinc	0.19	0.70	0.26	<0.005
Cyanide, total	0.22	0.35	0.01	0.01
Ammonium-N	<0.1	0.35	1.0	13
TOC	5.5	5.0	31	32
Surfactants	0.04	0.26	*	0.71

Note: Data generated during NPDES reapplication sampling and analysis.

• Parameter not measured

This technology usually reduces the concentration of various heavy metals in the effluent to below 1 mg/l, but is not effective for removal of most anions, many other cations, and organic compounds. Thus, the most common treatment of spent electroplating rinse waters does not remove many of the effluent's toxic constituents. Table 3 presents four examples of treated effluents.

B. 2. Cleaning Wastewaters Parts received at a job shop or in the plating department of an integrated facility are not ready for plating without some form of cleaning and possibly some additional surface preparation. Without proper preparation, the plate will not properly adhere. The three basic types of cleaning and the order in which they are used are: (1) organic/solvent degreasing, (2) alkaline cleaning, and (3) acid pickling. Occasionally a mechanical cleaning step is needed prior to the above if heavy scale is present on the parts.

Wastes from organic solvent cleaners are usually well segregated from the facility wastewater management system and are seldom a major concern in effluent toxicity. Problems arise only when drag out from the solvent cleaning process (degreasing) is not given sufficient opportunity to evaporate prior to immersion in a tank attached to the wastewater management system.

Alkaline cleaners are almost universally used in the electroplating industry and, depending upon the specific cleaner used, may necessitate the separate management of cleaning wastewaters. Constituents of some alkaline cleaners interfere with the treatment of electroplating wastewaters, thereby making separate wastewater management systems mandatory.

Most alkaline cleaners are a mixture of sodium hydroxide (NaOH), sodium carbonate (NaCO₃), one or more of several sodium phosphate compounds, and silicates. Alkaline cleaning operations are generally kept at 50-80°C. Proprietary chelating agents are commonly used where low or no phosphate cleaners are required due to local nutrient discharge limitations. These chelating agents are usually one or more of the following:

sodium citrate
sodium gluconate
triethanolamine

trisodium nitrilotriacetate
tetrasodium ethylenediamine tetraacetic acid

In addition, surfactants are also present to decrease surface tension, emulsify oils and suspend dirt particles.

Historically, cleaners have been discharged without any treatment other than neutralization and removal of free floating oils. For those facilities discharging to sewers, this is still often the case. In recent years most direct dischargers have been required to also reduce emulsified oils discharge and reduce the content of certain heavy metals. As with the treatment of electroplating wastewaters, many constituents still pass through with little or no treatment.

C. Causes of Effluent Toxicity

Effluent toxicity is not a question of the presence or absence of certain materials but rather a question of the presence of effluent constituents at concentrations sufficient to cause unacceptable levels of toxicity to test species. Fortunately, most metal finishing effluent constituents are usually not present at levels high enough to cause toxicity. In the majority of situations, unacceptable levels of toxicity can be traced to a few groups of materials (that is, heavy metals, chlorinated solvents, surfactants, etc.), thereby narrowing the investigation needed to determine the culprit(s). The following subsections present an overview of some of the more commonly encountered causes of effluent toxicity in metal finishing effluent.

C. 1. Inorganics. The most obvious constituents in metal finishing effluents that may cause excessive toxicity are the metals themselves. Although iron is the most prevalent of these metals, it has seldom been found to be a problem. Alloying and plating metals such as chromium, copper and nickel are, however, often found to be major contributors to effluent toxicity. The actual concentrations at which these metals cause excessive toxicity is highly dependent upon other characteristics of the effluent (i.e. the presence of chelating agents), characteristics of the receiving water (i.e. hardness), and the specific toxicity goals that have been set for that effluent. Experience has, however, allowed the development of rudimentary

guidelines for a few of the more common metals. The presence of any of the following heavy metals above the associated criteria is reason to suspect it to be a significant contributor to overall acute toxicity of the effluent to invertebrates such as *Daphnia pulex*:

Chromium	1.0 mg/l
Copper	0.05 mg/l
Iron	45.0 mg/l
Nickel	1.0 mg/l
Silver	0.01 mg/l
Zinc	0.5 mg/l

Other common inorganic constituents frequently found to be major contributors to effluent toxicity include free chlorine, ammonia, cyanides and surfactants. Again, the actual concentrations at which these substances cause unacceptable toxicity vary widely, but general guidelines can be given. The presence of any of these substances in concentrations above those listed below is reason to suspect the substance to be a significant contributor to overall acute toxicity:

Ammonia, unassociated	1.0 mg/l
Cyanide, amenable	0.5 mg/l
Chlorine, total residual	0.5 mg/l
Surfactants	No guide

It should be noted that surfactants is a broad class of compounds, with each member having its own toxicity characteristics. Many of these compounds are very difficult to detect using commonly available environmental chemistry analytical techniques. Others have analytical method detection limits much higher than the point at which they produce unacceptable toxic effects. Thus, if toxicity is traced to surfactants, it is quite possible that the specific compounds involved cannot be quantified or qualified.

In addition to specific inorganic constituents, it is relatively common to have an effluent exhibit unacceptable toxicity due simply to its ionic strength. As water conservation has become more prevalent, the overall ionic strength of many effluents has increased. Some have increased to the point that osmotic pressure effects created by high salt content is lethal to the test

species. Although it is highly variable from case to case, ionic strength often becomes a problem when the total dissolved solids (TDS) of the effluent exceeds 2,000 mg/l.

C. 2. Organics. As discussed earlier, a wide variety of organics can be found in metal finishing effluents. These range from unwanted materials, such as oils present on parts prior to plating, to materials intentionally added to the finishing process such as coloring agents and chelators. Others, such as organic solvents, are frequently the result of cross contamination from elsewhere in the facility.

Many of the organics used in metal finishing are very complex, and reliable analytical techniques for measuring them are not readily available. Thus, determination of an organic constituent as a contributor to effluent toxicity must often be accomplished by indirect methods. With the exception of a few groups, identifying specific organic constituents causing unacceptable toxicity usually requires complex and costly procedures.

Fortunately, most of the organics present in metal finishing effluents are usually not major contributors to effluent toxicity. Spent organic solvents and oils have, however, been found to be significant contributors to effluent toxicity in many situations. The concentration at which oils cause unacceptable toxicity is highly dependent upon many factors, including the additives which may be present with the oils, the test species used to measure toxicity, and the presence or absence of emulsifying agents. No general guidance can be given for this group of materials as the variation from case to case is very large.

Organic solvents commonly used in metal finishing operations are often found in final effluents. Many of these solvents are known or suspected human carcinogens and have discharge limits well below levels associated with acute aquatic toxicity. In general, the presence of organic solvents in effluents, at concentrations sufficient to cause a significant contribution to overall effluent toxicity, is indicative of solvent management problems and is likely a violation of the facility discharge permit conditions.

D. Pollution Prevention Techniques

Section 3002(b) of the Resource Conservation and Recovery Act requires generators of hazardous waste to certify that a waste minimization program is in effect every time they manifest a shipment of hazardous waste. The draft EPA guidance document on waste minimization programs (54 Federal Register 25056) states that a facility waste minimization policy should have specific goals for reducing the volume and toxicity of wastestreams. This is essentially the same goal as a TRE but for a broader spectrum of wastestreams. It is logical that these two programs be integrated.

Waste minimization efforts can be divided into two broad categories: recycling and source reduction. The remainder of this section presents an overview of several of these waste minimization activities that are both broadly applicable to the electroplating industry and impact effluent quality and quantity

D. 1. Water Conservation. Many states set whole effluent toxicity limits that consider the flow rate of the discharge in relation to the flow of the stream. Many wastewater treatment systems currently in use by electroplaters reduce an effluent contaminant to a specific concentration independent of flow within the hydraulic operation range of the system. Thus, a simple reduction flow to the treatment system may increase toxicant concentrations of influent to the treatment system while allowing waste concentrations in the effluent to remain the same.

Water conservation also has the added benefit of reducing costs for raw water and, where applicable, sewer costs. The higher concentrations of contaminants in the untreated wastewater also improves the opportunities for recovery. Despite these paybacks, many facilities have not made strong efforts to conserve water. Up to a fifty percent reduction in rinse water usage could be realized through use of well designed rinse tanks, flow controls and re-use of rinse water (Hunt, 1988).

Figure 2 depicts a well-designed rinse tank. Feed water is evenly distributed and well controlled. Air agitation helps remove plating solutions from the work pieces and circulates water within the tank. Flow control is easily maintained through the use of mechanical flow restrictors.

Spent rinse water from one operation may be ideal for use elsewhere in the plating operation. A model example of this reactive rinsing approach is presented in Figure 3.

D. 2. Process Modifications. Process modifications include measures using existing equipment taken to minimize the introduction of process materials into the wastewater system (drag out) and measures taken to minimize the introduction of contaminants into the process solutions. There is a wide variety of low cost, easily implemented measures in both categories that can significantly reduce both waste generation and the toxicity of a facility's effluent. Table 4 lists a variety of techniques that have been found successful.

Table 4: Process Modifications

Process Solution Quality Improvement

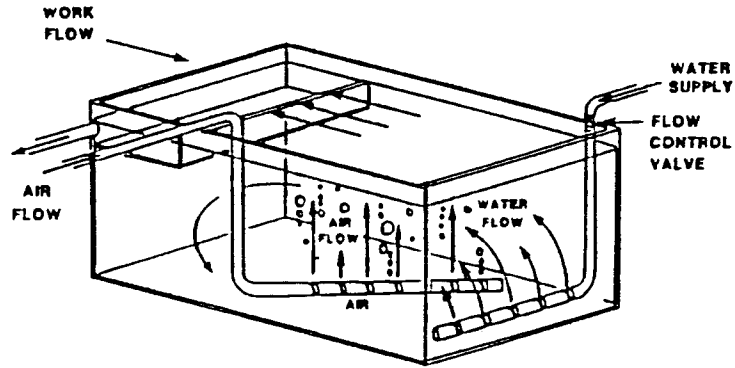
Minimize Drag Out
Precleaning Inspection
Proper Solution Make-up
Proper Solution Maintenance
Close Tolerance Temperature Control
Project Sludge Removed
Control Evaporative Losses
Avoid Work Shock (Vapor Degreasing)

Drag Out Minimization

Rack Parts to Maximize Drainage
Increase Drain Time
Rotate Barrels over Tanks
Use Minimum Metal Content in Bath
Maintain Racks and Barrels
Recycle Still Rinse to Bath Tank

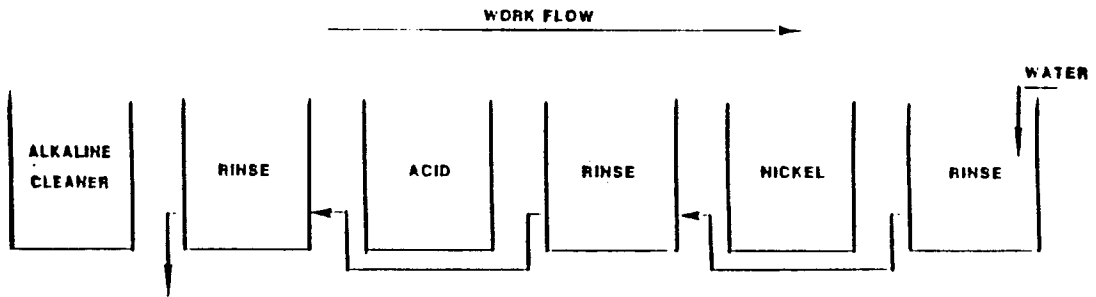
D. 3. Technical Changes. As with process modifications, there is a wide variety of equipment changes and additions that can reduce the amount of material entering the

Figure 2: Rinse Tank Design



Source: E. Saltzberg, A Manual of New Waste Conservation and Reuse Methods for the Electroplating Industry, EPA Contract No. 68-01-63-46, USEPA, 1982.

Figure 3: Reactive Rinsing



Source: J. Kushner, A. Kushner, Water and Waste Control, 2nd Edition, Gardner Publications, Cincinnati, OH, 1981.

wastewater stream. Many of these are relatively inexpensive while others involve significant capital outlays. Table 5 lists a variety of techniques that have been found to make a notable reduction in waste generation. The economic viability of each measure is highly dependent upon individual facility conditions and must be carefully evaluated prior to implementation. However, as the cost of waste disposal and discharge compliance continues to rise, more and more of these techniques become economically viable.

Table 5: Equipment Modifications and Additions

- o Install drain boards between the tanks.
 - o Design tank tops and free board to minimize floor spills.
 - o Install additional running rinse tanks.
 - o Install spray/fog rinses.
 - o Install/use deionized water for bath make-up water.
 - o Install hydroclone(s) on metal working fluids systems and/or cleaning fluids systems
 - o Install automatic water shut off system(s) in rinse water flow for when system is not in operation.
 - o Install ultrafiltration treatment system in alkaline cleaner systems
 - o Convert to dry tumbling methods.
-

D. 4. Treatment System Modifications. Typically, wastewater from electroplating operations is treated prior to discharge. This treatment usually consists of a pH adjustment to form metal hydroxide precipitate, a separation of the precipitate from the effluent stream and, if necessary, a final pH adjustment. There is a wide variety of commercially available equipment that augments or replaces this common treatment technique, improving the quality of the final effluent. While all systems have their advantages and disadvantages, many have the distinct advantage of reducing waste generation as well as reducing the concentration of process wastes in the effluent. Table 6 presents six examples of treatment equipment that also reduces loading to the treatment system or loading in the final effluent.

Table 6: Waste Recovery Techniques

- o Electrolytic metal recovery from still rinse tank
 - o Ion exchange coupled with electrolytic recovery on running rinse system
 - o Evaporative recovery of bath from still rinse
 - o Installation of electro dialysis for recovery of bath from still rinse
 - o Installation of reverse osmosis for recovery of bath from still rinse
 - o Installation of ion exchange on final effluent with electrolytic recovery
-

Use of methods listed in Table 6 can move a manufacturer closer to the ultimate goal of developing a "closed loop" process, but technology has not yet progressed to the point where all wastes from a process can be reused. Each method listed in this table goes as far as is practical in returning the desirable fraction of the wastestream to the process while sending contaminants and unwanted constituents to the final wastestream.

D. 5. Housekeeping. A manufacturer whose operations include electroplating may use thousands of materials, only a fraction of which are associated with electroplating. Thus, strict adherence to housekeeping procedures is needed to keep a large number of compounds and their cumulative toxic effect away from the wastewater management system.

D. 6. Raw Material Purity. It has been found that highly toxic constituents are often introduced as contaminants in raw materials, serving no purpose in production but causing considerable problems with effluent toxicity. Substituting a higher grade raw material may not only eliminate a toxicity problem but also improve production efficiency enough to recover the added cost of higher grade raw materials.

D. 7. Input Substitution. There has been tremendous progress in the past decade in development of high-quality, low-toxicity plating baths. In many cases, non-cyanide baths can be substituted for cyanide baths. This not only eliminates cyanide from the effluent but also eliminates the need for costly cyanide destruct components in wastewater treatment systems. This substitution may also reduce health risks to employees and, in some cases, render

wastewater treatment sludges nonhazardous. Similar benefits may accrue from the substitution of trivalent chromium baths as a substitute for hexavalent chromium baths.

In addition to the use of less toxic baths for a given metal, one may also consider plating with an inherently less toxic metal. A prime example of this is the substitution of zinc plate for cadmium. Quite often, cadmium is used only because "we've always used it, why change?" Although zinc is toxic to many aquatic species, its aquatic toxicity is only about 3 percent of that for cadmium (U.S. EPA 1986).

Successful substitutions have also been made with solvents. Aqueous based solvents have been used as a substitute for the more toxic trichloroethane and trichloroethylene. Naphthas are being used as substitutes for benzene, while terpenes are being found to be good substitutes for halogenated hydrocarbons (U.S. EPA 1989). The use of hot deionized water has been found to be a good substitute for CFC-113 in certain cleaning operations in the manufacture of disk drives (U.S. EPA 1989).

E. Bibliography

Hunt, G. E. 1988. "Waste Reduction in the Metal Finishing Industry." *Journal of the Air Pollution Control Association* 38:672-680.

U.S. EPA. 1986. Quality Criteria for Water 1986, EPA 440/5-86-001.

U.S. EPA. 1989. Waste Minimization in Metal Parts Cleaning, EPA 530-SW-89-049.

F. Case Studies

A Case Study of a Midwest Building Materials Manufacturer

Roger Dhonau
Pace, Inc.

The facility involved in this investigation is located in an industrial district of a small midwestern city. It employs approximately 500 people and is involved primarily in the manufacture of commercial aluminum frame windows. Specific manufacturing operations include extrusion of framing stock from aluminum billets, cutting, deburring, cleaning, anodizing, glass cutting and assembly into window frames. Wastewater generated from the anodizing, cleaning and rinse operations is treated and mixed with noncontact cooling water/boiler blowdown and is discharged to an adjacent stream. The maximum total discharge is 52 gpm with the process wastewater accounting for a maximum of 22 gpm. The receiving stream has a 7Q10 flow of approximately 90 gpm.

The aluminum cleaning and anodizing process is composed of the following stages:

1. Hot alkaline cleaner bath
2. Fresh water rinse
3. Chrome anodizing
4. Chrome treatment rinse
5. Fresh water rinse

Wastes from the three process tanks are treated to reduce hexavalent chromium to the trivalent state and to subsequently precipitate the chromium from the wastestream. This treated process wastewater is then mixed with the rinse waters in a final pH adjustment tank. After pH adjustment, the wastewater is then mixed with boiler blowdown and noncontact cooling water and discharged.

The facility's new discharge permit requires the effluent to pass a seven-day chronic toxicity test with the water flea, *Ceriodaphnia*. The effluent is deemed in compliance if an 18% percent effluent in clean dilution water causes no observable effect on *Ceriodaphnia* reproduction. Initial testing showed the effluent did not meet this criterion and a toxicity reduction evaluation (TRE) was deemed necessary.

Utilizing procedures outlined in the EPA guidance document *Generalized Methodology for Conducting Industrial Toxicity Reduction Evaluation*, the primary source of toxicity was traced to hydrazine utilized in the chromium reduction process. In addition, the layout, design, and operation of several portions of the anodizing line were found to generate unnecessarily large quantities of dragout.

At the time of this writing, alternative treatment procedures (i.e. sodium hydrosulfite, sodium bisulfite etc.) are being evaluated to determine which can be utilized with minimal process and financial impact. Bench-scale tests have shown this treatment revision will provide at least 70 percent effluent quality improvement required to meet toxicity requirements. Minor revisions to the anodizing room equipment and operations are also being implemented and are expected to provide sufficient additional reduction in effluent toxicity to allow the effluent to meet its permit requirements.

A Case Study of a Midwest Building Materials Manufacturer

Summary

Operations:	Extrusion, anodizing and painting of aluminum window frames. Assembly of windows
Wastewater Sources:	Rinse water from alkaline cleaning and chromating
Wastewater Treatment:	Chromating rinse waters are batch treated for reduction of hexavalent chromium to trivalent chromium. This water is then mixed with other rinse waters and pH adjusted.
Water Source:	City water supply
Toxicity Limits:	No observable chronic toxicity to <u>Ceriodaphnia</u> in an 18 percent (or less solution) of effluent in clean dilution water
Initial Toxicity:	No observable chronic toxicity was calculated at < 6 percent solution of effluent in clean dilution water.
TRE Findings:	1. Drag out was found to be excessive. A variety of drag out reduction procedures was implemented. 2. Hydrazine used in wastewater treatment was found to be highly toxic. Removal from the final effluent is expected to account for at least 70 percent of the required toxicity reduction. Substitutions, such as sodium hydrosulfite and sodium bisulfite were recommended.
Status:	Evaluating alternatives for hydrazine and the impact of drag-out reduction measures.

A Case Study of a Midwest Steel Finishing Plant

Roger Dhonau
Pace, Inc.

The facility in this investigation is a strip steel finishing plant in a small midwestern town. Primary operations include hot and cold annealing, bright annealing, cold rolling and pickling. Hot annealing lines consist of annealing furnaces followed by water quench, shot blasting (to remove scale), pickling in various mineral acids, rinsing and drying. Cold annealing lines consist of lower temperature annealing furnaces followed by air quench, kolene (strong caustic) bath, rinse, mineral acid pickling, rinse and drying. Soap cleaning is also frequently used in the cold annealing process.

Water consumption has been reduced by 40 to 60 percent over an eight-year period through recirculation and now ranges from 0.8 to 1.8 mgd. Water is used primarily for rinses after alkaline cleaning and pickling. All process water is supplied by an on-site well field. Spent rinse water (approximately 3.0 mgd) is first treated with waste pickle liquor (containing ferrous chloride) for hexavalent chromium reduction. It is then pH adjusted with lime to precipitate metals. Polymers are added as a flocculent. All treated water is routed to a large equalization lagoon where it cools. Approximately 1.2 to 2.2 mgd are recirculated from this lagoon, and the balance is discharged to a nearby stream. Sludge filtrate is also recycled to the head of the rinse water system.

The facility's NPDES permit requires that undiluted effluent not cause mortality to more than 50 percent of the test species *Ceriodaphnia* over a 48-hour exposure period. In addition, a 66.7 percent effluent solution cannot cause mortality to more than 50 percent of the test specimens over a seven-day period. These stringent limits were imposed because the discharge composes approximately 60 percent of the receiving stream's flow. Initial evaluations of effluent toxicity generated results far below the criteria for the permit.

Several factors complicated the toxicity reduction evaluation (TRE), adding time and expense to the investigation:

- Chemical usage, raw material usage and water usage at the plant are highly variable.
- Quality of the incoming water supply is also highly variable as usage of individual wells from the supply well field is dependent upon overall water demand and quality requirements for the specific grades of steel being processed.
- Extensive water recycling increased the difficulty in identifying contaminant sources.
- A portion of the process water is also recycled as noncontact cooling water. Cooling tower chemicals, therefore, also entered the system. The facility switched these chemicals several times during the investigation.

The primary cause of toxicity was found to be one or more unidentified nonpolar, nonvolatile organics which may be created in the production processes by degradation of raw materials. Due to the high variability in plant operations and extensive recycling of wastewaters,

the sources of these toxicants could not be specifically identified without exorbitant costs. Successful post-treatment of the effluent was achieved on a bench scale through ultrafiltration (2 micron nominal) and additional pH adjustment/precipitation. However, due to the volume of discharge, ultrafiltration was not deemed a practical option. Further investigation of additional pH adjustment/precipitation developed a procedure which allowed consistent compliance with the discharge limits under a wide variety of operating conditions. A modification to the existing wastewater treatment system is currently being designed that incorporates this additional treatment step.

A Case Study of a Midwest Steel Finishing Plant

Summary

Operations:	Hot and cold annealing and pickling of stainless steel
Wastewater Sources:	Rinse water from pickling and alkaline cleaning
Wastewater Treatment:	Wastewater is treated with pickle liquor containing ferrous chloride to reduce hexavalent chromium to trivalent chromium. Lime is then added to precipitate metals. Polymer is added as a flocculent aid. After clarification, treated water is discharged.
Water Source:	Process water is provided by on-site wells. Initially, water consumption was 2.0 - 3.0 mgd. Conservation (recirculation) measures taken over the past eight years have reduced this to 0.8 - 1.8 mgd.
Toxicity Limits:	Acute LC ₅₀ for <u>Ceriodaphnia</u> not to be exceeded in 100 percent effluent. No observable chronic toxic effects in solutions of 66.7 percent (or less) effluent.
Initial Toxicity:	Acute LC ₅₀ occurred at 34 percent effluent. No observable chronic toxic effects occurred at 10 percent.
The Findings:	<p>Toxicity is caused primarily by unidentified nonpolar, nonvolatile organics, possibly created in the production processes as a result of degradation of raw materials. Due to extensive water reuse, the source could not be identified.</p> <p>Toxicity was found to be sharply reduced by further upward pH adjustments followed by neutralization. The additional precipitate generated by the adjustment either co-precipitates the primary toxic constituents or the high pH chemically destroys them. Ultrafiltration also sharply reduced toxicity but was not an economically viable approach to toxicity reduction.</p>
Status:	Field tests of new treatment are currently underway.

A Case Study of a Metal Finishing Plant

Richard Mirenda and Scott Hall
Eckenfelder Inc.

A complete toxicity characterization study was initially conducted for a metal finishing plant's effluent as a result of acute toxicity problems. The initial phase of the toxicity reduction evaluation was a toxicity characterization study designed to determine the toxic component(s) of the effluent. The toxicity characterization procedures used were adapted from the U.S. EPA's Phase I Toxicity Characterization Procedure document. The results indicated several treatments successfully removed toxicity. The successful treatments included C₁₈ resin at pH 9, cation exchange, anion exchange, EDTA, sodium thiosulfate, powdered activated carbon, and pH 11 adjustment/filtration. These results strongly indicated metal(s) as a cause of toxicity. Ion exchange and EDTA addition are very effective in removing or binding metals or metal complexes, while powdered activated carbon has also been found to be effective in sorbing some metals. The effectiveness of the C₁₈ and filtration at a high pH is related to the removal of a precipitate which is formed as the pH is increased. The reduction of toxicity by sodium thiosulfate is probably a result of the binding of metal complexes, such as chlorides and hydroxides.

A subsequent treatability study was conducted which utilized the toxicity characterization results. The plant wastewater was normally adjusted to pH 8.5 and a polymer was added to precipitate and settle metals before discharging. Side by side tests of the normal treatment as well as a treatment where the pH was raised to 11.0 with polymer addition were conducted. The samples were either allowed to settle and were decanted or were filtered. The object of the study was to determine if the higher pH precipitated more metals than the current pH adjustment and whether filtering was more effective than settling. The toxicity test results (Table 1) indicated that pH 8.5 adjustment with settling or filtering of the sampling had LC50 values of 2.6 percent and 8.5 percent, respectively. The samples adjusted to pH 11 and then settled or filtered had no significant mortality in either test (Table 1). Chemical analysis indicated that copper appeared to be the primary cause of toxicity with zinc also contributing to some degree.

As a result of this study, the plant treatment of the effluent was modified to include pH adjustment to pH 11. A sand filter system was also installed at the end of the treatment basin to remove the precipitated metals. Since these modifications have been implemented the toxicity limits of the NPDES permit have been satisfied.

Table 1. Summary of treatability study results for case study of a metal finishing plant

Treatment	___Total Metals (mg/l)___		48 hr LC50
	Copper	Zinc	
Untreated	4.71	0.53	≈10
pH 8.5, settled	0.27	0.25	2.6
ph 8.5, filtered	0.12	-	8.5
pH 11, settled	BMDL	0.16	>100
Ph 11, filtered	BMDL	-	>100

Toxicity tests used Daphnia pulex as the test organism
 BMDL = below method detection limit (0.02 mg/l)

A Case Study of a Metal Finishing Plant

Summary

Discharger: Metal Finisher

Wastewater Source: Remwater (process wastewater)

Wastewater Treatment: pH adjust to 9.0 with caustic, add polymer, settle and neutralize

Toxicity Limits: acute - LC50 >90%

Toxicity of untreated effluent: 48-hour LC50 ≈ 3.0% for Daphnia pulex

TRE Findings: metals, primarily copper

Status: pH adjusted to 11.0 and sand filter system installed, toxicity alleviated

A Case Study of a Metal Plating Facility

Richard Miranda and Scott Hall
Eckenfelder Inc.

In response to a consistent toxicity problem, a series of toxicity characterization studies were conducted on the effluent from a metal plating plant. The initial phase of the toxicity reduction evaluation was a toxicity characterization study designed to determine the toxic component(s) of the effluent. The toxicity characterization procedures used were adapted from the U.S. EPA's Phase I Toxicity Characterization Procedure document. The data indicated several treatments which either removed or markedly reduced toxicity. These treatments included cation exchange, anion exchange, EDTA, sodium thiosulfate, and powdered activated carbon. Treatment of the effluent with C₁₈ resin at pH 9 also slightly reduced the toxicity. These results, along with analytical data, indicated that a metal (i.e. copper) was the primary source of toxicity. The inability of the treatments to completely remove the toxicity in some of the samples suggested that other toxic components might be present.

Since copper appeared to be the primary toxicant in this effluent, a treatability study was designed to reduce this metal in order to satisfy toxicity permit limits. The current treatment system operations were simulated in the laboratory and consisted of pH adjustment to 9.5, polymer addition and filtration. All of the subsequent treatability work and toxicity tests were done on this filtrate. Successful treatability procedures included pH adjustment to 12 followed by polymer addition and filtration, ferrous sulfide treatment, and adjustment to pH 12 followed by various doses of carbon and then filtration (Table 2). The data from these studies indicated that a threshold copper level of 0.06 mg/l appears to be required for removing toxicity. Modifications to the existing treatment process to achieve these copper levels included pH adjustment to 12 followed by filtration with a fine filter apparatus. A carbon system may be used in the future to treat any additional wastewater as a result of plant expansion or production modifications.

Table 2: Toxicity and copper results of treatability study conducted on a metal plating facility

Treatment	LC50 (%)	Total Copper (mg/l)
Untreated	--	240
pH 9.5, w/polymer and filtered (1.5 μ m)	3.2	0.22
ph 12 w/polymer and filtered (0.45 μ m)	93.2	0.06
FeS w/polymer and filtered (0.45 μ m)	>100	0.05
pH 12 PAC, 5.0 g/l	>100	BMDL
2.5 g/l	>100	BMDL
1.0 g/L	>100	BMDL
0.1 g/l	93.2	0.08

Toxicity tests used Daphnia pulex as the test organism.
 BMDL = Below method detection limit (0.02 mg/l)

A Case Study for a Metal Plating Facility

Summary

Discharger:	Metal plating
Wastewater Source:	Rinse water, pickling operations, contact cooling water, and cooling tower
Wastewater Treatment:	Equalization, two-stage pH adjustment, polymer addition, settling in a clarifier
Toxicity Limits:	Acute LC50 >30%, Chronic LC50 >90%
Toxicity of Untreated Effluent:	48-hour LC50 = 2.0 - 3.0% for <u>Daphnia pulex</u>
TRE Findings:	Metals, primarily copper, were the main source of toxicity; a small level of nonpolar organics also contribute to toxicity
Status:	Waste reduction and modification of existing treatment system; pH adjustment to 12.0 and fine filter system (carbon system may be installed in the future). Acute toxicity alleviated, chronic toxicity an occasional problem.

A Case Study of a Munitions Manufacturer with Metal Finishing Operation

Richard Mirenda and Scott Hall
Eckenfelder Inc.

An acute Phase I toxicity characterization study of a process wastewater was initiated as a result of violations of NPDES permit toxicity limits. The initial phase of the toxicity reduction evaluation was a toxicity characterization study designed to determine the toxic component(s) of the effluents. The toxicity characterization procedures used were adapted from the U.S. EPA's Phase I Toxicity Characterization Procedure document. The study results indicated partial or complete removal of toxicity as a result of several treatments. These treatments were cation exchange, anion exchange, EDTA, powdered activated carbon, and pH 3 air stripping plus chlorine addition. The toxicity results along with analytical data indicated that cyanide and copper were two of the major components of the effluent toxicity. The data also indicated that an organic compound may contribute to the toxicity. However, a treatment to specifically remove this compound without simultaneous removal of copper and/or cyanide was not found.

As a consequence of the toxicity characterization results, an on-site granular activated carbon (GAC) study was initiated. A series of three GAC columns were arranged in series and samples taken over time to determine breakthrough of copper, cyanide, and toxicity. The GAC columns were successful in removing these components from the effluent (Figure 1) and will be utilized in the treatment of the final effluent.

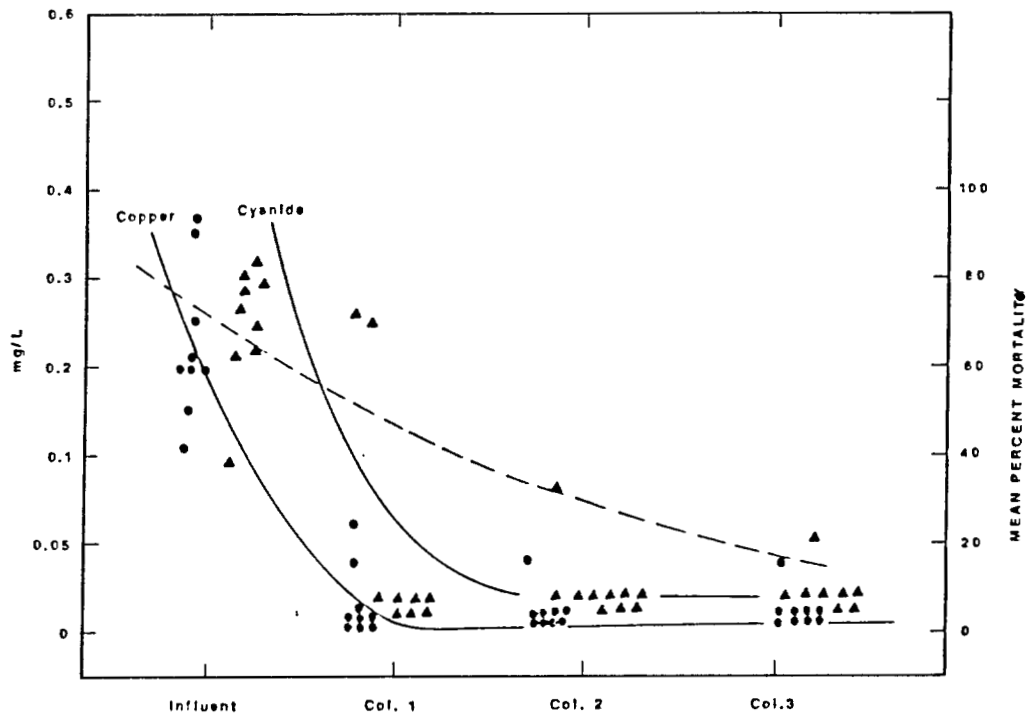


Figure 1: Toxicity, Copper and Cyanide Reduction due to GAC Treatment for a Munitions Manufacturer with Metal Finishing Operation

A Case Study of a Munitions Manufacturer with Metal Finishing Operations

Summary

Discharger:	Munitions manufacturer with metal finishing operations
Wastewater source:	Process wastewaters
Wastewater treatment:	Chemical precipitation, clarifier, filter system
Toxicity limits:	Acute LC 50 >100%
Toxicity of untreated effluent:	48 hour LC50 = 30-40%
TRE Findings:	Cyanide and copper were the primary toxicants
Status:	GAC system will be utilized in treatment system



V The Municipal Treatment Works Perspective on Toxicity Reduction

Case History: Toxicity Reduction in the City of High Point's Waste Treatment System

William D. Frazier
City of High Point Central Laboratory Services

Reducing and eliminating toxicity in municipal waste treatment systems has been the object of discussion and controversy for many years. It has become clear that there still is no single format for identifying, correcting and maintaining a system to completely eliminate the problem of toxicity. Numerous federal and state publications provide guidance on what must be accomplished, but they leave out one crucial feature—HOW.

A. Historical Introduction

The City of High Point Water and Sewer Department has formally been involved with effluent toxicity testing since March 1984 through its publicly owned treatment works (POTWs), but that effort was a natural extension of a historical commitment to improving environmental quality. As far back as records can be traced, the treatment works were managed and operated like the manufacturing processes in the community: they used the basic premise that optimum operation would provide a cost efficient and quality product. No one has labeled it as such, but this is nothing more than industrial process management. Observation of excessive foam or color and step-by-step monitoring of dissolved oxygen, solids, and pH in the treatment chain provided criteria for determining process efficiency and quality of effluent.

Early in the 1960s, the city formed a centralized lab to be responsible for testing the water and sewer system-wide. Although it was established in the Water and Sewer Department, Central Laboratory Services (CLS) was made physically and administratively separate from the POTWs to assure an objective point of view. If signs of treatment process inefficiency appeared, the cause was investigated. The result was that operational failures, analytical error, or

contributions to the waste stream from industrial sources could "impact" the treatment system. While the city had made a commitment to correcting damage to treatment systems, effluent regulation was not as stringent as it is today, and if a plant was damaged, the resulting multi-colored water, foam tsunamis, and fish kills were an unpleasant but accepted reality in the receiving stream.

In the early 1970s, regulation began to alter perspectives on treatment that was necessary at POTWs. Rules mandated that plants reduce pollutants in the effluent by specific amounts as stated in their NPDES permits. Engineering and operational improvements in the plants brought about some improvement in effluent quality, but plants were designed to treat only domestic waste loads. Therefore, permit limits could not be met without eliminating adverse impacts from industrial sources. The Industrial Pretreatment Section of the Water and Sewer Department was formed to carry out that responsibility. Central Lab Services expanded its analytical capabilities (personnel, instrumentation, etc.) to support the work of the pretreatment section.

Categorical pretreatment limits issued in the mid-1980s by federal and state regulatory agencies provided municipalities a tool for enlisting the aid of industries in meeting POTW permit limits. Also in the 1980s, a new environmental management "buzzword" emerged: toxicity. North Carolina became one of the first states to develop the capability to test for toxic effects of waste treatment plant effluent on aquatic life.

In the early 1980s, the N. C. Division of Environmental Management conducted extensive chemical and biological assessments on Deep River, one of the two streams to which High Point discharges. The report on their assessments concluded that "the toxicity of the [receiving stream] is alarming" (N.C. Division of Environmental Management, 1985). Central Lab Services consequently established a section to perform toxicity testing in-house. The initial testing effort concentrated on acute toxicity and the chemical-specific approach to identifying sources. Through the efforts of plant operators and pretreatment personnel and with accurate

data, effluent toxicity was reduced below acute levels in about two years. Then, regulatory changes established chronic toxicity limits in NPDES permits.

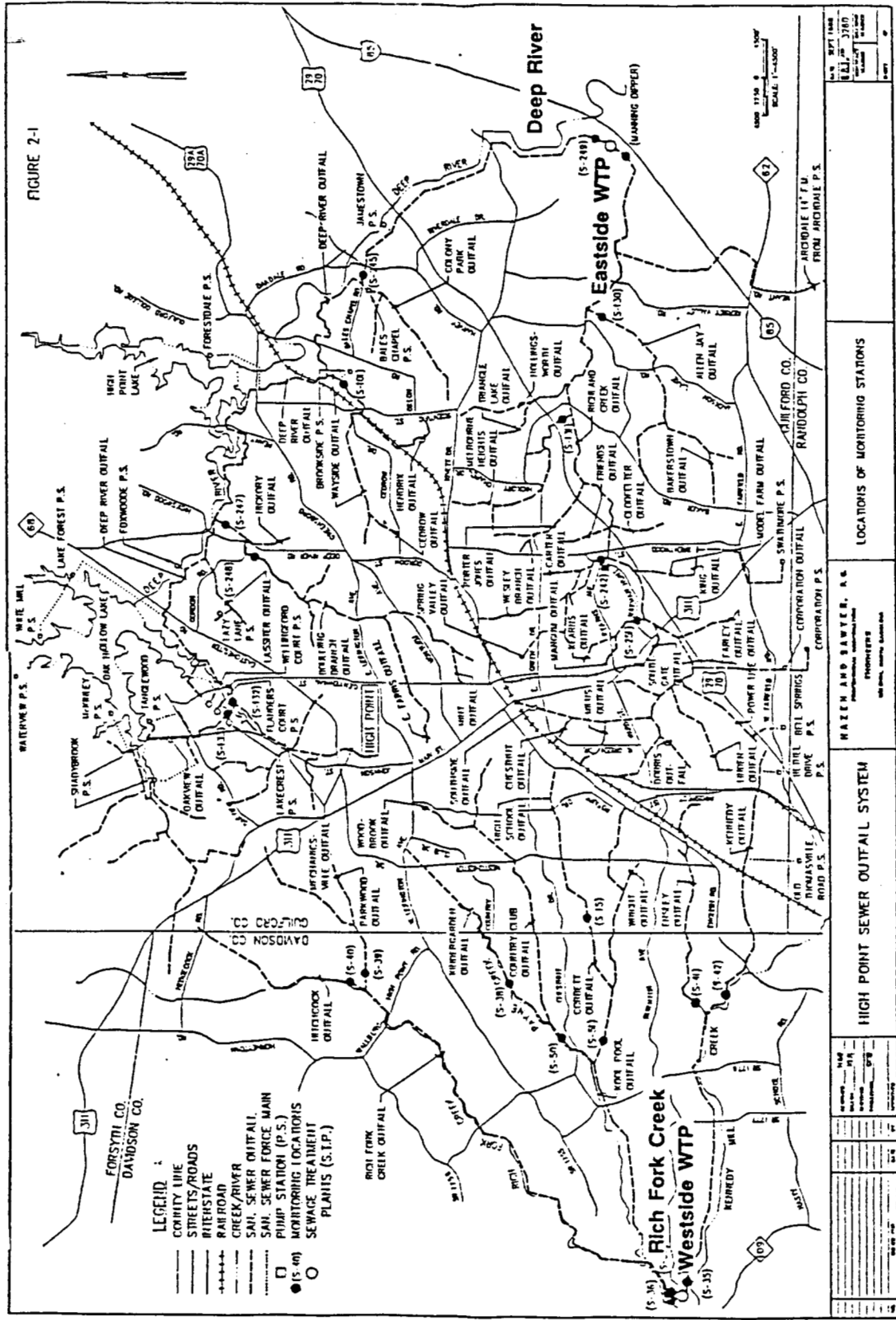
Chronic toxicity has proved to be a more difficult problem. The methodology is substantially more intricate, and test organisms are more sensitive. These organisms are so sensitive in fact that they may be affected by concentrations of substances below analytical detection levels.

In response to the chronic requirements, the pretreatment section performed a headworks analysis using updated versions of U.S. EPA's PRELIM computer program and contracted with consultants to assist in developing pretreatment limits for categorical and noncategorical parameters. The Central Laboratory Services section had years of process control monitoring data to use in performing the headworks analysis, had an existing set of criteria for assessing analytical data, and had historical information to use in setting pretreatment limits which reflect real-life conditions. The city also entered into joint research with the University of North Carolina at Chapel Hill to refine knowledge of toxic constituents in the waste stream and develop capability to perform whole effluent testing required for chronic toxicity limits. Ultimately, the necessary controls have been instituted, chronic toxicity limits have been met, and toxicity reduction and elimination is considered to be the primary goal of the city's environmental monitoring program.

B. Background Information

Some general information about POTW operations and pretreatment sections is needed in order to explain the way the City of High Point uses chemical and biological data to meet permitted toxicity limits. The city's waste treatment system is composed of a collection network which is physically divided between its two POTWs, as shown in Figure 1. The division results from the naturally occurring geographical drainage pattern. One drainage pattern is formed from the Eastside Wastewater Treatment Plant (WWTP) to Deep River. The other is from the

Figure 1. High Point Sewer Outfall System



<p>DATE: 8/17/88 DRAWN BY: J.M. CHECKED BY: J.M. SCALE: 1" = 1.500'</p>		<p>LOCATIONS OF MONITORING STATIONS</p>
<p>HIGH POINT SEWER OUTFALL SYSTEM</p>		
<p>HAZEN AND SAWYER, A.S. ENGINEERS</p>		<p>RAIFORD CO. RAILROAD P.S. SWANWIRE P.S. COOPERATION P.S.</p>
<p>DAVIDSON CO. DAVIDSON CO.</p>		

Westside WWTP to Rich Fork Creek. Table 1 summarizes the composition of the respective waste streams. Differences between domestic-plus-industrial and total flows

Table 1: Composition of waste streams of High Point POTWs

POTW	FLOW DATA*			
	Permitted (MGD)	Average (MGD)	Domestic (MGD)	Industrial (MGD)
Eastside WWTP	16	10.8	9.07	1.58
Westside WWTP	6.2	4.1	3.27	0.38

*Based on Feb 1990 headworks analysis

result from uncontrolled sources such as nonsignificant contributors and unregulated inflow. The industrial pretreatment program (IPP) has mapped the location of significant industrial contributors by outfalls and can further subdivide the collection system (Figure 1). The designation of "significant contributor" is determined by empirical observation (color, foam, etc.) and historical data (flow, BOD, metals, etc.) Using this information, an industry can also be categorized by activity type (Table 2).

Table 2: Significant industrial contributors to High Point POTWs by activity

	No.	% Flow	%BOD	%TSS	%Metals+	%COD*
Eastside: Total	33	15	15	13	34	41
Textile	14					
Metal Contributor	9					
Westside: Total	16	9	<10	<10	37	114
Metal Contributor	2					
Organic Chemicals	4					
Paints/Coatings	3					

+ Metals = Cd, Cr, Cu, Bp, Ni, Ag, Zn

* Derived from 1986 headworks analysis

Municipal Treatment Works Perspective on Toxicity Reduction

Figure 2: City of High Point Central Laboratory Services POTW Analytical Criteria Check

x values represent the amount > the allowable limit

POTW INFLUENT											POTW EFFLUENT											STREAM QUALITY			
HEADWORKS ANALYSIS											PERMIT LIMITS														
D	BOD	COD	TSS	Cd	Cr	Cu	Pb	Ni	Zn	pH	BOD	TSS	INHGN	IO	Fec	Cd	Cr	Pb	Ni	TOX	Fec	IO	Cd	Zn	
A FLOW	ppm	ppm	ppm	ppb	ppb	ppb	ppb	ppb	ppb	Unit	ppm	ppm	ppm	ppm	Coli	ppb	ppb	ppb	ppb	PF/F	Coli	(VAL)	(VAL)	(VAL)	
Y	MGD	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
1	56		4		2				100						30					0	550	67	74		
2	49		9		25		****		89										22	0	155	67	120		
3	42	10	52	53		83		****	53										41	0	37	133	120		
4	54	25	137	148		117			79										53	0		33	120		
5	49		7		5				5										37	0	5	30	120		
6	41				10															0		67	92		
7	39				10															0		67	32		
8	47	3	1		53				32											0			34		
9	52		4						56						140					0	****	33	120		
10	51				17				21						200					Pass	500		120		
11	37														500					0	****	33	30		
12	39				3		****													0	150	33	44		
13	103						****											40		0		67	20		
14	77																			0		67			
15	75				20				26											0		67	24		
16	59	3			32															0	50	67	120		
17	69	16	50	56	100				47						130					0	****	67	120		
18	82	54	23	146		33		****												0	75	33	120		
19	75				3				142											0		67	120		
20	63																			0		67	46		
21	38																			0		67	26		
22	60		2		27															0		32	****	50	
23	169						****								500					0	****	33			
24	121	25																		0	12	33			
25	120	32		2																0	67	33			
26	110														500					0	****	67			
27	71																			0		33			
28	64																			0		67			
29	66																			0		33			
30	65	18																		0		33			
31	55																			0	40	57			
AVG	75	3		2	9				13	****	0	0	0	0	61	0	0	1	5	Pass	416	51	33	50	
MAX	169	54	137	140	0	117	0	****	0	142	0	0	0	0	500	0	0	40	53	Pass	****	133	****	160	
IC/61	CT	C	C	C	C	C	C	C	C	G	C	C	C		G	C	C	C	C	C	C	G	G	C	C
LIMIT	16	136	1375	118	1100	60	140	4	160	100	106(S)	8	30	5	1000	2	50	25	50	Pass	200	10.3	7	50	

These industries are important because they frequently contribute to conditions that upset the treatment balance of the POTWs or because their influent (to POTWs) is toxicity-prone. Chemical oxygen demand (COD) is used to indicate the impact from organic chemical industries. A photographic operation and an organic chemical manufacturer contribute to Eastside's waste stream. Westside has a dairy and some light textile operations. Both Eastside and Westside wastewater treatment plants take effluent from drum cleaning operations that is capable of impacting the plants. At both plants, the wastewater of each significant industrial contributor is fairly distinctive. This distinction among industrial effluents is the basis for determining what is impacting a POTW and who is contributing to it.

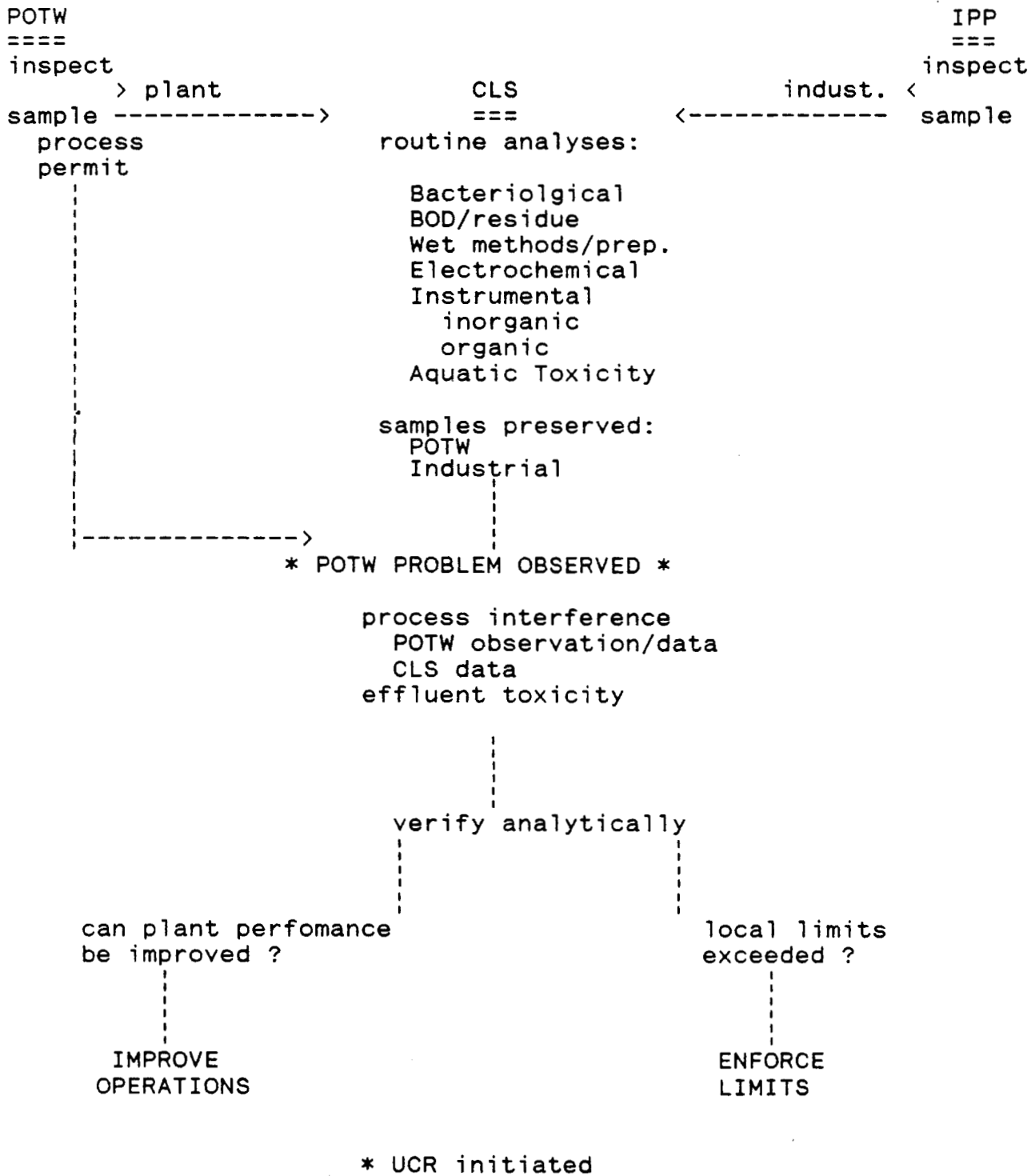
C. Analytical Monitoring

Sampling and analysis is separated into two categories: permitted and process control. Permitted sampling and analysis is that required for an NPDES permit. Both the sampling point and frequency are mandated by individual permits. Process control sampling and analysis is required to keep the POTW operating correctly. If the frequency in the permit requires weekly monitoring and process control analyses are performed daily, this would be described as permitted, process control data. There are very few instances where permitted parameters are not analyzed on a process control (more frequent) basis.

The city maintains long-term data sets which serve as reference points against which analytic data can be checked. These data sets are headworks analysis data, NPDES permit limits, and the averages of key nonpermitted parameters. Comparison of analytic data with the maintained data sets can help staff make a judgement on which pollutants are responsible for toxicity or other impacts and predict what the short and long-term effects will be. CLS uses a LOTUS computer spreadsheet to integrate sampling data with permit limits and system parameters to automatically evaluate noncompliance and toxicity potential (Figure 2).

Observation by POTW personnel and the automated criteria check are not independent factors. One supports the other. If a criteria violation is present in the influent and does not

Figure 3: Flow Chart for Tracing Operational Interruptions, Causes of Permit Violations and Toxic Events



show up in the effluent, the plant has performed beyond its capacity. Either the operators have made an adjustment or the in-coming waste could be assimilated by the POTW. For instance, in Figure 2, on day 8 chromium is shown to be above the allowable limit in the influent but is not present in the effluent. On the other hand, if there are criteria violations for the same constituent in the influent and the effluent, there is a compelling argument that the source is non-domestic. Note, for instance, in Figure 2 that on one day only—day 13, lead is elevated in the effluent and that this event also occurs during a second day of above-average flow when lead is elevated in the influent.

Residual chlorine (indicated as CL2 under Stream Quality in Figure 2) offers an example of toxicity due to treatment. Notice that on the day 10 when chronic test samples were taken, there was no criteria violation for residual chlorine.

Knowledge of the link between residual chlorine and toxicity illustrates the predictive ability of analytical monitoring. Violations accompanied by observable problems, such as foaming, can usually be traced to their source and corrected quickly by adjusting process parameters. Similarly, operational problems, such as a malfunctioning instrument, can easily be identified as the source of a potential violation and corrected quickly. In addition, analytical tests that can be done within a matter of minutes or hours, such as those for metals, allow quick violation prediction, source discovery, and correction. However, violations that can be revealed only by tests that require several days, such as those for BOD and chronic toxicity, may not be detected until the conditions causing the violations have disappeared. Knowing all the conditions that existed within the headworks and in the plant when samples that later reveal BOD or toxicity violations were taken can help staff predict when future violations might occur and determine what process adjustments can be made to prevent violations when the conditions reappear. Access to adequate data, both internal and external, can help reduce the impact on the receiving stream and the cost to the city of fines for violations.

Municipal Treatment Works Perspective on Toxicity Reduction

Figure 4: Unusual Conditions Reporting Process

Step 1: Initial observation at POTW

UNUSUAL CONDITIONS REPORT

Reported By: Operator	To: CLS								
Date: June 1, 1990									
Analysis	Sample Date	Time	Flow	Flow	Sample	Analysis	Flow Analyzed	Flow	Condition of Sample
COB	6-1	9:00	✓		Treatment				EXCESSIVE FOAM
Remarks:									

Step 2: Initial observation in Lab

UNUSUAL CONDITIONS REPORT

Reported By: Operator	To: CLS								
Date: June 2, 1990									
Analysis	Sample Date	Time	Flow	Flow	Sample	Analysis	Flow Analyzed	Flow	Condition of Sample
CA	6-1	9:00	✓		Treatment	COB	6-2	9:00	FOAMY
Remarks:									

Combined Step 1 and 2

UNUSUAL CONDITIONS REPORT

Reported By: Operator	To: CLS								
Date: 6-1-90									
Analysis	Sample Date	Time	Flow	Flow	Sample	Analysis	Flow Analyzed	Flow	Condition of Sample
COB	6-1	9:00	✓		Treatment				EXCESSIVE FOAM
CA	6-1	9:00	✓		Treatment	COB	6-2	9:00	FOAMY
Remarks:									

Step 3: Verify that cause of observed condition is not in-plant

UNUSUAL CONDITIONS REPORT

Reported By: Operator	To: CLS								
Date: 6-1-90									
Analysis	Sample Date	Time	Flow	Flow	Sample	Analysis	Flow Analyzed	Flow	Condition of Sample
COB	6-1	9:00	✓		Treatment				EXCESSIVE FOAM
CA	6-1	9:00	✓		Treatment	COB	6-2	9:00	FOAMY
Remarks: (1) Run Substrates 6-2-90 LS									

Step 4: (A) Residual effects of impact;
(B) Identify source

UNUSUAL CONDITIONS REPORT

Reported By: Operator	To: CLS								
Date: 6-1-90									
Analysis	Sample Date	Time	Flow	Flow	Sample	Analysis	Flow Analyzed	Flow	Condition of Sample
COB	6-1	9:00	✓		Treatment				EXCESSIVE FOAM
CA	6-1	9:00	✓		Treatment	COB	6-2	9:00	FOAMY
CA	6-1	9:00	✓		Treatment	HNH	6-2	9:00	FOAMY
CA	6-1	9:00	✓		Treatment	705	6-2	9:00	FOAMY
Remarks: (1) Run Substrates 6-2-90 LS (2) Run OCA's 6-3-90 LS									

Step 5: (A) Continued residual effects
(B) Indication of criteria-base violation

UNUSUAL CONDITIONS REPORT

Reported By: Operator	To: CLS								
Date: 6-1-90									
Analysis	Sample Date	Time	Flow	Flow	Sample	Analysis	Flow Analyzed	Flow	Condition of Sample
COB	6-1	9:00	✓		Treatment				EXCESSIVE FOAM
CA	6-1	9:00	✓		Treatment	COB	6-2	9:00	FOAMY
CA	6-1	9:00	✓		Treatment	HNH	6-2	9:00	FOAMY
CA	6-1	9:00	✓		Treatment	705	6-2	9:00	FOAMY
CA	6-1	9:00	✓		Treatment	PCA-A	6-3	9:00	FOAMY
AT	6-1	9:00	✓		Treatment	705	6-3	9:00	FOAMY
Remarks: (1) Run Substrates 6-2-90 LS (2) Run OCA's 6-3-90 LS (3) The level of COB can inhibit plant process 6-3-90 CA									

It is the responsibility of the pretreatment staff to help industrial dischargers understand their role in correcting conditions that have been identified as likely to cause toxicity violations. But which discharger is responsible?

D. Tracking

The city's pretreatment program staff collects daily samples from industries capable of POTW system impacts (Table 2). These samples are stored until needed. The operators monitor their in-plant parameters and observe conditions at the plant at various intervals around the clock. As samples are delivered to the laboratory and placed in the analytical train, they supplement operational indicators. A simplified flow chart (Figure 3) outlines the process the City of High Point uses to find and trace operational interruptions, causes of permit violations, and toxic events.

Reporting and documenting events which affect the system, whether from computer criteria checks or observation, are labor-intensive tasks. Both elements are both done through a system called an Unusual Condition Report (UCR). The flow diagram indicates when an UCR should be initiated and who should initiate one. It is important to note that the plant, lab, and pretreatment section are working concurrently.

If POTW staff observes unusual color, foam, etc., in the wastewater they will pull a grab sample and start an UCR. When the sample arrives in the lab, it will be stored, and no analyses will be performed unless routine samples were not able to properly identify the source of a problem. Based on what plant conditions may reveal and past experience, staff will try to make adjustments in operational parameters to affect a quick recovery. Once the POTW staff have completed these tasks, they have fulfilled their part of the upper loop in Figure 3. The types of interferences that completely disrupt plant processes are usually associated with acutely toxic events or other permit violations.

Sometimes an interference is not obvious to plant operators, and the lab personnel find out only after performing routine daily analyses. This is usually the case when headworks criteria are violated for trace chemicals or when chronic toxicity occurs. Central Laboratory Services would then initiate a UCR detailing the value and parameter responsible for the observed problem. In some cases, what the lab finds can be combined with the observation made by the plant personnel. The lab then becomes responsible for tracking down which discharger is impacting the POTW.

This is achieved by taking samples from industrial contributors which are stored and placing them in the analytical train. The daily monitoring and samples collected at the POTW help to fulfill the analysis required so not all of the retained industrial samples need to be analyzed. If metals have caused the problem, samples from industries that most commonly contribute metal-laden wastes are analyzed. It then becomes a process of elimination. Typically, one or more industries are found to have contributed to the impact. If no problem is indicated, samples are held until all data is recorded and then rotated out of storage and dumped.

The Unusual Conditions Reporting process is shown in Figure 4. This particular report shows impact from a chemical manufacturing process and the typical results. The impact from the chemical waste was much less specific than a metal dumped by an industry. Chemical oxygen demand (COD), a gross parameter, was used to pin-point the industry.

It is important to note that the most critical issue to be addressed in controlling toxicity is pinpointing NOT WHAT is causing the problem but WHO is responsible and HOW to eliminate or control the impact. Most industries cooperate with this system of control. When asked, they usually will admit that they have experienced a problem, such as wash-down or a batch process which did not react properly, that could have grossly affected the nature of their discharge.

If litigation becomes necessary, there are analytical measurements (such as gas chromatography or mass spectrophotometry) that could produce the "smoking gun," but the goal

is to correct the condition in the fastest, most effective manner possible without being oppressive to industry.

E. Conclusion

The longer the City of High Point is involved in toxicity testing, the more it learns. Many of the causes of in-stream toxicity are subtle, unexpected, and undefined. Recently, toxicity began to appear in the effluent of the Eastside POTW, which had not had a toxic event in two years. There were no significant industrial loadings or apparent operational problems, but staff in the aquatic toxicity section began noticing a light accumulation of solids that looked like cotton in cultures after a day or two. Further, if effluent samples were taken out of the white polyethylene containers in which they were collected and placed in glass, solids were visible. Total suspended solids (TSS) at Eastside had typically run between 2 and 4 mg/l. TSS levels in samples exhibiting toxicity averaged close to 6 mg/l. A quick look at operational parameters showed that higher TSS coincided with removal from service of a malfunctioning sand filter. An in-depth review of the process control data indicated relationships among the three solids analyses being performed (total, suspended, and settleable), along with the parameters of fecal coliform and chlorine. The problem remains undefined, but the cause is identified, and the solution is obvious—get the sand filter back in service!

By evaluating process control data trends, toxicity problems can be identified and eliminated and a virtually violation-free operational environment can be maintained. It has taken the City of High Point many years to accumulate the knowledge and develop the capability, but we can comply with the toxicity limits of our permits, and we are able to do so without formal toxicity identification evaluations. We have succeed because of the experience and dedication of all the people involved.

The Westside WWTP is approximately 95 percent effective in responding to incidental impacts from industrial contributors in order to prevent toxic impacts on the receiving stream. Of the impacts that the Westside plant was not able to accommodate, Central Lab Services and Industrial Pretreatment were more than 90 percent effective in finding the responsible

Municipal Treatment Works Perspective on Toxicity Reduction

contributor and enlisting the industry's help. Westside has not had a confirmed toxic response in its effluent in almost three years even while performing up to two chronic bioassays a month. The Eastside WWTP statistics were about the same as the Westside WWTP prior to the malfunctioning sand filter.

To improve performance in the future, the City of High Point is installing flow equalization basins at the headworks of the POTW. This should eliminate slug effects on the plant. The pretreatment section continues to encourage waste reduction and recycling efforts by industrial dischargers. By developing an organized, integrated monitoring and analysis system, the city has fine-tuned its wastewater treatment system to improve environmental quality.

F. Bibliography

- N.C. Division of Environmental Management. 1985. Water Quality Evaluations—Upper Deep River, Cape Fear River Basin—1983, Report No. 84-05. Raleigh, NC: N.C. Department of Natural Resources and Community Development.
- U.S. EPA. 1987. Guidance Manual on the Development and Implementation of Local Discharge Limitations under the Pretreatment Program. Washington, DC: EPA Office of Water Enforcement and Permits.
- U.S. EPA. 1987. Guidance Manual for Preventing Interference at POTWs. Washington, DC: EPA Permits Division.
- U.S. EPA. 1990. (Draft) Technical Support Document for Water Quality-Based Toxics Control, EPA-440/4-85-032. Washington, DC: EPA Office of Water.

VI Glossary

(Terms and definitions were taken from the publications referenced at the end of the glossary and from glossaries provided by some handbook authors.)

acute: in toxicity testing, a response observed due to exposure to a toxicant for a period of time that is short relative to the life cycle of the test organism ; effect is usually but not always measured in terms of lethality

BOD - biochemical oxygen demand: a measure of the tendency of wastewater to use oxygen in the receiving waters

CFR: Code of Federal Regulations. Reference to federal regulations is generally given by the volume, part, and subparts of the CFR. For instance, General Pretreatment Regulations are published in Volume 40, Part 403 of the Code of Federal Regulations, often written as 40 CFR 403 (subparts 403.1 through 403.16).

categorical: pertaining to regulatory statutes defining specific numerical limits for a given parameter

Ceriodaphnia: A water flea; one of the "sensitive species" designated by N.C. Administrative Code section 15 NCAC 2B .0202 (30) as acceptable for use in chronic aquatic toxicity testing.

chemical-specific: EPA term referring to an approach which looks for individual chemical constituents responsible for toxicity

chronic: in toxicity testing, a response observed due to exposure to a toxicant for a period of time that is long relative to the life cycle of the test organism; a chronic effect can be lethality, growth, reduced reproduction, etc.

ChV - chronic value: the geometric mean of the NOEL and LOEL

COD: chemical oxygen demand

conventional pollutants: pollutants that would typically be found in household or commercial wastewaters containing such things human wastes, food wastes, sand, leaves and laundry and bath waters. The broad categories of conventional pollutants include biochemical oxygen demand (BOD), suspended solids, fecal coliform, pH, oil and grease, and nutrients.

Daphnia pulex: A water flea; one of the "sensitive species" specified by N.C. Administrative Code sections 15 NCAC 2B .0202 (30) as acceptable for use in acute aquatic toxicity testing

Domestic wastewater (or wasteload): household discharges

EDTA: Ethylenediaminetetraacetic acid. A chemical used in characterizing metals toxicity.

Glossary

Headworks analysis: monitoring performed on the flow of wastewater into a treatment plant

LC₅₀: the toxicant concentration killing or predicted to kill 50 percent of exposed organisms in a specified time of observation

LOEL - lowest observed effect level: lowest measured continuous concentration of effluent or toxicant which causes an observed effect on the test organism

metals: One of the general groups of pollutants that are toxic to aquatic life. The metals of concern are the "heavy" metals and include lead, silver, mercury, copper, chromium, zinc, and cadmium.

NOEL - no observed effect level: the highest measured continuous concentration of an effluent or a toxicant which causes no observed effect on a test organism

NPDES - National Pollutant Discharge Elimination System: Federal program which regulates the direct discharge of wastewaters to surface waters

organic pollutants: One of the general groups of pollutants that are toxic to aquatic life; includes pesticides, solvents, PCBs, dioxins, etc.

POTW: publicly owned treatment works

7Q10: the discharge at the 10-year recurrence interval taken from a frequency curve of annual values of the lowest mean discharge for seven consecutive days. This is the low receiving stream flow used by North Carolina (along with permitted discharge volume) to specify the effluent concentration that must prove nontoxic to test species.

TIE - toxicity identification evaluation: Part of the TRE; a protocol performed in three phases: toxicity characterization (phase I), toxicant identification (phase II), and toxicant confirmation (phase III)

TRE - toxicity reduction evaluation: A step-wise process which combines toxicity testing and analysis of the physical and chemical characteristics of causative toxicants to zero in on the toxicants causing effluent toxicity and/or on treatment methods which will reduce the effluent toxicity

waste minimization (WM): According to EPA's working definition, waste minimization includes source reduction (waste reduction) and recycling.

waste (source) reduction: any activity that reduces or eliminates the generation of waste at the source, usually within a process (EPA usually applies the term to hazardous wastes.)

whole effluent toxicity: the aggregate toxic effect of an effluent measured directly with a toxicity test

References

- N.C. Division of Environmental Management, Water Quality Section/Environmental Sciences Branch. 1990. Aquatic Toxicity Testing: Questions, Answers, and Common Misunderstandings. Raleigh: N.C. Department of Environment, Health, and Natural Resources
- U.S. Environmental Protection Agency. 1986. Environmental Regulations and Technology: The National Pretreatment Program, EPA/625/10-86/005. Washington, DC: EPA Office of Water.
- U.S. Environmental Protection Agency. 1988. Waste Minimization Opportunity Assessment Manual, EPA/625/7-88/003. Cincinnati, OH: EPA Hazardous Waste Engineering Research Laboratory.
- U.S. Environmental Protection Agency. 1989. Generalized Methodology for Conducting Industrial Toxicity Reduction Evaluations (TREs), EPA/600/2-88/070. Cincinnati, OH: EPA Risk Reduction Engineering Laboratory.
- U.S. Environmental Protection Agency. 1987. Biomonitoring to Achieve Control of Toxic Effluents. Cincinnati, OH: EPA Center for Environmental Research Information.

VII Sources of Toxicity Information

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University of North Carolina at Chapel Hill

Author's note: Information on toxicity is available through the North Carolina Pollution Prevention Program (PPP), the National Library of Medicine (NLM), or through private vendors such as Chemical Information Systems, Inc. Appendix A provides a brief description of two of the most useful toxicological databases and general information about on line access. Actual examples of toxicity data for selected chemicals follow Appendix A.

APPENDIX A

I. Integrated Risk Information System (IRIS)

The Integrated Risk Information System, prepared and maintained by the U.S. Environmental Protection Agency, is an electronic data base containing health risk and EPA regulatory information on specific chemicals. The information in IRIS is intended for EPA staff without extensive training in toxicology, but with some knowledge of health sciences.

The heart of the IRIS system is its collection of computer files covering individual chemicals. These chemical files contain descriptive and quantitative information in the following categories:

- Substance Identification/Use
- Chemical & Physical Properties
- Noncarcinogenic Assessment - Lifetime Exposure
- Carcinogenicity Assessment - Lifetime Exposure
- Drinking Water Health Advisories/Acute Toxicity
- Aquatic Toxicity Assessment
- Exposure Standards and Regulations
- References

Registered NLM online services users are able to access IRIS and all other TOXNET system files through a number of telecommunications networks or by direct dial. The database is available 24 hours/day, 7 days/week, except for a brief daily maintenance period. Utilizing a free text search capability, a flexible command language and a variety of online user assistance features, TOXNET offers user friendly searching. For more information about IRIS and the TOXNET network, contact the National Library of Medicine at (800) 272-4787.

ALPHABETICAL LIST OF IRIS DATA ELEMENT MNEMONICS

ACUTE:	Acute Health Hazards
ALAB:	Drinking Water Analytical Procedures
AQUA:	Aquatic Toxicity Assessment (**)
AVOI:	Conditions & Materials to Avoid
BCF:	Bioconcentration Factors in Aquatic Species
BP:	Boiling Point
CAA:	Clean Air Act Requirements
CWA:	Clean Water Act Requirements (*)
CAR:	Carcinogenicity Assessment - Lifetime Exposure (**)
CAREV:	Evidence of Human Carcinogenicity
CARDR:	Carcinogenicity Assessment Documentation and Review
CARI:	Inhalation Exposure Carcinogenicity Assessment
CARO:	Oral Exposure Carcinogenicity Assessment
CERC:	Reportable Quantities
COFO:	Color/Form
CPP:	Chemical & Physical Properties
CRDF:	Carcinogenicity Assessment References
DATE:	Last Revision Date
DCMP:	Decomposition
DEN:	Density/Specific Gravity
DWHA:	Drinking Water Health Advisories/Acute Toxicity (**)
EVAP:	Relative Evaporation Rate
EXSR:	Exposure Standards and Regulations
FIFRA:	FIFRA Requirements
FIREV:	FIFRA Special Review
FISTD:	FIFRA Registration Standard
FLMT:	Flammable Limits
FLPT:	Flash Point
ID:	Substance Identification/Use (**)
HADR:	Health Advisory Documentation and Review
HADV:	Health Advisories (*)
HALIF:	Lifetime Health Advisory
HALTA:	Longer-Term Adult Health Advisory
HALTC:	Longer-Term Child Health Advisory
HAONE:	One-Day Health Advisory
HAREF:	Health Advisory References
HATEN:	Ten-Day Health Advisory
IREF:	Inhalation Reference Dose References
IRH:	IRIS Revision History
IRSN:	IRIS Number
MCL:	Maximum Contaminant Level
MCLG:	Maximum Contaminant Level Goal
MF:	Molecular Formula
MP:	Melting Point
MW:	Molecular Weight
NAME:	Name of Substance
NCAR:	Noncarcinogenic Assessment-Lifetime Exposure (**)

ODOR:	Odor
OLEP:	Organoleptic Properties
OREF:	Oral Reference Dose References
RCRA:	RCRA Requirements
RDI:	Reference Dose for Inhalation Exposure
RDO:	Reference Dose of Oral Exposure
REFS:	References (**)
RLEN:	Record Length
RN:	CAS Registry Number
SARA:	Title III Listing
SDWA:	Safe Drinking Water Act Requirements (*)
SMLC:	Secondary Maximum Contaminant Level
SOLW:	Solubility in Water
STAT:	IRIS Status
SUPER:	CERCLA/SARA Requirements (SUPERFUND) (*)
SY:	Synonyms
TSCA:	Toxic Substances Control Act Requirements
TREAT:	Drinking Water Treatment
UPDT:	Update History
USE:	Major Uses
VAP:	Vapor Pressure
VAPD:	Vapor Density
WQCAQ:	Ambient Water Quality Criteria for Aquatic Organisms
WQCHU:	Ambient Water Quality Criteria for Humans

Sources of Toxicity Information

1 - IRIS
NAME - Chromium(VI)
RN - 7440-47-3

WQCAQ-

Freshwater:

Acute -- 1.6E+1 ug/L (1-hour average)
Chronic -- 1.1E+1 ug/L (4-day average)

Marine:

Acute -- 1.1E+3 ug/L (1-hour average)
Chronic -- 5.0E+1 ug/L (4-day average)

Considers technological or economic feasibility? -- NO

CONTINUE PRINTING? (YES/NO)

USER:

Y

Discussion --

Reference -- 50 FR 30784 (07/28/85)

EPA Contact -- Criteria and Standards Division, OWRS
(202)475-7315 / FTS 475-7315

2 - IRIS
NAME - Chromium(III)
RN - 16065-83-1

WQCAQ-

Freshwater:

Acute -- 9.8E+2 ug/L (hardness dependent)
CONTINUE PRINTING? (YES/NO)
USER:

Y

Chronic -- 1.2E+2 ug/L (hardness dependent)

Marine: None

Considers technological or economic feasibility? -- NO

Sources of Toxicity Information

Discussion -- For freshwater aquatic life the concentration (in ug/L) of total recoverable trivalent chromium should not exceed the numerical value given by the equations "e**(0.8190 [ln (hardness)]+3.688)" for acute exposure and "e**(0.8190 [ln (hardness)]+1.561)" for chronic exposure (** indicates exponentiation; hardness is in mg/L). For example, at a hardness of 50 mg/L, the acute and chronic WQC would be 980 and 120 ug/L, respectively.

Reference -- 50 FR 30784 (07/29/85)

EPA Contact -- Criteria and Standards Division, OWRS
(202)475-7315 / FTS 475-7315

CONTINUE PRINTING? (YES/NO)
USER:

prt treat

1 . - IRIS
NAME - Chromium(VI)
RN - 7440-47-3

TREAT-

The treatment technologies that are available to remove chromium from water include coagulation/filtration, lime softening, ion exchange, and reverse osmosis.

2 - IRIS
NAME - Chromium(III)
RN - 16065-83-1

TREAT-

The treatment technologies that are available to remove chromium from
CONTINUE PRINTING? (YES/NO)
USER:

TREAT-

The treatment technologies that are available to remove chromium from water include coagulation/filtration, lime softening, ion exchange, and reverse osmosis.

2 - IRIS
NAME - Chromium(III)
RN - 16065-83-1

TREAT-

The treatment technologies that are available to remove chromium from
CONTINUE PRINTING? (YES/NO)

Sources of Toxicity Information

WQCAQ-

Freshwater:

Acute LEC -- 5.3E+3 ug/L
Chronic LEC -- None

Marine:

Acute LEC -- 5.1E+3 ug/L
Chronic LEC -- 7.0E+2 ug/L

Considers technological or economic feasibility? -- NO

CONTINUE PRINTING? (YES/NO)

USER:

CONTINUE PRINTING? (YES/NO)

USER:

y

Discussion -- The values that are indicated as "LEC" are not criteria, but are the lowest effect levels found in the literature. LECs are given when the minimum data required to derive water quality criteria are not available.

Reference -- 45 FR 79318 (11/28/80)

EPA Contact -- Criteria and Standards Division, OWRS
(202)475-7315 / FTS 475-7315

[IRIS] SS 8 /cf?

USER:

??

[IRIS] SS 8 /cf?

USER:

1 - IRIS
NAME - Benzene
RN - 71-43-2

TREAT-

Treatment technologies which will remove benzene from water include granular activated carbon adsorption and air stripping.

1 - IRIS
NAME - Phenol
RN - 108-95-2

WQCAQ-

Freshwater:

Acute LEC -- 1.02E+4 ug/L
Chronic LEC -- 2.56E+3 ug/L

Marine:

Acute LEC -- 5.8E+3 ug/L
Chronic -- None

Considers technological or economic feasibility? -- NO

CONTINUE PRINTING? (YES/NO)

USER:

CONTINUE PRINTING? (YES/NO)

USER:

Y

Discussion -- The values that are indicated as "LEC" are not criteria, but are the lowest effect levels found in the literature. LECs are given when the minimum data required to derive water quality criteria are not available.

Reference -- 45 FR 79318 (11/28/80)

EPA Contact -- Criteria and Standards Division, OWRS
(202)475-7315 / FTS 475-7315

II. Aquatic Information Retrieval Data Base (AQUIRE)

The Aquatic Information Retrieval Data Base was established to provide a comprehensive, computerized compilation of aquatic toxicity data. Prepared by the EPA Environmental Research Laboratory in Duluth, MN, scientific papers published worldwide on the toxicity of chemicals to aquatic organisms are collected and reviewed for AQUIRE on a continuing basis. Only data from primary references are included in the database. Selected toxicity test results and related information for any individual chemical from laboratory and field aquatic toxicity tests are extracted and added to the database. Toxicity tests on complex effluents, oils or combined pollutants are not included.

Information on aquatic toxicity can be searched under the following categories:

- test species (i.e. ceriodaphnia pulex [water flea])
- effect of interest (i.e. lethal concentration for 50% [LC50])
- test environment (i.e. salt, fresh, or estuarine water)
- chemical name or CAS number

Access to the AQUIRE database can be provided by the Pollution Prevention Program or directly through private vendors such as Chemical Information Systems (CIS) in Baltimore, MD. For more information about the AQUIRE database, contact Ann Pilly at the ERL in Duluth at (218) 720-5516, or the CIS at (301) 321-8440

AQUIRE
 AQUatic toxicity Information RETrieval
 3-FEB-91

U.S. Environmental Protection Agency
 Environmental Research Laboratory-Duluth

Contact: Scientific Outreach Program
 218/720-5548 or FTS 780-5548

Species Latin Name	Dur	Effect	Conc	Conc	R	Ref
Species Common Name	(days)		Type	(ug/L)	C	No.

7440473 CHROMIUM						
Daphnia pulex	2.00	LC50		48		2 11181
Water flea						

REFERENCES:

REFERENCE NUMBER: 11181
 Mount, D.I. and T.J. Norberg
 1984
 A Seven-Day Life-Cycle Cladoceran Toxicity Test
 Environ. Toxicol. Chem. 3(3):425-434

Retrieval complete - press any key to continue

AQUIRE
 AQUatic toxicity Information RETrieval
 3-FEB-91

U.S. Environmental Protection Agency
 Environmental Research Laboratory-Duluth

Contact: Scientific Outreach Program

Sources of Toxicity Information

108952.AQU

218/720-5548 or FTS 780-5548

Species Latin Name Species Common Name	Dur (days)	Effect	Conc Type	Conc (ug/L)	R C	Ref No.

108952 PHENOL						
Daphnia pulex Water flea	1.00	LC50		109000	2	518
Daphnia pulex Water flea	1.00	LC50		102500	2	518
Daphnia pulex Water flea	1.00	LC50		97000	2	518
Daphnia pulex Water flea	1.00	LC50		101000	2	518
Daphnia pulex Water flea	1.00	LC50		111000	2	518
Daphnia pulex Water flea	2.00	LC50		83000	2	518
Daphnia pulex Water flea	2.00	LC50		93000	2	518
Daphnia pulex Water flea	2.00	LC50		87800	2	518
Daphnia pulex Water flea	2.00	LC50		85000	2	518
Daphnia pulex Water flea	2.00	LC50		81000	2	518
Daphnia pulex Water flea	2.00	LC50		79000	2	518

REFERENCES:

REFERENCE NUMBER: 518

Cairns, J., A.L. Buikema, Jr., A.G. Heath, and B.C. Parker
1978

Effects of Temperature on Aquatic Organism Sensitivity to
Selected Chemicals

VA. Water Resour. Res. Center, Bull. 106, Office of Water
Res. Technol., OWRT Project B-084-VA, VA. Polytech. Inst.
State Univ., Blacksburg, VA:88 P.

108952.AQU

REFERENCE NUMBER: 5236

Kamshilov, M.M. and B.A. Flerov
1978Experimental Research on Phenol Intoxication of Aquatic
Organisms and Destruction of Phenol in Model Communities
Pages 181-192 In: D.I. Mount, W.R. Swain, N.K. Ivanikiw
(Eds.), Proc. First Second USA-USSR Symp. Effects Pollut.
Aquatic Ecosystems, U.S. NTIS ... (Author Communication
Used)

Retrieval complete - press any key to continue

AQUIRE

AQUatic toxicity Information RETrieval:
3-FEB-91U.S. Environmental Protection Agency
Environmental Research Laboratory-DuluthContact: Scientific Outreach Program
218/720-5548 or FTS 780-5548

Species Latin Name	Dur	Effect	Conc	Conc	R	Ref
Species Common Name	(days)		Type	(ug/L)	C	No.

7758987 CUPRIC SULFATE (CUSO4)						
Daphnia pulex	1.00	LC50		80	2	518
Water flea						
Daphnia pulex	1.00	LC50		70	2	518
Water flea						
Daphnia pulex	1.00	LC50		30	2	518
Water flea						
Daphnia pulex	1.00	LC50		20	2	518
Water flea						
Daphnia pulex	1.00	LC50		10	2	518
Water flea						
Daphnia pulex	2.00	LC50		70	2	518
Water flea						

Sources of Toxicity Information

Daphnia pulex Water flea	2.00	LC50	60	2	518
Daphnia pulex Water flea	2.00	LC50	20	2	518
Daphnia pulex Water flea	2.00	LC50	10	2	518
Daphnia pulex Water flea	2.00	LC50	56	2	518
Daphnia pulex Water flea	3.00	LC50	23.0	2	10987
Daphnia pulex Water flea	3.00	LC50	28.8	2	10987
Daphnia pulex Water flea	3.00	LC50	23.3	2	10987
Daphnia pulex Water flea	3.00	LC50	32.7	2	10987
Daphnia pulex Water flea	3.00	LC50	10.0	2	10987
Daphnia pulex Water flea	3.00	LC50	17.1	2	10987
Daphnia pulex Water flea	4.00	LC50*	28	3	8375

REFERENCES:

REFERENCE NUMBER: 518

Cairns, J., A.L. Buikema, Jr., A.G. Heath, and B.C. Parker
1978
Effects of Temperature on Aquatic Organism Sensitivity to
Selected Chemicals
VA. Water Resour. Res. Center, Bull. 106, Office of Water
Res. Technol., OWRT Project B-084-VA, VA. Polytech. Inst.
State Univ., Blacksburg, VA: 88 P.

REFERENCE NUMBER: 8375

McIntosh, A.W. and N.R. Kevern
1974
Toxicity of Copper to Zooplankton
J. Environ. Qual. 3(2):166-170

REFERENCE NUMBER: 10987

Winner, R.W.
1985

Bioaccumulation and Toxicity of Copper as Affected by
Interactions between Humic Acid and Water Hardness
Water Res. 19(4):449-455

Retrieval complete - press any key to continue

APPENDIX B

Another useful database is the Water Engineering Research Laboratory (WERL) Treatability Database prepared by the EPA Risk Reduction Engineering Laboratory in Cincinnati, Ohio. WERL differs from IRIS and AQUIRE in that it is primarily a matrix for the evaluation of treatment technologies versus removal efficiency. The database includes information on:

- Physical and chemical properties
- Water classification (i.e. ground water vs. domestic wastewater)
- Influent/effluent concentrations
- Treatment technologies
- Scale (i.e. bench top, pilot plant, or full scale)
- Percent removal
- Standard Industrial Classification (SIC) codes
- References

WERL is a useful complement to the waste auditing process, providing comprehensive reference listings for each treatment technology as well as performance parameters for percent removal. WERL also contains references on aquatic toxicity, however, the reference often leads back to the AQUIRE database. Following Appendix B are several examples of treatability data for selected chemicals as well as an explanation of the WERL legends and codes.

Access to the WERL database can be obtained through Stephanie Richardson, Director of the Pollution Prevention Program of North Carolina in Raleigh at (919) 571- 4100. For additional information on WERL, contact Kenneth A. Dostal of the EPA Risk Reduction Engineering Laboratory at (513) 569-7503.

Treatment Technologies Code and Abreviation Table

Treatment Technologies

-
- AAS - Activated Alumina Sorption
 - AFF - Aerobic Fixed Film
 - AL - Aerobic Lagoons
 - API - API Oil/Water Separator
 - AS - Activated Sludge
 - AirS - Air Stripping
 - AnFF - Anaerobic Fixed Film
 - AnL - Anaerobic Lagoons
 - BGAC - Biological Granular Activated Carbon
 - CAC - Chemically Assisted Clarification
 - ChOx - Chemical Oxidation (Parantheses shows oxidation chemical
ie. ChOx(Oz) - is ozone)
 - ChOx/Pt - Chemical Oxidation/Precipitation
 - ChPt - Chemical Precipitation
 - DAF - Dissolved Air Flotation
 - Fil - Filtration
 - GAC - Activated Carbon (Granular)
 - KPEG - Dechlorination of Toxics using an Alkoxide (Formed by the
reaction of potassium hydroxide with polyethylene
glycol (PEG400))
 - IE - Ion Exchange
 - PACT - Powdered Activated Carbon Addition to Activated Sludge
 - RBC - Rotating Biological Contactor
 - RO - Reverse Osmosis
 - SBR - Sequential Batch Reactor
 - SCOX - Super Critical Oxidation
 - SExt - Solvent Extraction
 - SS - Steam Stripping
 - Sed - Sedimentation
 - TF - Trickling Filter
 - UF - Ultrafiltration
 - UV - Ultraviolet Radiation
 - WOX - Wet Air Oxidation

NOTES:

- ___ + ___ is the first process unit followed in process train by
the second ie. AS + Fil - Activated Sludge followed
by Filtration.
- ___ w ___ is the two units together ie. UFWPAC - Ultrafiltration
using Powdered Activated Carbon.
- ___(B) is batch instead of continuous flow.

Scale

B - Bench Top P - Pilot plant F - Full scale

Number after letter refers to the plant number in a specific reference
(ex. F7 - plant 7 is the seventh full scale plant in the indicated report)

WERL Treatability Database

Rev. No. 2.0 08/31/89

Matrix

-
- C - clean water (ex. distilled)
 - D - domestic wastewater
 - GW - ground water
 - HL - hazardous leachate
 - I - industrial wastewater
 - I+HL - industrial waste combined with leachate from hazardous landfill
 - ML - municipal leachate
 - RCRA - RCRA listed wastewater
 - S - synthetic wastewater
 - SF - superfund wastewater
 - SP - spill
 - T - tap water
 - W - surface water

SIC (Standard Industrial Classification) Codes

For industrial wastewaters a 2 digit SIC code will be given following the letter code, i.e. I 22 is a Textile Mill Products wastewater. If the SIC code is unknown a U will be shown, I U.

- 10 - Metal mining
- 12 - Coal mining
- 13 - Oil and gas extraction
- 20 - Food and kindred products
- 22 - Textile mill products
- 24 - Lumber and wood products
- 26 - Paper and allied products
- 27 - Printing and publishing
- 28 - Chemicals and allied products
- 29 - Petroleum refining and related products
- 30 - Rubber and misc. plastic products
- 31 - Leather and leather products
- 33 - Primary metals industries
- 34 - Fabricated metal products except machinery & transportation equip.
- 36 - Electronic and electric equipment
- 39 - Misc. manufacturing industries
- 47 - Transportation services.
- 49 - Electric, gas, and sanitary
- 99 - Nonclassifiable establishments

Effluent Concentration

Effluent concentration will be given as a arithmetic mean to two significant figures. The number of samples used to calculate the mean is given after conc. as (n) (ex. 13 (5) - 13 is the mean of 5 sample values).

% Removal

Percent removal will be calculated on a concentration basis. If data are available, it will also be calculated on a mass basis for physical/chemical systems. Those values calculated on a mass basis will be noted by a (m). An example would be:

% Removal: 99.95 99.95 is based on concentration
 98(m) 98 is based on mass

where % removal = $\frac{\text{Influent} - \text{Effluent}}{\text{Influent}}$

Reference Codes

- A - Papers in a peer reviewed journal.
- B - Government report or database.
- C - Reports and/or papers other than in groups A or B not reviewed.
- D - Group C papers and/or reports which have been given a 'good' quality rating by a selected peer review.
- E - Group C papers and /or reports which have been given a 'poor' quality rating by a selected peer review. This data will only be used when no other data are available.

Codes Identifying Additional Data Presented In The Reference

- V - Volatile Emissions Data
- S - Sludge Data
- \$ - Costs Data

Physical/Chemical Properties Data

- (c) - Values presented are values that were reported calculated in the reference as is and are only used where measured are not available.
- NA - Values for the particular property have not been found in literature to date.

FREUNDLICH ISOTHERM DATA

ADSORBENT	MATRIX	K	1/N	Ce UNITS	X/M UNITS	REF.
FILTRASORB 400	C	49.8	0.156	mg/L	mg/gm	1576B

WERL Treatability Database

Ver No. 2.0

02/04/91

PHENOL

CAS NO.: 108-95-2

COMPOUND TYPE: PHENOLIC,

FORMULA: C6 H6 O

CHEMICAL AND PHYSICAL PROPERTIES

REF.

MOLECULAR WEIGHT: 94.11	333A
MELTING POINT (C): 43	333A
BOILING POINT (C): 181.7	333A
VAPOR PRESSURE @ T(C), TORR: 0.35 @ 25	1006A
SOLUBILITY IN WATER @ T(C), MG/L: 8 E4 @ 25	1006A
LOG OCTANOL/WATER PARTITION COEFFICIENT: 1.46	163A
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1:1.3 E-6 @ 25	191B

ENVIRONMENTAL DATA

REF.

CHRONIC NONCARCENOGENIC SYSTEMIC TOXICITY	4B
RISK ESTIMATES FOR CARCINOGENS	NA
DRINKING WATER HEALTH ADVISORIES/STANDARDS	NA
WATER QUALITY CRITERIA	4B
AQUATIC TOXICITY DATABASE	5B

FREUNDLICH ISOTHERM DATA

ADSORBENT	MATRIX	K	1/N	Ce UNITS	X/M UNITS	REF.
FILTRASORB 300	C	29	0.33	mg/L	mg/gm	138D
FILTRASORB 300	C	21	0.54	mg/L	mg/gm	3B
XAD 4	C	0.91	0.76	mg/L	mg/gm	193A
FILTRASORB 400	C	50	0.26	mg/L	mg/gm	72E
WESTVACO WV-L	C	13.3	0.299	mg/L	mg/gm	1083E
FILTRASORB 400	C	0.037	0.371	mg/L	mg/mg	450D
POLYBENZIMIDAZOLE	C	0.079	0.917	mg/L	mg/gm	381D
POLY(4-VINYL PYRIDINE)	C	0.223	0.894	mg/L	mg/gm	381D
FILTRASORB F400	C	78.1	0.212	mg/L	mg/gm	1721A
FILTRASORB 400	C	77.4	0.211	mg/L	mg/gm	489D

WERL Treatability Database

Ver. No. 2.0

02/04/91

PHENOL

CAS NO.: 108-95-2

TECHNOLOGY	MATRIX	SIC CODE	INFLUENT CONCENTRATION - 0-100 ug/L		PERCENT REMOVAL	REFERENCE
			SCALE	EFFLUENT CONCENTRATION (ug/L)		
AS	D	F31		<1 (6)	>98.3	1B -S-
AS	D	F4		<1 (3)	>96.4	1B -S-
AS	D	P		10 (11)	90.0	240A -S-
AS	D	F59		<26 (6)	>63	1B -S-
TF	D	F21		1 (6)	98.2	1B -S-
TF	D	P		8 (10)	91.3	240A -S-

WERL Treatability Database

Ver. No. 2.0

02/04/91

PHENOL

CAS NO.: 108-95-2

TECHNOLOGY	MATRIX	SIC CODE	INFLUENT CONCENTRATION - >100-1000 ug/L		PERCENT REMOVAL	REFERENCE
			SCALE	EFFLUENT CONCENTRATION (ug/L)		
AL	D	P1		84 (11)	33	203A -S-
AL	D	P2		18 (11)	86	203A -S-
AS	D	P		<14 (8)	>94.6	204A -S-
AS	D	F28		1 (6)	99.89	1B -S-
AS	D	P		14 (11)	89	203A -S-
AS	D	F38		<1 (6)	>99.44	1B -S-
AS	D	F19		<1 (5)	>99.33	1B -S-
AS	D	F		20 (31)	92.6	201B -S-
AS	D	P1		<8 (4)	>97.2	241B VS-
AS	D	F30		2 (5)	98.6	1B -S-
AS	D	F36		25 (6)	94.4	1B -S-
AS	D	F58		<61 (6)	>92.4	1B -S-
AS	D	F60		<8 (5)	>97.2	1B -S-

Sources of Toxicity Information

CAC	D		P	99 (11)	21	203A	-S-
TF	D		F52	<47 (6)	>82	1B	-S-
TF	D		P	64 (11)	49	203A	-S-
GAC	HL		F2	<10 (1)	>92.6	245B	---
AL	I	28	F12	<11 (3)	>90.8	6B	---
API+DAF+AS	I	29	F	85 (4)	89.5	1482D	---
AS	I	28	F4	<20	>87	975B	--\$
AS	I	28	F1	<10 (3)	>98.6	6B	---
AS	I	28	F3	<10 (39)	>96.4	6B	---
AS	I	28	F5	<15 (7)	>98.0	6B	---
AS	I	28	F31	<10 (11)	>96.3	6B	---
AS	I	28	F11	120 (3)	97.9	6B	---
AS + Fil	I	28	F29	<10 (15)	>98.0	6B	---
ChOx(Cl) (B)	I	28	B4	16	93.3	975B	--\$
ChOx(Cl) (B)	I	28	B1	<2	>98.3	975B	--\$
GAC	S		B2	10	99.00	1054E	V--
AL	SF		P	<10	>98.99	192D	---
AS	SF		P	<10	>98.99	192D	---
REC	SF		P	<10	>98.99	192D	---

PHENOL

CAS NO.: 108-95-2

TECHNOLOGY	MATRIX	SIC CODE	SCALE	INFLUENT CONCENTRATION -	EFFLUENT	PERCENT REMOVAL	REFERENCE
				>1-10 mg/L	CONCENTRATION		
				(ug/L)			
GAC	HL		F	<5 (1)	>99.89	237A	---
AS	I	28	F3	6.6	99.87	975B	--\$
AS	I	28	F1	160	95.0	975B	--\$
AS	I	28	F28	56 (4)	96.9	6B	---
AS	I	28	F42	<21 (10)	>99.64	6B	---
ChOx(Cl) (B)	I	28	B3	12	99.37	975B	--\$
PACT	I	28	B2	8	99.85	975B	--\$
PACT	I	28	B1	<2	>99.955	975B	--\$
PACT	I	28	F40	30 (3)	98.6	6B	---
RO	SF		F4	120	93.6	250B	---

TECHNOLOGY	MATRIX	SIC CODE	SCALE	INFLUENT CONCENTRATION -	EFFLUENT	PERCENT REMOVAL	REFERENCE
				>10-100 mg/L	CONCENTRATION		
				(ug/L)			
SBR	HL+I	U	P	1,000 (16)	97.7	1433D	---
AS	I	28	F17	<10 (3)	>99.944	6B	---
AS	I	28	F	4,000	95.2	1122E	---
AS + Fil	I	28	F26	<13 (3)	>99.976	6B	---
PACT	I	28	B	<1.8	>99.991	190E	---
AS	S		B2	1,000	95.0	1054E	V--

PHENOL

CAS NO.: 108-95-2

INFLUENT CONCENTRATION - >100-1000 mg/L
EFFLUENT

TECHNOLOGY	MATRIX	SIC CODE	SCALE	CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
SBR	HL		P	1 (1)	99.81	227D --\$
SBR	HL		B	3	99.63	64D --\$
SBRwPAC	HL		B	<1	>99.88	64D --\$
AS	I 28		F33	<0.010 (13)	>99.999	6B ---
AS	I 28		F8	<0.010 (2)	>99.996	6B ---
RBC	I 28		P	1.7	99.60	603E ---
SS	I 49		P	160	24	1082E ---
AS	S		B	<0.01	>99.994	202D VS-
AS	S		P	<0.5 (6)	>99.949	226B VS-
AS	S		B3	0.25	99.88	1054E V--
AnFF	S		P	0.07	99.981	231A ---
AnFF	S		P	0.01	99.999	231A ---
AnFF	S		B	<10	>98.97	230A ---
AnFF	S		P	0.24	99.86	235D ---
WOx (B)	S		B1	27	97.3	1054E V--

INFLUENT CONCENTRATION - >1 g/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
WOx (B)	C		B	3.6	99.920	1101D ---
WOx (B)	C		B	3.0 (1)	99.97	236A ---
AnFFwGAC	I 49		P	0.05	99.997	249D ---
SExt	I 49		P	210	95.4	1082E ---
AnFF	S		B	<1	>99.947	230A ---
AnFF	S		P	0.03	99.998	231A ---
AnFF	S		P	0.7	99.976	231A ---
WOx (B)	S		B2	20	99.89	1054E V--

WERL Treatability Database

Reference Number: 975A

Keinath, T.M., "Technology Evaluation for Priority Pollutant Removal from Dyestuff Manufacture Wastewaters", U.S. EPA Report No. EPA 600/2-84/055, IERL, Cincinnati, OH.

This report includes results from various studies conducted on six dyestuff manufacturing wastewaters. Four of the full-scale activated sludge treatment systems were sampled for removal of priority pollutants. No engineering information is available for these facilities.

Bench-top PACT studies were conducted on three of the raw wastewaters. Operational parameters were:

Aeration Volume	= 3 liters
HRT	= 1 day
SRT	= 20 days
Carbon Feed Rate	= 250 mg/L
Carbon Type	= Nuchar S-A 15

Chemical oxidation studies were conducted on the raw wastewaters using ozone. The glass reactor was 5.1 cm in diameter, 3.0 meters high with 1.5 meters of 6.3 mm ceramic Rasching rings. Four liters of wastewater were added to the reactor and it was recirculated at the rate of 4 L/min as the ozone was added to the bottom of the reactor. The following ozone dosages were applied:

B-1	= 1660 mg/L
B-2	= 500 mg/L
B-3	= 810 mg/L
B-4	= 1570 mg/L
B-6	= 1500 mg/L

END OF DATA

BENZENE

CAS NO.: 71-43-2

COMPOUND TYPE: AROMATIC, HYDROCARBON

FORMULA: C6 H6

CHEMICAL AND PHYSICAL PROPERTIES

REF.

MOLECULAR WEIGHT: 78.11	333A
MELTING POINT (C): 5.5	333A
BOILING POINT (C): 80.1	333A
VAPOR PRESSURE @ T(C), TORR: 95 @ 25	462A
SOLUBILITY IN WATER @ T(C), MG/L: 1780 @ 20	463A
LOG OCTANOL/WATER PARTITION COEFFICIENT: 2.13	379B
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1: 5.55 E-3 @ 25	191D

ENVIRONMENTAL DATA

REF.

CHRONIC NONCARCINOGENIC SYSTEMIC TOXICITY	NA
RISK ESTIMATES FOR CARCINOGENS	4B
DRINKING WATER HEALTH ADVISORIES/STANDARDS	346B
WATER QUALITY CRITERIA	345B
AQUATIC TOXICITY DATABASE	5B

FREUNDLICH ISOTHERM DATA

ADSORBENT	MATRIX	K	1/N	Ce UNITS	X/M UNITS	REF.
NORIT PEAT CARBON	C	0.73	0.61	ug/L	mg/gm	764B
NUCHAR WV-G	C	1.07	0.48	ug/L	mg/gm	764B
FILTRASORB 400	C	1.12	0.39	ug/L	mg/gm	764B
HYDRODARCO 1030	C	1.18	0.36	ug/L	mg/gm	764B
FILTRASORB 300	C	1.0	1.6	mg/L	mg/gm	3B

BENZENE

CAS NO.: 71-43-2

TECHNOLOGY	MATRIX	SIC CODE	INFLUENT CONCENTRATION - 0-100 ug/L		PERCENT REMOVAL	REFERENCE
			SCALE	EFFLUENT CONCENTRATION (ug/L)		
AS	D	F		6 (10)	81	201B -S-
AS	D	F58		<16 (6)	>84	1B -S-
AS	D	P		<0.2 (20)	>99.73	206B VS-
AS	D	F5		<0.7	>97.4	234A ---
TF	D	F11		1 (5)	97.5	1B -S-
AirS + GAC	GW	F		<1 (19)	>90.9	229A ---
RO	GW	F2		3.8	95.1	250B ---
AS	I 28	F2		<10 (28)	>89.6	6B ---
PACT	RCRA	B		<5	>83	242E ---
AS	S	B		0.5 (16)	97.8	200B VS-
RO	S	P		32 (1)	19	323B ---

TECHNOLOGY	MATRIX	SIC CODE	INFLUENT CONCENTRATION - >100-1000 ug/L		PERCENT REMOVAL	REFERENCE
			SCALE	EFFLUENT CONCENTRATION (ug/L)		
AL	D	F55		<10 (6)	>94.4	1B -S-
AS	D	F28		<1 (6)	>99.55	1B -S-
AS	D	F38		2 (6)	98.9	1B -S-
AS	D	F6		0.6	99.83	234A ---
AS	D	F30		<2 (6)	>99.00	1B -S-
AirS	GW	P		<0.5 (1)	>99.67	224B --\$
AirS	GW	F		<0.44 (22)	>99.74	322B --\$
AL	I 28	F24		<10 (2)	>92.3	6B ---
AL	I 28	F12		<10 (2)	>98.9	6B ---
AS	I 28	F5		<10 (7)	>98.8	6B ---
AS	I 28	F33		<10 (14)	>95.7	6B ---
AS	I 28	F3		<30 (22)	>91.7	6B ---
AS	I 28	F20		<10 (3)	>95.6	6B ---
SS	I 28	F1		<10 (10)	>96.3	251B V-\$
AS	S	B		0.8 (16)	99.30	200B VS-
AS	S	B		1.0 (8)	99.83	200B VS-
PACT	S	B		0.7 (12)	99.34	200B VS-
AirS	SF	P		1 (3)	99.09	1362E --\$
RO	SF	F4		67	92.7	250B ---
RO	SP	P2		50	78	250B ---

BENZENE

CAS NO.: 71-43-2

TECHNOLOGY	MATRIX	SIC CODE	SCALE	INFLUENT CONCENTRATION -	EFFLUENT	PERCENT REMOVAL	REFERENCE
				>1-10 mg/L	CONCENTRATION		
				(ug/L)			
AirS	GW		F	52 (19)		98.7	322B --\$
RO	GW		F3	140		92.2	250B ---
GAC	HL		F1	<10 (1)		>99.28	245B ---
API+DAF+AS	I 29		F	3.7 (4)		99.959	1482D ---
AS	I 28		F10	<10 (3)		>99.09	6B ---
AS	I 28		F1	<11 (27)		>99.80	6B ---
AS	I 28		F11	<10 (3)		>99.71	6B ---
WOX	RCRA		F	29		99.64	242E ---
AL	S		B	60		98.0	371D VS-
WOX (B)	S		B3	500		53	1054E V--
UF	SP		P2	230		78	250B ---

TECHNOLOGY	MATRIX	SIC CODE	SCALE	INFLUENT CONCENTRATION -	EFFLUENT	PERCENT REMOVAL	REFERENCE
				>10-100 mg/L	CONCENTRATION		
				(ug/L)			
AL + AS	I 28		F	13 (21)		99.900	233D VS-
AS	I 28		F31	<10 (15)		>99.974	6B ---
SS	I 28		F15	<10 (10)		>99.989	6B ---
SS	I 28		F32	10 (2)		99.971	6B ---
TF+AS	I 28		F21	<10 (3)		>99.974	6B ---
AirS	S		B2	9,300 (5)		90.0	1328E ---

TECHNOLOGY	MATRIX	SIC CODE	SCALE	INFLUENT CONCENTRATION -	EFFLUENT	PERCENT REMOVAL	REFERENCE
				>100-1000 mg/L	CONCENTRATION		
				(mg/L)			
AS + Fil	I 28		F26	0.020 (3)		99.994	6B ---
SS	I 28		F17	0.048 (12)		99.994	6B ---
SS	I 28		F32	0.20 (3)		99.938	6B ---
AS	S		B	0.040		99.974	202D VS-
WOX (B)	S		B1	180		82	1054E V--

WERL Treatability Database

Reference Number: 6B

Thomas, L.M., et. al., "Development Document for Effluent Limitations, Guidelines and Standards for the Organic Chemicals, Plastics and Synthetic Fibers Point Source Category", EPA Report, Report No. EPA 440/1-87/009, Washington, D.C. (October 1987).

The EPA Database used to develop the regulations in the above report was used for this activity with some changes in the editing rules. Only paired (influent/effluent) data sets were used and the influent concentration had to be 20 ug/L or the detection limit (if greater than 20 ug/L) to calculate the average influent and effluent concentrations.

No engineering information is available for these plants.

END OF DATA

CHROMIUM

CAS NO.: 7440-47-3

COMPOUND TYPE: INORGANIC, ELEMENT

FORMULA: CR

CHEMICAL AND PHYSICAL PROPERTIES

	REF.
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MOLECULAR WEIGHT: 52.00	333A
MELTING POINT (C): 1857	333A
BOILING POINT (C): 2672	333A
VAPOR PRESSURE @ T(C), TORR: 1 @ 1616	333A
SOLUBILITY IN WATER @ T(C), MG/L: INSOLUBLE	333A
LOG OCTANOL/WATER PARTITION COEFFICIENT:	NA
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1:	NA

ENVIRONMENTAL DATA

	REF.
-----	-----
CHRONIC NONCARCENOGENIC SYSTEMIC TOXICITY	4B
RISK ESTIMATES FOR CARCINOGENS	4B
DRINKING WATER HEALTH ADVISORIES/STANDARDS	NA
WATER QUALITY CRITERIA	345B
AQUATIC TOXICITY DATABASE	5B

FREUNDLICH ISOTHERM DATA

FREUNDLICH ISOTHERM DATA NOT AVAILABLE AT THIS TIME !

Sources of Toxicity Information

CHROMIUM

CAS NO.: 7440-47-3

TECHNOLOGY	MATRIX	SIC CODE	INFLUENT CONCENTRATION - 0-100 ug/L		PERCENT REMOVAL	REFERENCE
			SCALE	EFFLUENT CONCENTRATION (ug/L)		
AS	D		F	40 (33)	79	198E -S-
AS	D		F3	34 (7)	58	234A ---
AS	D		F5	16 (7)	82	234A ---
AS	D		F4	9	72	167E -S-
AS	D		F2	3 (7)	94.6	234A ---
AS	D		F2	22 (7)	69	1B -S-
AS	D		F5	35 (6)	65	1B -S-
AS	D		F2	3	96.1	167E -S-
AS	D		F31	36 (6)	64	1B -S-
AS	D		F2	12	83	243A -S-
AS	D		F6	7 (7)	84	234A ---
AS	D		F4	29 (6)	64	1B -S-
AS	D		F9	<5 (6)	>90.9	1B -S-
AS	D		F13	<6 (6)	>89	1B -S-
AS	D		F18	11 (6)	78	1B -S-
AS	D		F20	<6 (6)	>85	1B -S-
AS	D		F26	12 (6)	76	1B -S-
AS	D		F58	36 (6)	62	1B -S-
AS	D		F25	24 (6)	70	1B -S-
TF	D		F21	15 (6)	67	1B -S-
TF	D		F29	17 (6)	48	1B -S-

CHROMIUM

CAS NO.: 7440-47-3

TECHNOLOGY	MATRIX	SIC CODE	INFLUENT CONCENTRATION - >100-1000 ug/L		PERCENT REMOVAL	REFERENCE
			SCALE	EFFLUENT CONCENTRATION (ug/L)		
AS	D		F1	14 (7)	89	234A ---
AS	D		F3	6	98.5	167E -S-
AS	D		F	51 (35)	77	201B -S-
AS	D		F1	28	77	243A -S-
AS	D		F4	20 (7)	82	234A ---
AS	D		F1	12	92.3	167E -S-
AS	D		F1	46 (7)	89	1B -S-
AS	D		F12	48 (6)	88	1B -S-
AS	D		F34	28 (6)	93.5	1B -S-
AS	D		F17	35 (6)	68	1B -S-
AS	D		F32	50 (6)	54	1B -S-

Sources of Toxicity Information

AS	D		F37	26 (6)	80	1B	-S-
AS	D		F38	19 (6)	89	1B	-S-
AS	D		F7	52 (6)	82	1B	-S-
AS	D		F14	19 (6)	88	1B	-S-
AS	D		F19	19 (6)	83	1B	-S-
AS	D		F27	16 (6)	87	1B	-S-
AS	D		F28	40 (6)	76	1B	-S-
AS	D		F30	59 (6)	86	1B	-S-
AS	D		F36	38 (6)	84	1B	-S-
AS	D		F51	16 (6)	90.0	1B	-S-
TF	D		F40	180 (6)	25	1B	-S-
TF	D		F27	92 (6)	23	1B	-S-
TF	D		F11	44 (6)	71	1B	-S-
TF	D		F17	34 (6)	69	1B	-S-
TF	D		F37	57 (6)	56	1B	-S-
CAC	I	28	F	40	94.1	393A	---
CAC (B)	I	49	B2	<50 (1)	>62	638B	---
ChPt (B)	I	28	P3	77 (16)	76	254B	---
ChPt+Fil (B)	I	28	P3	75 (16)	77	254B	---
Fil	I	28	P7	39 (14)	90.2	254B	---

CHROMIUM

CAS NO.: 7440-47-3

TECHNOLOGY	MATRIX	SIC CODE	SCALE	INFLUENT CONCENTRATION -	EFFLUENT	PERCENT REMOVAL	REFERENCE
				>1-10 mg/L	CONCENTRATION		
				(ug/L)			
AL	D		F55	130 (6)	89	1B	-S-
AS	D		F6	62 (6)	95.6	1B	-S-
AS	D		F57	140 (96)	90.0	1B	-S-
AS	D		F60	110 (6)	97.4	1B	-S-
AS	I	28	P	390 (3)	64	1294B	---
ChOx/Pt (B)	I	34	B1	0.5 (1)	74	248A	---
PACT	I	28	P	320 (3)	71	1294B	---
Sed	I	28	P	1,100 (3)	66	1294B	---

TECHNOLOGY	MATRIX	SIC CODE	SCALE	INFLUENT CONCENTRATION -	EFFLUENT	PERCENT REMOVAL	REFERENCE
				>10-100 mg/L	CONCENTRATION		
				(ug/L)			
ChPt	HL		F2	34 (1)	99.951	245B	---
ChPt (B)	I	28	P6	170 (14)	99.66	254B	---
ChPt+Fil (B)	I	28	P6	47 (14)	99.905	254B	---

WERL Treatability Database

Reference Number: 254B

Martin, E.E., "Treatability Studies for the Inorganic Chemicals Manufacturing Point Source Category", Effluent Guidelines Division, EPA Report No. EPA 440/1-80/103, Washington D.C. (July 1980).

Pilot plant treatability studies were conducted for several categories in the inorganic chemicals industry. Chemical precipitation studies were conducted on a batch basis using a 30 gallon tank with mixer (wastewater volume 20-25 gallons). Filtration, when used, was done through a 4 in. ID filter containing 18 in. of anthracite coal over 9 in. of silica sand with a filtration rate of 3.1 gpm/ft². Filtration runs were conducted on the wastewater after the sludge had been removed from the batch ppt-clarification runs. (It should be noted that the removals achieved by filtration were generally poor because of the design and method of operation of the filter).

Nickel Sulfate Subcategory

- P1 Caustic Soda (NaOH) addition to pH = 12.5
- P2 Caustic Soda addition to pH = 10.7 (approx.)
(a second processing plant)

Hydrofluoric Acid Subcategory

- P3 Lime (Ca(OH)₂) addition to pH = 10.5 (approx.)

Copper Sulfate Subcategory

- P4 Lime addition to pH = 10 (approx.)
- P5 Caustic Soda addition to pH = 10 (approx.)

Titanium Dioxide Subcategory (chloride process)

- P6 Lime addition to pH = 10 (approx.)

Chrome Pigment Subcategory

- P7 Ferrous Sulfide addition of 10 mg/L (approx.) for each test, data herein for filtration of clarified effluent only.

END OF DATA

WERL Treatability Database

Reference Number:

1B

U.S. Environmental Protection Agency, "Fate of Priority Pollutants in Publicly Owned Treatment Works", EPA Report No. EPA 440/1-82/303, Effluent Guidelines Division, EPA, Washington, D.C. (September 1982).

Each of 50 POTW's were sampled for approximately 6 days and the samples were analyzed for the priority pollutants. The organic data used in the tables are averages of only those samples for which the influent concentration was 20 ug/L or higher. The metals data used for the database include only those data sets in which the influent had a measureable concentrations. Additional information on the POTW's is presented in the following (flow diagrams available in reference):

Plant No.	Treat. Tech.	Flow mg/d	Ind. Flow-%	BOD-mg/L		SS-mg/L	
				Inf.	Eff.	Inf.	Eff.
1	AS	91	30	201	13	139	20
2	AS	8.1	2	95	14	97	9
3	AS	10.6	10	131	14	266	44
4	AS	84	18	152	22	164	43
5	AS	22	12	138	13	147	12
6	AS	7.1	35	263	18	632	27
7	AS	49	15	169	29	135	18
8	AS	23	30	238	42	205	69
9	AS	52	7	113	5	149	14
10	AS	16.5	5	242	16	222	16
10	TF	6.9	5	242	23	222	14
11	TF	38	4	99	27	171	14
12	AS	38	50	105	10	178	14
13	AS	15	35	69	15	150	13
14	AS	11	25	281	13	190	9
15	TF	6.6	25	115	13	131	19
16	TF+AS	145	16	226	11	212	16
17	TF	5.0	45	194	13	129	9
17	AS	9.9	45	194	9	129	8
18	AS	63	10	208	37	268	21
19	AS	68	20	379	45	187	29
20	AS	119	19	247	21	421	13
21	TF	23	15	238	59	260	29
22	TF+AS	14	25	245	39	159	22
23	TF+AL	27	11	130	26	78	18
24	TF	7.1	30	275	13	111	31
25	AS	44	10	329	8	182	2
26	AS	212	8	108	17	113	6
27	AS	46	3	173	15	186	11
27	TF	155	3	173	44	186	36
28	AS	77	50	523	20	399	24
29	TF	5.6	24	187	63	98	44
30	AS	20	23	308	23	55	7
31	AS	31	10	144	12	133	19
32	AS	9.8	25	149	12	109	15
33	RBC	1.6	55	120	9	33	14

Sources of Toxicity Information

34	AS	15	13	264	4	104	11
35	AS	14	15	222	42	147	22
36	AS	42	65	435	87	327	38
37	AS	45	30	303	25	206	7
37	TF	20	30	303	90	206	22
38	AS	24	15	292	19	156	5
39	TF	8.4	5	323	32	90	20
40	TF	8.5	50	236	55	138	54
51	AS	40	3	299	4	508	9
52	TF	1.3	1	145	43	85	23
53	TF+AS	5.5	48	177	2	137	9
54	AS	15	7	137	6	253	50
55	AL	28	61	162	8	453	16
56	AS+FIL	16	27	94	15	430	5
57	AS	5.5	15	257	12	583	49
58	AS	22	35	93	16	116	11
59	AS	30	18	159	7	503	15
60	AS	3.2	26	557	17	442	33

END OF DATA



SERVICES FROM THE POLLUTION PREVENTION PROGRAM

The Pollution Prevention Program is a part of the North Carolina Office of Waste Reduction and provides free technical assistance to North Carolina industries on ways to reduce, recycle and prevent wastes before they become pollutants. This non-regulatory program addresses water and air quality, toxic materials, and solid and hazardous waste. Designated as the lead agency in waste reduction, the program works in cooperation with the Solid Waste Management Division and the Governor's Waste Management Board. The services and assistance available fall into the following categories:

INFORMATION CLEARINGHOUSE. An information data base provides access to literature sources, contacts, and case studies on waste reduction techniques for specific industries or wastestreams. Information is also available through customized computer literature searchers. Waste reduction reports published by the program are also available.

SPECIFIC INFORMATION PACKAGES. The staff can prepare facility or wastestream-specific waste reduction reports for industries and communities. Information provided by the facility is used to identify cost-effective waste reduction options. A short report detailing these options is provided along with references, case studies, and contacts.

ON-SITE TECHNICAL ASSISTANCE. The staff can provide comprehensive technical assistance through facility visits. During an on-site visit, detailed process and wastestream information is collected. The information is analyzed, and a series of waste reduction options are identified. A report is prepared detailing these options and includes literature, contacts, case studies, and vendor information.

OUTREACH. The staff can give presentations on pollution prevention to industries, trade associations, professional organizations, and citizen groups. Depending on the audience, these programs range from an overview of the state's Pollution Prevention Program to in-depth discussions of technologies for specific industries.

CHALLENGE GRANTS. A matching grant program provides funds for the cost of personnel, materials, or consultants needed to undertake pollution prevention projects. Projects eligible for grant funds range from characterizing wastestreams in order to identify pollution reduction techniques to conducting in-plant and pilot-scale studies of reduction technologies.

POLLUTION PREVENTION PROGRAM
P.O. Box 27687 Raleigh, NC 27611-7687
Telephone: (919) 571-4100

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT, HEALTH AND NATURAL RESOURCES

