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Regulatory Compliance and Enforcement: Industrial Wastewater Pretreatment Programs in Rhode Island 43 pp

Sutinen & Lee (URI)

Narragansett Bay Estuary Program

REGULATORY COMPLIANCE AND ENFORCEMENT: INDUSTRIAL WASTEWATER PRETREATMENT PROGRAMS IN RHODE ISLAND

A Report for the
Narragansett Bay Project,
Providence, RI

by

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FOREWORD

The United States Congress created the National Estuary Program in 1984, citing its concern for the "health and ecological integrity" of the nation's estuaries and estuarine resources. Narragansett Bay was selected for inclusion in the National Estuary Program in 1984 and designated an "estuary of national significance" in 1988. The Narragansett Bay Project (NBP) was established in 1985. Under the joint sponsorship of the U.S. Environmental Protection Agency and the Rhode Island Department of Environmental Management, the NBP's mandate is to direct a five-year program of research and planning focussed on managing Narragansett Bay and its resources for future generations. The NBP will develop a comprehensive management plan by December, 1990, which will recommend actions to improve and protect the Bay and its natural resources.

The NBP has established the following seven priority issues for Narragansett Bay:

* management of fisheries
* nutrients and potential for eutrophication
* impacts of toxic contaminants
* health and abundance of living resources
* health risk to consumers of contaminated seafood
* land-based impacts on water quality
* recreational uses

The NBP is taking an ecosystem approach to address these problems and has funded research that will help to improve our understanding of various aspects of these priority problems. The Project is also working to expand and coordinate existing programs among state agencies, governmental institutions, and academic researchers in order to apply research findings to the practical needs of managing the Bay and improving the environmental quality of its watershed.

This report represents the technical results of an investigation performed for the Narragansett Bay Project. The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement #CX812680 to the Rhode Island Department of Environmental Management. It has been subject to the Agency's and the Narragansett Bay Project's peer and administrative review and has been accepted for publication by the Management Committee of the Narragansett Bay Project. The results and conclusions contained herein are those of the author(s), and do not necessarily represent the views or recommendations of the NBP. Final recommendations for management actions will be based upon the results of this and other investigations.

Table of Contents

NOTE: The period under study in this project was June, 1985 through June, 1988; changes that have occurred in pretreatment programs since that time are not addressed in this report.

EXECUTIVE SUMMARY

This report characterizes the extent and nature of noncompliance with pretreatment regulations in Rhode Island. The three pretreatment enforcement programs described and analyzed are the Narragansett Bay Commission (NBC), Blackstone Valley District Commission (BVDC), and the City of East Providence. The period under study is June, 1985, through June, 1988.

NBC exhibits an overall pattern of having serious noncompliance problems early in the study period, followed by significant improvements in all areas. When local limits were introduced in September 1987, noncompliance escalated, but by the end of the study period, noncompliance had returned to a low level once again. NBC's noncompliance problems center around at least three pollutants (copper, nickel, and cyanide), a group of about 25 industrial users (IUs) that are consistently in noncompliance, and another 32 IUs in erratic noncompliance.

BVDC exhibits an overall pattern consistent with the slow start in implementing its pretreatment program. By the second half of the study period the noncompliance situation is comparable in many respects to NBC's. BVDC, however, has fewer IUs to monitor and has noncompliance problems with only one pollutant (cyanide). BVDC, with a much smaller program than NBC, has consistent noncompliance problems with 6 IUs, and erratic noncompliance problems with another 12 IUs.

East Providence's small pretreatment program exhibits an overall pattern of consistent compliance. What noncompliance problems existed occurred early in the study period.

The investigation of enforcement actions in the three pretreatment programs reveals low levels of enforcement activity during the first half of the study period. These levels increased significantly with NBC and BVDC during the second half. Even in the second half, low and modest levels of serious major enforcement actions were taken. Relative few notices of violation were issued, and even fewer civil penalty actions were taken.

The quantitative effect of enforcement actions on compliance with the regulations is estimated. An econometric analysis of enforcement effectiveness indicates that the more severe enforcement actions, civil penalties in particular, significantly reduce the time to compliance. While an action, such as a civil penalty, may have no immediate effect on an IU currently out of compliance, there is a definite delayed response by the individual IU being sanctioned, and both an immediate and delayed response by all other IUs in the program. Both specific and general deterrence are operable for civil penalty actions. For Notices of Failure, Deficiency, and Violation, only general deterrence is operable. No separate deterrence effect could be identified for publications of names of violators in the newspaper or other enforcement actions.

These results suggest that enforcement policy should emphasize civil penalty actions, using them more frequently and increasing their severity, in order to reduce further the time to compliance for violations of the discharge limits. Unfortunately, we cannot say whether an increased emphasis on civil penalty actions, or any other enforcement action for that matter, would reduce the over all incidence of noncompliance (our measures SNC, NC, Percent Exceedance, and the number of IUs in Consistent or Erratic Noncompliance). Our statistical analysis could not address this important issue.

Some noncoercive means of improving compliance are suggested. These include the following: (i) As a form of inducement to comply, award certificates to, and publicize IUs with strong records of compliance with pretreatment regulations. (ii) Persuade the general public to apply various forms of social pressure on noncompliant IUs to comply with pretreatment regulations. (iii) Enlist the IU community in the design and implementation of pretreatment programs, and encourage industry and political leaders to speak of the merits of pretreatment programs for protecting the environment. (iv) Inculcate proper compliance habits early in the implementation of new pretreatment programs.

This study falls short in a number of respects, but perhaps the most important concerns the analysis of enforcement effectiveness. Data limitations prevented the use of the most preferred way of measuring and analyzing effectiveness. These data limitations may not persist in the three programs as they improve their data management systems, and as the set of IUs stabilizes and matures. Therefore, future study of these same programs with another two or three years of data beyond that used here should prove more susceptible to intensive analysis. The additional data needed for future studies includes the following:

1) Complete time series by month, or at least quarter, of the monitoring data (self- or compliance-monitoring, or both) for each of the categorical IUs in each pretreatment program. This may require increasing the required frequency of self-monitoring to monthly or quarterly at NBC and BVDC.

2) Specific data for each of the categorical IUs, including employment and sales or some appropriate measure of production quantity on a monthly or quarterly basis, type of pretreatment equipment and the date it was installed, and the type of raw materials used and products made. These data could be made part of the permitting and reporting process.

3) Metals and cyanide loadings data for each of the POTWs, on a monthly or at least quarterly basis.

It would also facilitate the acquisition and assembly of the data for study if the data reporting was standardized across pretreatment programs. Certainly, entering the monitoring data on computer disks using the same commercially available software would greatly facilitate future study of the three programs.

I. INTRODUCTION

In its report to Congress, the Office of Technology Assessment (Levenson and Barnard, 1988) identified compliance and enforcement as one of four key issues in the management of industrial effluents being discharged into the marine environment. In particular, OTA identifies the need for (1) more and better information on the extent of noncompliance, and (2) for assessments of enforcement effectiveness in order to design improvements in the framework that regulates industrial discharges. This study is an attempt to satisfy those two demands. Using data from three pretreatment programs in Rhode Island, our purpose is to fully characterize the nature and extent of noncompliance with pretreatment regulations, and to assess the effectiveness of the enforcement efforts in each program.

The Issues

Enforcement is an essential link in the effort to manage the discharge of industrial effluents in the nations lakes, streams and marine waters. Levenson and Barnard (1988) review most of the literature concerning compliance and enforcement under the National Pollution Discharge Elimination System (NPDES) and the National Pretreatment Program. The existing evidence exposes weaknesses in three areas. First, the evidence shows a low level of response to permit violations, with less than half of significant violations receiving enforcement responses in the cases studied. Second, both formal and informal enforcement actions were ineffective in eliminating violations in a timely manner. And third, the ability to impose meaningful penalties is absent, collection of penalties is infrequent, and assessed penalties are usually small and inconsequential to the violator. Their review also concludes that it is difficult to reliably measure the extent of industry compliance with pretreatment regulations. This is due, they suggest, to the heavy reliance on self-monitoring by industries which is often not independently verified by pretreatment program monitoring.

The present study of three pretreatment programs in Rhode Island will investigate many of these same issues. Noncompliance with the regulations is measured and patterns of noncompliance are characterized. The role enforcement actions play in controlling noncompliance is investigated in an attempt to identify those actions that are most effective in reducing noncompliance. The period under study is June, 1985, through June, 1988, and changes and developments since then will not be discussed unless they are relevant to the analysis.

Before beginning the analysis, some background information is presented for those readers not familiar with pretreatment programs at the national, state, and local levels.

Background

Wastewater discharged by industry often contains a variety of toxic and other harmful substances, including heavy metals and cyanide from electroplating and metal finishing shops, and lead from battery manufacturers. Most sewage treatment system's were not designed to properly treat industrial wastes of this type. Such industrial wastes can interfere with the effective operation of sewage treatment plants, pass through untreated and contaminate local bodies of water, and increase the health and environmental risks of sewage sludge disposal.

The National Pretreatment Program The National Pretreatment Program is a cooperative Federal, State, and local effort to implement the practice of pretreating industrial wastewater to reduce the discharges of these harmful pollutants. The Program resulted from the Clean Water Act, as amended in 1977. In 1978 EPA developed the General Pretreatment Regulations[1]. The National Pretreatment Program requires sewage treatment plants, i.e., publicly owned treatment works (POTWs), to enforce the General

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1 The Regulations were subsequently revised in 1981 and updated in 1988.

Pretreatment Regulations[2] prohibiting the discharge of pollutants that interfere with POTW operations, pass through the POTW untreated, or contaminate sewage sludge. The POTWs are required to develop pretreatment programs that satisfy federal specifications, and to enforce the National Categorical Standards against the industries discharging into their sewerage systems. As of early 1989, there were 1450 approved pretreatment programs operated by sewage treatment facilities nationwide, with as many as 200,000 industrial users (IUs) enrolled in the programs (EPA, 1989).

The National Categorical Standards set specific limits on the discharge of toxic pollutants by industrial categories. The industrial categories subject to regulation under the Pretreatment Program include Electroplating and Metal Finishing, the most abundant categorical industries in Rhode Island. The federal regulations for these categorical industries specify numerical discharge limits, and require the industries to provide the control authority (CA) with onetime Baseline Monitoring and 90-Day Compliance Reports, and periodic Self-Monitoring Compliance Reports. The Baseline Monitoring and 90-Day Compliance Reports supply basic information to identify each IU, the characteristics of the IU's discharge, and the IU's compliance status. Self-Monitoring Reports contain the results of periodic sampling and analysis of the IU's wastewater discharge (EPA, 1988a).

The General Pretreatment Regulations also provide for the development by POTWs of local limits on industrial discharges. Local limits are usually more stringent than the National Categorical Standards in order to protect POTWs from pass-through, interference, or sludge inhibition. The implementation of local limits is one of the most important aspects of a pretreatment program.

Pretreatment in Rhode Island Rhode Island is one of 25 States that have approved State pretreatment programs. EPA delegated the authority to administer the pretreatment program to the State of Rhode Island in September, 1984. The approval authority for pretreatment programs in Rhode Island is the Department of Environmental Management, which has the responsibility of overseeing and approving local pretreatment programs in the state. There are thirteen approved pretreatment programs operated by POTWs in Rhode Island. Each pretreatment program has control over the industrial users (IUs) discharging industrial wastewater into the POTW's sewers.

DEM provides the POTWs with technical assistance and guidance in the development of local limits, interpretation of pretreatment regulations, and administration of the pretreatment programs. DEM has developed an IU classification scheme, and a monitoring/inspection/reporting system, which it requires all RI pretreatment programs to adopt. The IU classification scheme consists of seven categories. The first three categories, relevant for this study, are as follows:

Category 1. IUs subject to National Categorical Standards.
Category 2. IUs discharging toxic substances or prohibited pollutants but not subject to National Categorical Standards.
Category 3. IUs discharging, or having the potential to discharge, loads of conventional pollutants in sufficient quantities to cause the POTW to violate the limits of its permit under the RI Pollution Discharge Elimination System.

The monitoring/inspection/reporting system prescribes compliance monitoring of all IUs in categories 1-3 above at least once a year, and outlines specific sampling procedures to be followed. The pretreatment program of a POTW is required to supplement its compliance sampling with "demand monitoring" of those IUs with a history of noncompliance or whose self-monitoring report showed them in noncompliance. The system also requires manhole sampling and IU inspection frequencies, status reports, and DEM approval of any modification of the program's legal authority. (EPA, 1987) The present analysis will draw on data from the self-monitoring, compliance monitoring, and demand monitoring reports com-

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2 40 CFR Parts 122 and 403.

piled by the three POTWs. None of the data from the Baseline Monitoring Reports or the 90-day Compliance Reports is used.

The report is organized as follows: the three pretreatment programs are described in the next section (II); section III characterizes the patterns of compliance found in the three pretreatment programs; section IV examines enforcement and its effectiveness in the programs. Section V summarizes the findings and identifies some of the limitations of this study.

II. THREE PRETREATMENT PROGRAMS IN RHODE ISLAND

This section describes the principal elements of the industrial wastewater pretreatment programs operated by the Narragansett Bay Commission, the Blackstone Valley District Commission, and the City of East Providence. The elements described are the discharge limits, the monitoring activities, and the enforcement policies of each POTW. The three pretreatment programs were chosen for this study because they include in their jurisdiction most of the categorical industries in the State discharging into sewerage systems.

Narragansett Bay Commission NBC operates the Field's Point Wastewater Treatment Facility in Providence. The POTW processes sewage of Providence, North Providence, Johnston, and sections of Cranston and Lincoln, serving a population of about 200,000. It is the largest POTW in Rhode Island. The plant, which discharges near the mouth of the Providence River, is a secondary activated sludge facility and has a design capacity of 64 million gallons per day (mgd). About 20 percent of the plant's wastewater influent comes from industrial sources, most originating with electroplaters and metal finishers. (EPA, 1987)

NBC's pretreatment program was approved by EPA in September, 1984. NBC, established as a State Commission to provide wastewater treatment service, has complete jurisdiction over all users of its system. NBC implements and enforces its pretreatment program through its Rules and Regulations, amended in 1985 and in 1987 (EPA, 1987).

The Rules and Regulations provide for industrial wastewater discharge permits to be used as the IU control mechanism (NBC, 1985, 1987). Each industrial user discharging to the NBC's sewage lines must obtain a wastewater discharge permit. Each permit usually requires that the user meet the limits on discharges at all times and monitor its discharges, among other things (NBC, 1988). As of June, 1988, NBC had issued 207 permits (DEM, 1988). While the Commission was criticized for issuing permits too slowly in 1987 (see EPA, 1987), by late 1988 the Commission claimed it had issued permits to "all known industries discharging metals and cyanide, including all known categorical industries..." (NBC, 1988).

Due to staffing shortages, NBC's pretreatment program did not attain its monitoring and inspection goals for the 12 months prior to June, 1988. However, categorical IUs and those industries with the potential to impact the wastewater treatment plant were adequately monitored (DEM, 1988).

Blackstone Valley District Commission The Blackstone Valley District Commission (BVDC) operates the Bucklin Point Sewage Treatment Plant in East Providence. The plant, discharging directly into the Seekonk River, serves a population of about 100,000 in the cities of East Providence, Central Falls and Pawtucket, and the towns of Cumberland, Lincoln and part of Smithfield. It is the second largest POTW in the State. BVDC derives its authority from state law and interjurisdictional issues across the six municipalities are not a concern. The treatment plant, a secondary activated sludge facility, has a design capacity of 31 mgd and a peak capacity of 46 mgd. (EPA, 1987) The plant's wastewater influent is 14 percent industrial, largely from metal finishing and textile industries (Ferreira, 1990) .

BVDC's pretreatment program was approved by EPA in March 1983. BVDC implements and enforces it pretreatment program through its Rules and Regulations. The Rules and Regulations provide for industrial wastewater discharge permits to be used as the IU control mechanism (EPA, 1987). As of June, 1988, BVDC had issued permits to 94 IUs, with an additional 78 in pending status(DEM, 1988).

During the period 1985 - 1988, BVDC's pretreatment program experienced problems meeting its monitoring and inspection obligations (DEM, 1988).

East Providence The City of East Providence operates the Ponham Terrace treatment plant in Riverside, RI. The plant, which discharges through an outfall into the Providence River - Narragansett Bay, serves about two-thirds of the City and the entire Town of Barrington. The plant is an aerated activated sludge wastewater treatment facility with a design capacity of 10.5 mgd. The plant receives industrial wastewater from about 70 IUs. (EPA, 1985)

East Providence's pretreatment program was approved by EPA in September 1983. The East Providence pretreatment program is enforceable through sewer ordinances of the City of East Providence and the Town of Barrington, and a formal agreement between the City and the Town (EPA, 1985). In early 1988 there were 11 IUs subject to categorical pretreatment standards, two significant noncategorical IUs, and 36 other noncategorical IUs (DEM, 1988).[1]

The City of East Providence uses permits as its mechanism to establish program requirements and discharge conditions. All significant IUs are required to apply for a permit and provide information on their water consumption, wastewater characteristics, and pretreatment devices, among other things (EPA, 1985).

Discharge Limitations

Narragansett Bay Commission Of the more than 200 permits issued by mid 1988, 131 were issued to electroplaters, metal finishers, and other IUs subject to categorical standards. During the early part of the study period NBC applied federal categorical standards to the electroplaters and metal finishers in its pretreatment program. In response to operational and pass-through problems attributed to industrial discharges, NBC developed a set of local discharge limits. The more stringent local limits became effective in September, 1987, and apply to all IUs discharging industrial wastewater (except for non-contact cooling water and sanitary wastewater) into NBC's sewers regardless of the amount of flow (NBC, 1987d). Six of the 10 standards are the same as the federal categorical standards (daily maximum concentration). NBC is most concerned about copper, nickel, and cyanide because of the more stringent standards on these substances in its RIPDES permit.

The discharge limits for NBC are shown in Table 1. The daily maximum limit is the maximum allowable concentration for a sample taken during the course of one operating day, and the average limit is the average concentration of samples taken on ten operating days.

Blackstone Valley District Commission Of the 94 permits issued by June, 1988, 48 were issued to IUs subject to categorical pretreatment standards (DEM, 1988). The standards for electroplaters and metal finishers, and the local limits for other IUs are shown in Table 2. During the study period, electroplaters and metal finishers were regulated by a set of interim limits (DEM, 1988). Most of these standards are the same as the monthly average federal categorical standards.

BVDC's local limits, which date back to the original program submission, apply to other permitted IUs in the District (i.e., non-electroplaters and non-metal finishers). The local limits are more stringent than the categorical standards for most parameters

East Providence The City has two industrial category groups. Forty-nine industrial users had been permitted by early 1988, including 11 metal finishers, one textile mill, and one fastener manufacturer as Priority I users, and 35 as Priority II users. The City replaced the categorical electroplating and metal finishing standards with local limits in December 1985. The new local limits became effective January 1986. The pretreatment limitations applicable to Priority I users are shown in Table 3.

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1 There is some inconsistency in the numbers of IUs monitored for compliance with the discharge limits. The data obtained from East Providence's pretreatment program monitor 14 IUs for most of the 36 months of the study period.

Table 1. NBC Discharge Limits

	Effective 6/30/84 for Electroplaters				Effective 2/15/86 for Metalfinishers		Effective 9/17/87 for All Users	
	over 10,000 gpd		under 10,000 gpd					
parameter	max	avg	max	avg	max	avg	max	avg
Cadmium	1.2	0.7	1.2	0.7	0.69*	0.26*	0.11	0.07
Chromium	7.0	4.0	-	-	2.77	1.71	2.77	1.71
Copper	4.5	2.7	-	-	3.38	2.07	1.20	1.20
Cyanide	1.9	1.0	5.0	2.7	1.20	0.65	0.58	0.58
Lead	0.6	0.4	0.6	0.4	0.69	0.43	0.60	0.40
Mercury	-	-	-	-	-	-	0.005	0.005
Nickel	4.1	2.6	-	-	3.98	2.36	1.62	1.62
Silver	1.2	0.7	-	-	0.43	0.24	0.43	0.24
Zinc	4.2	2.6	-	-	2.61	1.48	2.61	1.48
Total Toxic Organics	2.13	-	4.57	-	2.13	-	2.13	2.13

Sources: NBC (1985, 1987a)

All units are in mg/l; gpd means gallons per day, max means maximum, avg means an average of ten (10) samples, and ND means not detectable when analysis is done in accordance with EPA approved methods.

* The limits for new metal finishers were .11 max and .07 avg.

Table 2. BVDC Discharge Limits

Parameter	METAL FINISHERS	ELECTRO-PLATERS	LOCAL LIMITS
Cadmium	0.26	0.70	0.40
Chromium	1.71	4.00	1.50
Copper	2.07	2.70	1.00
Cyanide	0.50	0.50	0.50
Lead	0.43	0.40	0.10
Nickel	2.38	2.60	1.50
Silver	0.24	--	0.03
Zinc	1.48	2.60	1.20
Total Toxic Organics	2.13	2.13	2.13

Source: BVDC

All units are in mg/l and are daily maximum values.

Table 3. EAST PROVIDENCE Discharge Limits

	Interim Discharge Limits Effective through 12/85				Effective from 1/86	
	Electro-platers		Metal Finishers		Priority I IUs	
parameter	max	avg	max	avg	max	avg
Cadmium	1.2	0.70	0.11	0.07	0.11	0.07
Chromium	7.0	4.0	2.77	1.71	2.77	1.71
Copper	4.5	2.7	3.38	2.07	3.38	2.07
Cyanide	1.9	1.0	1.20	0.65	1.20	0.65
Lead	0.6	0.4	0.69	0.43	0.69	0.43
Nickel	4.1	2.6	1.94	1.16	1.94	1.16
Silver	1.2	0.7	0.43	0.24	0.43	0.24
Zinc	4.2	2.6	2.61	1.48	2.61	1.48
Total Metals	10.5	6.8	–	–	–	0.65
Total Toxic Organics	0.58	–	TBA	–	2.13	–

Sources: EPA (1985), City of East Providence

Monitoring

Under the pretreatment program, sampling and analysis of industrial wastewater for the purpose of regular compliance determinations is done through industry self-monitoring and compliance monitoring done by the CA. The procedures and policies concerning self-monitoring and compliance monitoring for each pretreatment program are now described.

Narragansett Bay Commission The required frequency of self-monitoring reports depends on the type of IU and the volume of wastewater discharges by the IU. The frequency of self-monitoring may be increased to weekly when an IU consistently fails to meet the terms of its permit. IUs subject to federal categorical standards are required to resample their wastewater for any parameters violating the standards within 30 days of detecting the violation. IU self-monitoring must be performed in accordance with Federal Pretreatment Regulations (EPA, 1988a) and reported on a form signed by an authorized agent of the company. Samples by IUs may be either composite or grab samples, but most sampling consists of composite samples (NBC, 1989). These self-monitoring reports have been successful in helping NBC identify IU noncompliance and to set priorities for its own compliance monitoring activities (DEM, 1988).

NBC conducts compliance monitoring of all significant IUs once a year, and chronic violators are sampled more frequently. Compliance monitoring of IUs is conducted by NBC personnel as a check on IU self-monitoring. Sampling is done inside the IU facility and is random and unannounced. All analyses by NBC are performed by its own laboratory, and each IU is offered a replicate sample to have analyzed by an independent laboratory (NBC, 1989). Except for a 12 month period ending in mid 1988, NBC has satisfied DEM's frequency of compliance monitoring (EPA, 1987; DEM, 1988). The compliance monitoring by the Commission with respect to limitations is done at the discretion of the Commission. Compliance determinations may be made on the basis of either instantaneous grab samples taken over a 24 hour period, or over a longer or shorter time span, as determined by the Commission (NBC, 1985, 1987). The monitoring at key manholes is also performed to determine areas where significant discharges of pollutants may be occurring and to sample an industry upstream of a manhole undetected by industry personnel.

By its Rules and Regulations (NBC, 1985, 1987), the Commission can require an industrial user to install at its own cost suitable equipment for monitoring and measurement of the wastewater discharge. The monitoring and metering equipment must be located and maintained on the industrial user's premises. When more than one user discharges into a common sewer, the Commission may require installation of separate monitoring and metering equipment for each user. When there is a significant difference in wastewater constituents and characteristics produced by different operations of a single user, the Commission may require that separate monitoring and metering facilities be installed for each separate discharge.

Blackstone Valley District Commission All categorical IUs are required to submit self-monitoring reports at least twice a year which indicate the nature and concentration of pollutants in their effluent which are limited by the discharge limitations. Some IUs are required to submit self-monitoring reports as often as every month. The reports contain measures of the average and maximum daily flow of the pollutants (BVDC, 1986). Both grab and composite samples are required for self-monitoring. An audit by EPA and inspections by DEM indicate that several IUs have been delinquent in submitting their self-monitoring reports (DEM, 1988, EPA, 1987).

The compliance monitoring activities of the BVCD pretreatment staff were minimal for most of the study period. As of mid-1988, the end of the study period, the BVCD Pretreatment Program had not consistently fulfilled its obligation to monitor each significant IU at least once a year. This failure was reportedly due to lack of trained staff and equipment (DEM, 1988).

East Providence All Priority I users are required to conduct monthly self-monitoring. The categorical industries are required to sample monthly for specific pollutants of concern and bi-annually for all regulated pollutants. Other Priority I users conduct monthly sampling for pollutants likely to be found in their discharge. Compliance monitoring, conducted by the City, consists of compliance inspections along with announced and unannounced sampling events at each permitted industry. There is no evidence that the POTW has had difficulty meeting any of its monitoring and inspection obligations.

Enforcement

Each POTW, as the Control Authority for its pretreatment program, is the principal enforcement entity governing industrial users' discharges into the sewer system. In addition, enforcement actions may be taken by EPA and DEM, and citizens may file suit against violators. The enforcement aspects of each of these is described below.

Narragansett Bay Commission A large number of different enforcement actions are used by NBC to secure compliance from IUs in the pretreatment program. The actions include telephone calls, notices of failure, notices of deficiency, increased demand sampling, meetings with noncompliant IUs, notices of violation and public hearings, orders to cease discharges, publication of IU's names, civil penalties, and criminal penalties (NBC, 1987a, 1989).

Telephone calls are used to discuss the violation and attempt to resolve the problem. A notice of failure (NOF) is a letter prescribing ways to correct the detected violation. A NOF is automatically sent every time any monitoring reveals a violation of the permit. It is used as a first step in getting the IU to correct the violation(s) or deficiency before a notice of deficiency is sent. The notice of deficiency (NOD) is formal notification that the IU is in violation of its permit and that the violation must be corrected within a prescribed time frame. Failure to make such corrections within the time frame may result in a notice of violation (NOV). A NOV results in a formal public hearing to collect civil penalties for the violation(s). Meetings with the IU are often used to discuss the problem and resolve the problem before beginning administrative action to collect civil penalties.

Increased demand monitoring is used to demonstrate progress toward rectifying the violation of discharge limitations. Orders to cease discharge are issued when human health or the environment is in im-

minent danger. Finally, a list of significant violators (IUs) is published annually in the Providence Journal newspaper. (NBC, 1989)

Blackstone Valley District Commission Enforcement actions available include telephone calls, compliance schedules, written notices of violation or of deficiency, administration orders (to install equipment, submit reports, etc.), suspensions and revocation of permits, termination of service, and monetary penalties. The imposition of monetary penalties is done in accordance with the following guidelines:
Level I - significant non-compliance violation, subject to a fine of $2,500 to $5,000 per violation per day;
Level II - middle level violations, subject to a fine of $1,000 to $2,500 per violation per day;
Level III- minor violations, subject to a fine of $50 to $1,000 per violation per day.
The factors considered in the determination of the fine are the amount of variance from the pretreatment standards or legal requirement, duration of violation, previous enforcement actions taken against the violator, and the deterrent effect of the response in similar facilities.

East Providence Formal enforcement procedures are detailed in the Sewer Use Ordinance of the City. The program's enforcement strategy is based on the EPA Guidance (EPA, 1986), but was not instituted until 1988. Most of the industrial users of the City are in compliance. The compliance categories are the Baseline Monitoring Report, local limits, categorical standards, and inspections. The City is working to clarify the program's enforcement mechanism to make it more definitive in the event it must be used. The precedures for formal court action have not been used; however, other enforcement actions (letters of deficency, notices of violation, and consent orders) have been used successfully. All of the procedures for enforcement action have not yet been tested due to the cooperation of industry in working toward the program's goals.

Approval Authority Enforcement EPA and DEM, as Approval Authories, oversee the implementation and enforcement of the pretreatment programs in the state. As part of their oversight role, EPA and DEM conduct evaluations and can take direct enforcement actions in cases of national or regional significance. While each POTW handles most of the enforcement actions against IUs in noncompliance, EPA and DEM have the option to initiate direct enforcement actions themselves. DEM may initiate an enforcement action alone, or in conjunction with EPA or with a POTW, against a noncompliant IU. Such action may be based on information supplied by the POTW or by a citizens group. DEM enforcement actions include Notice of Violation, and Order and Consent Decree which may specify a penalty assessment. POTWs that do not engage in dilligent and effective enforcement of the pretreatment regulations are themselves subject to direct enforcement actions by EPA and DEM (EPA, 1989).

Citizen Enforcement The Clean Water Act, through section 505, also provides citizens with the authority to bring civil action against violators of the pretreatment regulations. In Rhode Island, the Conservation Law Foundation of New England and Save the Bay, Inc. have filed citizens suits against IUs in violation of pretreatment regulations.

The incidence and patterns of enforcement actions taken by each of these entities are described in Section IV below.

III. NONCOMPLIANCE WITH WASTEWATER DISCHARGE LIMITS

In this section we examine noncompliance activity in each of the three pretreatment programs. The following description and assessment of noncompliance is not intended to indicate the success or effectiveness of the three pretreatment programs. Here, we measure noncompliance, which is not necessarily related to the effectiveness of a pretreatment program. The appropriate measure of effectiveness of a pretreatment program is the extent to which it reduces loadings of pollutants to the influent of the POTW.

Successful and effective pretreatment programs, as measured by influent loadings, may exhibit either high or low levels of noncompliance. For example, a successful pretreatment program may exhibit high levels of noncompliance because of stringent standards and intensive monitoring. Conversely, a less effective pretreatment program may exhibit low levels of noncompliance because of liberal discharge standards and/or inadequate monitoring.

There are numerous ways to measure noncompliance and, unfortunately, no one way is fully satisfactory for our purposes. Next, we discuss the five measures used in this study, including their advantages and disadvantages, followed by a presentation of the evidence characterizing noncompliance in the three pretreatment programs. The evidence is first presented for each noncompliance measure, and then summarized for each pretreatment program at the end of this section[1]. Appendix 2 describes the sources and nature of the data used in this study[2].

Measuring Noncompliance

The five basic means of quantifying and characterizing noncompliance used in this study are Significant Noncompliance, Noncompliance, Compliance Style, and Time to Compliance.

Significant Noncompliance (SNC)

Significant Noncompliance is where either or both of the following conditions hold: (a) Sixty-six percent or more of the wastewater samples analyzed in a six-month period exceed the same daily maximum, or average, limit. (b) Thirty-three percent or more of the wastewater samples analyzed in a six-month period exceed the same daily maximum, or average, limit by more than 20 percent. An advantage of SNC as a measure is that it distinguishes minor from major violations, and chronic from occasional violations. Some disadvantages of this measure is that the conditions are arbitrary and, for some purposes, six months and 20 percent are too liberal.

EPA (1986) established a definition of Significant Noncompliance patterned after criteria used in the National Pollution Discharge Eliminations System[3]. The intent of the definition is to enable pretreatment program authorities to identify the more significant violations or patterns of violations by IUs and establish priorities for taking enforcement action. A version of this definition of SNC is used by NBC to identify which IUs' names to publish annually in the newspaper (NBC, 1987, 1988, 1989). Recent amendments to NBC's Rules and Regulations provide a definition of chronic violations related to EPA's. Apparently, violations deemed to be chronic will trigger specific enforcement actions under the new rules. BVDC does not formally employ the concept of SNC; and East Providence has had little occasion to use it.

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1 Only noncompliance with established discharge limits is measured here. Violations of compliance schedule milestones, failures to submit reports on schedule, failures to report noncompliance, and any other violation are not considered.

2 Since most of the data comes from self-monitoring reports of the IUs, we were concerned about the veracity of this data. As explained in Appendix 2, our tests of this data revealed few statistically significant differences between the self-monitoring data and the compliance monitoring data obtained from sampling by the POTWs. These test results allow us to place a relatively high degree of confidence in the data.

3 Actually, EPA's definition is broader than that given here.

Noncompliance (NC)

Noncompliance is any violation of the discharge limits, regardless of its size or frequency. This measure does not distinguish between large and small, chronic and occasional violations. Two measures of NC are calculated, one for IUs and one for samples. An IU is in Noncompliance if one or more of the samples analyzed during the period violates a discharge limit for any parameter. The percent of IUs in NC is calculated for monthly intervals. The percent of samples in NC is the proportion of all IUs samples analyzed during the period for which one or more discharge limit is violated. The sample NC measure also is presented for selected parameters subject to discharge limits. Each NC rate is calculated for monthly intervals. The NC and SNC measures are useful complements since NC captures the violations missed by the SNC measure.

Percent Exceedance (%EX)

Prior to 1987, when EPA's definition of significant noncompliance became effective, each pretreatment program used different criteria to trigger an enforcement action. Each POTW had its own policy regarding the length, magnitude, and severity of violation that would trigger enforcement actions. This measure is an alternative to SNC for quantifying the magnitude and severity of a given violation.

The extent to which sampled discharges exceed the discharge limits is measured by the Percent Exceedance measure of noncompliance. It is defined as the ratio of the actual discharge quantity, for only those samples exceeding the limit, divided by the standard. The measure presented here is an average of averages. First an average is calculated for each parameter of each IU's monthly samples. Finally, an average is calculted for each parameter across all sampled IUs in the month. The principal advantage of this measure is that it reflects the seriousness of noncompliance across parameters and over time. A disadvantage is that it is an average and, as such, masks the extreme values of the more serious violations.

Compliance Styles

This measure, adapted from Brubaker and Byrne (1989), summarizes the various styles of compliance behavior exhibited by IUs during the study period. IUs are grouped into the following categories:

(a) Regular Compliance. IUs with less than five violations over the 36 month period.

(b) Improved Compliance over time. IUs with a decreasing incidence of violations over the 36 month period, and compliance in the later months.

(c) Erratic Compliance. IUs in and out of compliance, with no trend over the 36 month period.

(d) Deteriorated Compliance over time. IUs which exhibited compliance in the early months, and an increasing incidence of violations in the later months of the 36 month period.

(e) Consistent Noncompliance. IUs consistently out of compliance over the entire 36 month period.

Any and all violations are used in this calculation, so there is no distinction between minor and major violations.

Time to Compliance (TVC)

Time to Compliance is simply the number of days between the time a violation is detected (reported on a self-monitoring or a compliance-monitoring report) and the time compliance is next reported. This measure is calculated as an average over all IUs against which formal enforcement actions were taken.

Patterns of Noncompliance

Significant Noncompliance (SNC)

Figure 1 shows SNC rates by month. **NBC's** SNC rate improves through September, 1987, and then increases, reflecting the imposition of the more stringent local limits. But for most of the study period, NBC's SNC varies between 30 and 40 percent, higher than the SNCs of the other two programs. **BVDC's** SNC rate varied widely in 1986, reflecting the small number of IUs monitored. However, for the second half of the study period, BVDC's SNC rate stabilized at between 20 and 30 percent. **East Providence's** SNC rate began high in 1986 and dropped to zero by the end of 1986.[4] For most of the second half of the study period, East Providence's SNC rate remained below 10 percent.

For most parameters, NBC's discharge standards are more stringent than those for the other two programs. When NBC's standards are imposed on BVDC and East Providence, the rates of SNC are somewhat higher (see Figure 2). With NBC standards, BVDC's SNC rate is between 30 and 40 percent during the last 24 months of the study period. East Providence's SNC rate with NBC standards ranges between 10 and 20 percent during the last 12 months of the study period. The picture when common discharge standards are use remains roughly the same: East Providence exhibits the lowest rates of SNC, and NBC and BVDC exhibit nearly comparable high rates of SNC for much of the period.

Noncompliance (NC)

The rates of simple Noncompliance (NC) for IUs in the three programs are shown in Figure 3. The charts show the monthly percentages of monitored IUs in Noncompliance. Since the NC measures all, including the less serious, violations, its values are higher than the values of SNC. The NC patterns are similar to the SNC patterns.

The NBC pattern again reflects the more stringent local standards invoked in September 1987. The heavy line, labeled NC2, which allows for this change from the federal categorical standards to local limits, shows an oscillating but improving trend up to September 1987. In October 1987 there is a shift up in NC followed by a gradual improvement. By the July 1988 the percent of IUs in NC is down to about where it was in August of 1987. The lighter line, labeled NC1, represents what NC would have been if the local limits had been invoked from the very beginning. As expected, the early months show rather high rates of NC for IUs, with nearly 100 percent of IUs in NC in a couple of the early months.

BVDC shows an erratic pattern of NC in the early months. This erratic pattern is due to the small number of samples being taken at that time. The pattern from mid-1986 to the end is more reliable, showing little improvement with the NC rate oscillating between 60 and 40 percent. **East Providence** presents a picture of low NC over the entire period, with most values between zero and 20 percent. Since the number of all firms being monitored is small (13), the variation in NC is not surprising. Two or three firms, each with an occasional minor violation, could cause the observed variation in NC.

Figure 4 shows the NC for samples by month.

NBC's sample NC rate shows substantial variation during the first half of the study period. The measure improves steadily during the first nine months of 1987, reaching a low of about 15 percent in August and September. As the more stringent local limits were imposed, the sample NC rate rose dramatically to over 50 percent by the end of 1987. By mid 1988, however, the sample NC rate improved to less than 40 percent.

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4 East Providence was monitoring all of its categorical IUs in 1986, therefore, this pattern accurately reflects the situation in the pretreatment program.

Figure 1. Percent of IU's in SNC

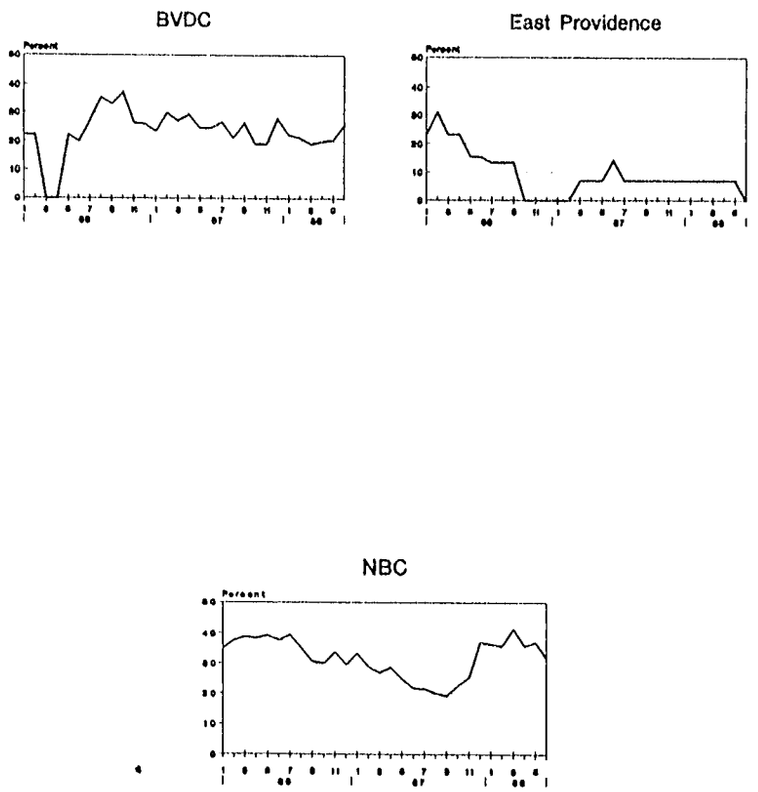
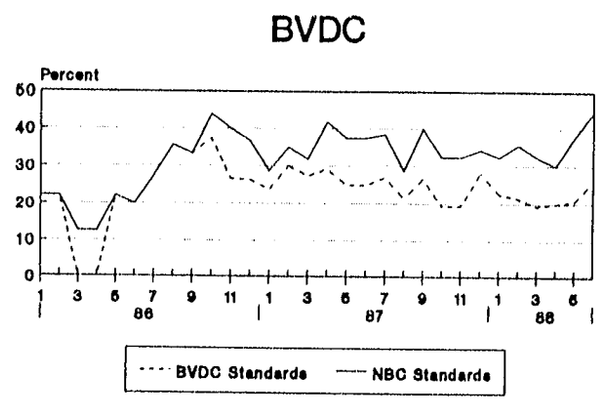


Figure 2. Percent IUs in SNC Using NBC's Standards



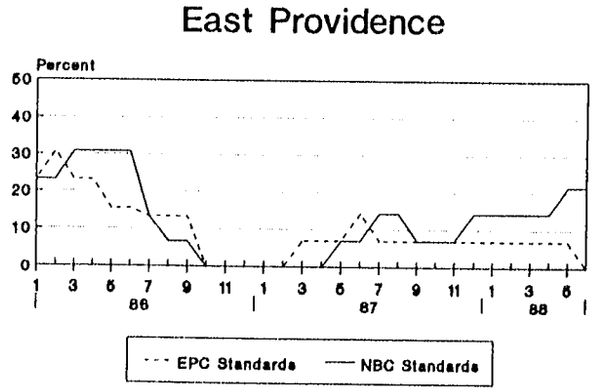
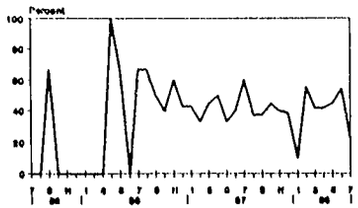
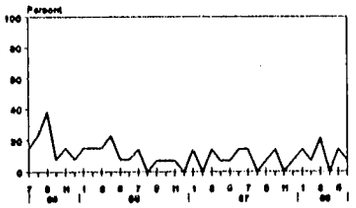


Figure 3. Percent of IUs in Noncompliance

BVDC



East Providence



NBC

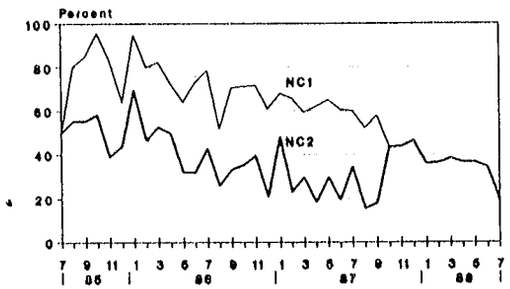
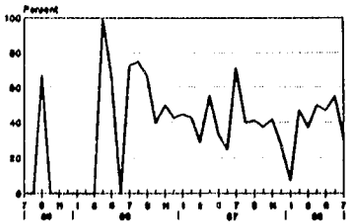
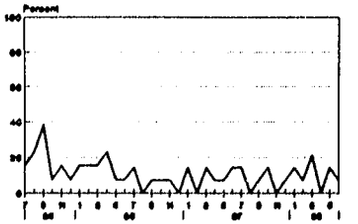


Figure 4. Percent of Samples in Noncompliance

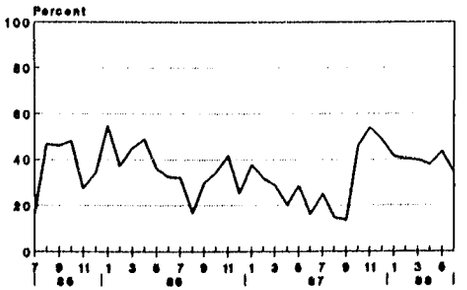
BVDC



East Providence



NBC



BVDC's sample NC rate exhibits wide variation in the first half of the study period, reflecting the small number of samples taken. Considerable variation remains in the second half, with sample NC rate values regularly above 40 percent. In 1988 the sample NC rate was near or above 50 percent in four of the six months. **East Providence**'s sample NC rate varies between zero and 20 percent for most of the study period. The monthly average for the entire study period is just above 10 percent.

Figures 5 and 6 show NC sample rates for selected pollutants.

NBC's most common problem pollutants during the study period were with copper, nickel, zinc, and cyanide. Copper, nickel, and cyanide reflect the overall pattern of NBC's sample NC rate with improvements in 1987 through September. After the local limits were imposed, the NC rates for these three pollutants rose in late 1987, followed by significant improvement during 1988. Zinc exhibits a NC rate consistently between one and 15 percent, with an average of less than 10 percent for the entire study period.

BVDC's most common noncompliance problem was with cyanide, which nearly mirrors the overall sample NC rate. In the second half of the study period, cyanide's NC rate was regularly above 20 percent, once at 45 percent. The most frequent NC rates for other pollutants is zero, with occasional high values occurring for copper, nickel, and zinc. **East Providence**'s most problematic pollutant is nickel, but the incidence of noncompliance is much lower than for the problematic pollutants of NBC and BVDC. The only other pollutant to record a violation in the last six months of the study period was zinc.

Percent Exceedance (%EX)

Figures 7-9 show the Percent Exceedance measures of the problematic pollutants for each of the three programs. This evidence is similar to the NC measures for individual pollutants. For NBC, cyanide was more than 1000 percent above the limit briefly in the early part of the study period; since mid-1986 it has varied between 100 and 500 percent above the limit. Zinc, nickel, and copper exhibit considerable variation over the entire period, with occasional peaks above 500 percent.

For BVDC, cyanide was more than 1000 percent above the limit in most of 1987 and early 1988. Zinc, nickel and copper were frequently above 100 percent of the limits during the study period. For East Providence, the amount of exceedance by nickel is relatively low over the study period.

Compliance Styles

Figure 10 displays the Compliance Styles for the three programs. Less than half (46 percent) of **NBC**'s IUs regularly comply or have improved their compliance over the study period. Over 20 percent of NBC's IUs were in consistent noncompliance, and over 25 percent exhibited erratic noncompliance.

The pattern of Compliance Styles for **BVDC** is less encouraging. Only 30 percent of the IUs regularly comply or have improved their compliance. A hefty 70 percent of the IUs are either in consistent noncompliance or display erratic noncompliance. As expected by now, the picture for **East Providence** is the brightest. All of the 13 IUs regularly comply, with only an occasional violation.

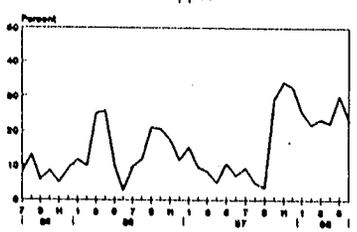
Time to Compliance (TVC)

The average Times to Compliance for six month intervals are shown in Figure 11. **NBC** realized a substantial improvement in TVC from over 400 days in the first two semesters to 90 days during the last semester of the study period. **BVDC** experienced short TVCs during the first half of the study period, but TVC rose to around 100 days in the second half. **East Providence** took very few formal enforcement actions; but on average the TVC was less than 100 days.

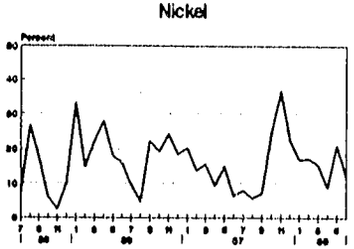
Figure 5. Percent of Samples in Noncompliance by Pollutant

NBC

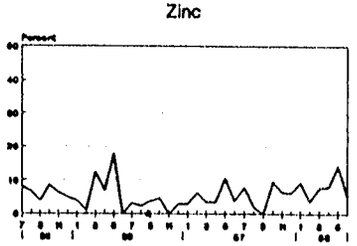
Copper



Nickel



Zinc



Cyanide

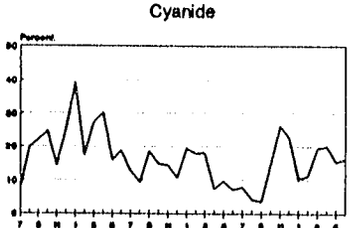
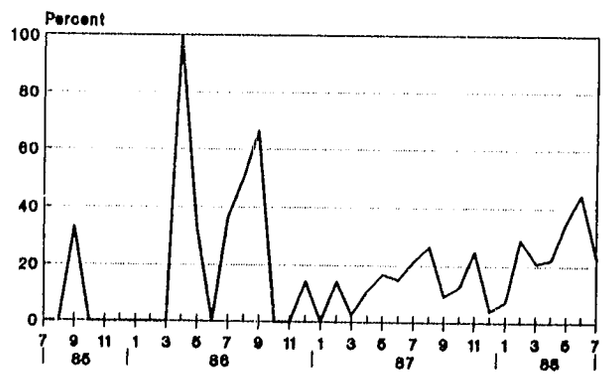


Figure 6. Percent of Samples in Noncompliance by Pollutant

BVDC



East Providence

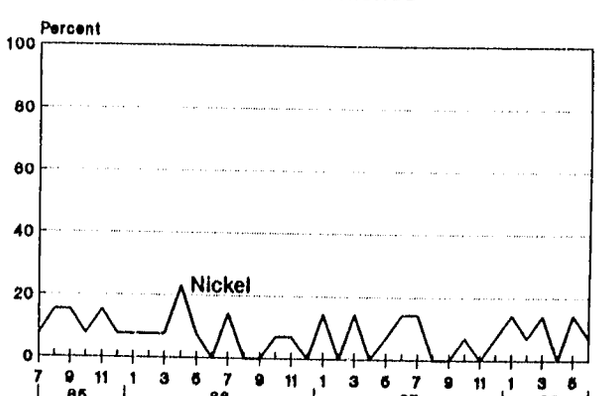
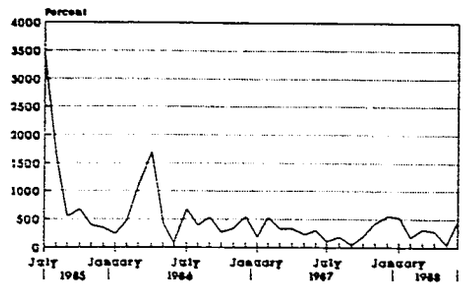
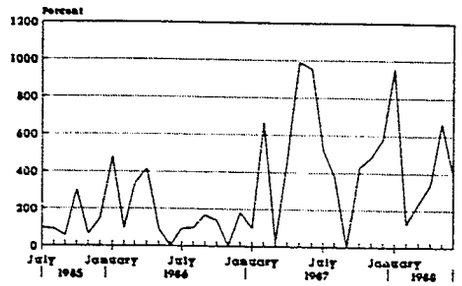


Figure 7. Percent Exceedance, NBC

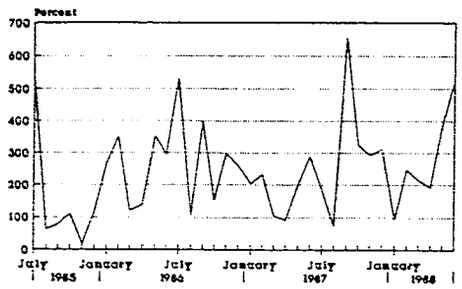
Cyanide



Zinc



Nickel



Copper

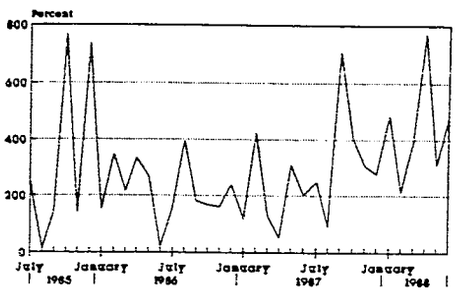
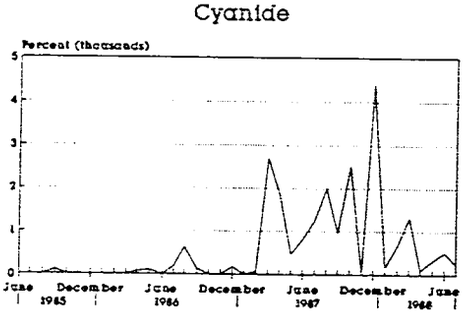
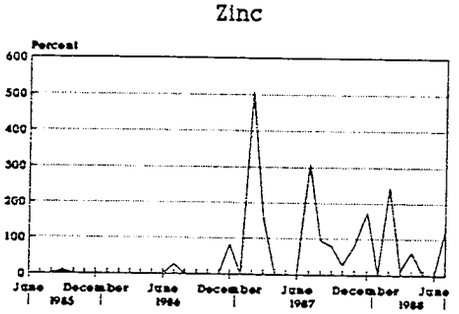


Figure 8. Percent Exceedance, BVDC

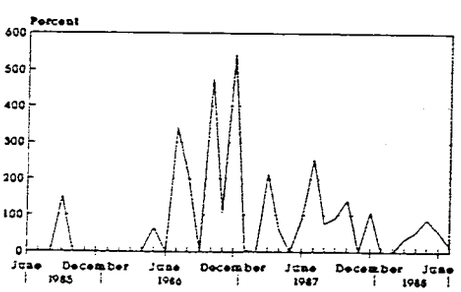
Cyanide



Zinc



Nickel



Copper

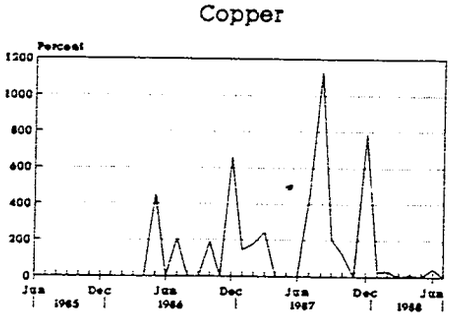
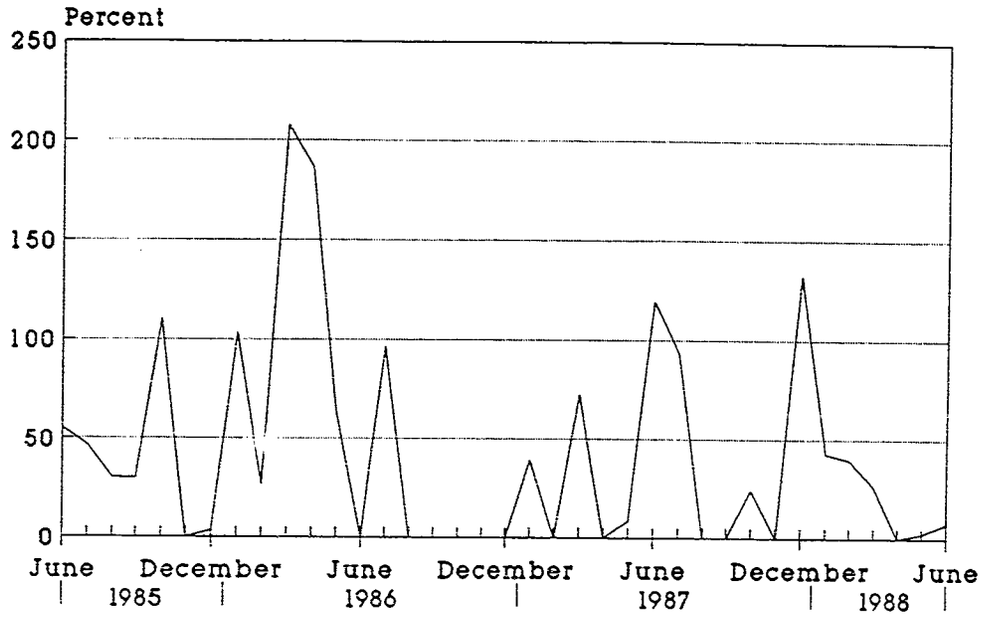


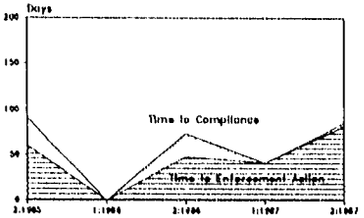
Figure 9. Percent Exceedance
East Providence



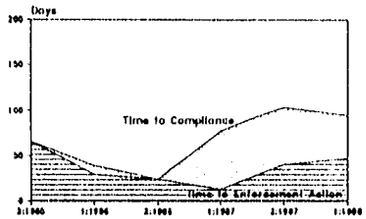
Nickel

Figure 11. Average Time to Compliance and Average Time to Enforcement Action

East Providence



BVDC



NBC

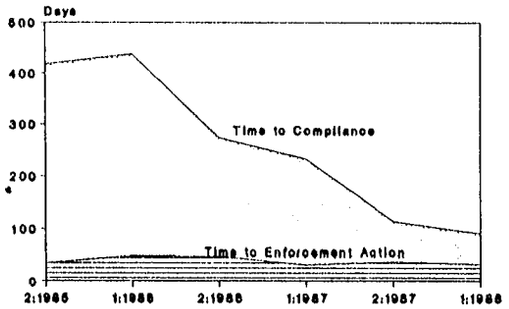
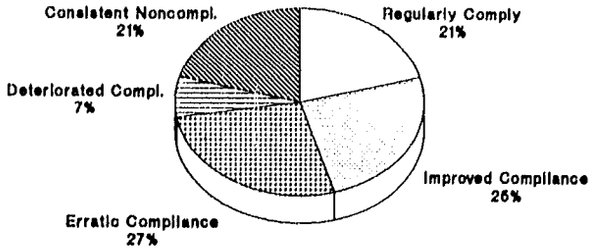


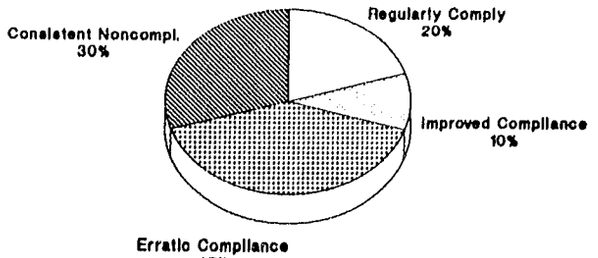
Figure 10. Compliance Styles

NBC



(120 firms)

BVDC



(20 firms)

Summary

NBC exhibits an overall pattern of having serious noncompliance problems early in the study period, followed by significant improvements in all areas. When local limits were introduced in September 1987, noncompliance escalated, but by the end of the study period, noncompliance had returned to its low level once again. NBC's noncompliance problems center around at least three pollutants (copper, nickel, and cyanide), a group of about 25 IUs that are consistently in noncompliance, and another 32 IUs in erratic noncompliance.

BVDC exhibits an overall pattern consistent with the slow start in implementing its pretreatment program. By the second half of the study period the noncompliance situation is comparable in many respects to NBC's. BVDC, however, has fewer IUs to monitor and has noncompliance problems with only one pollutant (cyanide). BVDC, with a much smaller program than NBC, has consistent noncompliance problems with 6 IUs, and erratic noncompliance problems with another 12 IUs.

East Providence's small pretreatment program exhibits an overall pattern of consistent compliance. What noncompliance problems existed occurred early in the study period.

In the next Section we examine the patterns of enforcement and attempt to identify how enforcement actions have affected the noncompliance patterns described here.

IV. ENFORCEMENT

This section seeks to determine how enforcement actions have affected noncompliance in the three pretreatment programs. The patterns of enforcement are described first; and then the results of an econometric analysis of enforcement effectiveness are discussed.

Patterns of Enforcement

To review, the enforcement actions are classified as minor and formal. The minor enforcement actions include telephone calls, letters, and informal meetings to discuss violations and measures for coming into compliance. Formal enforcement actions include the Notices of Failure, of Deficiency, of Violations, Civil Penalties (fines), and Publication of the names of significant violators in the local newspaper. The volume of minor enforcement actions (telephone calls, meetings, etc.) is the largest and roughly proportional to the size of each pretreatment program. There is not much informational content in these statistics. The statistics on the formal enforcement actions, however, is interesting.

NBC employed all five formal enforcement actions. Notices of Failure were the most common, the numbers steadily increasing over the study period. The overall pattern shows very little formal enforcement activity during the first half of the study period, followed by a significant increase in the numbers of all formal actions in the second half of the study period. NBC increased significantly its use of Notices of Failure in 1987 and 1988. From mid 1985 to the end of 1986, NBC issued an average of 4.5 NOFs per month. For all of 1987 and through mid 1988, it issued an average of 27 NOFs a month. The use of Notices of Deficiency, on the other hand, remained steady at between 4 and 5 NODs issued per month on average. Notices of Violation were issued less frequently, and their use increased from the end of 1986 forward. Only one NOV was issued during the first half of the study period; whereas 7 NOVs were issued during the second half of the study period.

The assessment of Civil Penalties occurred with roughly the same frequency as NOVs were issued. The amount of one of these penalties was initially assessed at nearly $220,000 (the Ronci case). However, this penalty was later negated by the RI Supreme Court. Four other civil penalties were successfully assessed in 1987 and 1988, averaging just under $40,000 a case. All of the penalties were assessed after 1986.

Publication of the names of significant violators in the Providence Journal occurs annually. NBC published the names of 53 IUs in 1986, 37 in 1987, and 74 in 1988. Of these, 51, 28, and 50 IUs, respectively, were in significance noncompliance for exceeding discharge limits in each of the three years.

BVDC employed Notices of Failure and Violation, and Civil Penalties during the study period. Like NBC, the overall pattern for BVDC shows very little formal enforcement activity during the first half of the study period, followed by an increase in the numbers of all formal actions in the second half of the study period. During the first half of the study period, mid 1985 through 1986, only a few Notices of Failure were issued (7 in total), and no Notices of Violation or Civil Penalties were used. During the second half, the incidence of enforcement actions increased somewhat. Notices of Failure were issued an average of one (1) a month, Notices of Violation nearly two (2) a month, and two Civil Penalties were assessed, one for $1000 and another for $18,000 (both in 1987).

East Providence, with its compliant set of IUs, had less enforcement activity than NBC and BVDC, and what activity existed remained somewhat steady over the entire study period. East Providence issued 17 Notices of Deficency, one (1) Notice of Violation, and no Civil Penalties during the entire study period.

DEM, EPA, and Citizen Groups Enforcement actions by the Approval Authorities (DEM and EPA) and legal suits brought by citizen groups also occurred during the study period. DEM took enforcement actions directly against four IUs in NBC's pretreatment program. Two of the IUs closed their businesses, one case was taken over by NBC, and the fourth case resulted in the IU coming into compliance.

Two additional enforcement actions were joint with EPA. The joint enforcement actions by DEM and EPA resulted in two civil penalties, one for $50,000 and the other for $125,000. EPA initiated two actions against IUs in the BVDC pretreatment program. The actions consisted of letters requesting information, and resulted in enforcement actions being taken by BVDC's pretreatment program.

In 1987, the Conservation Law Foundation of New England and Save the Bay, Inc., joined together to file legal suits against two IUs in NBC's pretreatment program. In one case (Rolo Manufacturing), the suit resulted in a $25,000 civil penalty. The other case (RIBCO) was subsequently taken over by EPA and DEM, and resulted in a $125,000 civil penalty.

The coverage of these enforcement actions is now examined. Specifically, we calculate the extent to which significant violators have had formal enforcement actions taken against them. This calculation results in a measure of the percent of IUs in Significant Noncompliance which have had at least one formal enforcement action taken against them. The results for the three pretreatment programs are shown in Figure 12[1]. **NBC**'s coverage was poor in the early months, modest in the middle months, and good in the latter months of the study period. **BVDC**'s coverage is poor until late 1987, and good in the last four months of the study period. **East Providence**'s coverage varies widely reflecting the small numbers of enforcement actions.

An important feature of enforcement is its timeliness, the amount of time from detection to when a formal enforcement action is taken. Referring back to Figure 11 the average time to enforcement action is shown for each pretreatment program[2]. NBC averaged 39 days to an enforcement action for the entire study period; and for the second half the average is 34 days. BVDC's average was slightly better at 36 and 33, respectively. The averages for the early part of the period are deceptive, however, since there were so few enforcement actions by BVDC. Interestingly, East Providence's formal enforcement response time was higher than the other two pretreatment programs. East Providence averaged 58 days to a formal enforcement action over the entire period, but this is also deceptive because so few enforcement actions were taken. This higher average may also reflect the POTW's policy of "working with its IUs" on compliance issues rather than sanctioning them (i.e., emphasizing the carrot more than the stick in their approach to noncompliance).

Enforcement Effectiveness

A principal objective of this study is to identify which enforcement actions are most effective in bringing about compliance. The ideal way of measuring enforcement effectiveness is to estimate the extent to which noncompliance is reduced by enforcement actions. This method has been employed to study the effects of incarceration and capital punishment on the crime rate.[3] Unfortunately, this method cannot be employed with the data maintained by the pretreatment programs. Next, we explain why this estimation is not possible, and present an alternative to this conventional estimation method.

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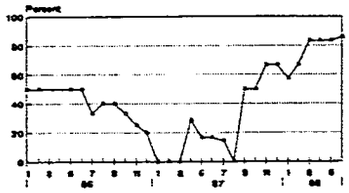
1 Since the calculation of significant noncompliance involves the monitoring data for the previous six months, the data in these charts begin in January, 1986. SNC is being used here only as an indicator of major or serious violations. EPA's definition of SNC did not become effective until 1987, and prior to 1987 each program had its own criteria for initiating enforcement actions.

2 It should be noted that this data is only for those violations where a formal enforcement action was taken.

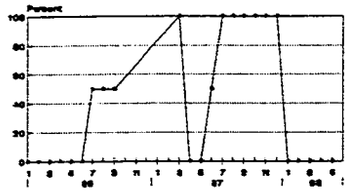
3 See, for example, Blumstein, Cohen and Nagin (1978), Ehrlich (1973), and Heineke (1978).

Figure 12. Percent of IUs in SNC with Major Enforcement Actions

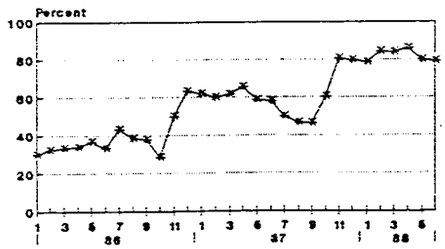
BVDC



East Providence



NBC



Drawing on the seminal work of Becker (1968), Sutinen and Andersen (1985) and Sutinen (1987) show that an individual's propensity to violate a regulation is negatively related to the possible enforcement actions that may be taken against him if he violates. Specifically, the greater the expected value of penalties and other costs of being caught, the less likely he is to violate. Assuming individuals form their expectations based on the recent history of enforcement actions, there should be a negative correlation between the incidence of violations and the extent and severity of recent, but not current, enforcement actions.[4] These expectations can be based on the individual's own history with enforcement and/or on the wider community's history with enforcement. Therefore, an enforcement action may have a specific deterrence effect directly on the individual against which an enforcement action is taken, and a general deterrence effect on others in the community.

With the appropriate data it is possible to estimate the statistical relationship between the detected violation rate and lagged values of enforcement actions. Doing this requires time-series data on a cross section of IUs. However, most IUs do not have data for every month of the period under study. There are often significant periods of time when no monitoring data exist for a given IU. This lapse in data apparently is due to sampling requirements of less than once a month, to some IUs moving or going out of business, and to new IUs being permitted. Therefore, the ideal form of analysis cannot be performed with this data.

We can speculate on some reasons for the different patterns of noncompliance among the three programs, and the extent that enforcement might account for these differences. East Providence's low incidence of noncompliance must certainly reflect the characteristics of the IUs in its program. Many of the IUs in the East Providence program are high-quality gold platers with the incentive to retrieve metals from their waste streams. Many of the IUs in NBC's program, on the other hand, are costume jewelry manufacturers with little or no incentive to retrieve the low value metals used in production. The discharge limits imposed on East Providence's IUs are less stringent than NBC's, also contributing to the lower levels of noncompliance.

The programs have different histories and are administered differently. For example, East Providence's program began in 1960 with the enactment of the City's sewer ordinance, while NBC's sewer ordinance was enacted in 1979 and the pretreatment program began in 1984. In addition, East Providence, with its small number of IUs, was able to work closely with its industries to cooperatively develop and implement its pretreatment program. NBC, with nearly twenty times the number of categorical IUs than East Providence and a proportionately smaller staff, did not have the luxury of such a cooperative approach when implementing its program. These and other differences may explain much of the variation in the patterns of noncompliance among the three programs. To some degree the combined differences of each program are accounted for by the POTW dummies used in the statistical analysis below. There are no peculiar approaches to enforcement by any one of the programs that appear to explain the differences in noncompliance.

A comprehensive comparative evaluation of enforcement across the three pretreatment programs also is not possible. That is, we cannot say that the approach to enforcement in one program is better or worse than the other programs. As stated above, noncompliance is only indirectly related to the over all success or effectiveness of a pretreatment program. The best indicator of pretreatment program effectiveness, of which enforcement is only a part, is the extent to which the program is responsible for reducing loadings of the regulated pollutants to the sewage treatment plant. Data on influent loadings are available only for NBC, and it shows that loadings of metals declined by 56% and cyanide by 68% from 1985 through 1988 (NBC, 1989). To what extent these reductions in loadings are due to the pretreatment program, and to enforcement in particular, can not be determined at this time. Before NBC instituted its pretreatment program, metals loadings in the plant's influent were declining. From 1981, a peak year for loadings, through

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4 We should note that a higher violation rate should result in more enforcement actions, other things equal. That is, there is a positive correlation between the current violation rate and the current amount of enforcement actions.

1983, loadings declined by 42 percent -- an improvement not due to the pretreatment program and enforcement. Factors other than pretreatment undoubtedly played a role. For example, changes in the composition of IUs, in production technology, and in the magnitude and nature of IUs' production may have contributed to these reductions.

An alternative to the ideal approach mentioned above is to measure enforcement effectiveness in terms of the time it takes to bring IUs into compliance following a violation[5]. Employing similar reasoning as above, we postulate that the greater the expected value of penalties and other costs of being sanctioned, the sooner an IU is likely to come into compliance. In this instance, these expectations can be based on the current enforcement actions taken for the violation as well as the IU's own history with enforcement and/or on the wider community's history with enforcement. Therefore, we expect an IU's propensity to continue violating a regulation to be negatively related to the enforcement actions taken against it for the detected violation, and negatively related to the lagged values of enforcement actions taken against it, and also actions taken against the larger community of IUs in the same pretreatment program.

In addition, we expect a positive correlation between the time to compliance and the time to enforcement action, where time begins when the violation (on which the enforcement action is based) is detected. This is based on the argument by Stigler (1970) and others that reducing the time from detection to sanction will improve compliance.

In formal terms, we estimate statistical relationships of the following form:

$$\text{(1)} \qquad TVC = F(\underset{-}{EA}, \underset{+}{TVE}, \underset{}{X}),$$

where TVC is the time between detection of the violation of a regulation and the time of subsequent compliance with the same regulation, $\underline{EA}$ is a vector of enforcement actions (e.g., a notice of violation, a civil penalty), TVE is the time between detection of the violation and formal enforcement action, and $\underline{X}$ is a vector of characteristics that may affect an IU's time to compliance; the signs above the variables indicate the nature of the expected relationship between the variables and TVC.

Several alternative specifications of (1) were estimated. Multicollinearity was a pronounced problem with those specifications where the general deterrence variables were entered separately. In an attempt to overcome the problem of multicollinearity the coefficients on the separate general deterrence variables are constrained to be equal. This is accomplished by adding three variables (CPENALTY + TFORMAL + FORMAL(-3)) to form one general deterrence variable GDETER. The estimate of (1) is shown in Table 4. The definitions of the variable names follow the table.

The results on the effects of the various enforcement actions are complicated. We will discuss the specific and general deterrence effects of the actions, both in terms of their current impact and lagged, or delayed, impact. First, the specific and current deterrence effect of the actions. The coefficients on the enforcement actions taken against the IU for the current violation (i.e., NOF, NOD, NOV, PENALTY, FINE) are not significantly different from zero. That is, there is no statistically significant specific and current effect on time to compliance of these actions.

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5 This alternative approach was suggested by a reviewer of an earlier draft of this paper.

Table 4. Enforcement Effectiveness

Variable	Coefficent	t-value
INTERCEPT	289.8*	7.02
NOF	-7.7	-0.51
NOD	-11.1	-0.36
NOV	33.3	1.02
PENALTY	2.7	0.12
FINE	-0.4	-0.77
CFINE	-0.5*	-2.10
MAJOR-3	9.6*	2.11
GDETER	-1.7*	-4.18
SNC	48.6*	2.93
TVE	1.0*	2.37
FLOW	-0.03	-0.28
EMPLOY	0.1*	2.05
D	-33.2*	-0.93
EPROV	-227.3*	-3.77
BVDC	-254.2*	-5.64
Q1	2.0	0.09
Q2	6.3	0.26
Q3	-39.1	-1.44
F-value = 6.86; R-Square = 0.38; Adj R-Sq = 0.33		

Significance at the 5 percent level is indicated by an asterix (*); 216 observations.

The variables of the model are defined as follows:

TVC = the time between detection of the violation of a regulation and the time of subsequent compliance with the same regulation

NOF = Notice of Failure issued for the current violation.

NOD = Notice of Deficiency issued for the current violation.

NOV = Notice of Violation issued for the current violation.

PENALTY = The number of civil penalty actions taken, consent decrees or settlements issued regarding the current violation (usually 1 or 0).

FINE = Dollar amount of a civil penalty assessment regarding the current violation.

CFINE = Cumulative sum of an IU's FINEs to date, not including the current FINE.

MAJOR-3 = Cumulative sum over the previous 3 months of an IU's NOF, NOD, NOV, PENALTY.

GDETER = Sum of general deterrence variables, CPENALTY + TFORMAL + TFORMAL(-3), where:
CPENALTY = The total number of civil penalties assessed, consent decrees and settlements issued since the beginning of the study period (6/85);
TFORMAL = Total number of formal enforcement actions issued to all other violating IUs during the period of the current violation;
TFORMAL(-3) = Total number of all formal enforcement actions issued during the past three (3) months.

SNC = 1 if the IU is in significant noncompliance at the time of this violation; = 0 otherwise.

TVE = Time between detection of the violation and formal enforcement action.

FLOW = Average daily flow of wastewater discharged by the IU in gpd.

EMPLOY = Number of employees.

D = 1 for NBC if the local limits applied at the time of the violation; = 0 otherwise.

EPROV = 1 if the observation is from East Providence; = 0 otherwise.

BVDC = 1 if the observation is from BVDC; = 0 otherwise.

Q1,Q2,Q3 = Seasonal dummy variables; Q1 is for the first quarter of a year, Q2 for the second, and Q3 for the third.

The past enforcement history of an IU does have a statistically significant effect. The cumulative total dollar amount of civil penalties an IU has been assessed (CFINEIU) reduces significantly the time to compliance. That is, the greater the amount of penalties an IU is assessed overtime, the less the time to compliance, other things equal. Attempts to include IUs' history of having their names published in the newspaper as a deterrence variable were unsuccessful. A publication history variable (PUB) is collinear with CFINEIU and the cumulative total of civil penalty actions taken against the IU. Adding PUB to CFINEIU resulted in an inferior set of estimates. Adding PUB to the cumulative total number of civil penalties also resulted in an inferior set of estimates. Neither set of these inferior estimates are reported here[6]. We conclude that publication of a violator's name in the newspaper may have a separate deterrence effect but we cannot isolate the significance or magnitude of the effect.

Similar attempts to identify a deterrence effect of demand monitoring also were unsuccessful. A variable representing the sum of samples taken over the previous three months proved to be collinear with some of the other variables, and the resultant estimates were inferior. As with publication, demand monitoring may have a separate deterrence effect, but the significance and magnitude of the effect cannot be established with available data.

The number of major enforcement actions taken against the IU over the past three months is positively correlated with time to compliance. Certainly this does not mean major enforcement actions slow down time to compliance. What it likely means is that IUs with a history of several major enforcement actions also have a habit or tendency to stay out of compliance longer than average.

The results indicate there is a significant general deterrent effect at work. The general deterrence variable, GDETER, is negative and statistically significant. As noted above, GDETER is the sum of three separate general deterrence variables (CPENALTY + TFORMAL + TFORMAL(-3)). CPENALTY is the cumulative civil penalties assessed by the program; TFORMAL is the total number of formal enforcement actions issued to all other violating IUs during the period of the current violation; and TFORMAL(-3) is the total number of formal actions taken during the preceding three months. This result has both theoretical and intuitive appeal. Theoretically, we expect IUs to base their expectations of penalties on the recent history of enforcement actions in their pretreatment program. And, their expected penalty, not their actual penalty, is what governs their decision whether to invest in reliable pretreatment equipment, to maintain it and keep it in good repair. Once an accident or breakdown in the equipment occurs, there may be little that can be done to hasten the return to compliance. The evidence is at least consistent with this explanation.

The timeliness of an enforcement action, TVE, is significant and has the expected sign. That is, the less time between detection and a formal enforcement action, the less the overall time to compliance. The estimated coefficient on TVE equals 1.0, indicating that one day saved in the time to an enforcement action saves roughly one day overall in the time to compliance. There is no added compliance effect as predicted by theory (e.g., see Stigler, 1970).

Employment (EMPLOY) is a statistically significant variable, suggesting the IUs with larger employment take longer to come into compliance, other things equal. To the extent that EMPLOY is a proxy for the size of an IU, this indicates larger industries stay out of compliance longer, other things equal. However, the flow of daily discharge, which may also may be a proxy for size, is not a significant explanatory variable.

The significant and positive coefficient on the SNC variable indicates an IU takes longer to come into compliance if it is in significant noncompliance (SNC) at the time of enforcement action. That more serious violators take longer to be brought into compliance is consistent with theory and intuition.

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6 They can be obtained from the authors upon request.

The date at which NBC introduced its local limits, which are more stringent than the early discharge limits it enforced, is a significant variable (the variable D). The negative sign indicates that imposition of the more stringent limits reduced the time to compliance. We initially expected this to have the opposite effect, i.e., more stringent limits causing IUs to require more time to come into compliance, other things equal. This date may not be reflecting only the new limits, but also the onset of a more aggressive enforcement program. As we describe above, 1987 was a watershed year for increased enforcement activity by NBC. Also, by September, 1987, the IUs had accumulated considerable experience with the pretreatment program and may have become better equipped to come into compliance more promptly. The variable D may be picking up such related effects that are not fully captured in the level of enforcement actions measured here.

The dummy variables for the pretreatment programs, EPROV and BVDC, indicate that the BVDC and East Providence programs induce quicker compliance than NBC, even when accounting for the differences in enforcement actions, etc. This may be due to the differences between NBC and the other two programs noted above (i.e., the number and nature of IUs, staffing, and history). The seasonal dummy variables were not generally significant, suggesting that times of the year are not influential in determining the time to compliance.

Summary

The investigation of enforcement reveals low levels of enforcement activity during the first half of the study period. Enforcement activity increased significantly in the NBC and BVDC programs during the second half of the study period. Even in the second half, however, low and modest levels of serious major enforcement actions were taken. Relatively few notices of violation were issued, and even fewer civil penalty actions were taken.

The econometric analysis of enforcement effectiveness indicates that the more severe enforcement actions, civil penalties in particular, significantly reduce the time to compliance. While an action, such as a civil penalty, may have no immediate effect on an IU currently out of compliance, there is a definite delayed response by the individual IU being sanctioned, and both an immediate and delayed response by all other IUs in the program. Both specific and general deterrence are operable for civil penalty actions. For Notices of failure, deficiency, and violation, only general deterrence is operable. No separate deterrence effect could be identified for publications of names of violators in the newspaper or other enforcement actions.

V. SUMMARY AND CONCLUSIONS

This study has investigated enforcement and compliance in three pretreatment programs in Rhode Island. Noncompliance with pretreatment regulations is measured and patterns of noncompliance are characterized. The role enforcement actions play in controlling noncompliance is investigated in an attempt to identify those actions that are most effective in reducing noncompliance.

Regarding the patterns of noncompliance, we found that **NBC** exhibits an overall pattern of having serious noncompliance problems early in the study period, followed by significant improvements in all areas. When local limits were introduced in September 1987, noncompliance escalated, but by the end of the study period, noncompliance had returned to its low level once again. NBC's noncompliance problems center around at least three pollutants (copper, nickel, and cyanide), a group of about 25 IUs that are consistently in noncompliance, and another 32 IUs in erratic noncompliance.

BVDC exhibits an overall pattern consistent with the slow start in implementing its pretreatment program. By the second half of the study period the noncompliance situation is comparable in many respects to NBC's. BVDC, however, has fewer IUs to monitor and has noncompliance problems with only one pollutant (cyanide). BVDC, with a much smaller program than NBC, has consistent noncompliance problems with 6 IUs, and erratic noncompliance problems with another 12 IUs. And **East Providence's** small pretreatment program exhibits an overall pattern of consistent compliance. What noncompliance problems existed occurred early in the study period.

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The econometric analysis of enforcement effectiveness indicates that the more severe enforcement actions, civil penalties in particular, significantly reduce the time to compliance. While an action, such as a civil penalty, may have no immediate effect on an IU currently out of compliance, there is a definite delayed response by the individual IU being sanctioned, and both an immediate and delayed response by all other IUs in the program. Both specific and general deterrence are operable for civil penalty actions. For Notices of Failure, Deficiency, and Violation, only general deterrence is operable. No separate deterrence effect could be identified for publications of names of violators in the newspaper or other enforcement actions.

These results suggest that enforcement policy should emphasize civil penalty actions, using them more frequently and increasing their severity, in order to reduce further the time to compliance for violations of the discharge limits. Unfortunately, we cannot say whether an increased emphasis on civil penalty actions, or any other enforcement action for that matter, would reduce the incidence of SNC, NC, Percent Exceedance, or the number of IUs in Consistent or Erratic Noncompliance. Our statistical analysis could not address this important issue.

The literature identifies some noncoercive factors other than enforcement that affect compliance and which may have some use for policy in the present context. Young (1979) identifies inducement, social pressure, obligation, and habit as other considerations by individuals when faced with compliance decisions.

Inducement Whereas enforcement works directly on increasing the expected costs of noncompliance, inducement works directly on increasing the expected benefits of compliance. That is, inducement raises the expected value of compliance relative to the expected value of noncompliance. Inducement can be formalized or institutionalized by explicitly recognizing compliant behavior and rewarding the compliant individuals or groups of individuals. Enforcement and inducement are not always mutually exclusive. Public authorities often pursue both "carrot and stick" policies. The Environmental Protection Agency, for example, offers incentives for firms and communities to install water treatment facilities and metes out

penalties to those who do not comply with schedules for the installation of such equipment (Wasserman, 1987).

As with enforcement, the relevant variables here are the probability that compliance will be detected and rewarded, and the nature of the reward. It may be that the probability of being detected and rewarded for compliance is more important to the compliance choice than the nature of the reward, but no evidence on this exists yet. If this is true, however, using low value certificates or publishing the names of IUs who have a strong compliance record may significantly lower the incidence of noncompliance in pretreatment programs.

Social Pressure Ostracism or expulsion from a group, avoidance, lack of trust, and dissemination of negative opinions about a person represent negative forms of social pressure; and social approval, the extension of status, and offers of friendship represent forms of positive social pressure. While most individuals appear to be sensitive to social pressure, some individuals act as if they are immune to most forms of it. As with enforcement and inducement, individuals consider both the probability of experiencing social pressure and the type of social pressure applied when making the compliance decision. The source of the social pressure is important. That is, the opinion of a certain group may be more important to the individual than other groups. The publication of the names of IUs who have violated pretreatment regulations certainly must help to bring about social pressure against noncompliant IUs. Another way would be to educate the general public in the community about the deleterious environmental effects of discharging toxics and other harmful substances into sewers and to enlist the community's assistance to pressure noncompliant IUs to follow pretreatment regulations.

Obligation The term obligation is used to capture the incentives to comply which stem from a general sense of duty and which do not rest on explicit calculations of costs and benefits. That is, individuals may feel the obligation to comply regardless of the consequences in order to avoid violating one's own convictions. Not much is known about how people form their feelings of obligation. Individuals are expected to feel more obligation to regulations that they had a role in formulating than regulations that appear dictated by a distant authority. They are expected to feel more obligation to regulatory measures that are credible (in terms of protecting the environment and the future economic health of the industry). They are expected to feel more obligation to measures that distribute the sacrifices and rewards fairly. If valid, this consideration suggests that cooperative pretreatment programs that actively involve the IU community in the development and implementation of pretreatment programs will tend to be more successful in securing compliance that command and control programs that do not involve the participation of IUs. Advisory panels of IU representatives could be used to establish this involvement and cooperation, thus helping to develop a strong sense of obligation to pretreatment among the IU community.

Political (and industry) leaders can play powerful roles in shaping people's sense of duty and what is right. For example, Ronald Reagan was elected on a platform that criticized the size of government and waste in government. Some researchers claim this message had the unintended effect of reducing taxpayers compliance and the amount of taxes paid in the early years of the Reagan administration (Carroll, 1988). It would be useful to have political and industry leaders speak in favor of pretreatment programs and to explicitly support the regulatory measures in place. This kind of opinion shaping, if successful, can strengthen the IUs' sense of obligation and, in turn, induce greater compliance.

Habit Regular patterns of behavior that involve little or no conscious thinking constitute habits. Given our limited decision-making capacity, habits would tend to emerge as simplifying devices in coping with compliance problems that are (i) of marginal importance, (ii) of frequent occurrence, and (iii) similar,or stable over time. For such conditions, habits are an efficient way to deal with numerous choices at the same time. Habits, of course, are formed by frequent repetition. Therefore, a regulatory climate that is stable is more likely to breed more compliance over time than a climate where the regulations and the enforcement of the regulations fluctuate overtime. New regulations take time to get used to, to adapt to complying with them. Compliance habits are usually formed in the early stages of a new regulatory regime. Thus, it is important to increase enforcement intensity in the early stages of a pretreatment program to inculcate proper compliance habits.

This study falls short in a number of respects, but perhaps the most important concerns the analysis of enforcement effectiveness. Data limitations prevented the use of the most preferred way of measuring and analyzing effectiveness. These data limitations may not persist in the three programs as they improve their data management systems, and as the set of IUs stabilizes and matures. Therefore, future study of these same programs with another two or three years of data beyond that used here should prove more susceptible to intensive analysis. The additional data needed for future studies includes the following:

1) Complete time series by month, or at least quarter, of the monitoring data (self- or compliance-monitoring, or both) for each of the categorical IUs in each pretreatment program. This may require increasing the required frequency of self-monitoring to monthly or quarterly at NBC and BVDC.

2) Specific data for each of the categorical IUs, including employment and sales or some appropriate measure of production quantity on a monthly or quarterly basis, type of pretreatment equipment and the date it was installed, and the type of raw materials used and products made. These data could be made part of the permitting and reporting process.

3) Metals and cyanide loadings data for each of the POTWs, on a monthly or at least quarterly basis.

It would also facilitate the acquisition and assembly of the data for study if the data reporting was standardized across pretreatment programs. Certainly, entering the monitoring data on computer disks using the same commercially available software would greatly facilitate future study of the three programs.

Similar analysis of pretreatment programs in other parts of the U.S. would prove doubly beneficial. First, it would serve as a test of the approach used here and the results obtained. That is, are the effects of specific and general deterrence significant in other programs? Second, pretreatment programs in other parts of the country use very different approaches to monitor IUs and to enforce the discharge regulations. It would be interesting and fruitful to compare and contrast the compliance and enforcement situations across several different styles of programs. In particular, to show which approaches to compliance and enforcement are the most effective.

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APPENDIX 1
Glossary of Acronyms Used in the Study

avg - average

BMR - Baseline Monitoring Report
BVDC - Blackstone Valley District Commission

CA - Control Authority
DEM - Rhode Island Department of Environmental Management
EPA - U.S. Environmental Protection Agency

gpd - gallons per day
IU - Industrial User

NBC - Narragansett Bay Commission
ND - Not Detectable
NOF - Notice of Failure
NOD - Notice of Deficiency
NOV - Notice of Violation
NPDES - National Pollution Discharge Elimination System

max - maximum
mg/l - milligrams per liter
mgd - million gallon per day

OTA - Office of Technology Assessment
OWEP - Office of Water Enforcement and Permits, EPA

PCI - Pretreatment Compliance Inspection
POTW - Publicly Owned Treatment Works

SIC - Standard Industrial Classification
SNC - Significant Noncompliance

TSS - Total Suspended Solids
TTO - Total Toxic Organics

RIPDES - Rhode Island Pollution Discharge Elimination System

APPENDIX 2
The Data

The data analyzed in this study are from the pretreatment programs of the Narragansett Bay Commission (NBC), the Blackstone Valley District Commission (BVDC), and the City of East Providence. The data include the results of periodic monitoring of the wastewater discharges (which provide measures of the permitted pollutants), the permitted discharge limits of each pollutant, and the enforcement actions taken by each POTW against the permitted IUs. Also included is each IU's SIC code, and it daily average water flow. These data extend from July 1985 through June 1988 for a total of 36 months.

The **NBC** monitoring data cover 179 electroplating and metal finishing IUs, the enforcement data 147 IUs. These two data sets overlap for 130 IUs. The **BVDC** monitoring data (on metal) cover 33 electroplating, metal finishing and other metal using IUs, the enforcement data 42 IUs. They overlap for 32 IUs. The **East Providence** data cover 14 metal finishing IUs. In all three data sets, the monitored pollutants are cadmium, chromium, copper, cyanide, lead, mercury, nickel, silver, and zinc.

All three data sets have one flaw that severely limits the analysis. The flaw is an incomplete monitoring record on most IUs. That is, most IUs do not have data for every month of the period under study. There are often significant periods of time when no monitoring data exist for a given IU. This lapse in data apparently is due to sampling requirements of less than once a month, to some IUs moving or going out of business, and to new IUs being permitted. As explained in the main text, this incomplete record severely constrains our options for quantitative analysis.

The data sets combine the results of both self-monitoring and compliance-monitoring, since each pretreatment program uses the combined data on which to base its enforcement actions. We were concerned about the veracity of the self-monitoring data and tested for difference between it and the compliance-monitoring results. Specifically, we used a Chi-Square test of differences in the violation rates from the two sources of data. The test of difference between violation rates for all pollutants taken together was negative, showing no statistical difference in any of the three programs. We also tested for differences in violation rates for each monitored pollutant taken separately. We found only a few differences. Of the seven pollutants monitored by NBC, two (cadmium and copper) showed a statistically greater violation rate in the compliance-monitoring data set than in the self-monitoring data set. Of the six pollutants tested for East Providence, two (copper and cyanide) showed a statistically greater violation rate in the compliance-monitoring data set than in the self-monitoring data set. No statistical differences were detected for BVDC's data sets.

Since these tests showed a relatively low incidence of differences (or bias) between self-monitoring and compliance-monitoring data, we combined them for our analyses of the data. While it would be interesting to perform all of our analyses on the two data sets separately, the small number of observations in the compliance-monitoring data set would not make this a feasible undertaking.

Another concern with the data is the possible bias introduced to our measures of noncompliance by the control authorities' monitoring policy. When violations are detected, NBC engages in more frequent monitoring. Other things equal, the measured incidence of noncompliance may be biased upwards by this increased monitoring since there will be a greater number of samples taken when noncompliance is high than when it is low. The data, however, show quite the opposite: monitoring in the NBC program became more frequent and intensive later in the study period when noncompliance was lower. The average number of samples (parameter measures) per IU sampled was less than four a month in 1986; rising to over five in 1987 and over six in the first half of 1988. For BVDC the trend is the same, with about one sample per sampled IU per month in 1986, and rising to over three in 1987 and the first half of 1988. East Providence shows a steady average of six samples per sampled IU per month for the entire period. Therefore, we conclude that our measures of noncompliance are not significantly affected by this monitoring policy.

The regression analysis is based on data from 62 IUs, 29 from NBC, 20 from BVDC, and 13 from East Providence. Note that only 29 of the 130 IUs in NBC's pretreatment program are used. These 29 IUs had sufficient data to support the regression anlaysis.