DOI: 10.1007/s00267-001-0001-7

Policy, Principle, and Practice in Industrial Pollution Control: Views from the Regulatory Interface

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ABSTRACT / There has been much criticism of the system for the control of industrial pollution, but not much is known about the views of the regulators and the industry. The objective of this study was to explore the attitudes at this regulatory interface towards the current and proposed regulatory system and make recommendations for improvements. The methodology involved a questionnaire survey sent to over 700 key personnel. Statistical analysis revealed similarities and significant differences between the views of industry and the regulator on the effectiveness of the current regime. Weaknesses related to the derivation and enforcement of standards were identified. The Environmental Quality Standards system was acknowledged to be flawed by both operators and regulators who agreed it should be improved by the expansion of listed chemicals, the introduction of sediment environmental quality standards and direct toxicity assessment of effluents. This paper concludes that these measures should be incorporated into the regulatory system, together with more rigorous enforcement of environmental performance standards including serious sanctions for non-compliance. In the longer term, a reappraisal of the regulatory system is required in order to establish an appropriate framework to ensure that environmental policy commitments are implemented.

The control of pollution from industrial installations remains a key issue in the protection of the marine environment. In industrialized areas, heavy metals and hydrocarbons make a significant contribution to the toxicity of estuarine and coastal waters and sediments (Kirby and others 1998; NRA 1995, Matthiessen and others 1995). Recent international policy commitments for the northeast Atlantic area set the agenda for industrial pollution regulation in the 21st century, calling for the complete cessation of discharges of hazardous substances into the marine environment by the year 2020 (OSPAR 1998). The successful implementation of the policy is likely to be determined by the attitudes of the industry and regulators towards the processes involved in the determination and enforcement of environmental standards (Brickman and others 1985). Previous work (Richards and others 2000) highlighted perceived weaknesses within the current regulatory system. This study focuses on the UK chemical industry and examines the attitudes of key personnel at the regulatory interface to the regulation of water pollution.

KEY WORDS: Regulation; Integrated pollution control; Implementation; Marine pollution; Industrial discharge; Monitoring; Compliance

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Discharge Licenses

Although major incidents of water pollution are highly publicized and are a cause for concern, most contaminants routinely enter the marine environment from industrial sources through licensed discharges. In 1951, the Rivers (Prevention of Pollution) Act was introduced in the UK. The key feature of this and subsequent acts was the concept of controlling discharges by means of the consent system which enables the authorities to impose conditions on a discharge (Garbutt 1995). These conditions relate to the maximum allowable concentrations of pollutants in the effluent and the volume of effluent discharged. Although the consent system has expanded, both in terms of scope and content, its main characteristics have remained unchanged through successive legislation. In some cases the specified discharge limits have been transcribed unaltered from one legislative framework to the next.

Scientific Principles Underlying Regulation

Underlying the consent system is an assumption that certain safe concentrations for each hazardous substance can be determined using scientific techniques. These values are subsequently used to derive acceptable discharge levels for industrial sectors, individual factories and their receiving waters. In the UK, discharge consent or authorization conditions are determined to ensure protection of the use of the receiving waters. Environmental quality standards (EQSs) are derived for priority substances, which are selected on the basis of their toxicity, persistence, and tendency to bioaccummulate (Agg and Zabel 1990), using a well-established risk assessment procedure (Zabel and Cole 1999). However, toxicity data are limited: it is estimated that of the 100,000 chemicals currently registered within the EU (Agg and Zabel 1990), less than 0.1% have been tested for their toxicity on aquatic or marine species. In addition, these procedures do not take into account the combined synergistic or antagonistic effects of mixtures. Other chronic and subtle toxic mechanisms, such as genotoxicity and endocrine disruption are also outside the current testing system. In the absence of empirical data, physicochemical data are used extensively to predict environmental fate and pathways and even to predict the toxicity of mixtures (Xu and Nirmalakhandan 1998). These weaknesses have led to widespread criticism of the EQS concept and risk assessment procedures (Johnston and others 1996, Matthiessen 1998). Once EQSs have been set, effluent discharge consents should be reviewed so that the EQS will be achieved after allowing for initial and acceptable dilution around the discharge point. However, this mixing zone will vary depending on the methodology and can result in permitted pollutant loads varying by up to a factor of 3 (Ragas and Leuven, 1999).

Consents for discharge of effluents were initially set in terms of gross pollution parameters such as suspended solids concentration and five-day biochemical oxygen demand. Later approaches took into account oils and metals and, more recently, the growing number of synthetic organic chemicals. Over the last 10 years, the use of ecotoxicological measures for effluent consenting have been proposed as a solution to the problems of complex industrial effluents and the Environment Agency (EA) initiated a program to demonstrate the role of direct toxicity assessment (DTA) in pollution control. In the Netherlands, a similar program has revealed the need for further work before using DTA as a regulatory tool (Tonkes and others 1999). Experience in the United States has demonstrated that an effluent biomonitoring program of some industrial point source discharges, as part of the regulatory process, can result in a marked reduction in the acute toxicity of those discharges (Fisher and others 1998). The historical legacy of industrial pollution means that sediments, rather than point sources may now be the most important future source of contaminants in some areas (Sanudo-Wilhemy and Gill 1999) and the pollution control system may need to address this issue in the future.

Integrated Pollution Control: Regulation in Practice

In 1990, as part of the Environmental Protection Act (EPA'90), the industrial processes with the greatest potential to produce significant discharges of the most harmful (Red List) substances (Agg and Zabel, 1990) became regulated under integrated pollution control (IPC) (Castle and Harrison, 1996). The regulatory bodies now responsible are the Environment Agency (EA) for England and Wales, and the Scottish Environment Protection Agency (SEPA) for Scotland. Within IPC, the regulatory body exercises considerable discretion in setting the standards within a legislative framework that attempts to reconcile the cost of pollution control measures with the perceived environmental benefits by applying the strategy of "best available techniques not entailing excessive costs" (BATNEEC). The implementation stage therefore has a significant impact on policy output. The difficulty of obtaining accurate economic and technical information required to make BATNEEC judgements has led to an increasing involvement of the operators in the negotiation of standards (Smith 1997).

The legally binding IPC authorization conditions should facilitate strict enforcement, but this requires a monitoring regime capable of ensuring compliance and detecting breaches. It is also important that the regulator be willing to impose sanctions, where appropriate. However, the 1998 annual report summary (EA 1999a) shows that the EA brought few prosecutions for breach of discharge limits, and the level of fines imposed is often seen as being too low to act as an effective deterrent. Consequently, the issue of environmental sanctions is currently being addressed by the UK government (ENDS 1999a). For large companies, the main incentive to comply with their consent or authorization conditions may be the avoidance of negative publicity, rather than financial penalties (Mehta and Hawkins 1998). Evidence from the United States demonstrates that publication of information concerning toxic releases can make an effective contribution to the tightening of regulatory standards (Fisher and others 1998). The publication of the top polluters list in the

UK highlighted by Friends of the Earth was criticized by the Chemical Industries Association, but this approach has been adopted by the EA in their "Hall of Shame" publication on their web site (EA 1999b).

The wider involvement of stakeholders in the setting of environmental standards has been recommended by the Royal Commission on Environmental Pollution (RCEP 1998), is an integral part of IPC, and will be a key feature of the forthcoming EU Water Framework Directive (Bloch 1999). Public access to information is an important part of this involvement, but Taylor (1997) was critical of the information held in the public registers and concluded that these alone were not facilitating public involvement in pollution control. Indeed, it is unclear as to which methods facilitate successful public participation (Chess and Purcell 1999).

2020 vision

The ministerial meeting of the combined Oslo and Paris Commission (OSPAR) in July 1998 agreed to "make every endeavour to move towards the target of cessation of discharges, emissions and losses of hazardous substances by the year 2020" (OSPAR 1998), but there remains confusion over the roles of various stakeholders and how the agreement should be implemented. The UK government recently stated that it would develop ways of meeting its commitments under OSPAR. However, the OSPAR agreement has not been incorporated into the EU Water Framework Directive and therefore has not yet been given legal force. In the UK the Chemical Industries Association has publicly said that it supports the achievement of the OSPAR targets and has announced a comprehensive program to assess the effects of a number of industrial chemicals (Hackitt 1998).

Aims and objectives

Previous study, based on structured interviews with industrial operators and regulators, highlighted areas of contention and uncertainty within the current regulatory system, including doubts about the effectiveness of the EQS system for the control of water pollution (Richards and others 2000). This study aims to explore the attitudes of operators within the chemical industry and their regulators towards the current pollution regulation regime and to suggest how the outcome of pollution policy may be affected. It seeks to identify attitudinal differences, on both an institutional and regional basis, between those who are at the regulatory interface and therefore most closely involved with the implementation of pollution policy. The investigation will analyze their suggestions for improvements to the current regime and the longer term implications for the implementation of the OSPAR strategy.

Table 1. Details of response rate to main survey

	Dispatched	Returned	% returned
IPC inspectors	114	41	36.0
Operators	603	254	42.1
Total	717	295	41.1

Methods

The sample representing the regulatory interface was defined as all chemical industry environmental managers and the environment agency inspectors responsible for their regulation. A list of agency IPC inspectors and chemical process operators in the UK was obtained from the EA and SEPA. These operators were contacted, by telephone, to obtain the identity of their environmental manager so that the survey could be targeted to named individuals. As the total sample consisted of over 700 personnel and the methodological approach required a large data set for the successful use of statistical analysis, a postal questionnaire survey method was selected as the most appropriate research instrument (Oppenheim 1992).

Postal Survey

The advantages and disadvantages of postal surveys are well documented in the literature (see for example, Moser and Kalton 1993, Oppenheim 1992, Frankfort-Nachmias and Nachmias 1996). The main survey was despatched in February 1999. The usable response rate after one reminder was 41.1% (Table 1), which was considered to be sufficient to meet the research objectives. This response rate for this type of survey is seen as very favorable. Recently in a survey of over 700 environmental directors of industrial companies in the United States, Fryxell and Vryza (1999) achieved a response rate of 32%. They observed that this was satisfactory considering that environmental issues are sensitive matters for most companies.

Questionnaire Design

The questionnaire was designed in seven main sections each dealing with a different theme. These themes were: (1) UK industrial policy, (2) environmental quality standards, (3) hazardous chemicals and risk assessment, (4) BATNEEC and the economics of pollution control, (5) monitoring and compliance, (6) the chemical industry, and (7) the future. Of the total 58

attitudinal questions, 42 used a 5-point Likert scale to measure responses (Moser and Kalton 1993). The five response categories were "strongly disagree," "disagree," "neither agree nor disagree," "agree," and "strongly agree." Likert scales are useful for multiple-item measures and are more likely to capture the totality of a broad concept than a single question, and it can help make finer distinctions between respondents (Bryman and Cramer 1999). The remaining 16 questions were based on a ranking or dichotomous scale. A final section consisting of six questions related to personal and organizational details of the respondent. Pretesting of the questionnaire was carried out using well-informed professionals prior to pilot testing with 24 environment managers, IPC inspectors, and representatives of environmental groups.

Analysis of Data

Descriptive statistics were calculated for the Likert-scale variable responses, with mean scores derived from the 5-point scale ranging from "strongly disagree" (=1) to "strongly agree" (=5), with the middle point (3) representing "neither agree nor disagree." Standard deviation was calculated for all the of valid responses (N) for each variable. These calculations were performed both for the whole sample and separately for the regulator data and operator data. Operator and agency subsample means were compared by using one-way analysis of variance (ANOVA) to identify any significant differences between the respective attitudes of the two groups. Differences between the groups were indicated by the test statistic and categorized in order of increasing significance: at the 5% level ($P < 0.05$), at the 1% level ($P < 0.01$) and at the 0.1% level ($P < 0.001$). Due to the qualitative nature of some of the variables, chi-square analysis was used, rather than ANOVA.

Results

The pattern of respondents was examined to identify any nonresponse bias. The return rate was higher from the Scottish sample, with 56.6% returning completed questionnaires compared with 39.8% from England and Wales. A higher proportion of operators (42.1%) responded to the survey than regulators (36.0%). Within the operator sector, multinational companies were more likely to return questionnaires (49.8%) compared to the smaller operations (36.5%). No other response bias was identified.

Table 2. Association between respondent type and perceived most effectively controlled category of pollution[a]

	Releases to air	Aqueous discharges	Solid waste disposal
Regulators	51.5	45.5	3.0
Operators	28.9	45.6	25.5

[a]Figures are given in percentages for each respondents type. Absolute values: $N = 272$, $df = 2$, $\chi^2 = 11.14$, $P < 0.05$

UK Industrial Pollution Policy

Regarding the regulation of emissions to the environment, 45.6% of the respondents believed that aqueous discharges were more effectively controlled than releases to either air or land. The corresponding figures for the other media were air (31.6%) and land (22.7%). There were significant differences between the operators and regulators (Table 2), with the regulators selecting air releases as the most effectively controlled and solid waste disposal the least. Operators identified aqueous discharges as the most effectively controlled and their responses were more evenly distributed across the choices than those of the regulators. Regional differences were also identified, with 70% of the respondents from Scotland identifying aqueous releases as the most effectively controlled, while the corresponding figure for England and Wales was 42.7%.

Considering the various categories of contaminants (Figure 1a), toxic metals were identified as the substances the majority of respondents (56.3%) believed to be the most effectively regulated. By contrast, few (7.9%) selected organic micropollutants.

The European Union was clearly perceived (72.3% of respondents) to have had the most influence on UK government pollution policy (Figure 1b). The next most influential was indicated as the environment agencies (9.9%) and environmental groups (5.5%). The legislation that was considered to have had the most effect in controlling aqueous discharges from industrial sources was EPA'90 (59.4%) (see Figure 1c), followed by the Water Resources Act (WRA) 1991 (14.5%). This was not surprising since the sample had been selected from IPC operators and regulators. Again, regional differences were highlighted, with 42.9% of the Scottish respondents selecting the Control of Pollution Act (COPA), but none selecting WRA. This reflects the case that WRA does not apply in Scotland. In contrast, only 4% of respondents from England and Wales identified COPA as the most effective piece of legislation.

Table 3 shows descriptive statistics for the variables measured using the attitude scale.

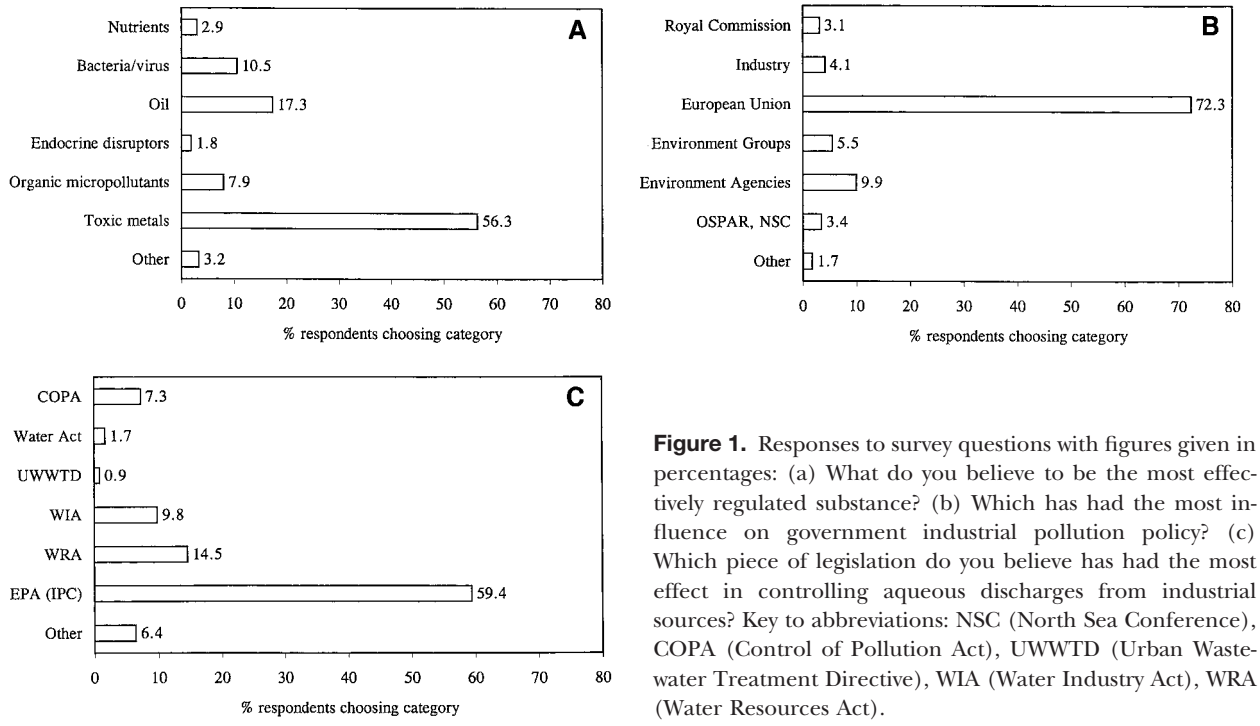

Figure 1. Responses to survey questions with figures given in percentages: (a) What do you believe to be the most effectively regulated substance? (b) Which has had the most influence on government industrial pollution policy? (c) Which piece of legislation do you believe has had the most effect in controlling aqueous discharges from industrial sources? Key to abbreviations: NSC (North Sea Conference), COPA (Control of Pollution Act), UWWTD (Urban Wastewater Treatment Directive), WIA (Water Industry Act), WRA (Water Resources Act).

EQS and Hazardous Chemicals

There were no significant ($P < 0.05$) differences between the respective views of the regulators and operators towards the current system of EQS and the listing of hazardous substances. Respondents indicated that compliance with all relevant EQSs does not necessarily prevent environmental harm and exceedence of an EQS would not always cause harm. It was also believed that the EQS system does not allow for additive/synergistic effects of mixed wastes, nor does it take into account chronic and/or subtle ecosystem effects. The respondents agreed that the EQS should be widened to include sediment quality and thought the system would need to be revised in light of improved detection limits. The view was expressed that an authorization (or consent) does not specify discharge limits for all hazardous substances posing an environmental risk that could be present in an effluent. Regarding the priority lists of hazardous substances, fewer respondents from Scotland (49.1%) than from England and Wales (56.3%) felt that they reflected current environmental priorities.

Although both operators and regulators agreed that there were chemicals which should be listed but were not, more regulators (88.2%) than operators (58.1%) expressed this view.

The addition of hazardous chemicals to the prescribed list was perceived to be a lengthy process (Figure 2). Approximately 60% of respondents thought it would take at least five years for a chemical to become prescribed. Most respondents (64.8%) supported the concept of direct toxicity assessments (DTA) being included in the authorization. Scottish respondents were particularly positive (91.7%).

BATNEEC and the Economics of Pollution Control

There was a clear difference of opinion between the regulators and operators (Table 3), with the regulators exhibiting a more positive view of BATNEEC and its achievements. The regulators expressed the opinion that BATNEEC acted as a driver for technological change, while the operators were less positive, but both groups agreed that BATNEEC had resulted in environmental improvements. The operators indicated that the application of BATNEEC was affected by the interpretation of the individual IPC inspector, while the regulators were more equivocal. In the provision of information, the operators considered themselves to be in a better position than the regulators to determine what entails excessive cost. The regulators generally accepted this but showed only weak agreement. Both groups identified operators as the regulators' main source of economic information, with guidance notes seen as more influential in providing technological and process information, although operators considered

themselves to be the most important source for both types of information.

Monitoring and Compliance

No regulator thought that monitoring schemes could detect all breaches of conditions that could cause harm to the environment, while operators expressed more confidence in the system (Table 3). Operators and regulators considered that there should be more self-monitoring by operators, who, in contrast with the regulators, indicated that operators with recognized environmental management systems required less regulatory monitoring. Although prosecution was viewed by both groups as a last resort, operators indicated that the sanctions imposed for breaches of an authorization were sufficiently severe, whereas the regulators did not. The operators' main concern associated with prosecution for noncompliance with environmental legislation was negative publicity, according to 79.9% of respondents, with fines selected by 4.9%. No Scottish respondent identified fines as the main concern.

The Chemical Industry

There was a consensus that industry associations, such as the Chemical Industries Association and the European Federation of Chemical Industries, help to counter the effects of lobbying by environmental groups (Table 3). The operators believed more strongly than the regulators that it was in the interests of the chemical industry to adopt uniform environmental standards, although it was recognized that tighter regulation creates opportunities for competitive advantage within the sector. Neither group indicated that most of the significant environmental improvements had already been made by the chemical industry. It was felt, very strongly, that the public generally failed to understand the relative risks and benefits associated with the chemical industry and its products. This was the strongest response observed in the entire survey.

The Future

Valid response numbers for the OSPAR 2020 questions were substantially lower than for the other sections of the survey and 83 respondents (28%) indicated they had insufficient knowledge to answer the questions. The operators considered the targets to be impractical and unlikely to be achieved, whereas the regulators were more positive. However, there was a recognition that the operators and regulators would need to work together if the targets were to be achieved. The respondents generally believed that the implementation of the OSPAR agreement would require new legislation, increased investment in effluent treatment capability, and substitution of some products by cleaner alternatives. Regulators indicated more strongly than operators that some older production technologies would need to be phased out. New management and control techniques and accelerated risk assessment for chemicals were also seen by the two groups as necessary to achieve the targets. When questioned about future environmental policy, the overriding concern of the operators was the need for a level playing field across Europe and worldwide, so that UK industry would not become uncompetitive as a result of strict environmental legislation.

Discussion

In the UK the EQS system is used as a basis for setting parameter limits for listed substances in discharged effluents, and as such it is the scientific 'cornerstone' of the regulatory system.

Agreement on Principles

This study has shown that although the operators and regulators expressed different views concerning the detailed application of the regulations, they nevertheless shared a perception of the underlying principles of EQS-based regulation.

Operators and regulators both had their doubts about the effectiveness of the EQS system and believed that compliance with all relevant EQSs would not necessarily prevent harm to the environment, yet exceedence would not necessarily lead to harm. This highlights an ambiguity and implies the system is unable to encompass the range of chemicals and the information concerning their complex effects that is required to set safe concentration limits. As a result, some of these EQS levels are set either too high or are unnecessarily strict or, as is the case for many substances, are not derived at all. Due to the complex nature of industrial effluents, the list of chemicals detailed in an authorization does not specify discharge limits for all hazardous substances that could be present in a particular effluent, and this was recognized by most respondents. There may be additive and synergistic effects between components but most respondents did not believe that these effects were incorporated into the derivation of an EQS. The key benefit of the EQS based approach may be that it is a convenient bureaucratic system that facilitates uncomplicated management.

Toxic metals have been the subject of a great deal of environmental research over the previous three decades, and it is only comparatively recently that organic chemicals have become the major focus. This emphasis was reflected in the belief of both operators and regu-

Table 3. Descriptive statistics calculated using responses measured on 5-point Likert scale.[a] Significant differences between agency and operator responses are indicated by test statistics (*P*)

Variables	All respondents			Agencies			Operators			Difference significant at *P*
	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	
Environmental quality standards and hazardous chemicals										
Provided there is compliance with all relevant EQSs, then no harm will be caused to the environment	2.68	1.17	282	2.81	1.29	38	2.66	1.15	244	
Exceedence of an EQS will lead to environmental harm.	2.77	1.28	282	2.43	1.32	40	2.82	1.26	242	
The EQS system allows for additive and/or synergistic effects of mixtures of pollutants.	2.43	1.19	226	2.30	1.27	37	2.46	1.18	189	
Chronic and/or subtle ecosystem effects are not considered in the derivation of EQS levels.	3.39	1.15	189	3.08	1.22	25	3.44	1.14	164	
The identification of a hazardous chemical should result in the derivation of an appropriate EQS.	3.74	1.23	272	3.74	1.29	39	3.74	1.22	233	
EQSs should be defined for sediment as well as water.	3.87	1.05	254	3.77	1.09	35	3.89	1.04	219	
The EQS system will need to be revised in light of improved detection limits.	3.42	1.30	274	3.38	1.25	39	3.43	1.32	235	
The composition of the red, black, and grey lists, etc., accurately reflects current environmental control priorities	3.31	1.16	254	3.23	1.11	35	3.32	1.17	219	
An authorization (or consent) specifies discharge limits for all hazardous substances, posing an environmental risk, that could be present in that effluent.	2.69	1.42	288	1.37	38	2.71	1.43	250		
BATNEEC and the economics of pollution control										
The application of BATNEEC depends on the interpretation by the individual IPC Inspector.	3.75	1.13	291	3.24	1.41	41	3.84	1.05	250	<0.01
The application of BATNEEC has resulted in environmental improvements.	4.08	0.88	285	4.80	0.40	41	3.95	0.88	244	<0.001
It is the responsibility of the operator to prove to the agency that what they propose is BATNEEC.	4.44	0.73	293	4.90	0.30	41	4.37	0.75	252	<0.001
BATNEEC will differ depending on the quality of the receiving waters.	3.37	1.38	283	3.44	1.47	41	3.36	1.36	242	
BATNEEC acts as a driver for technological change.	3.50	1.16	288	4.34	0.94	41	3.36	1.13	247	<0.001
The operator is in a better position to determine what entails excessive cost than the agencies	4.10	1.05	292	3.20	1.21	41	4.25	0.94	251	<0.00
The agencies cannot impose standards on industry which could radically affect an operation.	2.53	1.28	291	1.66	0.79	41	2.68	1.29	250	<0.001
Economic instruments are the only way to ensure that the polluter pays principle is realised in practice.	3.29	1.19	267	3.11	1.24	36	3.32	1.18	231	
Monitoring and compliance										
Monitoring schemes detect all breaches of conditions that could cause harm to the environment.	1.91	0.98	291	1.44	0.63	41	1.98	1.01	250	<0.001
There should be more self-monitoring by operators.	3.64	1.07	290	3.98	0.85	41	3.59	1.10	249	<0.05
Operators with recognized environmental management systems require less agency monitoring.	3.64	1.25	295	2.80	1.23	41	3.78	1.20	254	<0.001
As analytical methods improve, more hazardous substances will have to be included in authorizations and consents.	3.22	1.25	286	3.34	1.17	41	3.20	1.27	245	
No operator should be prosecuted for a breach of authorization (or consent) limit, unless significant environmental harm is caused.	2.94	1.41	293	1.83	0.95	41	3.12	1.39	252	<0.001
Prosecution of operators for breach of authorization conditions is seen as last resort.	3.81	1.22	291	3.49	1.36	41	3.86	1.19	250	
Legal sanctions imposed for breaches of authorization conditions are sufficiently severe.	3.17	1.38	286	2.34	1.33	41	3.31	1.34	245	<0.001
The chemical industry										
Industry associations such as CIA and CEFIC help to counter the effects of environmental group lobbying.	3.61	0.94	262	3.50	0.85	40	3.63	0.95	222	
It is in the interests of the chemical industry to adopt uniform environmental standards.	3.92	1.05	274	3.54	1.21	39	3.98	1.00	235	<0.05

Table 3 (Continued)

Variables	All respondents Mean	SD	*N*	Agencies Mean	SD	*N*	Operators Mean	SD	*N*	Difference significant at *P*
Tighter regulation of industrial pollution creates opportunities for competitive advantage within the chemical sector.	3.53	1.15	279	3.76	1.02	41	3.50	1.17	238	
Most of the significant environmental improvements have already been made by the Chemical industry.	2.78	1.08	264	2.68	1.02	40	2.80	1.09	224	
The public generally fail to understand the relative risk and benefits associated with the chemical industry and its products.	4.57	0.61	286	4.46	0.64	41	4.59	0.60	245	
Implementation of the OSPAR agreement will require:										
New legislation to be introduced.	3.76	1.14	200	3.46	1.10	26	3.80	1.14	174	
Increased investment in effluent treatment capability.	4.22	0.71	217	4.10	0.74	28	4.24	0.71	189	
The adoption of new, cleaner production technologies.	4.13	0.73	216	4.24	0.74	29	4.12	0.73	187	
The phase out of some older production technologies.	4.09	0.84	216	4.41	0.57	29	4.04	0.86	187	<0.05
Substitution of some products by cleaner alternatives.	4.03	0.78	218	4.14	0.69	29	4.01	0.79	189	
New management and control techniques/systems.	3.77	0.96	215	3.55	1.06	29	3.81	0.94	186	
Accelerated risk assessment for chemicals.	3.72	1.01	211	3.48	1.09	29	3.76	0.99	182	
The implementation of the Precautionary Principle.	3.28	1.09	174	3.19	1.14	27	3.29	1.09	147	
New chemicals should only be introduced to replace more hazardous existing substances.	2.55	1.36	213	2.46	1.37	28	2.56	1.36	185	
The OSPAR targets are impractical and unlikely to be achieved.	3.29	1.02	156	2.92	1.10	24	3.36	0.99	132	<0.05
The regulators and the chemical industry should work together to implement the OSPAR agreement.	4.21	0.79	217	4.24	0.87	29	4.21	0.78	188	

[a]Responses coded 1–5, where 5 = "strongly agree" and 1 = "strongly disagree". Significant differences between agency and operator responses were calculated using one-way ANOVA test.

lators that toxic metals were the most effectively regulated substances but, in spite of this, industrial pollution has resulted in metal levels in shellfish exceeding proposed food safety standards (ENDS 1999b). New research highlights an ever-increasing number of organic chemicals not regulated under the existing regime that are cause for concern, and few respondents identified organic pollutants as being well regulated. Industrial organic chemicals may be the most significant environmental estrogens in estuarine and coastal waters (ENDS 1998a), yet most respondents were unsure as to whether these sorts of chronic and subtle biological effects were included in the derivation of EQS concentrations.

Among the possible improvements to the system, supported by most respondents, was the listing of more substances and the derivation of EQSs for chemicals found to be hazardous. The regulators believed particularly strongly that there were chemicals that should be priority listed but were currently not. However, the process of officially listing chemicals was perceived by operators and regulators to be a lengthy procedure. It took the EU a whole decade to issue the first 10 daughter directives relating to the regulation of individual priority blacklisted substances (ENDS 1992). Despite

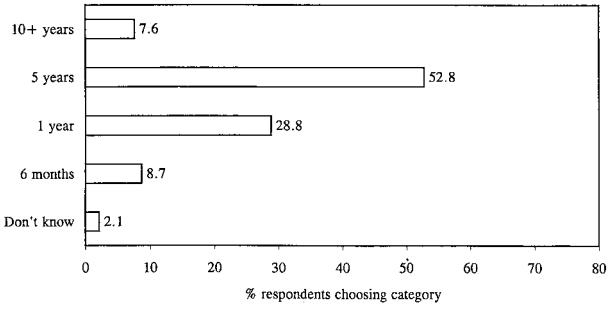

Figure 2. Respondents' estimate of time taken for a nonprescribed chemical, found to have serious biological effects, to become prescribed.

the discovery of the serious biological effects of tributyltin (TBT), an antifouling compound, it still took several years for legislation, now considered inadequate, to be adopted (Evans and others 1995).

Attempts are being made, with the support of chemical industry associations in both Europe and the United States, to generate toxicity data concerning industrial chemicals. The US EPA in conjunction with the Chemical Manufacturers Association has suggested that 87,000 possible endocrine disruptors should be tested (C & I 1999a). The lessons from the TBT debacle,

however, show that laboratory tests are unable to predict long-term subtle effects. On an operational basis, the difficulties inherent in identifying the many components of complex industrial effluents create serious problems with determination, control, and enforcement (Johnston and others 1991). An expanded list would present obligations to the regulator, which, given finite resources, it may not be able to fulfill.

One suggested solution to the problem of combined and subtle effects of effluents is using an integrated response, such as DTA, and most respondents, particularly those in Scotland, were positive about this. However, the EA's pilot program is unlikely to lead to DTA being incorporated into the authorization (ENDS 1999c). Furthermore, the program has only assessed acute toxicity using a single species of organism, and there are problems extrapolating data to predict ecosystem effects (Elliot 1996). There will need to be further work on the development of toxicity assessment techniques for liquid effluents discharged to the environment before it can be widely applied to pollution management (Coombe and others 1999).

The elevated contaminant levels in sediments near industrial discharges stand testament to the failings of the regulatory regime to predict future environmental problems. Contaminated sediment is a potential source of future contamination of the water column and could have a significant ecotoxicological impact in rivers and estuaries (Lang and others 1998, Matthiessen and others 1995) and this was widely recognized by those surveyed. Indeed, it has been argued that monitoring sediment quality is more relevant to the protection of the marine environment than water column measurements (Gray 1999). A recent study by Sanudo-Wilhemy and Gill (1999) found that although regulation of point sources had reduced the levels of some dissolved trace metals in the Hudson River, benthic remobilization of sediment was now an important source of such contaminants. The operators and regulators surveyed agreed that sediment quality should be included in the EQS system, but it is not clear how sediment quality standards could be incorporated into the regulatory regime. The US EPA has recently acknowledged that current scientific understanding does not support the setting of enforceable numerical standards for sediment quality (Renner 1998). Chapman and Mann (1999) propose the use of sediment quality values in ecological risk assessment procedures for environmental monitoring, rather than for regulatory purposes, and it is perhaps in this role that sediment quality measures will be most appropriate.

Differences in Practice

Significant differences between the perceptions of the operators and regulators have been discovered in the practical aspects of IPC regulation. The regulators are clearly more positive about the environmental benefits achieved by the implementation of BATNEEC than the operators. The study has shown that an inspector who makes the final BATNEEC judgement is perceived by both groups to affect the outcome, although the regulators are more equivocal, and this individual discretion could lead to inconsistencies in the determination and enforcement of emission limits. The BATNEEC negotiation requires detailed economic, technological, and process information from the operator. The regulators recognize that they are dependent on the operators to provide the economic information and therefore the operators are better able to determine what entails "excessive cost." In a relationship where knowledge represents power, this dependency places the regulators at a disadvantage in the negotiation process, a situation identified by Smith (1997). Industrial operators appear confident that the regulators cannot impose standards which would severely affect their operations, but resistance by industry to tightening environmental regulation on the grounds of economic costs may be misplaced. Recent case studies (Sharrat and Sparshott 1996) have demonstrated that an improvement in environmental performance can result in considerable cost savings through reduced raw materials consumption and increased output. Innovations borne of the increasing environmental pressures are gradually translating into new commercial processes and products, thus providing the industry with new opportunities. However, a report by Boyd (1998) examined trial projects at three major chemical companies in the United States and concluded that industry's desire to develop pollution prevention technology is often inhibited by rigid prescriptive regulations. With the introduction of the Integrated Pollution Prevention and Control (IPPC) Directive (EC 1996), operators will have more flexibility in managing their site emissions, which may provide them with more scope to develop novel techniques. Both operators and regulators indicated that significant improvements have yet to be made by the chemical industry, but within the BATNEEC framework, it is likely that the regulators will require increasingly sophisticated and detailed information concerning the operators in order to propose improvements as they become less obvious.

When standards have been set, compliance is normally measured using monitoring schemes. Operators and regulators agreed that current monitoring schemes

could not detect all breaches of an authorization that could lead to environmental harm. This could be improved by the use of continuous monitoring, and tamperproof technology is currently being developed. As part of an authorization the operator is obliged to provide monitoring data to the regulator while the regulators carry out their own routine monitoring to establish compliance and to assess environmental effects. The regulators, in particular, believed that operators should carry out more of their own monitoring. This could result in the regulators developing increasing dependence on the operators for information and shift the power balance even further in favor of the operators. The sanctions imposed for noncompliance were perceived by the regulators to be insufficiently severe, although there are signs that this is changing (ENDS 1998b). Prosecution was seen by both parties as a last resort, with the regulators expressing a need for more severe sanctions to be applied in the case of a breach of conditions. Operators indicated that the sanctions for breach of authorization conditions were sufficiently severe and that they should not be prosecuted for such breaches unless significant environmental harm is caused. However, negative publicity, not fines, were the operators' main concern, particularly in Scotland, where the legal system does not really support the regulator and fines are low (ENDS 1997). These findings indicate that while the financial penalties of last resort are not a deterrent, the EA's recent "hall of shame" approach to naming the worst polluters may be an effective sanction.

The Future

The more precautionary approach, long-advocated by the environmental groups, has now been adopted by OSPAR. This will be seen as a victory for the environmental groups who have been influential in the adoption of a precautionary approach by other policy-makers such as the North Sea Conference and in establishing a European ban on phthalate plasticizers in baby toys (ENDS 1998c). It is therefore surprising that few operators or regulators perceived environmental groups to have much influence on pollution policy. There are calls for wider stakeholder involvement in the setting of environmental standards (RCEP 1998), it is an integral part of the Water Framework Directive, and it will be an important part of the implementation of the OSPAR strategy. However, there is a clear message from the operators and regulators in this study that they do not believe the public understands the relative risks and benefits of the chemical industry and its products. This perception could inhibit public involvement and therefore diminish their influence on future regulatory decision-making.

There appears to be a lack of awareness concerning the details and implications of the OSPAR agreement. Those who did respond indicated that, even at this early stage, the targets were unlikely to be achieved. However, OSPAR together with the North Sea Conference have a proven track record of establishing marine protection measures, such as the ban on the marine dumping of sewage sludge, which was implemented in the face of opposition from the UK. The common position recently agreed by EU Environment Ministers did not contain provisions to incorporate the OSPAR agreement into the framework Directive on water resources (ENDS 1999d) and therefore no legal force has yet been given to the agreement. There was some recognition among the respondents that a range of measures and improvements would be required, including the phasing out of some older production technologies and products. It will be very difficult for industrial operators to achieve the OSPAR targets through "continuous improvement" because the law of diminishing returns will make successive incremental improvements to existing processes prohibitively costly and inefficient. Consequently, despite a vigorous defense of some older processes and products, it may be the case that some (PVC and bromine, for example) will naturally disappear from the market (C & I 1999b). In addition, the tightening of controls could result in the relocation of some chemicals production to areas outside the OSPAR region where less stringent regulation applies, and this was one of the main concerns expressed by the operators.

Conclusion

This study has shown that the EQS system, the scientific cornerstone of the UK regulatory system, is perceived by regulators and operators to be flawed. The key personnel responsible for implementing pollution policy have thus indicated a lack of confidence in the ability of the system to deliver its primary objective, i.e., to prevent environmental harm. However, despite their reservations, the regulators and operators continue to promote the familiar and convenient bureaucracy of the EQS concept within the regulatory system. Although the system has become increasingly sophisticated, the principle underlying the consenting (licensing) of industrial discharges has remained essentially unaltered for 50 years. It is time that pollution regulation moved out of this comfort zone with a new approach, more appropriate to the environmental problems of the 21st century.

Those involved at the regulatory interface recognized the many weaknesses in the system, including lack of relevant toxicity data, inadequate priority lists, and no incorporation of additive or synergistic effects of complex effluents. However, merely expanding lists and generating toxicity data will not solve the problem, although many respondents identified this as the way forward. As more becomes known about the biological effects of an ever increasing number of chemicals and their interactions in complex effluents and, as detection limits are improved, the current regime will be overwhelmed. The requirements to test, control, monitor, and enforce will create a system that is impossibly complex and costly, eventually rendering it unmanageable and thus removing the only positive feature of the current EQS bureaucracy.

DTA, seen as a solution by some, is not envisaged to become an integral part of the license, but may be more appropriately used as a screening tool. This methodology must be developed to encompass a range of toxic effects, both acute and chronic, and a range of indicator organisms representative of a number of trophic levels. The recognition that contaminated sediment is a significant future source of pollutants necessitates the incorporation of sediment quality into the regulatory system. Sediment quality is a measure of the effectiveness of past and current regulation. Sediment quality should therefore be mapped and a strategy developed to monitor and improve quality. This should signal a shift in regulatory emphasis, from defining safe levels of contaminants, to improved monitoring of environmental health and increased understanding of environmental processes.

The knowledge asymmetry within IPC has produced an imbalance in the power relationship between the regulator and operator, which both parties recognize places the regulator at a disadvantage. This power balance may shift even further in favor of the operators should proposals for more self-monitoring be implemented. In order to redress the balance, the regulatory bodies should urgently address the need for more economic and technological expertise within their organizations, investigate new working methods, and reexamine the need for increased operator self-monitoring. The regulators should cooperate in the development of continuous monitoring technology, so that compliance can be assessed more effectively. More severe penalties for breach of conditions must be introduced, since the level of fines is clearly of little concern to most operators. Such rigorous enforcement will be particularly important following the introduction of IPPC which should provide operators with more flexibility to manage their site emissions. There should be less regulatory prescription regarding technology, thereby encouraging more product and process innovations, which would result in cleaner processes with less emissions. Encouragingly, there is some evidence that the chemical industry is prepared to move in this direction (Service 1998).

In the longer term, a more precautionary approach has been advocated by OSPAR and government should now seek to establish the required legal basis for implementation. The lack of awareness of the OSPAR agreement, identified in this study, is of concern and needs to be addressed by government and the regulatory bodies who must take the initiative to prevent industry from setting the agenda. A new approach is required to ensure the marine environment is protected through precautionary regulation and that industry is encouraged to innovate solutions rather than fight a doomed rearguard action. This long-term strategy must also address the complex issue of regional and global inconsistencies in water pollution regulation.

Acknowledgments

This study was supported by a Natural Environment Research Council (CASE) award (Reference: GT04/97/236/MAS) in collaboration with Greenpeace Environmental Trust.

Literature Cited

Agg, A. R., and T. F. Zabel. 1990. Red-list substances: Selection and monitoring. *Journal of the Institute of Water and Environmental Management* 4:44–50.

Bloch, H. 1999. The European Union Water Framework Directive: Taking European water policy into the next millennium. *Water Science and Technology* 40:67–71.

Boyd, J. 1998. Searching for the profit in pollution prevention: Case studies in the corporate evaluation of environmental opportunities. Resources for the Future, Washington, DC, 45 pp.

Brickman, R., S. Jasanoff, and T. Ilgen. 1985. Controlling chemicals: The politics of regulation in Europe and the United States. Cornell University Press, London, 389 pp.

Bryman, A., and D. Cramer. 1999. Quantitative data analysis with SPSS release 8 for Windows: A guide for social scientists. Routledge, London, 298 pp.

Castle, P., and H. Harrison. 1996. Integrated pollution control. Cameron May, London, 181 pp.

Chapman, P. M., and G. S. Mann. 1999. Sediment quality values (SQVs) and ecological risk assessment (ERA). *Marine Pollution Bulletin* 38:339–344.

Chess, C., and K. Purcell. 1999. Public participation and the environment: Do we know what works? *Environmental Science and Technology* 33:2685–2701.

C & I. 1999a. Testing for testing's sake. *Chemistry and Industry* 19:737.

C & I. 1999b. An industry under threat? *Chemistry and Industry* 14:547–552.

Coombe, V. T., K. W. Moore, and M. J. Hutchings. 1999. TIE and TRE: An abbreviated guide to dealing with toxicity. *Water Science and Technology* 39:91–97.

E.A. 1999a. Water pollution incidents in England & Wales, 1998 report summary. Environment Agency, Bristol, 3 pp.

E.A. 1999b. Environment Agency hall of shame. http://www-.environment-agency.gov.uk/files/shame.htm

EC. 1996. Directive 96/61 EC. Integrated pollution prevention and control. *Official Journal of the European Commission* L257:26–40.

Elliot, M. 1996. The derivation and value of ecological quality standards and objectives. *Marine Pollution Bulletin* 32:762–763.

ENDS (Environmental Data Services). 1992. Dangerous substances in water: A practical guide. Environmental Data Services, London, 64 pp.

ENDS (Environmental Data Services). 1997. SEPA's prosecution record held back by fiscals, low fines. *ENDS Report* 273:45.

ENDS (Environmental Data Services). 1998a. Industrial discharges linked to sex-change fish. *ENDS Report.* 281:13.

ENDS (Environmental Data Services). 1998b. ICI fined £300,000 for major chloroform spill. *ENDS Report* 278:47.

ENDS (Environmental Data Services). 1998c. Top toy producer drops phthalates from teethers as bans build up. *ENDS Report* 284:34.

ENDS (Environmental Data Services). 1999a. Move to toughen sentencing for environmental offences. *ENDS Report* 297:56.

ENDS (Environmental Data Services). 1999b. Shellfish polluted with industrial metals, MAFF study finds. *ENDS Report* 297:14.

ENDS (Environmental Data Services). 1999c. Agency reports progress on effluent toxicity assessment. *ENDS Report* 288:9.

ENDS (Environmental Data Services). 1999d. Proposed EC priority list for hazardous substances in water. *ENDS Report* 297:54–55.

Evans, S. M., T. Leksono, and P. D. Mckinnell. 1995. Tributyl tin: A diminishing problem following legislation limiting the use of TBT-based anti-fouling paints. *Marine Pollution Bulletin* 30:14–21.

Fisher, D. J., M. H. Knott, B. S. Turley, L. T. Yonkos, and G. P. Ziegler. 1998. Acute and chronic toxicity of industrial and municipal effluents in Maryland, U.S. *Water Environment Research* 10:101–107.

Frankfort-Nachmias, C., and D. Nachmias. 1996. Research methods in the social sciences, 5th ed. Edward Arnold, London, 600 pp.

Fryxell, G. E., and M. Vryza. 1999. Managing environmental issues across multiple functions: An empirical study of corporate environmental departments and functional co-ordination. *Journal of Environmental Management* 55:39–56.

Garbutt, J. 1995. Environmental law. A practical handbook, 2nd en. Chancery Law Publishing Ltd, Chichester, UK, 240 pp.

Gray, J. S. 1999. Using science for better protection of the marine environment. *Marine Pollution Bulletin* 39:3–10.

Hackitt, J. 1998. The implications of the OSPAR strategy for industry: A view from the chemical industry. Pages 51–56 *in* Proceedings of the wildlife and countryside link conference on endocrine disrupting chemicals in the marine environment. November 1998. WCL, London.

Johnston, P. A., D. Santillo, and R. L. Stringer. 1996. Risk assessment and reality: Recognising the limitations. Pages 223–239 *in* M. Quint, R. Purchase, and D. Taylor (eds.), Environmental impact of chemicals: Assessment and control. Royal Society of Chemistry, Cambridge, UK.

Johnston, P. A., R. L. Stringer, and M. C. French. 1991. Pollution of UK estuaries: Historical and current problems. *The Science of the Total Environment* 106:55–70.

Kirby, M. F., M. A. Blackburn, J. E. Thain, and M. J. Waldock. 1998. Assessment of water quality in estuarine and coastal waters of England and Wales using a contaminant concentration technique. *Marine Pollution Bulletin* 36:631–642.

Lang, J. L. A., W. A. House, A. Parker, and J. E. Rae. 1998. Micro-organic compounds associated with sediments in the Humber Rivers. *Science of the Total Environment* 210/211: 229–253.

Matthiessen, P. 1998. Aquatic risk assessment of chemicals: Is it working? *Environmental Science and Technology* 32:460A–461A.

Matthiessen, P., M. Blackburn, M. Kirby, R. Law, D. Sheahan, and J. Thain. 1995. Toxicity of estuarine waters and sediments resulting from industrial chemicals. Pages 23–26 *in* R. Earl (ed.), Marine environmental management. Review of 1994 and future trends, 2. Kemperley, Glos., UK.

Mehta, A., and K. Hawkins. 1998. Integrated pollution control and its impact: Perspectives from industry. *Journal of Environmental Law* 10:61–77.

Moser, C. A., and G. Kalton. 1993. Survey methods in social investigation, 2nd ed. Dartmouth Publishing Company, Aldershot, UK, 549 pp.

NRA (National Rivers Authority). 1995. The Mersey estuary. A report on environmental quality. NRA Water Quality Series No.23. HMSO, London, 44 pp.

Oppenheim, A. N. 1992. Questionnaire design, interviewing and attitude measurement, new ed. Pinter Publishers, London, 303 pp.

OSPAR. 1998. OSPAR strategy with regard to hazardous substances. Ministerial meeting of the OSPAR Commission, Summary record. OSPAR 98/14/1, Annex 34. OSPAR, London.

Ragas, A. M. J., and R. S. E. W. Leuven. 1999. Modelling of water quality-based emission limits for industrial discharges in rivers. *Water Science and Technology* 39:185–199.

Renner, R. 1998. EPA softens stand on controversial contaminated sediment standards. *Environmental Science and Technology* 32:306A.

Richards, J. P., G. A. Glegg, and S. Cullinane. 2000. Environmental regulation: industry and the marine environment. *Journal of Environmental Management* 58:119–134.

RCEP (Royal Commission on Environmental Pollution). 1998. Twenty-first report. Setting environmental standards. HMSO, London, 232 pp.

Sanudo-Wilhemy, S. A., and G. A. Gill. 1999. Impact of the Clean Water Act on the levels of toxic metals in urban estuaries: The Hudson River estuary revisited. *Environmental Science and Technology* 33:3477–3481.

Service, R. F. 1998. Chemical industry rushes toward greener pastures. *Science* 282:608–610.

Sharrat, P., and M. Sparshott (eds.) 1996. Case studies in environmental technology. Institute of Chemical Engineers, UK, 209 pp.

Smith, A. 1997. Integrated pollution control. Ashgate Publishing, Aldershot, UK, 246 pp.

Taylor, M. 1997. Your right to know about industrial pollution—a case study at Avonmouth. Friends of the Earth, London, 15 pp.

Tonkes, M., de P. J. F. Graaf, and J. Graansma. 1999. Assessment of complex industrial effluents in the Netherlands using a whole effluent toxicity (or WET) approach. *Water Science and Technology* 39:55–61.

Xu, S., and N. Nirmalakhandan. 1998. Use of QSAR models in predicting joint effects in multicomponent mixtures of organic chemicals. *Water Research* 32:2391–2399.

Zabel, T. F., and S. Cole. 1999. The derivation of environmental quality standards for the protection of aquatic life in the UK. *Journal of the Institute of Water and Environmental Management* 13:436–440.