ON PRECAUTION, CLEAN PRODUCTION & PARADIGM SHIFTS

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ABSTRACT

Present environmental policy in the countries around the North East Atlantic is in a state of transition; in part made up of old attitudes that assumed the environment to be largely capable of absorbing contamination, in part a new precaution that recognises that we cannot fully predict the result of such actions. Precaution will prevail, and be implemented by a form of pollution prevention, known as clean production, that emphasises the need to reduce and eliminate pollution at all stages of the manufacturing cycle. There are three reasons why change is inevitable. First, toxicological problems, along with serious ecological uncertainties, mean that we will be unable to predict 'safe' levels of marine contamination for the foreseeable future. Second, demonstration projects make it clear that clean production is now feasible and economically attractive, even in 'problem' industries. Third, the targets now being set for the reduction and elimination of potentially problematic substances – for instance by the 1990 North Sea Conference and the 1992 Paris Convention Ministerial meeting – have developed to the point where clean production provides the only feasible means of implementation. This change has significant implications for the water treatment industry.

KEYWORDS

North East Atlantic, marine pollution, precautionary principle, eutrophication, biological monitoring, pollution prevention, clean production, water treatment industry, Paris Convention, North Sea Conference.

INTRODUCTION

Planning in the water treatment industry usually looks forward a few years at most. This means that problems can unexpectedly emerge, causing unnecessary delays and disruption. Marine eutrophication is one example. This was clearly apparent by the early 1980s and was predictable even earlier. Yet a political response was delayed, in part, because initially it was not clear that the removal of nitrogen nutrients from sewage would be possible at a cost politicians considered acceptable. Had the water treatment industry been more proactive the response could have been faster, to the benefit of the environment and of forward looking companies.

A similar situation is now being played out at an even larger scale. A paradigm shift in environmental policy is underway that will, over the coming years, radically change the water treatment industry. This is the move from pollution treatment and waste disposal to pollution prevention at source. The need for such a change has, of course, been paid much lip service already; officially for some years pollution prevention has been placed at the top of government and corporate policies, with waste disposal the last option. But the actual priority, demonstrated by spending, has remained the opposite of this. However recent developments in environmental science, in pollution prevention and in policy are finally forcing practice to follow theory. The result will be that much of the technology currently shown, for example at the annual Amsterdam Aquatech exhibition, will become redundant and companies that have not adapted to change will be in severe trouble.

For many in the industry, such a proposition may seem startling. But for those involved in environmental science and policy who, of necessity, take the longer view, the astonishing point is not that such a change is taking place, but that it is taking so long for those in industry, including the water treatment industry, to perceive the realignment, and for innovative companies to take advantage of the situation.

There are three reasons why such change is predictable. First, unresolved toxicological problems, along with less appreciated but serious concerns stemming from ecological research, make it clear that we will be unable to predict 'safe' levels of contamination in the marine environment in the foreseeable future. Second, industrial demonstration projects make it clear that pollution prevention ('clean production') is now feasible and economically attractive, even in 'problem' industries. Third, the targets now being set for the reduction and elimination of potentially problematic substances – for instance by the 1990 North Sea Conference and the 1992 Paris Convention Ministerial meeting – have developed to the point where clean production methods provide the only feasible means of implementation.

This paper describes these developments and the opportunities they present to the water treatment industry.

THE POLITICAL CONTEXT

Change occurs in fits and starts, at irregular intervals shifting from one paradigm to another. It is in the nature of such transformations that while in their midst it can be very difficult to see what form the new paradigm will have, or even that such a switch is underway.

Present environmental policy in the countries around the North-East Atlantic is in the midst of such a change. It is a chimera; an ambiguous and contradictory monster, in part made up of old attitudes that assumed the environment to be largely capable of absorbing the effects of our actions, in part a new precaution that recognises that we cannot fully predict the result of such actions, but accepts that they can serious damage the environment. This reflects a deeper change in society, which is shifting from regarding nature as a resource where human interests are paramount towards a view that requires protection of the natural environment, either out of enlightened self interest or, increasingly, for its own sake.

This transition is occurring in all parts of society. There has never been greater general interest in the environment, and the 'green consumer' has become a significant force in the market. In philosophy, 'environmental ethics' or 'ecophilosophy' has grown since the 1970s, when participation could be regarded as grounds for refusal of university tenure (Hargrove, 1987), to now, where it is one of the most rapidly developing and stimulating areas (e.g. Naes, 1989; Fox, 1990). Changing attitudes have also influenced many professions involved in marine protection, who have argued for sweeping changes in regulatory frameworks. As a result new international agreements, such as the 1992 Paris Convention for the Protection of the Marine Environment of the North-East Atlantic, now legally require countries to adopt policies that recognise 'the inherent worth of the marine environment' and apply a more stringent form of precautionary action than earlier agreements (Oslo & Paris Commission, 1992a).

Nevertheless it follows that during such a period of transition there are deep divisions between old and new attitudes amongst the public, opinion formers, scientists and policy makers. The intermediate result is that although governments in Europe are increasingly creating framework agreements that incorporate the precautionary principle, requiring the reduction and elimination of contaminants *per se*, this is taking time to trickle down. Much of the detail of environmental policy is still as yet based on the attempt to dilute and disperse pollution to supposedly harmless levels; a notion that depends on highly questionable criteria.

THE IMPLICATIONS OF ECOLOGICAL UNCERTAINTIES

The growing emphasis of the precautionary principle in NW European marine environmental policy largely results from concern about the toxicological difficulties of assessing the effects of contaminants. We address some of these issues in a companion paper (Johnston *et al.*, 1993). However, similarly dubious assumptions are made concerning the ecological workings of marine systems and our effect upon them. Yet this important aspect has been virtually ignored, despite a vigorous debate amongst theoretical and pure ecologists since the early 1980s, the conclusion of which is that it is far more difficult to understand ecological processes than was once hoped. The seminal book of Peters (1991) highlights the many shortcomings that currently riddle ecological analysis. Leading researchers, such as Roughgarden (1989) and Kareiva (1989), have concluded that ecology still lacks sound scientific foundation, and that ecologists should give up trying to establish grand unifying theories of the factors that control and regulate ecological communities and concentrate instead on far more specific, narrowly defined issues. Events in marine ecology have mirrored this wider debate (Underwood and Denley, 1984; Roughgarden, 1989; Underwood, 1992), and it is now clear that even the processes that govern what were thought to be the best understood communities – temperate rocky intertidals – are actually far more complex, and far less understood, that was believed a decade ago.

This uncertainty has serious implications for environmental protection, which currently presumes a high level of understanding of ecosystem dynamics (MacGarvin, submitted). For example toxicologists often assume that it is possible to monitor just a few species for the effects of contaminants, using these as indicators for the whole ecosystem. In the early 1980s this could perhaps be supported by reference to marine ecology, which indicated the existence of just a few 'keystone' species, where changes in population levels resulted in a cascade of effects throughout the community. Alteration of the population levels of most other species, it was thought, had little effect on the ecosystem (Dayton, 1984). However keystone species need not be particularly obvious (Paine, 1966, 1980), so simply monitoring common species does not ensure that keystone species are being included. Instead an exhaustive series of experiments are required, involving the exclusion of each species in turn, and the comparison of any subsequent changes in community structure with experimental controls. Moreover the discovery of a keystone species at one site does not guarantee that it plays a similar role elsewhere (Paine, 1980). To make matters even more complex, keystone species have as yet only been convincingly demonstrated for a few temperate rocky shore habitats. In soft sediments there are great technical difficulties in carrying out the necessary experimental manipulations (Dayton, 1984), while in the plankton – which lie at the heart of the marine foodweb – the experimental problems are acute and mechanisms that regulate populations have remained unresolved (Hutchingson, 1961; McGowan and Walker, 1979; Dayton, 1984). Finally, even if the keystone species are determined this does not mean that other species, apparently playing a minor role in the community, can be ignored. It is a well established principle that species are often kept rare by natural enemies or disease. If this control is disturbed a previously innocuous species can change abundance and disrupt the ecosystem.

Research is also hampered by the lack of understanding of natural fluctuations. Recent work warns that this deficiency will not be easily overcome. Data on the population fluctuations of copepods – water-flea like crustaceans that feed on phytoplankton – has been gathered in the seas around the British Isle for over 40 years – one of the most comprehensive data sets available. Yet sophisticated mathematical decoding techniques are unable to determine whether the fluctuations in their numbers during this period are random events, or due to a simple cause that results in apparently chaotic fluctuations (Godfray and Blyth, 1990). The run of data is simply too short for such methods. The implication is that one might have to gather data for hundreds of years before being able to (possibly) determine whether a factor such as increased nutrient concentrations has an effect on an ecosystem!

Research is still further confounded because the gathering of basic information during this century has been coupled with unprecedented and increasingly widespread human activities. This provides yet further barriers to our understanding of how the natural ecosystem would function, and means that we do not have true controls with which to compare areas affected by human activities. Unfortunately research by different groups almost invariably concentrates on single issues, such as fishing or contamination, without attempting to untangle the possible interactions. The information available even for well studied marine areas such as the North Sea is therefore far removed from the rigorously controlled experimental conditions and sophisticated statistical analyses that are required to allow different hypotheses to be isolated and tested (Peters, 1991).

In short, the message from theoretical ecology to the non-specialist is that for the foreseeable future policy will have to be formed in the face of great uncertainty about the effects of our activities.

Case example: eutrophication

The problems of theoretical ecology, that may seem rather esoteric to the non-specialist, are brought sharply into focus by considering just one area very much of practical interest to the water treatment industry, that of marine eutrophication. To the casual observer this issue may seem more or less understood, the result of systematic research over many years. But scratch beneath the surface and significant gaps become apparent in our knowledge, and the inferences that are drawn about the effects of anthropogenic nutrient inputs. For instance, one can only speculate about the importance of keystone species of phytoplankton and their predators – there is simply not enough information to do more. This represents a huge gap in our understanding. Nevertheless, from what we know of other aspects of phytoplankton ecology it is plausible that the disturbance of marine ecosystems by anthropogenic inputs of nutrients are both more widespread, and occurs at far lower levels, than generally considered.

Much attention has been given to large phytoplankton blooms, such as of *Phaeocystis* – the species responsible for the masses of foam that now frequently disfigure the coastline of continental Europe (Lancelot *et al.*, 1987; Cadée, 1990). This highly visible stimulus, coupled with strong evidence that the length and size of such blooms had grown as nutrient concentrations in the North Sea increased, probably did much to encourage North Sea ministers to require a reduction in nutrient inputs. Yet this foam is just one aspect of eutrophication, and need not be the most significant.

Phytoplankton forms the food-base of much of the marine foodweb, and it is well known to phytoplankton ecologists that the species composition is extremely sensitive to nutrient concentrations (Goldman *et al.*, 1979), and that this can be changed by altering the average concentration of nutrients, and by changing the distribution of nutrient inputs over time (Turpin and Harrison, 1979a, b; Harrison and Turpin, 1982). These effects can occur at far lower concentrations than those usually considered synonymous with 'eutrophication'. This is worrying, not least because species such as copepods, which graze on the phytoplankton and in turn form food for other animals, are selective in which species they eat (e.g. Davies *et al.*, 1992). Alterations in phytoplankton species composition could therefore have major effects on the marine ecosystem and fisheries. Yet the implications of such disruption are rarely considered, and includes some very contentious work (Boddeke and Hagel, 1991; Gerits, 1992). One reason for this – but not an excuse – is that it is extremely difficult working out the consequences of such changes on the marine ecosystem. Given the considerable natural fluctuations in plankton populations, attributing the additional role, if any, of anthropogenic inputs will be extremely complex. Even for a species at the centre of attention, *Phaeocystis,* the story is very difficult to untangle. For example there is some evidence that it is distasteful to the most important copepod in the south east North Sea, *Temora longicornis* (Lancelot *et al.,* 1987; Davies *et al.,* 1992). But the data is inconstant, some of which may be accounted for by the recent discovery that there is a protozoan ciliate that lives in association with *Phaeocystis* which *Temora* will also feed upon (Hansen, submitted). So it is now clear that to understand this most prominent of food chain links requires not only an understanding of the roles of *Phaeocystis* and *Temora* in the food web, but also on the distribution of the ciliate on *Phaeocystis* and other species of phytoplankton. Such research is not helped because, astonishingly, of taxonomic uncertainty over the identification of difference species of *Phaeocystis*.

There are also other misconceptions about eutrophication. For instance it is not always appreciated that seabed deoxygenation (Brockmann *et al.,* 1988), and the smothering of seaweed and seagrass beds – both important coastal habitats (Swedish Environmental Protection Agency, 1988) – are mainly due to the enhancement of background levels of algal growth, rather than exceptional blooms. Moreover, although seabed deoxygenation captures political attention, this only occurs when the rain of phytoplankton debris becomes so extreme that decomposers remove all of the oxygen. But detrimental changes in community structure occur long before this stage is reached. As organic debris accumulate in the sediments the normal community is displaced by species that are better adapted to these unusual conditions (Grey, 1979; Warwick, 1986). As bottom feeding animals higher up the foodweb, such as different species of flatfish, have distinct dietary preferences (c.f. Wheeler, 1978), it would not be surprising if their abundance was affected by such changes. Unfortunately, once again there is little information on such effects.

Perhaps the most remarkable oversight concerns the 50% reductions of anthropogenic nitrogen inputs in parts of the North and Baltic Seas, required as a result of international agreements. In order to do this countries have attempted to compute nitrogen budgets from polluting activities such as agriculture, the combustion of fuel, and discharges from industry and sewage works. However one extremely important factor has often been overlooked in these calculations. This is that a side-effect of the essential task of removing the biological oxygen demand, BOD, from sewage and other effluents discharged to rivers is that certain bacteria able to thrive, in the anoxic stretches of rivers and estuaries created by such pollution, broke down nitrogen nutrients. The incongruous effect of introducing secondary sewage treatment is that the higher levels of river oxygenation that result drastically reduce or eliminate this source of nitrogen nutrient reduction. It therefore does not necessarily follow that a 50% reduction of nitrogen inputs at source will result in a 50% reduction of nutrients entering the sea. In the case of the Scheldt, the introduction of secondary sewage treatment is predicted to result not in the 50% reduction of nitrogen nutrients to the marine environment required by international agreement, but a 50% increase (Lancelot *et al.,* 1987)! Similar problems have been noted by Vries *et al.* (1988) for the Rhine and by Thurston (1992) for the Tees, in the United Kingdom. Overall it seems likely that nitrogen inputs to the marine environment have recently increased substantially, or are about to increase substantially, due to the introduction of secondary treatment at sewage plants. As a result of such complications the only certain way to establish that targets such as 50% reductions are met is to compare current concentrations in the marine environment with precautious estimates of natural levels.

Overall, given that the North Sea states are experiencing considerable problems meeting even 50% reductions at source, and given that there is no reason to believe that even 50% reductions in the marine environment will eliminate disruption of the natural community, it is clear that nutrient reductions will remain a contentious issue on the international environmental agenda, and that far more effective methods need to be initiated. This implies yet further investment in the services of water treatment companies.

PRECAUTION AND BIOLOGICAL MONITORING

Clearly the lack of knowledge and theoretical uncertainty presents a formidable obstacle for pollution scientists and policy makers. This is apparent from the difficulties that bodies such as ICES (International Council for the Exploration of the Sea) and PARCOM (Paris Commission) has encountered trying to set up programmes to monitor the health of the marine environment. These have lagged well behind those for the measurement of contaminant levels and the determination of 'safe' levels of contamination in human foodstuffs (McIntyre and Pearce, 1980; ICES Advisory Committee on Marine Pollution, 1985; Paris Commission, 1985; MacGarvin & Johnston, 1988; Stebbing *et al.*, 1990; Hoogweg *et al.,* 1991). The selection of a few species for biological monitoring has not been started with a search for keystone species, as required. Instead species have been selected because they conveniently absorb contaminants (mussels), are quick and easy to test (the oyster bioassay) or need to be monitored for human health (commercial fish species). Such a scheme does not guarantee that the marine ecosystem is protected; indeed it creates a false sense of security.

In any case such biological monitoring forms a small part of monitoring programmes, which centre on less informative measurements of contamination levels of heavy metals, some token organohalogens and nutrients. Even this modest effort falls far short of what should be acceptable standards. An example is provided by the Paris Commission (1991) report on land-based inputs of contaminants entering the North East Atlantic. By then the data nominally presented, for 1989, was already two years out of date. This would be unsatisfactory enough, but the footnotes reveal that much of the data is actually older that this, dating back as far as 1984. Much is also of dubious precision, for example because the sampling frequency is statistically insufficient to account for likely fluctuations, are based on assumptions concerning industrial discharges, or are otherwise incomplete. The tables also have many gaps due to the failure of countries to provide information. Indeed it is acknowledged that the methods are provisional and that it is not possible to compare these measurements with those made in previous years. Such a state of affairs is not acceptable for the body that is the principle safeguard of the health of the North East Atlantic.

Making monitoring credible

Two changes are needed to give monitoring a credible role. First, in an era of computerisation and electronic communication which allows international commercial organisations to compile information on their activities within the day, the data used by bodies such as the Paris Commission should at worst be weeks or months old, not years!

Secondly, and more challengingly, the whole basis of monitoring requires a major shift of emphasis to incorporate the precautionary principle. Precaution applies as much to the rejection of methodology that is open to doubt as to the levels of contaminants that these methods are supposed to monitor. Rather than the incredible attempt to set safe levels of contamination for the marine environment, monitoring should play the subsidiary, but vital, role of determining whether the targets being set for the reduction and elimination of substances are being met. These targets should always be assessed by direct and comprehensive measurements within the marine environment, and compared with a precautious estimate of natural levels.

When both of these changes have been made marine monitoring will become a credible and scientifically defensible undertaking.

CLEAN PRODUCTION – THE KEY TO THE PARADIGM SHIFT

There has been a growing realisation amongst policy makers that science cannot provide precise answers. As a result, concurrent with the gradual change within the scientific community, there has been a move away from policy based upon a judgement of the assimilate capacity of the environment, and towards simple *ad hoc* reduction targets for entire groups of substances. Thus the 1987 and 1990 North Sea Conferences required countries to reduce various substances by at least 50%, and to require at least 70% reductions for matter believed to pose the greatest threat, including dioxins, mercury, cadmium and lead. They also required 50% reductions of nutrient inputs into marine areas where this is likely, directly or indirectly, to cause pollution (North Sea Conference Secretariat, 1990).

The Declaration at the 1992 Ministerial meeting of the Oslo and Paris Commissions goes still further (Oslo and Paris Commissions, 1992b), requiring 'as a matter of principle ... that discharges and emissions of substances which are toxic, persistent and liable to bioaccumulate ... be reduced, by the year 2000, to levels that are not harmful to man or nature with the aim of their elimination'. This supersedes the earlier requirement to reduce and eliminate *pollution* by such substances which, being difficult to prove, resulted in disagreement and prevarication. It also endorses, for a major group, the precautionary view that given limited knowledge the only harmless level that can be stated with confidence is zero. There is also a requirement, and a mechanism, for establishing clear goals and timetables for product phase outs and bans. Meanwhile, the accompanying action plan (Oslo & Paris Commission, 1992c) highlights organohalogens, and requires the elimination of those that can be substituted by other materials. This is a significant step towards the end of organohalogen production.

The 1992 Paris Convention is likely to prove an important point in the metamorphosis of the environmental chimera into a consistent, precautionary, policy. Meanwhile it is already clear that at least some North Sea Conference targets, for instance on nutrients, are proving exceptionally difficult to meet using current waste management policies; indeed the organochlorine industry has yet to show how it plans to meet the target of at least 70% reductions of dioxins.

The only plausible way of meeting such targets is to switch the major emphasis from waste management to pollution prevention. Originally pollution prevention meant the elimination of waste, particularly hazardous waste, from production processes. Terms coined at the time include no- and low-waste technology, and hazardous waste minimisation. But some of these technologies create extremely concentrated hazardous waste. This resulted in acute disposal problems and helped create an undesirable toxic waste trade, where waste is shipped to countries with the least stringent disposal standards (e.g. Puckett, 1991). Moreover it became clear that the dramatic reductions required cannot be achieved if attention is concentrated on production waste alone, because severe problems are also caused during other stages of a product's life-cycle.

Some might argue that this later point is addressed by the regulation of both point and diffuse pollution sources. However this has resulted in an unhelpful schism in pollution control strategies, whose rational approach, it is becoming clear, is best served by a holistic assessment of the scale of contamination by a substance at all stages of the production cycle – raw material extraction, product manufacture, use, disposal and dispersal. One example is the calculation of mass balances of problem substances, such as nutrients and chorine, making possible efficient and rational reduction programmes. Moreover, the division between point and diffuse pollution controls does not sufficiently emphasise the responsibility of manufacturers to ensure that the goods they market do not cause harm at any stage of their life cycle.

Clean production

For this reason bodies such as UNEP, as well as independent technical institutions, are turning to a new concept of pollution prevention, that of 'clean production' (Baas *et al.*, 1990). Clean production methods can be summarised as those which meet the needs of society – for food, water, energy, transport, goods and services – without damaging the natural world or risking the health of workers or the wider community. They cover all aspects of a product's life cycle – design, raw material extraction, manufacture, use and eventual fate. They aim to avoid the use or manufacture of hazardous products or waste. They are designed to employ only reusable and renewable materials and to conserve energy, water, soil and other raw materials.

Clean production has been recognised since 1989 by the United Nations Environmental Programme (UNEP Governing Council, 1989), and in UN maritime agreements, such as the London Dumping Convention (Ad hoc group of experts on annexes to LDC Convention, 1992), whose provisions have binding force on North Sea states, as elsewhere. Similarly the new Convention for the Protection of the Marine Environment of the North-East Atlantic, agreed in Paris in September 1992, contains many of the elements of clean production (Oslo & Paris Commission, 1992a).

So much for the theory. More important is that there are now many examples showing how clean production can be implemented by problem industries. A crucial element is the auditing of the materials used and produced by production process. This does not mean the superficial 'environmental audit' produced by some companies as a public relations exercise, but the preparation of a systematic, quantitative, chemical mass balance of the materials involved. Such methods received a boost when the United States EPA produced a waste minimisation handbook (US Environmental Protection Agency, 1988) which developed the techniques and provided step-by-step worksheets in a form appropriate for normal companies. These methods have since been developed in Europe, for instance as part of the Dutch PRISMA project (de Hoo *et al.*, 1991).

The potential of auditing is illustrated by surprising inefficiencies even in major companies (Sarokin *et al.*, 1985). It took stricter regulations for solvent emissions in the US for one Exxon plant to realised that floating ceilings on storage tanks would result in major financial benefits by preventing annual losses of over 300 tonnes of chemicals. Without regular audits broken equipment can also go undetected – a faulty valve, leaking 180 tonnes of cumene per year at a cost of $100,000, was only discovered at USS Chemicals when an employee finally chanced to smell its characteristic odour. And there can be huge variations in efficiency. For example, of two US plants using phenol, Exxon used 2,600 tonnes per year and lost 2 tonnes (0.08%) while Rhone-Poulenc used 1,600 tonnes and lost 17%, over 272 tonnes. Similarly a survey of small and medium sized companies in Copenhagen (Larsen and Olsen, 1989) showed huge differences in waste production levels between companies producing the same products and services. Such findings are typical. Systematic auditing offer a rapid means of significantly reducing pollution levels.

A co-operative venture between companies from 'problem' sectors of industry in the town of Landskrona, Sweden, and the TEM department of Lund University illustrate the steps in introducing clean production (Backman *et al.*, 1991). TEM would first hold a workshop with senior management (whose support is essential) to discuss clean production concepts and case histories from similar companies. TEM and company technicians would then co-operate in producing a mass balance of materials used and produced during manufacture. This revealed problem areas. TEM would then propose clean production options, which the company would then evaluate and adopt where possible. Further auditing would mark the start of a new cycle. The introduction of cleaner production processes not only resulted in the reduction of pollution: companies found that they could often make considerable financial savings from reduced losses of raw materials, from money saved from increasingly expensive waste disposal costs, and by avoiding costs resulting from ever tougher environmental regulations on traditional processes.

As a result of the programme a major lighting fixtures manufacturer at Landskrona, Thorn Järnkonst AB, was able to switch from using mineral lubricating oils during the machining of metal – which was then cleaned using organochlorine solvents – to vegetable-based oils that could be removed using a mild alkali rinse. This avoided the need to meet increasingly stringent organochlorine emission standards, and saved the disposal costs of exhausted mineral oils. They also switched from using organochlorine solvent based paints to powder-based paints for 95% of production. Overall these not only resulted in cleaner production processes but also resulted in annual savings of $460,000. Other examples from Landskrona include a printing works that switched to water based inks, significantly reduced pollution from an electroplating firm as a result of improved housekeeping, and the discovery by a chemical plant that 3% of the matrix material produced for water-based emulsion paints was being discharged with waste water, resulting in annual losses of hundreds of thousands of dollars.

Elsewhere bodies such as the Technical Institute of Copenhagen (Christiansen and Kryger, 1989), the Erasmus University at Rotterdam, the University of Amsterdam and the Netherlands Organisation of Technology Assessment (all involved in the Dutch PRISMA project) along with many other initiatives, have demonstrated that there is no shortage of cleaner production methods. For example, for organohalogens, one of the most problematic chemical groups, it is now clear that their are suitable candidates for the substitution for all major applications (Rossander and Fredman, 1989; Umweltbundesamt, 1992), including degreasing, dry cleaning, paint and print removal, their use as solvents by industry (including CFCs used by the electronics industry), as foaming agents, in PVC and other plastics, for cooling, and in the manufacture of medicinal pills, glues, paints, lacquers, lubricants, rust preventers and removers, furniture polish and fabric spot removers. Even more remarkable has been the dramatic European switch to chlorine free paper, lead by consumer pressure in Scandinavia and Germany (Pearson, 1991). This resulted in a fall in organochlorine pollution from Swedish pulp and paper mills by 50% in three years (Swedish Environmental Protection Agency, 1991). Companies that had the foresight to install chlorine-free bleaching processes benefited enormously.

Implementing clean production

Of course there are shortcomings in the current implementation of clean production. Companies still rarely assess those stages in the life cycle of a product that take place outside the factory gates (Dieleman *et al.*, 1991), (even though, as Lindhquist (1989) points out, in countries such as Germany and Sweden companies have a legal responsibility for the ultimate fate of their products), and many measures adopted are far from perfect – clean*er* production rather than clean production.

But the most important obstacle until now has been neither the lack of suitable processes or higher costs, but that of inertia, in particular the failure of governments to promote clean production policies (Huisingh, 1989). The importance of legally binding requirements is crucial. Many of the examples cited above resulted in considerable financial gains for the companies, yet it was impending regulations that prompted their interest in these methods. Legislation for companies needs to be accompanied at national and international level by comprehensive plans to eliminate problem groups such as organohalogens, rather than the partial and ineffective measures taken at present. This will require the compilation of a mass balance of inputs and outputs within and between countries, information which at present is surprisingly scarce. The 1992 Paris Convention incorporates many of these aspects, although not mentioned clean production by name; the initiative now rests with national and local authorities to provide the necessary detail.

THE IMPLICATIONS FOR THE WATER TREATMENT INDUSTRY

It is becoming increasingly apparent that current practices of pollution control and waste management cannot meet the increasingly stringent requirements for the reduction of environmental contamination. As a result an inevitable shift is underway, towards a precautious environmental policy implemented by clean production methods. Some in the water treatment industry, deriving substantial income from end-of-pipe treatment and disposal, may be tempted to resist this change, but this would be a mistake.

Once this change is accepted it becomes apparent there are substantial benefits for the water treatment industry. At a prosaic level the clean up costs for pollution entering drinking water supplies is substantial (Greenpeace International, 1992). In just one part of Denmark, covering only 100,000 hectares, the capital cost of providing equipment to reduce nitrate in drinking water to 50 mg/l (double the EC limit) will be 1.3 billion kr. And in Germany it costs 200,000 DM to remove one kilogram of the pesticide atrazine at a water treatment plant. In the UK the government estimates that it will cost £450 million to remove levels of pesticides above the EC limit for drinking water. Another example is that with the introduction of clean production methods, industry will no longer discharge waste into the sewers, and this will ease the use of sewage sludge for agriculture and other purposes.

More remarkably, clean production provides a major opportunity for water treatment companies. Institutions such as TEM have already demonstrated the potential for providing industry with mass balance audits and assistance with the introduction of clean production methods. There is no reason why water treatment companies should not provide and develop these services, an area that will become of great importance. In some cases clean production simply requires a change in operating practices. But elsewhere new technology will be required. For example it is apparent that in NW Europe current agricultural practices are a major contributor to eutrophication, and it is proving very difficult to reduce such inputs, due to intensive animal rearing, the segregation of animal husbandry from crop growing, and the consequently high use of artificial fertilisers. If nutrients from this source are to be significantly reduced it is becoming obvious that this will require marked change, including a move towards a greater integration of animal and crop farming, and a significant reduction in the use of artificial fertilisers with the aim of their elimination (Greenpeace International, 1992). Such a change will benefit from an increased efficiency in the capture and recycling of nutrients on and off the farm, and this is an area where water treatment companies are in a good position to develop a important market niche.

In conclusion, the precautionary principle, implemented by clean production represents a paradigm shift that is well underway. Progressive water treatment companies will benefit from this change, which will drastically alter the orientation of this industry.

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