JYVÄSKYLÄ STUDIES IN BUSINESS AND ECONOMICS 26

Alain Rajotte

Knowledge and Decisions in Environmental Contexts

A Case Study of the Pulp and Paper Industry

Esitetään Jyväskylän yliopiston taloustieteiden tiedekunnan suostumuksella julkisesti tarkastettavaksi yliopiston vanhassa juhlasalissa (S212) kesäkuun 9. päivänä 2003 kello 12.

Academic dissertation to be publicly discussed, by permission of the School of Business and Economics of the University of Jyväskylä, in Auditorium S212, on June 9, 2003 at 12 o'clock noon.

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2003

Knowledge and Decisions in Environmental Contexts

A Case Study of the Pulp and Paper Industry

JYVÄSKYLÄ STUDIES IN BUSINESS AND ECONOMICS 26

Alain Rajotte

Knowledge and Decisions in Environmental Contexts

A Case Study of the Pulp and Paper Industry

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2003

Editors
Tuomo Takala
School of Business and Economics, University of Jyväskylä
Pekka Olsbo, Marja-Leena Tynkkynen
Publishing Unit, University Library of Jyväskylä

ISBN 951-39-1495-X (nid.), 978-951-39-5339-3 (PDF)
ISSN 1457-1986

Jyväskylä University Printing House, Jyväskylä
and ER-paino, Lievestuore 2003

ABSTRACT

Rajotte, Alain
Knowledge and decisions in environmental contexts: A case study of the pulp and paper industry
Jyväskylä: University of Jyväskylä, 2003, 190 p.
(Jyväskylä Studies in Business and Economics,
ISSN 1457-1986; 26)
ISBN 951-39-1495-X (nid.), 978-951-39-5339-3 (PDF)
Diss.

This articles-based dissertation examines how environmental risks are perceived, defined, investigated and managed within the pulp and paper industry. It combines the sociology of science with a comparative policy research approach to analyse the link between knowledge and decisions as a 'social construct'.

The five papers making up the dissertation map out the economic, regulatory, scientific and technological context affecting knowledge and decisions in the P&P industry. By focussing more closely on the controversy concerning the environmental impacts of chlorine bleaching, the papers show how each kinds of particular issues and decision-making units shaped, while also being shaped by the broader political economic context. In so doing, the changing and differing correlation between the perception of environmental risks and that of organisational risks is seen as a central explanatory variable. It shows that risk perception and the validation of knowledge guiding decisions vary in accordance with the particular incentives and constraints associated with each of the particular decision settings surveyed (e.g. competitiveness, national security, political influence, public interests, etc.).

Though knowledge remained a variable subject to the inherent conflicts of interest built into policymaking, the analyses show it to be a crucial variable from the point of view of timing and the advantages it may confer in specific local context, as well as in the changing competitive environment affected by an increasingly risky and global world.

Keywords: environmental risks, technology, pulp and paper, sociology of science, comparative policy research, chlorine bleaching controversy

Author's address Alain Rajotte
620, Bouchette
Sherbrooke, Québec
CANADA, J1J 2T3

Supervisor Professor Tapio Pento
School of Business of Economics
University of Jyväskylä, Finland

Reviewers Dr. Maurie Cohen
New Jersey Institute of Technology, USA

Dr. Lassi Linnanen,
Helsinki University of Technology
University of Helsinki, Finland

Opponent Dr. Maurie Cohen,
New Jersey Institute of Technology, USA

ACKNOWLEDGEMENTS

Although I only registered in 1998 in the PhD programme in Environmental Management at the School of Business and Economics, this dissertation draws on the results of work that spreads over nearly ten years. Thus, I am indebted to many individuals. Unfortunately, it is impossible to list them all here by names. However, I would like to acknowledge some of them, particularly:

Tapio Pento who, after supervising my work in the Technology and Environment Policy (TEP) project and agreeing to serve as director of my PhD studies, has always found ways to encourage and support me in those times when doubts and overwork threatened to weaken the dissertation.

Emilie Enckell and Elina Karhu, for their friendship and unlimited help and support in getting access to key people and data, whether for my research duties or accommodation needs during my stay in Finland.

Camille Limoges who, as director of my doctoral scholarship in Sociology at the Université du Québec in Montreal, sponsored my internship at the OECD's Environment Directorate and for a seminar at the Centre de sociologie de l'innovation de l'École des mines de Paris in 1994. This seminar gave me the opportunity to deepen my understanding of the different sociological studies of science, in particular the critical concept of controversy in understanding the cognitive bases of collective decision-making.

Christopher Freeman whom I had the good fortune to meet at the Maastricht Economic Research Institute on Innovation and Technology (MERIT) when I was doing research for the TEP project. This encounter made me realize the importance of his work on evolutionary economics. It has been a constant source of inspiration in grasping the dialectics of change linking the economics and ecology in industrial sectors.

These individual acknowledgements should not be seen in any way as a means to assign the shortfalls that may underline this dissertation. Nevertheless, I wish to express my gratitude. Their invaluable contribution has allowed me to deepen my understanding of the multifaceted issues shaping environmental decision-making.

I would like also to thank Maurie Cohen and Lassi Linnanen who agreed to serve as examiners of my dissertation and who generously gave some of their precious time to provide counsel and advice towards its successful achievement.

Finally, I wish to express my gratitude to my beloved wife and daughter, Nathalie and Mathilde, for their support in good times and bad times, and for all the time that was taken from them.

FOREWORD

This document begins with an introduction to the dissertation work and includes a summary of the five papers making up the dissertation. This is followed by a literature review on the problematic at issue. In conclusion, recommendations are made regarding further research and about the political and economic implications of this work.

The five papers draw on different researches conducted by the author between 1994 and 2001. In particular, the following projects have provided much of the data and qualitative information that have inspired this dissertation:

- The project 'Environmental Requirements for Industrial Permitting' (1994-1999), sponsored by the Pollution Prevention and Control Group of the Organisation for Economic Co-operation and Development (OECD);
- The project 'Environmental Outlook and Strategy' (1999-2001), sponsored by the OECD's Environmental Directorate, in particular the chapters on the pulp and paper sector; and
- The project 'Technology and Environmental Policy' (1998-2000), funded under the 4th Framework Programme of DG XII of the European Commission, in particular the case study on chlorine-free policies in Finland, France and Sweden.

The references for the policy research documents produced within the framework of these projects can be found among the sources cited in the dissertation papers.

CONTENTS

Section 1

INTRODUCTION
AND
SUMMARY OF THE PAPERS

1 INTRODUCTION

This article-based dissertation can be seen as an attempt to develop the sociology of knowledge in an environmental context, using the pulp and paper (P&P) industry as a blueprint. Its objective is to examine how science and other forms of knowledge, interest and evaluation interact in shaping how environmental risks are perceived, defined, investigated and managed over time. It combines descriptive cases with comparative studies of environmental policies and historical review of environmental and economic performance of the P&P industry over time, with a view to understanding changes in social response to environmental risks. The link between knowledge and decisions acts as Ariadne's clew, which cuts across the different themes and analytical contexts taken up in the dissertation.

The P&P industry faces a plethora of environmental issues: forest management, fibre recycling, climate changes, water pollution, solid waste disposal, etc. Their complexity and uncertainty often makes the available knowledge controversial and turns it into a vehicle for implicit political and economic interests. To narrow the scope of investigations, this work focuses primarily on issues associated with bleached kraft pulp production. This emphasis is deemed appropriate since this sector has been, by far, responsible for most of the environmental impacts caused by paper manufacturing, while being the fastest growing segment of the industry since World War II. The increase in pollution has been obviously connected to the very fast expansion of market demands for value-added paper products since the latter part of the 20th century. Accordingly, causal inferences in the link between kraft pulp production and downstream environmental effects have been continuously evolving, providing a benchmark to compare national responses to environmental problems as they develop.

1.1 A case study: the chlorine bleaching controversy in Sweden and Finland

The chronology of the events studied spans from the 1970s to the 1990s, which corresponds to the rise of environmental regulatory regimes within OECD countries, although events outside this time scale are reviewed as required. While the scope of the work is international in essence, the dissertation is primarily based on a comparative review between Sweden and Finland. Both are appropriate representatives of developments affecting this industry over time, being major P&P producers and exporters as well as technological leaders in process and environmental technologies. Both have been important protagonists of the evolution of environmental regulations affecting more specifically bleached kraft pulp production. The similar aspects of their history, political culture, international obligations and regulatory systems present a definite analytical interest since these neighbouring countries have exhibited diverging views over both risk assessment and risk management of chlorinated effluents. Despite its limitations in terms of transferability of results, a bi-national comparison is thus considered appropriate to shed light on the problem at hand, while making the number of independent variables studied manageable.

The chlorine bleaching controversy is a main concern in the dissertation papers. The issue over how much, if any, chlorinated compounds are safe for the environment has been anything but consensual. Whatever the levels of scientific and technical developments, expertise could not substitute for politics in driving the policy agenda. Conflicting priorities and disagreements between countries led to uneven policy and technological developments. Differences further reflected the faceted effects of national contexts on risk priority ranking and allocation of resources. Many experts doubted the scientific basis of chlorine-free policies,[1] pointing out their environmental and economic trade-offs.[2] Yet, the technological response was sudden and spectacular. In less than 20 years, chlorine gas was virtually phased out as a bleaching agent in most OECD countries. The changes were radical, although largely based on the refinement and diffusion of on-the-shelf techniques. This suggests that policy pressures and market forces played a key role in altering an economic level playing field that had been previously favourable to chlorine bleaching (Simons, 1994).

---

1 "[T]he possibly largest industrial process restructuring performed in a short time within the Swedish industry – and followed by the Finnish and North American industry – largely was done on the basis of unproven suspicions." In Tana and Lehtinen (1996, 8).

2 "Current changes in kraft pulping will lead to reduced environmental impacts but also to considerable complications […]. Wood demand is increasing due to lower yields. More equipment, with increased energy consumption and complicated control and back-up systems as well as escalated chemical costs are consequences of these new approaches. The wisdom of all this is highly questionable." (Gullichsen, unpublished).

1.2 The socially constructed nature of science in policy settings

The analytical focus on the chlorine controversy is not incidental. Moreover, it has been clearly established in sociology of science that controversies offer the most fruitful context for seeking social factors that determine the acceptance of particular evidence, because adversarial pressure forces the social bias of each side out into the open. Studying controversies further serves to illustrate the social organisation of expertise in forensic context. It also serves to illustrate how expertise is tributary to different kinds of knowledge and decision-making units, regulatory approaches and culture, interest groups and market forces. Sociological studies of science are important in that they have shown that 'adequate evidence' is fundamentally problematic in contexts of endless scepticism. The need of science for efficient environmental policy is based on the premise that the skills and procedures sustained by scientific institutions are warranted by the neutrality and objectivity of the knowledge produced. Yet, as the role of science in policy increases, administrative and political interference grow, and expert knowledge inevitably mixes up with social motives.

The uneasy match between science and policy explains the multiplication of environmental controversies whose dynamics are fed by debates between experts. These controversies can be seen, in part, as the result of conflicting knowledge authentication processes between scientific and political institutions. The phenomenon certainly illustrates why science can play – at best – an incomplete and partial role in policymaking. Decision-makers, which seek to frame the problem at issue in factual terms, rely on experts to identify what is at issue and what are the relevant facts that should form the basis of decision. While it may be convenient to think of science as enlightening policy, the narrowing of the agenda already implies the imposition of particular views and values over the problem at issue, including the avoidance of deeper and/or ignored uncertainties. The requirement of validity can also be exploited in demands for better science by particular interests seeking *status quo*. The equivocal nature of science is often put down to procedural problems rather than to the inherent properties of its conceptual content or methods (Jasanoff, 1989). Accordingly, much debate has centred on procedural innovations and different views of the relationship which attempt to make such decisions more neutral and authoritative (Mayo, 1991).

Obviously, any attempt to examine the role of knowledge in policy contexts must proceed on the premise that these settings are much more complex, variable and contradictory than those in which the scientific practice normally operates. The overall pressures on the particular decision-making process itself must be taken into account, including how the changing relationships of economics, administration, and regulation interact and affect the knowledge being produced. This acknowledgement points to social factors in either limiting or allowing cognitive dissonance. It is the knowledge actually driving the decisions that matters, “not the knowledge in process of development or validation, nor even the knowledge clearly apparent to particular individuals or organizations somewhere in the society" (Sowell, 1980, 11). In that frame of analysis, the framing and validation of knowledge in decision settings must be seen as a 'social construct'.

Conventional theories of social change have stressed that the link between knowledge and decision is essentially tributary to power and interest (Bennett and Howlett, 1992). The role of knowledge in decision-making appears herein secondary or seen as organically flowing from some maximising scheme (Nelson, 1991). This view continues to hold much influence over decision-makers and reflects, by itself, a bias about the ways power, interest and science are conveyed in the decision-making process. Yet this view is usually too strict because it ignores the fact that decisions are what they are because each decision-making unit faces a particular set of constraints and incentives. Most decision units are structured so that the framing of issues and updating of decision variables are part of a continuous process which brings knowledge to bear on decisions (Majone, 1993). This cumulative nature of knowledge puts the emphasis on the routines, incentives and constraints of decision settings. These characteristics ultimately determine the knowledge being produced, its accuracy and effectiveness.[3]

1.3 Framing the central issue

In view of incomplete and inadequate knowledge in facing environmental risks, the ambition of this dissertation is not so much to assess whether decisions were right and informed by the best available evidence. The central questions are rather what has been learned from living with environmental problems, whether the lessons learned have increased management capacity and what have been done to improve the performance. This framing of issues requires an integration of results and interpretations including business and economics, environmental policy and culture as well as social science studies. In particular, it is necessary to examine different areas of decisions tied to the political economy of the sector and to focus on the distinctive advantages and disadvantages of different institutions and processes shaping the knowledge called upon when making specific decisions.

Thus, each of the papers analyse different policy settings and different areas of interactive situations which, taken together, shed light on the broader environmental context of decisions. Article 2, which focuses on the evolution of regulatory approaches and instruments over time may appear astray in the

[3] As such, the evolutionary perspective is fruitful in view of the competitive implications of environmental issues. Focusing the analysis of the companies' adaptation strategy to changes in the competitive environment through perfected routines and innovation manifestly raises the issues of management capacity and learning. The evolutionary perspective has clearly inspired the first paper of the dissertation: "Environment and technological change: the case of the pulp industry".

dissertation as it focuses on the similarity with which countries define their environmental level playing field, i.e. economic considerations. Yet, using this diversion, it is possible to distinguish how performance-based standards and environmental quality objectives are subjected to variations through different linkages between economics considerations and local factors of context.

Considering the multidisciplinary nature of the task undertaken, the literature review in Section 2 discusses different theories, analytical typologies and relevant empirical material that examine the link between knowledge and decisions in different social aggregates: organisational learning, scientific knowledge and policy settings. In addition, an annex to the dissertation provides a detailed comparative background of the legislative, regulatory, economic, and technological issues shaping the P&P industry in the jurisdictions under review. The information stresses differences and similarities in regulatory and industrial developments, underlying the different policy and technological responses of the Swedish and Finnish firms to the environmental risks from bleached kraft mill effluents (BKMEs).

In section 4, the dissertation closes with some recommendations for further research, as well as some policy and business implications.

1.4 Introducing the dissertation papers

Three of the five papers, which are regrouped in Section 3, have been published in refereed journals or as book chapters, while the other two are currently undergoing a peer review process. All but one have been or will be presented in social sciences conferences and relevant policy workshops, either in their present forms or in original drafts. Particular information on each of the papers is included in the following summaries:

[1] Rajotte A. 2002. Environment and technological change: the case of the pulp industry, submitted to *Business Strategy and the Environment* (accepted for publication).

This paper examines how the P&P industry has adapted, over a period of time, patterns of economic growth to environmental developments. Drawing on a dialectical and evolutionary perspective of the link between technology and environment, the paper analyses two investigational contexts – industry structure and regulatory settings – in order to identify converging trends and the differential responses of P&P firms to environmental risks. The results show that both innovation and diffusion are occurring in response to environmental pressures and that the ability of firms/countries to innovate varies in line with different couplings between their inner growth resources and the socio-economic structures in which they compete. Regulatory settings play a crucial role in the diffusion of best available technologies, although with different lockin effects and competitive implications among national segments of the industry. Through a comparison of the regulatory environments between P&P producing countries, the paper argues that chlorine-free policies in Sweden have clearly provided a competitive edge both to its domestic P&P manufacturing industry and to its equipment supplier industry. It is concluded that the cross feeding of analytical contexts is required in understanding the evolving link between economic competitiveness and environmental effectiveness.

[2] Rajotte A. 2002. Limits and Inconsistencies of Environmental Regulation of Industrial Point Sources: The Challenge of Integration.[4]

This paper draws attention to the relationships between the main determinants of environmental policy, emphasising the role of ambient quality standards, the concept of best available technology and economic considerations in setting environmental conditions. Inconsistencies and contradictions are identified along the development of environmental policy over the past decades. The series of rebounds in environmental management serves to illustrate that changes often appeared to respond for gaps and failures of past policies, rather than being systematic attempts at introducing comprehensive strategies and means. In spite of clear governmental will to improve environmental protection through better integration of principles and tools, current strategies do not break with the acquired right-to-pollute of industrial point sources. It is argued that only the adoption of environmental quality objectives may be capable of counterbalancing economic considerations in defining the link between industrial development and environmental sustainability. It is concluded that current regulatory approaches raise the issue of integration rather than resolving it.

[3] Rajotte A., Smith A. 2001. When markets meet socio-politics: the introduction of chlorine free bleaching in the Swedish pulp and paper industry[5], in *Technology and the Market: Demand, Users and Innovation*, Coombs R., Green K., Richards A., Walsh V. (eds.), Cheltenham: Edward Elgar, 136-155.

This paper tests the view that the introduction of chlorine-free bleaching technology was a case of market-driven innovation. Although not refuting its relevance, the paper explores the confluence of scientific, policy, and economic factors which drove the issue and concludes that the demand-pull explanation overlooks some important policy-push dimensions. Market demand is

---

4 A French version, "Évolution de la réglementation environnementale des secteurs industriels : les ambiguïtés d'une stratégie réglementaire de développement durable", was presented at the *70e Congrès de l'Association canadienne-française pour l'avancement des sciences* (ACFAS), Québec City, 14-16 May 2002. It will be published as a book chapter by the Presses Universitaires du Québec in 2003.

5 This paper was presented at the *5th International Conference on Advances in the Sociological and Economic Analysis of Technology*, Manchester, 14-16 September 1999.

considered to have triggered or accelerated the diffusion of innovations already underway in the development of chlorine-free bleaching technology. Sweden was in the vanguard of this development, and the paper analyses the role played by Swedish authorities and firms. This case illustrates how economic analysis, while useful for mapping market influence and responses, can be poor in providing richer, socio-political accounts of factors behind technological changes.

[4] Rajotte A. 2002. Paper Production Technology and Environmental Performance in Sweden and Finland: Policy, Science, Market Share[6], *Society and Natural Resources*, forthcoming issue 16.8.2003.

This article examines the controversy involving Sweden and Finland over the perceived risks of chlorinated discharges by P&P facilities. Pulp production changed when Sweden progressively adopted a chlorine-free policy. The analysis shows that the information that drove policy changes in Sweden, and ultimately across OECD, had different causal inferences linking pulp mill discharges and environmental impacts that were related to mill siting. Furthermore, Sweden and Finland had differing perceptions of risks over knowledge gaps linking bleached pulp mill effluent and downstream environmental effects. What appeared as a scientific debate was thus rooted in differences in local contexts. Through examining factors leading to closure of the controversy, it is argued that a measure of reconciliation between science and legislative actions was reached through a complex dynamic of knowledge validation tied to the political economy of pulp production. The paper concludes that knowledge-based analyses are a necessary counterpoise to conflict-related theories in understanding the link between policy and technology.

[5] Rajotte A. 2002. Science and expertise in environmental policymaking: a socio-political perspective.[7]

This article looks at the role of expert knowledge in environmental policymaking. A review of the relevant literature indicates that it plays a limited role, which may be related to the normative tension induced by interests and values in dispute inherent to the policymaking process. The issue does not appear substantive, but rather procedural and political. Through an examination of Sweden's decision to target chlorine bleaching in spite of inconclusive evidence, it is shown that the scientific dispute was connected to

---

6 The French version of this paper, titled "Savoir et décision en matière de réglementation environnementale", was presented at the *69e Congrès de l'Association canadienne-française pour l'avancement des sciences* (ACFAS), Sherbrooke, 16 May 2001.

7 A French version of this paper, "Savoirs et décisions en contexte environnemental : une perspective socio-politique", will be presented at the international workshop "Environnement, individu et société : motivations, savoirs et décisions au cœur de la gouvernance environnementale", *71e Congrès de l'ACFAS*, Rimouski, 19-22 May 2003.

differing views over the appropriate relationship between scientific facts and the precautionary principle. Through the examination of different causal linkages between structural interests and local contexts among competing countries, the paper further shows that knowledge authentication can be seen as socially constructed, while acknowledging objective grounds for criticism and corrective. Counter expertise appears to break the chlorine connection and to incriminate natural wood constituents in effluents. Yet the Swedish policy still proves beneficial because it furthers the closure of mill effluent. Thus, the paper illustrates a case of *bad* science turning into good policy, suggesting that the variables of environmental decision-making are complex and multivariate.

Section 2

KNOWLEDGE AND DECISIONS:
A LITERATURE REVIEW

2 KNOWLEDGE AND DECISIONS IN ENVIRONMENTAL CONTEXTS: A REVIEW OF DIFFERENT THEORY AND EMPIRICAL WORK

2.1 Introduction

Studying the link between knowledge and decision conceals great diversity. The number of theoretical perspectives varies proportionally to the number of analytical focus and levels of investigation (individual, group, organisation, professional category, country, society) and disciplinary fields (e.g. philosophy, sociology, political science, economics, management science, etc.).

Differences in approaches, each with differing methodologies and mixed empirical success, are partly an upshot of the dual nature of the link between knowledge and decision. The ambiguity has been clearly captured by the paradox pointed out by Polanyi (1966). Indeed, to search for knowledge in a particular decision-making process and to claim to have found it presupposes that it was already known. This link between the 'what to decide' and the 'who decides' reflects the two most enduring tensions underlying the making of human societies: the role of individuals and society in the creation and validation of knowledge, and the appropriate relationship between the civil society and the political and expert authority in the decision-making process. Their interpenetration in the analysis of social change and social order has inspired the grand social and political theories from the classics, throughout the Enlightenment to the present century.

To render the scope of the survey manageable, the literature review is organised around a set of questions that are directly relevant to the core problems discussed in the dissertation, namely: What historical and political premises account for the rise of science and professional expertise in policy settings, particularly with respect to environmental settings? What has been learned from living with environmental problems? Why? Under what conditions and procedures, and with what effectiveness? Is the knowledge produced related to particular knowledge categories, stimuli or events, scientific or otherwise? Did it increase understanding and management capacity? How can the effectiveness of expertise and other forms of knowledge be increased in the future? These questions map some of the main boundary variations linking expertise and other forms of knowledge, which, taken together, provide a fairly good illustration of the broader social process enabling the functioning of a complex activity such as P&P manufacturing.

The literature review begins with a discussion of the historical roots in the rise of science and professional expertise, and of the social tensions that come with it. Part 3 of this section situates the dynamics more specifically within the context of environmental issues. Part 4 then takes a closer look at the three social aggregates directly concerned with knowledge production and decision-making within industrial regulated sectors: organisational learning, advances in scientific knowledge, and change in policymaking as instances of knowledge and decisions in actual context. In closing this section, some remarks are made about how the literature review offers theoretical and methodological guidance in examining the link between knowledge and decisions in environmental settings.

2.2 From positivism to deconstruction - science in policy: the essential tension

Substituting science and expert knowledge to traditional forms of politics as a prerequisite to freedom and prosperity has been one of the greatest political challenges from the Enlightenment to Modernity. It was thought that the alleged objectivity and neutrality of science in curing social and political issues would bring progress and freedom to human societies. For the founder of positivism, Saint-Simon, the administration of affairs guided by scientific truth was to be substituted to the government of men (Fisher, 1992). Descartes had already spread the seeds of positivism claiming that the quest for a fixed foundation of knowledge was the celestial way to “escape the forces of darkness that envelop us with madness, with intellectual and moral chaos” (Bernstein, 1983, 18). Mastering nature through science was not to be understood as human will, but God’s will. Science was the vehicle for overcoming the savage forces of nature that impeded human aspiration to freedom and knowledge. French sociologist Auguste Comte followed the work of Saint-Simon, further developing the theoretical and methodological principles of positivism.

The faith in the utilitarian and normative roles of science provided the moral basis for the progressive instrumental rationalisation of nature and society. In the wake of Modernity, Karl Marx and Max Weber claimed, although under different assumptions, that scientific rationality was the

superior and preferred mode of governance.[8] For Weber, the ascent of experts as professional politicians was the mere logical solution to irrational outcomes of politics based on tradition and the inescapable response to evolving complex economies in modern societies.[9] The increasing diffusion and specialisation of scientific expertise in bureaucratic organisations became structuring characteristics, affecting both scientific and political ends. Thus, new regulatory framework, legislation and standards, which had been implemented in most Western countries, supported massive private and public investments by the late 19th century (Freeman and Soete, 1997).
However, these structuring effects led to significant trade-offs. No one better than Max Weber has described its social and political consequences. Under the pressures of economic development, the increasing instrumental rationalisation of society leads to a dual phenomenon:

- The "disenchantment of the world", whereas the instrumental rationalisation is concentrated in technocratic and bureaucratic organisations, reducing mankind to a "cold" collective of facts and;
- The "war of the gods", whereas the loss of omniscience gives way to endless disputes over world states.

The combined effects of increasing administrative and political power in private and public bureaucracies, the extensive use of scientific means to objectify nature and society, and the rise of professional experts in the realm of decision-making further affected the link between knowledge and policy in at least three ways:

- Decision-makers have been increasingly relying on statistical and remote means of knowledge, such as market trends and opinion polls, as a basis for decisions;
- Accordingly, decision-making have been drifting away "from those most immediately concerned and towards institutions increasingly remote and insulated from feedback" (Sowell, 1980, 163); and
- As citizens have been losing direct influence on decision-making, the means and ends of private and public bureaucracies tended to become confused with public benefit.

In sum, the combined effects of the rational and structuring dimensions of Modernity led to an epistemological and political paradox: as the use of scientific rationality reaches its peak, it simultaneously becomes ideology and turns into an opposite logic of social constraints objectivation (Bouretz, 1996). Though positivism has freed science from the clutches of obscurantism and developed methodological conditions of empirical inquiry (Ullmo, 1969), its faith in the value-free and objectivity of scientific practice leads to an ideological scheme which reflects and reinforces the established structures of society. (Brunner and Ascher, 1992)

---

8 "The basis (*Grundpfeiler*) of production and wealth (...) stems from the intelligibility and mastery of nature through men as social body [such that] the general social knowledge (...) becomes direct forces of productivity." Marx quoted in Lyotard (1979).

9 "Without rational calculus, the foundation of economy, in other words without a set of concrete circumstances linked to the history of economy, instrumental rationality would have never been born." (Weber, 1971)

The positivist doctrine particularly takes a distorted view by conceiving the whole of human experiences under the sole mode of formal and technical operating concepts (Atlan, 1986). Scientists tend to conceive natural environments as mere abstracts, easily reducible to mathematical conceptualisation, without taking into account how they actually maintain, reproduce and develop their structural integrity over time (Passet, 1980). This postulate of a "natural" dividing line between science and politics has been increasingly challenged by critical views. They refute that something "out there", independent of us, can be objectified by proper empirical and theoretical work so that policies may be optimally defined. It has long been accepted that the production and legitimacy of science cannot be dissociated from the norms and values of its social and political contexts.[10] Although the world outside is assumed to be independent of our will, "science […] is grounded in and shaped by the normative assumptions and social meanings of the world it explores" (Fisher, 1992, 333). What is true is tied to what is right, although each sphere has its own rules and institutions. As such, history has witnessed that the legitimacy of social justice and science has been oriented toward the optimisation of system performance (Lyotard, 1979), a notion considered a logical point of departure for empirical enquiry (Brunner and Ascher, 1992). Consequently, the belief that optimal levels of behaviours can be determined, without social interference, is misleading and merely leads to the reification of social structures and values and, thereby, political status quo.

2.3 The rise of science and expertise in environmental policy matters

In spite of the limits and controversies associated with the role of science in policy, governments have been using it more than ever. This trend is attested by the review of developments over time.[11] It was reinforced in the solving of specific policy and operational problems concerned by efficient military operations. Following World War II, the American political elite came to the conclusion that since "federally funded science helped so much to win the war, it could also contribute to a successful economy in peacetime".[12] Programmes

---

10 Durkheim and Mauss (1903) already recognised that the scientific practice was conditioned by the social structuring of its organisation.

11 For additional references, see: Price, D. K., 1967. *The Scientific Estate*, London: Cambridge University Press; Benveniste, G., 1972. *The Politics of Expertise*, New York: Glendessary Press; Gouldner, A. W., 1979. *The Future of Intellectuals and the Rise of the New Class*, New York: Seabury Press; Ben David, J., 1984. *The Scientist's Role in Society - A Comparative Study*, Chicago: University of Chicago Press; Mukerji, C., 1989. *A Fragile Power: Scientists and the State*, Princeton: Princeton University Press; Jasanoff, S., 1990. *The Fifth Branch: Scientist Advisers as Policy Makers*, Harvard: Harvard University Press; Fisher. F., 1990. *Technocracy and the Politics of Expertise*, New York: SAGE.

12 A conclusion reached by Vannevar Bush, advisor to President Franklin D. Roosevelt and director of the Office of Scientific Research & Development, in the 1950 report "Science: The Endless Frontier". In Lepkowski (1991, 35).

such as Roosevelt's "New Deal" or the overt political support to the "Green Revolution"[13] were legitimated on the belief that science could prevent social calamities such as poverty, hunger or illiteracy (Jackson, 1990; Fisher, 1992).

However, to better appreciate how science and expert knowledge came to serve a central position in environmental settings, we must focus more closely on the 1970s and the distinct, yet interrelated, three separate constituencies:[14]

- First, by substituting the concept of best available technology (BAT) to ambient-based approaches (the 'dilute-and-disperse' philosophy), the initial wave of legislation imposed significant costs on industry. Well-briefed industry experts quickly understood that science's inherent doubt could be used to force delay. As long as the credo of 'safe until proven otherwise' prevailed, science could work at the benefit of the *status quo*;
- Second, environmental activists were more than eager to substantiate the fight for stronger legal provisions through science. Scientists, such as Rachel Carson, Barry Commoner and Paul Ehrlich had already put the authority of their voices to environmental awareness in the public arena. During an era in which science was revealing numerous abuses of the environment, its usefulness in exacting environmental standards appeared obvious; and
- Third, the deployment of government apparatus and OECD-wide legislative actions during the 1970s was first based on the belief that pollution could be properly delineated and controlled. The next wave of environmental turmoil, characterised by systematic scientific accounts of global threats (e.g. acid rains, bio-diversity losses, ozone depletion and climate change) showed the inadequacy of policy approaches and resources. Policymakers became aware that de-coupling economic growth from environmental degradation was far more complicated than previously believed. It would require significant human and financial resources as well as new guidelines ensuring that decisions would remain democratic and accountable in making the value choices inevitably faced in devising environmental regulations.

Few will dispute that the cross feeding of science and policy has significantly improved management capacity in facing environmental risks. Developments of environmental awareness and policy cannot be dissociated from advances in basic and applied sciences and from the research development resulting in better analytical tools, e.g. the nuclear programme, space exploration, etc. Yet, in what may appear as a paradox (Limoges, 1993), the use of experts often leads to a deadlock by promoting political polarisation and conflict of interests at the expense of public well-being and benefit. The inherent complexity regarding the physico-chemical, temporal and spatial relationships between pollutant releases and ambient pollution concentrations compound large uncertainties in cause-and-effect inferences that are likely to become even larger where chronic toxicity is involved (Dethlefsen *et al.*, 1993). The intractable portion of observed reality calls into question the view of science as a snapshot technique for illuminating decision. Given this situation, the political process necessarily

---

[13] W. Jackson (1990) suggests that the neglect of environmental impacts associated with the massive spreading of insecticides, pesticides and fertilisers proceeded on the belief that endless productivity through science and technology unambiguously meant social progress. The chemical "warfare" was state-of-the-art policy and its unintended environmental and social trade-offs mere externalities to be solved by policy fine-tuning.

[14] This passage draws on comments made by Maurie Cohen on a paper that I presented at the Conference on Ecological Modernisation at the University of Helsinki in September 1998.

substitutes itself to science in standard setting with the focus of negotiation shifting from optimality to cost-efficiency (Lave and Gruenspecht, 1991).

The uncomfortable connection between the emergence of environmental management as a policy field in itself and environmental science as its chief attribute stresses the difficulties inherent to the link between knowledge and decisions in policy contexts. The burden of proof in regulation has been the matter of most controversies in environmental policy (Funtowicz and Ravetz, 1990). The problem is at the junction of legislation – which seeks to enhance the rigour of scientific assessment – and science – which aims to enhance the factual basis of decisions (Smith and Wynne, 1989). In policy contexts where the facts are routinely uncertain and values in dispute, the validation of evidence becomes inevitably open to interpretation and negotiation (e.g. Jasanoff, 1991). The hypothesis has formed the basis for two sociological variants: either the social factors are seen to fill in for the knowledge gaps revealed by scientific inquiry, i.e. social relativism (e.g. Wynne, 1982); or all cognition are seen as socially determined, whatever the facts, since the normative assumptions and moral judgement are always seen as structuring the context in which science operates, i.e. social reductionism (e.g. Douglas and Wildavsky, 1982).

By and large, the uneasy match between science and policy, and a good deal of the epistemological and political thinking that have come with it, can be characterised by the analogy of the swing of the pendulum, at least in the US. Thus Jasanoff (1989) identifies three phases in which the relationship between science and politics is first thought as mutually exclusive, leading ultimately to a measure of reconciliation, though each are judged unsatisfactory:

- In the early years of legislation, the development of legal cases made environmental agencies the ultimate judge of what to do with scientific uncertainties about environmental risks. The so-called "strict constructionist fallacy" entirely disqualified scientific authority to political rulings;
- The intolerable excess soon turned into the exact opposite. Under the Reagan's administration, the "separatist fallacy" was intended to place the entire scientific decision-making burden upon scientists alone. Several experts then continuously questioned the possibility – or desirability – of separating the facts from the values that invariably enter both risk assessment and risk management procedures (Mayo, 1991); and
- In view of the apparent dichotomy between scientific practice and policy science, the "stepsister fallacy" was promoted by leading scientists such as Alvin Weinberg on the basis that science in policy could require less demanding standards in terms of scientific proofs than in ordinary science.

As Jasanoff further discussed, though commentators rightly identified uncertainty as the central problem of regulatory science, they were wrong in thinking that it could be appropriate to resolve the implicit tension between science and policy through lesser standards of scientific evidence. Obviously, environmental policy settings differ markedly from those earlier contexts with relatively well-defined and well-structured technical problems in which early principles of risk assessment were developed (Wynne, 1993). The intractable complexity of ecosystem dynamics does not only stress the limits of science to predict problems. Ignorance of what actually happens in complex environments becomes a factor of decision. The part of indeterminacy in deciding what to do about ill-defined risks led to the recognition of the precautionary principle as a basis for policy actions and of the concept of BAT as a means of implementing the principle in view of potential, yet uncertain risks. The change implies some epistemological issues. Regarding assessment and evaluation procedures, the uncertainty about environmental effects has to be tracked down from different angles, e.g. downstream, upstream, throughout the pollutant lifecycle, etc. A collective learning process is needed to reconcile the different worlds of relevance with the problem at issue and optimise expert knowledge in the decision-making process (Limoges, 1993; Funtowicz and Ravetz, 1990).

2.4 Knowledge and decisions in social aggregates: an overview

Although it starts with a discussion of the two extreme models of individual learning, this section focuses on social aggregates. Yet, individual and collective factors are so tightly intertwined that, following Durkheim's postulate (1895), social aggregates can be analysed through analogy of individual phenomena while being autonomous and irreducible to individuals.
If we ask which analytical angles best inform the continuum of human thinking that ultimately brings knowledge to bear on decisions, the general response will likely fall in two opposing models: the rational or the behaviourist model. The difference lies in their respective analytical focus:

- The rational model is a problem-centred approach. It is a normative theory predicated upon the rational belief that problems contain their own logic so that actors can optimise their choices by assessing and revising probability distributions of world states. The theory has nothing to say about actor's interests and values; it is purely instrumental.
- The behaviourist model is an actor-centred approach. The focus is on actors' behaviour, whose nature and direction is set on the range of stimulus and response induced by existing reinforcement regimes. Notwithstanding the variety and sophistication of the different strains of behaviourist theory, the social context of apprenticeship and choice is basically limited to socially-delivered sets of incentives and constraints.

The difference between these two extreme views may be more an artefact of the respective analytical focus rather than an actual recognition of most decision-making processes. In the reality of incomplete and imperfect knowledge involved in the various types of decision-making processes, the assumptions of optimality and omniscience must be relaxed. Simon (1955)'s concept of 'bounded rationality' is an early example of adjustments acknowledging the limits inherent to the realm of human knowledge. Any analytical approach that seeks to examine the process linking knowledge and decision must likely integrate aspects of both models. Indeed, in view of incomplete and imperfect knowledge in the decision-making process, data updating and behaviours are continuously subjected to revision in light of implementation gaps between aspiration values and desired outcomes. Actors interacting among themselves expect to get something from the relationships they created and are thereby motivated to give something in return. Social exchange entails both rationalistic and behavioural patterns of action (Simon, 1978).

2.4.1 Organisational learning

Studies of knowledge and decisions in formal organisations involve either rationalistic or behavioural types of analysis, or combine both. The neo-classical theory of the firm discusses managerial trends by analogy to the rational-actor model (Nelson, 1991). Within the eclectic field of strategic management, a swing of the pendulum involving two very different paradigms (Hoskisson, 1999) suggests both behavioural and rationalistic concerns in the analysis: in the so-called 'structure-conduct-performance' paradigm, the conduct of firms is essentially ignored and their performance explained in the aggregate by the industry structure; within the resource-based view of the firms, the ability of individual firms to shape the competitive field is more recognised (e.g. Porter, 1980). In the frame of the latter perspective, evolutionary economics has further developed an understanding of social changes by focussing on learning rates as major variables underlying the differential responses of individual firms in the competitive environment (Silverberg, 1990; Nelson, 1991).

Most studies of organisations focus on the internal mechanisms, procedures, routines and rules in assessing performance in terms of individual behaviour and cognition. March and Olson (1976)'s feedback model may be compared to the domino effect in which individual values and social cognition interact in a closed loop: individual interaction influences the aggregate, which determines individual behaviour, which influences organisational choices, which determines the organisational context and ultimately the behaviours of individuals. The complete learning cycle, though, can meet obstacles, which brings the analysis into appraisal of limited apprenticeship. Levitt and March (1988)'s approach can be seen as inspired by the "muddling through" analogy of Lindblom (1959). Organisational behaviour is analysed through routines: which improvements reflect more 'learning-by-using' and 'learning-through-errors' (Rosenberg, 1982), than rational calculus. Changes and adaptations are based on the interpretation of results between desired objectives and observed outcomes through feedback mechanisms, with adjustments typically incremental and in response to shortfall and scarcity, rather than success. Plausibility is to be distinguished from validity or optimality in comprehending how knowledge and learning come to bear on decisions (Schon, 1995).

Organisations can also be viewed from a rational actor perspective as a system of relationship in which actors negotiate, set up and manage value-creating relationships among themselves. These networks consist of individuals and groups who communicate, co-operate, confront and mutually define one another through 'intermediaries', whether a set of rules, a technology or a commitment in seeking value-creative relationships (Callon, 1989). Problem, information sharing and transfer occur through both transmittable and tacit knowledge (Polanyi, 1966). Yet, organisation ruling implies conditions of access and control over who should be conveyed and what stimuli should be noticed. Imperfect recollection of routine successes and failures must be taken into account as a result of internal conflicts or inadequacy of procedures and feedback mechanisms (Crozier and Friedberg, 1977; Levitt and March, 1988).

There have also been attempts to assess the meta-logic and meta-theories behind organisational goals and routines (Beer, 1972). The inertia force of day-to-day routines or of the external environment selection pressures (Silverberg, 1990) can act as an inhibitor to more profound or required changes, even if extinction is the price to pay. Such an approach tries to identify the unspeakable premises of organisations so as to understand the conditions and requirements of paradigmatic change, much in line with the critical theory of social transformation (Habermas, 1973). This approach may be particularly insightful to environmental studies, in view of the very rapid changes in paradigms of environmental management over the last three decades (Colby, 1991).

Finally, a number of case studies focus on issues and knowledge sharing among experts and officials of national and international bodies, and non-governmental organisations. These are further reviewed in the section on policymaking.

2.4.2 Scientific knowledge

Science may be held as a special category of professional expertise. Historically, it was granted a particular status because it was believed that its methods of verification made the resultant knowledge more reliable and less liable to social explanations than other forms of knowledge. Conventional views of science considered scientific institutions and the social use of scientific knowledge as the main objects of sociological interest, not its conceptual content (Mulkay, 1979). This special status was increasingly challenged, particularly in the fields of philosophy and history of science, by raising issues of cognitive versus social factors: first, by showing that science progresses through conjectures, falsification and rectification, and is therefore cumulative (Popper, 1973); next by arguing that particular theories and practices are bounded to macro-theories (paradigms) coming into existence as a result of social consensus, which may be overruled through increasing counter-evidence (Kuhn, 1970); finally, by acknowledging that different, even conflicting, paradigms can coexist and evolve over time (Lakatos, 1970).

The developments in science studies can be traced back, to a certain extent, to the classics. Two of the founding fathers of sociology, Émile Durkheim and Marcel Mauss (1903) already recognised that the hierarchical classification of every kinds of knowledge was modelled on social organisation and convention. In framing the problem in terms of social reproduction, they argued that the division of knowledge in different categories and species was tied to the localisation of the given object in time and space. People living in these spaces shape knowledge formation and classify them in accordance to their beliefs, values, needs, interests and practices. Trying to explain the functioning of the reproduction cycle, they referred to a sort of *affective* attachment towards the classed objects, varying between different regions and historical era. They recognised that the progress of reason in Western societies led to a certain weakening of these affections, but reaffirmed that the anthropological basis of classifying persists. They used the term "technological classification" to distinguish between classifications deriving from certain practices and theoretical concepts lying at the origin of categories of knowledge. For Durkheim and Mauss, there could be no essential difference between "modern science" and pre-modern classification. The social embedding of classification of different forms of knowledge, science included, is set up as a counterpoise to the proclaimed superiority of scientific rationality as a universal element of human condition.

Early roots of the sociology of science are clearly inspired from these developments. David Bloor makes it explicit when arguing for the "strong programme in the sociology of knowledge": "There is indeed truth in the conviction that knowledge and science depend on something outside of mere belief. […] What is 'outside' knowledge; what is greater than it; what sustains it is, of course, society itself" (Bloor, 1976, 19). Subsequent developments can be broadly divided into two camps (Bowden, 1985), one which focuses on the concept of interests, with a tendency towards a more macro-sociological interpretation of science as a social dynamics, and the other which analyses knowledge formation and validation as a process of attribution, with a clear orientation towards micro-sociological methodology:

- On the one hand, the sociology of interest analyses actors' behaviour within a '*satisficer*' model (Simon, 1978). The precept is that social agents carry some rational view of the coherence of their choices in seeking the greatest possible 'want satisfaction'. Knowledge of particular time and place is here analysed through the structuring of individual and collective interests.[15]
- On the other hand, the concept of attribution does not exclude the notion of interests, but sees through knowledge *in the making*. Drawing on ethno-methodology, the analytical focus here is on the series of local acts constituting facts as valid, following a logic of symmetry tying people, things, beliefs and interests, i.e. a social construct (e.g. Brannigan, 1981; Pinch and Bijker, 1984; Callon, 1986; Latour and Woolgar, 1986).

The sociological trend – sometimes referred to as 'social constructivism' – has attempted, sometimes persuasively, to demonstrate social factors behind the existence of scientific theory or evidence. The approach has led to many studies of routine operation of scientific laboratories and of scientific controversies (e.g. Latour and Woolgar, 1986; Latour, 1987; Knorr-Cetina, 1992). The study of controversies has led to the development of different notions for sociological accounts of science. The notions of interpretative flexibility and closure mechanisms (Pinch and Bijker, 1984) have been developed to reflect that the stabilisation of social, scientific and economic relations underlying the

15 Raymond Boudon, Michel Crozier and Pierre Bourdieu represent this view in French sociology. For a counter-view, see Caillé (1981). For a review of English representatives, see Bowden (1985).

controversy requires a compromise between the social and the technical (Callon, 1986). In cases of scientific uncertainties and conflicts of interests, knowledge production and validation become tied to social networks, involving a host of actors, each pursuing specific objectives and competing between themselves for the primacy of driving evidence. In that frame of analysis, explaining why actors disagree and then eventually come to terms with emergent phenomenon invariably entail that social determination precedes the factual terms.

Perhaps the most basic and provoking claims posited by laboratory studies is that there are no significant epistemological differences between scientific knowledge, everyday practices and politics. Obviously, the idea behind the proposal is to get rid of the normative notions of the conventional sociology of science, such as Merton's prescription of scientific norms. Indeed, a radical act in laboratory studies was to give up any theoretical ambitions and rely exclusively on empirical accounts. Consequently, a major consequence of the descriptive turn taken by the new anthropology of science was a radical questioning of epistemology and macro-sociological theory. With reference to epistemology, the belief of a specific scientific logic was to be dismissed on the basis that "nothing epistemologically special" (Pinch and Bijker, 1984; Rorty, 1995) is happening when scientists at work are observed. With reference to theory, the idea of a reality "out there", waiting to be solved through science, was to be refuted as leftover of the positivist ideology. Facts observed and explanations of phenomenon are to be understood as 'constructed' representations in specific local settings, e.g. laboratory. In that frame of analysis, every macro-phenomenon is made up by aggregations and repetitions of many micro-episodes, observable in time and space. Thus, social structure is internal to aggregates of situations and not made up by "objective relations" in a given field or a system (e.g. Collins, 1981; Knorr-Cetina, 1981). The reproduction model is accepted, but in the narrow sense as in Durkheim's theory: it is social practice that is expressed through factual classifications of these categories taken as 'natural entities', not an abstract view of scientific practice or objective view of reality. Theory herein loses its privileged position.

The posture taken by empirical constructivism[16] raises two important features with respect to understanding science in actual contest. On the one hand, it insists on the dimension of space and time, corporality and orality in the research process and validation of evidence. For Knorr-Cetina (1992), this analysis is fundamentally rooted in a "behavioural theory". On the other hand, it challenges the theoretical basis underpinning the "strong programme in the sociology of knowledge". Bloor claims that every form of knowledge should be treated alike, including scientific fraud or errors, which have to be held methodologically equal to accurate theories. Both cases entail social explanations. The empirical constructivist view claims that human and non-

16 The term "empirical constructivism" is used by Knorr-Cetina (1992) to designate a certain unity within the constructivist counter-movement in social studies of science. However, the reality is much more complex and the term should be taken as a broad generalisation of trends.

human elements have to be treated alike. Bruno Latour (1991) insists on this point as a normative principle, while Knorr-Cetina (1992) regards it consequently as an empirical question. According to these views, if all cognition is socially determined, then sociology turns itself into an objectivist view of reality by eluding refutation (Woolgar and Pawluch, 1985). Thus, even sociology has to be abandoned since the privileged position of the analyst reproduces an asymmetry between humans and non-humans.

Whether this hypothesis is right is beyond the scope of this dissertation. However, against this radical proposition, it is worthwhile to recall that science would not exist without people believing in it, that "some studies, predictions, and hypotheses reflect nature more faithfully than other, even if the picture is incomplete" (Jasanoff, 1989, 271). Though some studies have manifestly demonstrated social factors in the acceptance of particular scientific knowledge, many have yielded mixed results. Laudan (1977) suggests a compromise in which scientific knowledge should be first investigated on rational grounds of success in solving problem and consistency with established theory, and in which social explanation should be sought only when results are ambiguous or erroneous. Historical accounts of scientific knowledge appear to confirm Laudan's proposal: social factors usually play a larger role when issues were uncertain and incomplete, but their influence diminish as scientific investigation mature. As such, the reality of incomplete, inadequate and disputed evidence of environmental problems make them clear objects of sociological interest.

2.4.3 Expert knowledge and policymaking

Knowledge use in policymaking is obviously relevant to our study. At variance with the classical deference accorded to scientific production, the conventional view is that knowledge is a mere partial corrective to power, interests and coalition alignments in driving policy changes (Bennett and Howlett, 1992). Yet, this view is a function of both historical and political factors underpinning the rise of professional expertise in policy matters.

In accordance with the pervasive positivist belief, early trends have led to an extreme view, according to which problems at issue were better left to experts to discover the facts and the solutions among well-defined alternatives. Such separation between facts and values is out-of-sync with the reality of most policy contexts, particularly with respect to environmental issues. Even when decision-makers know what scientific and technical problems are at issue, the challenge is often beyond what science actually knows (Weinberg, 1972). In messy decision settings, where interests and goals are multiple and contested, decision-makers may not even know what to ask. As the urgency of situations often precludes the time needed for more convincing evidence, decisions are driven by political pressures and compromises. In such a context, insightful politics can resolve uncertainties and values in dispute, not good science (Majone, 1977). Issues that are not epistemic to begin with cannot be resolved by the logic of epistemic arguments (Allen, 1987).

The view that science and professional expertise can unambiguously support policymakers with objective and value knowledge in making a decision is a caricature. It is a "godlike approach" to social policy which ignores both the diversity of values and the costs of agreements among human beings (Sowell, 1980). Thus, it does not come as a surprise that most expert knowledge produced in context of uncertainty is often mediocre and used for secondary purposes (Clark and Majone, 1985). Moreover, the many complex and different problems facing the variety of localised decision settings suggest anything but straightforward management schemes. The costs of information search must be taken into account. Therefore, financial and human resource constraints affect not merely the quantity, but also the quality of knowledge produced. These constraints influence the range of relevant issues that can be investigated, as well as the effectiveness of feedback programmes, which influence the quality and accuracy of the information on which to base decisions. As Thomas Sowell (1980, 41) rightly put it up, "[t]his feedback is not only additional knowledge, but knowledge of a different kind. It is direct knowledge of particulars of time and space, as distinguished from the second-hand generalities known as "expertise. […] Certainly expertise is not sufficient in itself without the additional direct knowledge […]."

In addition, expert knowledge is one among many different factors of the broader social process shaping the political economy of regulated sectors in environmental terms (Jasanoff, 1990). As such, the review of international negotiation of issues, such as ozone depleting substances, climate change or acid rains, obviously shows that expertise plays at best a partial corrective to policy changes, while being mainly used to impose delays in decisions.[17] Many social scientists have stressed that the increasing interface between science and policy gives rise to a new form of political strategy, a 'politics of expertise', which draws its bargaining power from the inherent uncertainty tied to technical and scientific issues. It can be argued that it is only new in form, not in essence, reflecting the primacy of power and interest in problem framing and decision outcome (Bennett and Howlett, 1992). In contexts of uncertainty and conflicts of interests, the scientific-side of decisions becomes a resource and an issue of power and interest-driven strategies (Crozier and Friedberg, 1977; Duclos, 1991), disqualifying science as a neutral agent (Weinberg, 1976). The trend further confirms Lasswell (1965, 117)'s assumption that "[...] the aggregate impacts of the scientific revolution have failed to revolutionise the basic structures of world politics [...]".

Power and interest-driven analyses of social change have little interest. Thus, the axiom of interest eludes refutation and is open to various interpretations of ontological nature (Caillé, 1981). The fact that the link between knowledge and social change remains an underdeveloped area of research and ill-defined relationship reflects the difficulty of developing

---

17 For an illustration of these trends in international environmental settings, see Roqueplo, P., 1993. *Climat sous surveillance*, Paris : Economica; on acid rains and ozone depleting substances, see Faucheux, S. and J. F. Nöel, 1990. *Les menaces globales sur l'environnement*, Paris: La Découverte.

acceptable theoretical and methodological guidance (Bennett and Howlett, 1992). Yet, policies, technologies, science and economic competition change in many ways. Some radically shift the environment in which they operate, while others are incremental improvements of existing practices, yet ultimately destined to disappear. As politics finds its sources not only in power but also in uncertainty, policy settings provide much opportunity for investigation, problem and information sharing, and learning (Heclo, 1974). The analysis of policy change requires reconsideration of the conventional view, which assimilates these decision settings to "the medieval exercise of the *disputatio* in which two parties argue one against the other" (Limoges, 1993, 417). These contexts rather call on scientific and technological experts to jump into the fray and acknowledge their role as rhetoricians and persuaders of truth (Majone, 1989).

An increasing number of case studies have attempted to analyse policy changes under the angle of knowledge and learning. In the field of comparative policy research, studies suggest competing answers (Weale et al., 1996). While some studies identify similarities in policy outcomes, despite significant differences in policy design and process (e.g. Vogel, 1986), others postulate differences tied to national distinctiveness (Lundqvist, 1974).

Yet, in the various studies focussing on different policy settings, there is a trend towards convergence in recognising that knowledge production and learning occur through the sharing of experiences and common problems, in line with the inevitable harmonisation of solutions in transnational issues. There have been a number of political science studies conducted with a view to being a counterpoise to conventional conflict-oriented theories of policy change (Bennett and Howlett, 1992). The notions of learning and knowledge sharing vary noticeably depending on the different sets of questions used – Who learns? What is learned? What is the effect on policy changes? – and on the focus on particular agents and levels of investigation, e.g. state officials, experts, policy networks, policy communities, etc.; local, regional, international, etc. Heclo (1974) sees "policy learning" as a response to perceived stimulus. For Sabatier (1978), "policy-oriented learning" comes from alterations/interactions of policy networks, involving both core and peripheral value changes. As for Etheredge (1981), governmental learning increases through expertise and improved effectiveness of operations, while Hall (1988) sees "social learning" as the result of incremental refinement of policymaking. Rose (1991) views "lesson drawing" as the outcome of experience. Peter Haas (1990)'s study of pollution control agreements on the Mediterranean Sea suggests that scientists influence outcomes through the power that "epistemic communities" would detain in defining solutions under high scientific uncertainty. Jasanoff (1996) questions this view of uncertainty "as an independent factor empowering disparate communities of scientists" (p. 188), which "overrid[e] the evidence that scientific knowledge is deeply embedded in politics and culture" (p. 173).

In conclusion, studies attempting to examine instances of knowledge and learning in policymaking involve elements of rationality, but they are fundamentally rooted in behavioural analyses. One part focuses directly on individuals, the other on instances of learning through sharing among agents of localised, national or international aggregates. Theoretical and methodological guidance differs and the overall approach is still at an early stage of development. Bennett and Howlett (1992) connect the ambiguity of the different theories and methodologies, once again in the difficulty to unequivocally demonstrate that a given change came in response to an instance of learning.

2.5 Concluding remarks

The purpose of the literature review has been to explore different theories and methods, levels of analysis and empirical material relevant to the interplay between knowledge and decisions in environmental settings. In attempting to bridge the differences in approaches and concepts, as well as the lack of studies attributing knowledge as a key decision variable, we now need to draw on this literature with a view to developing a coherent theoretical and methodological framework for examining social responses to environmental risks associated with bleached kraft pulp production.

The literature – and common wisdom – suggests that different forms of knowledge occur at all levels of society and affect how environmental risks are perceived, named and managed. The literature review suffices to show that the rational-actor and the behavioural-actor models are endemic, even ubiquitous throughout society. The factors of context have been shown to be key components by which environmental issues win recognition, whether as intervening beliefs, perceptions, visions, or scientifically-advanced facts. Integrating the interplay of rational and behavioural patterns of development together with changes in the structural, institutional and cultural factors shaping environmental policies is obviously helpful towards the development and testing of a coherent analytical framework.

Another important issue, which has been adequately reviewed in the sociology of scientific knowledge and environmental studies, is the role of scientific uncertainty in environmental settings. Scientific uncertainty has been identified as a distinctive component of environmental risk assessment in shaping and limiting both long-run and direct response to environmental risks. Yet, changes in policies must, in some ways, be characterised as responses to shifts in costs and benefits among concerned parties. In attempting to attribute an intervening power in decision to particular knowledge or stimulus, the analyst must examine the dynamics by which the interplay between cognitive, technical and normative processes interact in shifting consensus on environmental risks and prescriptions. The permeability of scientific claims, or of any forms of knowledge, to localised constraints subordinates the compromise between knowledge and decisions to political closure. As Jasanoff (1996) suggests, the nature of the relationship between science and policy renders the political organisation of the process a relevant explanatory variable.

Yet, in keeping with the focus on the knowledge basis of decisions, we must frame the analytical framework so as to identify the stimulus and/or learning by which some shifts in the political economy of the issue under review occur. As such, the comparative policy approach has proven to be a fruitful methodology "to highlight the structural, institutional and cultural constraints of policies" (Knoepfel *et al.*, 1987, 173). This method helps identify the policy features subject to variation in relation to the political, economic, legal and institutional factors shaping national choices. In addition, a central assumption of this dissertation is that factors and events accounting for these variations can only be revealed by adopting an historical perspective. "[S]ome sort of politico-historical determinism is required to understand […]" (*ibid.*, 17b) how differential responses among countries to environmental risks, whether in terms of policy, science or technology, are rooted into the distinctive features of their history.

By way of conclusion, studying the link between knowledge and decision requires the acknowledgement of specifics and contextual factors for each particular issues and decision-making units. Intrinsically, the terms of the problems require a multidisciplinary approach to the analysis, a focus on procedural rather than substantive rationality, an interpretative posture and a resistance to complacency in seeking specific events as independent factors empowering a particular group of actors or categories of social exchange. In keeping with the richness and plurality of decision-makers, the central issue is to identify the links by which human beings, as 'maximiser', come to term with the multifaceted environmental risks.

BIBLIOGRAPHY

Allen, G. E., 1987, "The Role of Experts in the Scientific Controversy", in *Scientific Controversies*, Engelhardt, H. T., Caplan, A. L. (eds.), Cambridge: Cambridge University Press, 169-202.

Alm, A. L., 1992. "Science, social science, and the new paradigm", *Environmental Science & Technology*, vol. 26, no. 6, 1123.

Ashford, N., 1994. "An Innovation-based Strategy for the Environment", in *Worst First*, Finkel, A. (ed.), RFF, 275-314.

Atlan, H., 1986. *À Tort et à raison - Intercritique de la science et du mythe*, Paris : Édition du Seuil.

Beer, S., 1972. *Brain of the Firm*, New York: Herder and Herder.

Ben David, J., 1984. *The Scientist's Role in Society - A Comparative Study*, Chicago: University of Chicago Press.

Bennett, C. J., Howlett, M., 1992. "The lessons of learning and policy change", *Policy Sciences*, vol. 25, no. 3, 275-294.

Benveniste, G., 1972. *The Politics of Expertise*, New York: Glendessary Press.

Bernstein, R. J., 1983. *Beyond Objectivism and Relativism - Science, Hermeneutics and Praxis*, United States: University of Pennsylvania Press.

Bloor, D., 1976. "The Strong Programme in the Sociology of Knowledge", in *Knowledge and Social Imagery*, Bloor, D. (eds.), London: Routledge and Kegan Paul, 3-22.

Bouretz, P., 1996. *Les promesses du monde. Philosophie de Max Weber*, Paris: Gallimard.

Bowden, G., 1985. "The Social Construction of Validity in Estimates of US Crude Oil Reserves", *Social Studies of Science*, vol. 15, 207:240.

Brannigan, A., 1981. *The social basis of scientific discoveries*, Cambridge: Cambridge University Press.

Brunner, R. D., Ascher, W., 1992. "Science and Social Responsibility", *Policy Sciences*, vol. 25, no. 3, 295-332.

Caillé, A., 1981. "La sociologie de l'intérêt est-elle intéressante?", *Sociologie du Travail*, vol. 3, 257-274.

Callon, M., 1989. *La science et ses réseaux*, Paris: La Découverte.

Callon, M., 1986. "Some elements of a sociology of translation – domestication of the scallops and the fishermen of St Brieuc Bay", in *Power, Action and Belief: a New Sociology of Knowledge*, Law J. (ed.) Sociological Review Monograph 32: Toutledge.

Clark, W. C., Majone, G., 1985. "The Critical Appraisal of Scientific Inquiries with Policy Implications", *Science, Technology, and Human Values*, vol. 10, no. 3, 6-19.

Colby, M. E., 1991. "Environmental management in development: the evolution of paradigm', *Ecological Economics*, vol. 3, 193-213.

Collins, R., 1981. "On the Microfoundations of Macrosociology, *American Journal of Sociology*, vol. 86., no. 5, 984-1014.

Crozier, M., Friedberg, E., 1977. *L'acteur et le système*, Paris : Seuil.

Dethlefsen, V., Jackson, T., Taylor, P., 1993. "The Precautionary Principle – towards anticipatory environmental management", in *Clean Production Strategies*, Jackson T. (ed.), London: Lewis Publishers.

Douglas, M., Wildavsky, A. 1982. *Risk and Culture*, Berkeley: University of California Press.

Duclos, D., 1991. *L'homme face au risque technique*, Paris : l'Harmattan.

Durkheim, É., 1895. Les règles de la méthode sociologique, Paris : Presses Universitaires de France (réédition, 1968).

Durkheim, É., Mauss, M., 1903. "De quelques formes primitives de classification. Contribution à l'étude des représentations collectives", *L'Année sociologique*, Paris, vol. 6, 1-72 (reedited in Mauss, M. 1968/69. *Œuvres*, vol. 2).

Etheredge, L., 1981. "Governmental Learning: An Overview", in *The Handbook of Political Behaviour*, Long, S. L. (ed.), vol. 2, New York: Pergamon.

Fisher, F., 1992. "Reconstructing policy analysis: a postpositivist perspective", *Policy Sciences*, vol. 25, no. 3, 333-340.

Fisher. F., 1990. *Technocracy and the Politics of Expertise*, New York: SAGE.

Freeman, C., Soete, L., 1997. *The Economics of Industrial Innovation*, London: Pinter.

Funtowicz, S., Ravetz, J., 1990. *Global Environmental Issues and the Emergence of Second Order Science*, Brussels: Commission of the European Communities.

Gouldner, A. W., 1979. *The Future of Intellectuals and the Rise of the New Class*, New York: Seabury Press.

Gullichsen, J., "The Changing Kraft Pulping Process" (Unpublished), Helsinki University of Technology.

Haas, P., 1990. *Saving the Mediterranean: The Politics of International Environmental Cooperation*, New York: Columbia University Press.

Habermas, J., 1973. *La technique et la science comme idéologie*, Paris: Gallimard.

Hall, P. A., 1988. "Policy paradigms, social learning and the state", *International Political Science Association*, Washington DC.

Heclo, H., 1974. *Modern Social Politics in Britain and Sweden: From Relief to Income Maintenance*, Boston: Yale University Press.

Hoskisson, R., E., 1999. "Theory and research in strategic management: a swing of a pendulum", *Journal of Management*, May-June.

Jackson, W., 1990. "Third World Agricultural Tragedies", *Chemical & Engineering News*, December, 32.

Jasanoff, S., 1996. "Science and Norms in Global Environmental Regimes", in *Earthly Goods – Environmental Change and Social Justice*, Hampson, F. O., Reppy, J. (eds), Ithaca: Cornell University Press, 173-197.

Jasanoff, S., 1991. "Acceptable Evidence in a Pluralistic Society", in *Acceptable Evidence*, Mayo, D. G., Hollander, R. D. (eds), Oxford University Press, 29-47.

Jasanoff, S., 1990. *The Fifth Branch: Scientist Advisers as Policymakers*, Harvard: Harvard University Press.

Jasanoff, S., 1989. "Norms for Evaluating Regulatory Science", *Risk Analysis*, vol. 9, no. 3, 271-273.

Knoepfel, P., Lundqvist, L., Prud'homme, R. and P. Wagner, 1987. "Comparing environmental policies: different styles, similar content", in *Comparative Policy Research – Learning from Experience*, Dierkes, M., Weiler, H. N., Antal, A. B., (eds.), New York: St. Martin's Press, 171-187.

Knorr-Cetina, K., 1992, "Laboratory Studies: The Cultural Approach to the Study of Science", in *Science, Technology and Society Handbook*, Pinch, T. J. (eds.),.

Knorr-Cetina, K., 1981, "The micro-sociological challenge of macro-sociology – Towards a reconstruction of social theory and methodology", in *Advances in social theory and methodology – Towards a reconstruction of social theory and methodology*, Knorr-Cetina, K.,, Cicourel, A. V. (eds.), London: Routledge and Kegan Paul, 1-48.

Kuhn T. 1970. *The Structure of Scientific Revolution* (2nd ed.), Chicago: University of Chicago Press.

Lakatos I. 1970. Falsification and the Methodology of Scientific Research Programmes, In *Criticism and the Growth of Knowledge*, Lakatos I., Musgrave M. (eds.), Cambridge: Cambridge University Press.

Lasswell, H., 1965. *World Politics and Personal Insecurity*, New York: Free Press.

Latour, B., 1991. *Nous n'avons jamais été modernes – Essai d'anthropologie symétrique*, Paris : La Découverte.

Latour, B., 1987. *Science in Action*, Cambridge: Harvard University Press.

Latour B., Woolgar S. 1986. *Laboratory Life: The Construction of Scientific Facts*, Princeton: Princeton University Press.

Laudan, L., 1977. *Progress and its Problems: Toward a Theory of Scientific Growth*, Berkeley: University of California Press.

Lave, L., Gruenspecht, H., 1991. "Increasing the Efficiency and Effectiveness of Environmental Decisions: Benefit-Cost Analysis and Effluent Fees – A Critical Review", *Journal of Air Waste Management Association*, vol. 41, no. 5, 680-693.

Lepkowski, W., 1991. "Writing about Science", *Chemical & Engineering News*, February, 35-36.

Levitt, B., March, J. G., 1988. "Organisational Learning", *Annual Review of Sociology*, vol. 14, 319-340.

Limoges, C., 1993. "Expert knowledge and decision-making in controversy contexts", *Public Understanding of Science*, 417-426.

Lindblom, C. E., 1959. "The Science of "Muddling Through", *Public Administration Review*, vol. 19, 79-88.

Lundan, S., 1996. *Internationalization and Environmental Strategy in the Pulp and Paper Industry*, Ph.D thesis, Rutgers, State University of New Jersey.

Lundqvist, L., 1974. "Do Political Structures Matter in Environmental Politics? The Case of Air Pollution Control in Canada, Sweden, and the United States", *Canadian Public Administration*.

Lyotard, J. F., 1979. *La condition postmoderne*, Paris : Les Éditions de Minuit.

Majone, G., 1993. "Cross-National Sources of Regulatory Policymaking in Europe and the United States", *Journal of Public Policy*, vol. 11, no. 1, 79-106.

Majone G. 1989. *Evidence, Argument, and Persuasion in the Policy Process*, New Haven: Yale University Press.

Majone, G., 1977. “Technology assessment and policy analysis”, *Policy Sciences*, vol. 8, 173-175.

March, J. G., Olson, J. P., 1976. *Ambiguity and Choice in Organizations*, Bergen: Universitetsforlaget.

Mayo, D. G., 1991. “Sociological Versus Metascientific Views of Risk Assessment”, in *Acceptable Evidence*, Mayo DG., Hollander RD. (eds.), New York: Oxford University Press, 249-279.

Moilanen, T., Martin, C., 1996. Financial Evaluation of Environmental Investments, Rugby: Institution of Chemical Engineers.

Mukerji, C., 1989. *A Fragile Power: Scientists and the State*, Princeton: Princeton University Press

Mulkay M. 1979. *Science and the Sociology of Knowledge*, Controversies in Sociology Series 8: London.

Nelson, R., 1991. “The role of firm differences in an evolutionary theory of technical advance”, *Science and Public Policy*, vol. 18, 347-352.

Nlk, 1992. *The Way Ahead for Environmentally Driven Papers*, London.

Passet, R., 1980. *Une approche multidisciplinaire de l’environnement*, Paris : Economica.

Phillips, R. B., 2000. “Research and Development in the P&P Industry”, *TAPPI Journal*, vol. 83, no. 1, 42-46.

Pinch, T. J., Bijker, W. E., 1984. “The Social Construction of Facts and Artefacts: or How the Sociology of Science and the Sociology of Technology might Benefit Each Other”, *Social Studies of Science*, vol. 14, 399-441.

Polanyi, K., 1966. *The Tacit Dimension*, New York: Doubleday.

Popper KR. 1973. *La logique de la découverte scientifique*, Paris : Payot.

Porter, M. E., 1980. *Competitive Strategy*, New York: Free Press.

Price, D. K., 1967. *The Scientific Estate*, London: Cambridge University Press.

Rorty, R. 1995. *L’espoir au lieu du savoir*, Paris : Albin Michel.

Rose, R., 1991. “What is lesson-drawing”, *Journal of Public Policy*, vol. 11, no. 3, 3-30.

Rosenberg, N., 1982. *Inside the Black Box – Technology and Economics*, Cambridge: Cambridge University Press.

Sabatier, P. A., 1987. “Knowledge, policy-oriented learning, and policy change”, *Knowledge: Creation, Diffusion, Utilization*, vol. 8, 649-692.

Schon, D. A., 1995. “Causality and Causal Inference in the Study of Organisations”, in *Rethinking Knowledge – Reflections Across the Disciplines*, Goodman, R. F., Fisher, W. R. (eds.), New York: State University Press, 69-101.

Schot, J., 1989. “Constructive Technology Assessment and Technology Dynamic: Opportunities for the Control of Technology”, *Society for the History of Technology*, Sacramento, 12-15 October.

Silverberg, G., 1990. “Adoption and diffusion of technology as a collective evolutionary process”, in *New Explorations in the Economics of Technological Change*, Freeman, C., Soete, L. (eds), London: Pinter Publishers, 177-192.

Simon, H., 1978. "Rationality as a Process of Thought", Richard T. Ely Lecture, *American Economic Association*, March, 1-16.

Simon, H., 1955. "A Behavioural Model of Rational Choice", *Quarterly Journal of Economics*, vol. 69, 99-118.

Simons Consulting, 1994. *Forestry Sector Benchmarking Initiative - A Case Study in Environmental Regulations*, Canadian Forest Service & Industry Canada.

Smith, R., Wynne, B., 1989. *Expert Evidence: Interpreting Science in the Law*, London: Routledge.

Sowell, T., 1980. *Knowledge and Decisions* (2nd ed.), New York: Basic Books.

Tana, J., Lehtinen, K.-J., 1996, *The aquatic environmental impact of pulping and bleaching operations – an overview*, Helsinki: Finnish Environmental Institute.

Ullmo, J., 1969. *La pensée scientifique moderne*, Paris : Flammarion.

Vogel, D., 1987. "The comparative study of environmental policy: a review of the literature", in *Comparative Policy Research – Learning from Experience*, Dierkes, M., Weiler, H. N., Antal, A. B., (eds.), New-York: St. Martin's Press.

Vogel, D., 1986. *National Styles of Regulations: Environmental Policy in the United States and Great Britain*, Ithaca: Cornell University Press.

Weale, A., Pridham, G., Williams, A. and M. Porter, 1996. "Environmental Administration in Six European States: Secular Convergence or National Distinctiveness?", *Public Administration*, vol. 74, 255-274.

Weber, M., 1971. *Économie et Société*, Tome I, Paris : Plon.

Weinberg, A., 1976. "Science in the Public Forum: Keeping it Honest", *Science*, no. 191, 4225.

Weinberg, A., 1972. "Science and its limits: the Regulator's Dilemmas", *Issues in Science and Technology*, no. 2, 209-222.

Woolgar, S., Pawluch, D., 1985. "How shall we move beyond constructivism?", *Social Problems*, vol. 33, no. 2, 159-162.

Wynne, B., 1993., "Uncertainty and environmental learning", in *Clean Production Strategies*, Jackson T. (ed.), London: Lewis Publishers, 63-83.

Wynne, B., 1982. "Institutional Mythologies and Dual Societies in the Management of Risks", in *The Risk Analysis Controversy: An Institutional Perspective*, Kunreuther HC., Ley EV. (eds.), Berlin: Springer-Verlag, 63-83.

Zurer, P., 1993. "Ozone Depletion's Recurring Surprises Challenge Atmospheric Scientists", *Chemical & Engineering News*, 10.

Section 3

THE DISSERTATION PAPERS

Paper 1 –

ENVIRONMENT AND TECHNOLOGICAL CHANGE THE CASE OF THE WOOD PULP INDUSTRY

Introduction

This paper examines how the environmental issue has left its fingerprints on the pulp and paper (P&P) industry as it develops.[1] Through the concrete phenomenon and through perceptions, concepts and instruments that determine its scope, the paper seeks to understand how environmental developments have affected industrial structuring modes and the commitments made by the firms in the pursuit of economic competitiveness and environmental effectiveness. The analysis focuses on chemical pulp, the main area of environmental concern in papermaking, as well as one of the fastest growing segments of the industry with a rate of environmental innovations greater over the past 30 years than at any other time in the history of pulping technologies (Malinen, 1993; FEI, 1996).

Taking a long view approach is justifiable on two accounts. Firstly, a preliminary view suggests adaptability and shift of technologies in co-optimising economic and environmental developments. Identifying ordered patterns of change, as well as discontinuities, is clearly more discernible in the long term and necessary to understand forces at work (Freeman, 1990). Secondly, the very identity and definition of environmental issues proved to be plastic over time. Conceptions of what should be economically and ecologically rational is in a period of flux (Colby, 1991). Policy and institutional changes in industrially-advanced nations reflect, as such, a progressive trend in seeking a better integration of economics and ecology into decision making and policy planning as a way to overcome ecological impasses of economic growth (Tietenberg, 1996). The question to ask, therefore, is not so much whether a particular development has been effectively informed by the *best* expertise of that time, but rather how incentive structures have evolved in altering the link between economic competitiveness and environmental effectiveness (Parson and Clark, 1997).

The paper begins with a discussion of the link between technology and environment. Its dual nature signals the importance of an evolutionary perspective in understanding the forces of change. Two contexts are explored to examine how environment considerations are factored in the dynamics of technological change within the P&P industry. The paper first reviews the industry structure and the characteristics of its competing environment. It then analyses how regulatory incentives affect linkages between business-oriented technologies and compliance measures. It is concluded that the cross-feeding of analytical contexts is required in understanding the link between economic competitiveness and environmental effectiveness.

Technology and environment: a dual relationship

Making a distinction between business-oriented and environment-related technological changes is challenging. Though pervasive, environmental considerations are usually marginal aspects among the more general factors that

drive technologies (Wheeler and Martin, 1992). Related costs account for only 1 to 5% of total manufacturing costs within OECD economies (Simpson and Mangan, 1997). Moreover, environmental benefits arise often incidentally out of efforts directed specifically at improving economic efficiency (Johnstone, 2001).
The importance of technological changes towards a sustainable development has been well established among policymakers and industrialists (OECD, 1999b). Regulatory changes testify of a shift in perceptions from viewing technologies as the source of environmental deterioration to being the means by which the correlation between economic growth and pollution increase can be untied. Government and industry turned early in the 1970s and 1980s to pollution control. Regulatory approaches and industrial responses are now shifting away from the pollution control paradigm to global efficiency paradigms in order to co-optimise economic and environmental developments.[2] Yet, no matter how significant, environmental benefits of technology can often be dwarfed by the aggregate effects of increases in economic activities and economic and demographic growth. Ecological risks can even be exacerbated as the pollution intensity of technology decreases, as shown by the unsustainable growth of fossil-fuelled, yet more energy-efficient, vehicles (OECD, 2001).

Developments in the P&P industry are a good illustration of such trends. Up to the 1970s, the industry had few regulations and was perceived as a notorious industrial polluter. The increase in pollution and bio-diversity impacts was obviously connected to the very rapid expansion that paper markets had been experiencing since the turn of the 20th century. Since then, industrial responses to converging public pressures, tightening regulations and *greening* market forces have led to a progressive de-coupling of production growth and pollutant outputs within the Organisation for Economic Co-operation and Development (OECD) countries (Rajotte, 2000a).[3] Technological developments have substantially increased the ratio of paper produced for every tonne of wood, while the use of chemicals, energy and water has been decreasing and the volume of recycled papers and wood residues for papermaking has been increasing (PPI, 1999). Yet, in order to meet the projected 77% increase in world demand between 1995 and 2020, it is expected that an approximate increase of 71% water and 53% energy, along with more wood and recycled paper, will be required. Over that period, carbon dioxide (CO_2) and sulphur oxide (SO_x) emissions would increase by 62% and 23%, respectively, in OECD economies while doubling world-wide (OECD, 2001).[4]

The foregoing indicates that technological change can only offer a partial, even dual response, in bringing development to sustainable patterns. It may either lead to an increase or reduction of environmental impacts by intensifying or decreasing energy and resource use, introducing more toxic or benign compounds, or inducing effects eluding analytical detection across time and space. Yet, in the face of increasing economic and environmental pressures, socio-economic discontinuities are likely to emerge, opening the way for radical changes. To consider such a scenario for the P&P industry, it is necessary to start the discussion with the evolutionary perspective from which this paper largely motivates its assumptions.

The evolutionary view on technology

Evolutionary economics postulate that it is the dynamic imbalance created by economic crises and the continuous flow of innovation, and not the maximising profit scheme evolving under states of equilibrium, which constitutes the central problem of economic theory and practice over the long run. Uneven distribution of costs and benefits is such that the market alone cannot provide an optimal rate of technological change. In contrast to standard economics, Schumpeterian economics stresses the supply-side factors and the role of individual firms as vectors of innovation, competitiveness and wealth (Nelson, 1991). In such a perspective, technology cannot be simply seen as a given factor in market incentives. Differing growth patterns and economic gaps between firms/nations show that economic behaviour cannot either be understood in homogeneous terms. Confining the study of technologies within the equilibrium theory offers no real starting point in understanding why some economies/firms are more effective than others. The logical inference is that competitiveness – and its corollary, technological change – are shaped through various factors, on both supply and demand sides, and not all of them economically-based.

A technological strategy can be seen as the diagnosis performed by a firm over its economic reality, both internal and external, in the pursuit of competitiveness. Innovative firms are the ones with a *sixth sense* to seize opportunities and perceive threats arising in rapidly changing environments, i.e. the *animal spirit* (Freeman and Soete, 1997), while having the capacities to adapt their strategy, structure and core capabilities accordingly (Nelson, 1991). Thus, a firm behaviour resembles that of species in biological evolution: competitiveness determines the survival of the fittest. The analogy is a fruitful heuristics to investigate technologies as processes shaped by incentive structures evolving under various states of cognition. Evolutionary views suggests two analytical assumptions:

- The first is deterministic. Standardisation is such in mature sectors that the behaviour of a firm is strongly conditioned by the environment in which it competes. Within a structure-conduct-performance paradigm, the conduct of individual firms can be ignored and their performance best explained by the industry structure (Hoskisson, 1999).
- The second is phenomenological and firm-oriented. Empirical work indicates that a competitive environment has various effects and triggers differential responses among firms. On the assumption of a diversity of responses, it can be shown that the development and appropriateness of innovative strategies are very much a function of learning, both internal and external to the firms (Silverberg, 1990; Nelson, 1991).

Given the foregoing, it is more appropriate to study technological change as a social dynamics (Lundvall, 1992). A technology is indeed an apprenticeship whose nature and direction are determined through three critically interrelated levels (Cohendet *et al.*, 1992). It is *localised*, in the sense of being a unique product of a particular place in time, yet shaped by the incentive structures of its competing environment. It is based on *tacit* knowledge, developed through day-to-day operational routines (the learning-by-doing and learning-by-using), which is not easily codified or transmittable. It is rooted in *history* as the founding choice determines the range of future options (Nelson and Winter, 1982), given the irreversible effects of positive externalities and technological interdependency of techno-economic networks, a dynamics labelled as path dependency (David, 1986).

The realm of technological potential is bounded and only some areas are likely to be explored and developed by cost-sensitive organisations (Rosenberg *et al.*, 1990). The economic viability of radical change is typically diminished because it requires the creation of new relationships and networks, complementary skills and assets. Yet this does not mean that innovation is strictly a matter of economic calculus. It indicates that decisions are more characterised by organisational and discursive attributes, rather than what is suggested by standard economics (Lundvall, 1992).

Growth and change in the P&P industry: an overview

The P&P sector plays a central role in today's economies as one of the world's top ten manufacturing industries (McDonough, 1998). In the US, in 1997, its products were valued at more than US$230 billion per year, with exports estimated at $13.5 billion or 2% of US merchandise exports (Koleff, 1999). In Canada, in 1998, wood-based products were valued at more than US$52 billion, with exports estimated at $39 billion. Turnovers of forest-related businesses in the European Union (EU) were estimated at US$348 billion for the same year (Ahlstrom, 1999). In countries such as Canada, Finland and Sweden, the industry is of utmost importance as a founding block of industrial modernisation and a significant source of export revenues and employment (Sinclair, 1990).

Competitiveness is based on a number of critical input, including wood (±55% of costs) and energy (± 30% of costs), manufacturing and transport costs, domestic market and access to world paper and capital markets. Added to this list are industry scale, agglomeration economies, policy regimes and national contexts (Wheeler and Martin, 1992; Kuisma, 1993).[5] Once highly fragmented, protected by national tariffs, and concentrated in the forest belt of the Northern hemisphere, the industry has become highly competitive in keeping abreast of changes in demographic and economic structures. Owing to the enormous amounts of resources processed and increased sophistication of technologies, the industry has grown very capital intensive and large in scale.[6] Consolidation and concentration have constituted the main response to spread increasing manufacturing costs over larger output,[7] while better controlling gaps between demand and supply.[8] Between 1980 and 1990, over 20% of paper mills were shut down within the OECD, their number decreasing from 677 to 538 in the US, from 1654 to 1239 in Western Europe and from 593 to 444 in Japan. Affected Mills were mostly of 50,000-tonnes/year capacity, becoming uneconomical in a highly competitive market based on large economies of scale. Bigger units offset closures. The average capacity of the top 100 paper firms increased by 60% in the 1980s.[9] The progressive change in the regional focus of production and consumption also drives the industry towards further concentration. From 1990 to 1995, growth rates averaged 27% in Asia and 17% in Latin America, two to four fold that of North America, averaging 6.5%. In addition, developing markets contribute to the emergence of strong competitive players in Asia and South America, which benefit from fast growing tree plantations, while opening up business opportunities for OECD-based companies.[10]

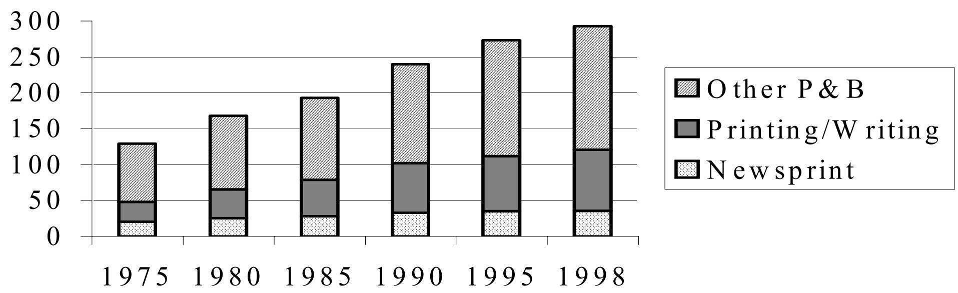
Developments over time suggest that growth maximisation may be a more appropriate concept than profit maximisation in understanding patterns of growth and change within the P&P industry. The recourse to scale economies reflects a competition based significantly on price within a sector long managed as a bulk producer (MEB, 1993). The trend has obviously increased with the economic pressures in line with the globalisation of paper markets and the emergence of low cost competitors in fast growing economies. Forecasts are that the industry will rationalise itself to 20 global firms, each capable of producing 15 Mt of paper per year (PPI, 1999). The capital intensity of P&P making is also propitious to incremental improvements of established technologies through economies of scale, a factor earning the industry the reputation – maybe undeserved (Rosenberg *et al.*, 1990) – of being overly conservative (Norberg-Bohm and Rossi, 1998).[11] Yet the forest cluster has been extremely innovative in a number of countries, both in economic and environmental terms.

Technological change in the pulping industry: a dialectical perspective

Pulp production[12] evolved along a technological trajectory which took place in the mid 19th Century within the chemical/electrical industrial paradigm (Laestadius, 1998). Developments in pulping technologies correspond to changes in the competitive structure of pulp production, in line with evolving markets, science and technology, and policy regimes. Stone Groundwood pulping (1844) steadily declined as a result of the decreasing share of newsprint in total demand. It became necessary to improve the mechanical file to compete in higher-grade markets, while keeping the economic advantage of high production yield. Thermomechanical Pulp - TMP (1939) increased its viability in the 1970s by adding an initial stage that uses steam to soften wood chips prior to cellulose extraction, minimising damages to the fibres and resulting in a stronger pulp. In 1978, Chemi-Thermomechanical Pulp – CTMP brought these improvements a step further by adding a chemical stage to heating and mechanical defibration, enabling *custom tailoring* of the pulp properties by altering chemical and temperature parameters. The chemical pulp file has had a similar journey. Up to the 1930s when it started losing market shares to kraft pulping, the sulphite process (1866) was the dominant technique. The competitive situation first changed between the sulphite process and the kraft process because of the latter versatility in using various wood species.[13] The second major change came with the tightening of environmental regulations, which forced sulphite mills into chemical recovery.[14]

Obviously, these changes were fed by the expansion and diversification of paper markets. Developments of industrial goods, information technologies and personal care products have taken over from the newspaper age in fuelling demand for higher grade products. Figure 1 shows the evolution of paper and board (P&B) demand between 1975 and 1998. Rigid, lightweight and printable materials are increasingly required for packaging use. The advertising industry demands more colour printed paper. Counter current to the "paperless office" predictions, the electronic age brings new resources, e.g. photocopiers, computer printers, all of which require substantial amounts of high-quality papers.

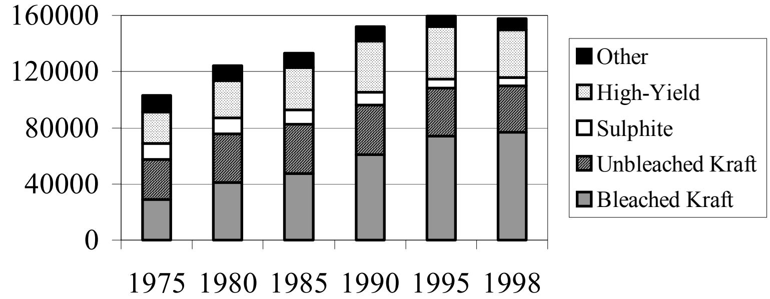
Figure 1 - P&B per Category (million tonnes)



Source: CPPA 1999

Obviously, the brighter, stronger, and more versatile kraft pulp has been the net beneficiary of the growth in higher grades supply and its dominance is predicted to continue well into the next century (Tana and Lehtinen, 1996). The evolution of world production shares among the main production techniques are provided in Figure 2. Despite the scale and capital intensity of kraft mills[15], developments have been remarkable since the 1970s. Development of O_2 delignification, modified and extended batch cooking, improved pulp and chemical mixing, and pH adjustments increased the economics of the process while leading to significant reduction of wastewater. Modified and extended cooking and O_2 delignification impacted on the entire process by lowering the kappa number of the pulp prior to bleaching, thereby reducing the amount of bleaching chemicals needed and easing the introduction of bleaching alternatives to chlorinated compounds, e.g. ozone (O_3), hydrogen peroxide (McDonough, 1998). Concurrently, increased substitution of ClO_2 to Cl_2 reduced the generation and release of harmful chlorinated compounds. Since the mid-80s, elemental chlorine-free (ECF) and totally chlorine-free (TCF) schemes have increased their world share of bleached pulp production. ECF pulp now accounts for nearly 50% of world capacity, while TCF pulp has stalled at around 6% since 1994, following a steady growth in the early 1990s (AET, 1999). Thus, the industry has come full circle from using Cl_2 as the most efficient and affordable bleaching agent to virtually phasing it out in the course of two decades.

Figure 2 - World Pulp Production (000s tonnes)



Source: CPPA 1999

Changes in pulping technologies clearly illustrate that the "creation of best practice technology [is] endogenously intertwined with, and inseparable from, the process of diffusion" (Silverberg, 1990). Established technologies have been usually superior to the original matrix through development and adaptation, and user/producer interactions. The dynamics is part of the maturation of a technology and extension of its frontiers. Then, the larger the industry scale, the faster the development and diffusion of new technologies.[16] There is also a correlation between the scale and sophistication of technologies, as bigger mills tend to be more cost-efficient, while causing less environmental impacts (FEI, 1996).

Yet, economies of scale can actually turn into diseconomies of scale as increasing energy and resource use, and technological sophistication increase overall costs and environmental effects per unit of production, while bigger and more stable markets are needed to absorb the growing output (Laestadius, 1998). When markets and technologies are ranked according to their economic and environmental impacts, it become apparent that the patterns of industry growth and change have been shaped by two contradictory economic trends (Sinclair, 1990). On the one hand, market trends towards added-value products increase industry's revenues through increasing demand for higher grades products and higher priced pulp. On the other hand, improving pulp properties (strength, absorbency, brightness, smoothness) increases the sophistication of technologies, requires more inputs (fillers, additives), and generates more environmentally complex effluents.[17] As a result, overall costs are increasing, while more complicated techniques and management systems must be developed to offset these effects (Gullichsen, 1998). In so doing, a shift away from large-scale solutions has become attractive, opening possibilities for niche players and smaller scale firms, alongside giant mills.[18] *Green* competitiveness may be seen as a sub-category of this trend.

The foregoing shows that the environmental factors of growth patterns can be a key element of sustainable industrial economics, even up to the point that they may cause a radical shift in technologies. Consequently, environmental regulations can be felt at different points and times of the incentives structures shaping the making of technological strategies.

Regulations as a technological driver

When the transition to new bleaching processes began in the 1970s, pulp mills were one of the most polluting industries with significant emissions to air and water. The 1970s environmental reform represented a major departure from past policies, substituting standards based on best available technologies (BAT) to the prevailing ambient quality approach, considered then a free ticket for dilute-and-disperse strategies. Performance-based standards appeared the proper answer for what was then thought to be reversible problems within realistic time and investments (Tietenberg, 1996).[19] Owing to a combination of tightening performance-based regulations and effective industry innovations, the most urgent and obvious environmental problems were successfully tackled. Yet, approaches differed among countries whether the emphasis was put on external treatment or internal changes. If ones examines the techniques implemented by pulp mills to control effluents, most facilities located nearby small, freshwater streams had to install secondary treatment works to control, degrade and convert oxygen-depleting compounds into harmless components. In countries such as Canada, Finland, and the US, the biochemical oxygen demand (BOD) parameter was the principal means of quantifying the objectives being sought. Sweden, on the other hand, substituted early the chemical oxygen demand (COD) to BOD as its main regulatory focus. Since 80% of mills were to be found within 50 km of the Baltic Sea coastline, the high dilution factor conferred a lesser degree of urgency to oxygen depletion. The COD focus directed measures further upstream in pulping and bleaching operations.[20] Concurrently, BOD limits were less restrictive, between 8 and 17 kg BOD/tonne of pulp, compared with the US limits of 4 to 8 kg BOD/tonne of pulp (SIMONS, 1994). As a result, most Swedish mills did not have to invest into costly external treatment (Nyström, 1998).

Despite the difference of emphasis, pollution abatement and control costs were roughly comparable among countries (MEB, 1993; OECD, 1999a). In the early 1970s, environmental expenditures in the American P&P industry rose up to more than 30% of total capital spending. Secondary treatment systems required the greatest compliance cost.[21] In Sweden, environmental investments into internal changes were also significant, even leading to an initial increase of production costs over those of competing countries (Tarnvik, 1998). Changes in the relative input cost structure, such as increasing costs of wood, energy, and chemicals in line with the rise of regulatory controls and the oil shocks of the 1970s, were providing a strong incentive for innovation. Yet, these conditions were further exacerbated when dioxins and other persistent compounds were detected in the paper lifecycle and international environmental concern turned to chlorine (Cl_2) bleaching. Environmental investments increased again, to between 10 and 25% of manufacturing costs up the early 1990s (NLK, 1992). Sweden's early focus on internal process changes positioned favourably its industry in furthering investments into Cl_2 free alternatives, against those mills that had invested into secondary treatment.

Regulatory regimes and technological trajectories: a co-evolving dynamics

Why should environmental regulations affect the competitiveness and behaviour of firms? Whether directly or indirectly, they affect the price of the use of environmental assets relative to other inputs, providing incentives for more environmentally-benign and less resource-intensive alternatives, while creating market opportunities for environmental-oriented innovations. Thus, in the 1970s, the price of pulping chemicals increased by 50% or more as a result of regulatory controls on the chemical supplier industries. Concurrently, a shortage of wood fibre, associated with environmental concerns over forest harvesting, increased the price of wood. Changing prices of critical inputs led to a significant effect on the competitive structure of pulping technologies (Wheeler and Martin, 1992).
Studies, which focus on specific aspects of policy regimes often tend to explain differences in regulatory successes or shortcomings among jurisdictions through procedural and design aspects, such as technology forcing (Tana and Lehtinen, 1996) and cost incentives (Norberg-Bohm and Rossi, 1998). Though not without relevance, these generalisations can often be too strict by overlooking local contextual factors by which developments are what they are precisely because the actual regulatory unit deal with a particular incentive structure. Thus, policy analysts have come to recognise that differing interpretations of science, risk, economics, and other factors shaping policies and technologies, ultimately reflect deeper patterns of national culture (Jasanoff, 1991).

When comparing Sweden and the other major pulp producing countries, three interrelations between regulation and technology may be identified: (i) the design and direction of standard-setting is inseparable from the industry context it regulates (Salter and Hawkins, 1990); (ii) BAT-based performance standards are more suitable for technological diffusion rather than radical breakthrough (OECD, 1999b); and (iii) a regulatory focus on internal changes is more likely to anticipate on emerging issues and be the source of competitive advantage (Porter, 1990; MEB, 1993).

According to most experts, the shift to Cl_2 free bleached pulp production in Sweden was driven by political pressures on West European markets (SIMONS, 1994; Tana and Lehtinen, 1996). The *ex post* explanation is fair enough, yet it does not account for the fact that the Swedish industry had been working *ex ante* of regulatory change on the economics and environmental aspects of Cl_2 bleaching since the 1960s (Jirvall, 1998).[22] What makes the case so interesting is how environmental factors coincided with industrial economics in bringing Swedish authorities and firms into first movers. When comparing the cost structure among the most important competitors on the European markets, the Swedish industry is one of the most vulnerable primarily due to its highest wood costs, nearly twice that of US mills (Siro, 1998), having the highest selling price requirements to ensure profitability of the mills. It may be argued that R&D

efforts into Cl_2 free alternatives was perceived as a win-win situation, i.e. coupling productivity gains through reduction of chemical volume with improvements in environmental performance. Local conditions of mill siting made obvious the regulatory shift to a COD focus. Subsequent adoption of Cl_2 free policies was a logical extension of a regulatory culture embracing the notion of prevention, while implementing a level playing field protecting the most innovative firms.

Likewise, arguing that the small cost differential between alternative compliance measures may explain the industry tendency to stick to end-of-pipe technology, rather than more lasting internal change (Norberg-Bohm and Rossi, 1998) can be misleading. It cannot be denied that BOD limits have locked industry into end-of-pipe investments, but it is questionable whether it fully reflects a regulatory influence on the strategic behaviour of firms. Expenditures into bigger, state-of-the-art mills made by far the major share of total manufacturing investments (Rajotte, 2000). At the onset, this led to significant gains both in terms of productivity and environmental performance. However, for most firms, markets and regulatory incentives made that industrial economics did not coincide with doing business differently. In particular, the strong North American market insulated its industry from the changing conditions on the North European markets. Regulatory-wise, BOD standards mandated on a nation-wide basis provided little room for flexibility. Emerging issues, such as the detection of dioxins, were channelled through the legally-binding compound-by-compound approach, constraining the capacity of stakeholders to redefine the means and ends of established strategies. The regulatory focus on BOD relied merely exclusively on existing techniques, reflecting a substantial industry influence on the drafting of regulations.[23] There was little cross-fertilisation between compliance technology development and the development of manufacturing technologies. In this context, the combination of technology scaling and end-of-pipe control techniques reflected a compliance strategy that did not deviate from "business-as-usual" and a failure to anticipate the future (Phillips, 2000).[24]

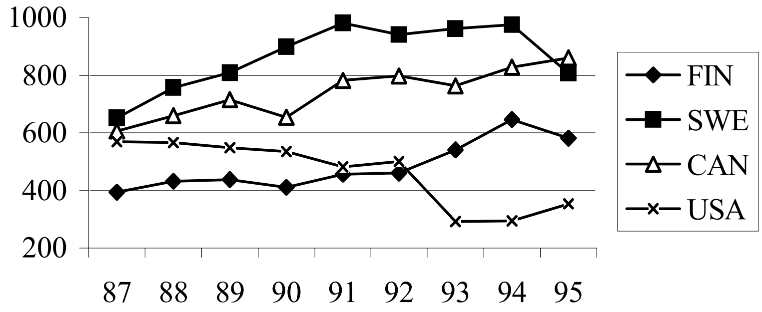
Environmental regulations and competitiveness

Yet, the economic impact of environmental regulations is often a matter of contention among experts. Front-running regulations is either seen as stifling innovation and putting an industry at a competitive disadvantage to less regulated countries (Kalt, 1988) or being the source of improved competitiveness (Porter and Linde, 1995). Both views are criticised as being overly based on anecdotal and weak evidence (Jaffe *et al.*, 1995). We can only conclude with Albrecht (1998) that inadequate methodologies and a shortage of empirical case studies may be the source of this evidential gap[25]. Our case study suggests that there is more than anecdotal evidence supporting the fact that environmental regulations have an effect on industry competitiveness. This is reflected at the level of both products and pulping and bleaching equipment market shares, which makes it also possible to identify factors in differential responses of firms to environmental risks.

When looking at the years that correspond to protracted discussions and adoption of Cl_2 free policies, it can be argued that Sweden's first mover efforts into pulping and bleaching developments provided a competitive and marketing edge on the very important and volatile German market that was also experiencing some severe recessions. Figure 3 provides bleached kraft pulp exports of the main producing countries onto the German market between 1987 and 1995. Swedish firms were able to increase their market shares, against their main competitors, except for minor decreases, which are mainly due to the economic recession suffered by the market between 1991 and 1995. The burgeoning demands for Cl_2 free pulp and papers, which spread across the German economy in the late 1980s in reaction to the dioxin scare, obviously put Swedish firms in a favourable position.[26] Swedish firms were alone to capture the burgeoning Cl_2 free market niche. Early on, Aspa Bruk of Sweden was able to supply TCF pulp at a grade that would not has been normally selected for such a product. One by one, pulp producers had to follow suit and this led to the launch of many ranges of TCF papers for high quality advertising, business forms, letter-headings, copier papers, greetings cards and other uses. Taking advantage of the momentum, the Swedish market pulp mill producer, Södra, used aggressive *green* marketing to position its TCF pulp on the European markets, borrowing rhetoric from the political debate by suggesting that Cl_2 and ClO_2 bleached papers may be poisoning its users (Lövblad, 1998).[27] Up to 1991, Södra was even successfully commanded a 25% premium for its TCF products (NLK, 1992).

As Cl_2 free policies were eventually adopted internationally, pulp firms became increasingly dependent on Scandinavians for new pulping and bleaching technologies. Once the largest equipment supplier, the US began to suffer a sizeable trade deficit, losing what had been a strong world trading position. By 1992, Sunds Defribator had supplied nearly 50% of O_2 delignification equipment, while Kamyr had provided more than 20% of modified and extended modified cooking systems, world-wide (Axegård, 1998). Both were successful in negotiating foreign joint ventures, particularly within the US P&P equipment market estimated at nearly $2 billion (MEB, 1993). From the 1980s onward, Sweden took over in leading the market in pulping and bleaching equipment (McCubbin, 2002).

Figure 3 - German pulp imports (1000 tonnes)



Source: PPI 1997

Conclusion

Through examining developments in pulping and bleaching equipment and product market shares, environmental regulations have been shown to lead to significant changes in the competitive situation of the industry. Yet gaining competitive advantages through environmental technologies did not come free. Co-optimising economic and environmental variables was the results of continuous developments and adaptation of established and foreseeable technologies. Regulatory controls were particularly efficient to the diffusion of best available technologies. However, differing risk perceptions, in line with national contexts, led to different pathways. These were later revealed when international environmental concerns turned to Cl_2 bleaching of pulp. In most countries, the early regulatory focus on oxygen depleting effluents locked the industry into end-of-pipe thinking and investments into external treatment, making the switch to Cl_2 free technologies uneasy and uneconomical. In Sweden, the early focus on internal process changes positioned its industry favourably to take advantage of the changing environment, both *ex ante* and *ex post* of regulatory changes. The case study shows that the link between competitiveness, technology, and environment is complexly contingent on changing interactions between supply-side and demand-side factors. In this, the link between regulation and technology is part of a co-evolving process, which brings knowledge and learning to bear on decisions. By more explicitly linking regulatory incentives and technological strategies, this case study stresses the need to cross-fertilise different analytical contexts in deepening our understanding of environmental policies.

BIBLIOGRAPHY

Ahlstrom. 1999. The industry looks back on 40 years and on into the future, *PPI*, Interview on the internet, www.pponline.com.
Albrecht J. 1998. Environmental regulation, international competitiveness and the Porter hypothesis, *International Workshop on Ecological Modernisation*, Helsinki, 19 p.
Alliance for Environmental Technology (AET). 1999. http://www.aet.org/facts/ .
Axegård P. 1998. Interview, Former EKA Chemical expert, Stockholm.
Cepi 1998. *Environmental Report*, Confederation of European Paper Industries, Brussels.
Cohendet P., Heraud JA., Zuscovitch E. 1992. Apprentissage technologique, réseaux économiques et appropriabilité des innovations, in *Technologie et Richesse des Nations*, Foray D., Freeman C. (eds), Economica: Paris, 63-78.
Colby ME. 1991. Environmental management in development: the evolution of paradigm, *Ecological Economics*, 3: 193-213.
Cppa 1999. Wood Pulp Data, *Canadian Pulp and Paper Association*, Montreal.
David P. 1986. Understanding the Economics of QWERTY: the Necessity of History, in *Economic History and the Modern Economist*, Parker E. (ed), Basil Blackwell: London.
Ekono Consulting 1996. Personal communication. Helsinki.
Fei 1996. The Finnish Background Report for the EC Documentation of Best Available Techniques for P&P Industry, *Finnish Environment Institute*, Helsinki, 144 p.
Freeman C., 1990. Technological innovation in the world chemical industry and changes of techno-economic paradigm, in *New Explorations in the Economics of Technological Change*, Freeman C., Soete L. (eds), Pinter: London, 74-92.
Freeman C., Soete L. 1997. *The Economics of Industrial Innovation* (3rd Edition), Pinter: London.
Gullichsen J., 1998. Bleaching Differences, *Nordicum*. 5: 44.
Hoskisson RE. 1999. Theory and research in strategic management: a swing of a pendulum, *Journal of Management*, May-June:54 p.
Jaakko Pöyry Oy 1997. *BAT in the Manufacturing of Pulp*, Confederation of European Paper Industries, Brussels, ISBN 87 7303 362 6, 96 p.
Jaffe A., Peterson S., Portney P., Stavins R. 1995. Environmental regulation and the competitiveness of U.S. manufacturing: what does the evidence tell us?, *Journal of Economic Literature*, 33: 132-163.
Jasanoff S. 1991. Acceptable Evidence in a Pluralistic Society, in *Acceptable Evidence*, Mayo DG., Hollander RD. (eds), Oxford University Press, 29-47.
Jirvall N. 1998. Interview, Stockholm, Swedish Forest Industries Association.
Johnstone N. 2001. Technological Change, Public Policy and the Environment, background document for the *OECD Environmental Outlook*, OECD:Paris, 21 p.

Kalt JP. 1988. The impact of domestic environmental regulatory policies on U.S. international competitiveness, in *International Competitiveness*, Spence AM., Hazard H. (eds), Harper and Row: Cambridge, 221-262.

Koleff AM., 1999. Paper and forest products industry view, Workshop on Climate Change: Industry view on the climate change challenge with special emphasis on the Kyoto mechanisms, *Oecd*: Paris.

Kuisma M. 1993. *Green Gold and Capitalism – Finland, Forests and World Economy*, SHS:Helsinki.

Laestadius S., 1998. The relevance of science and technology indicators: the case of pulp and paper, *Research Policy*, 27: 385-395.

Lundvall BA. 1992. Relations entre utilisateurs et producteurs, systèmes nationaux d'innovation et internationalisation, in *Technologie et Richesse des Nations*, Foray D., Freeman C. (eds), Economica: Paris, 355-388.

Lövblad R. 1998. Interview, Södra Cell Ab, Stockholm.

Malinen R. 1993. Pollution-Free Kraft Pulping and Bleaching - Utopia?, *Proceedings of the XXV EUCEPA Conference*, Vienna, Austria, 51-63.

Mccubbin N. 2002. Personal Communication. Independent consultant, Montreal.

Mcdonough TJ. 1998. Foreword, in *Chlorine and Chlorine Compounds in the Paper Industry* Turoski V. (ed.), Ann Arbor Press: United States, 359 p.

Meb 1993. *Competitive Implications of Environmental Regulation in the Pulp and Paper Industry* (Draft), Management Institute for Environment and Business, Washington, 102 p.

Nelson R. 1991. The role of firm differences in an evolutionary theory of technical advance, *Science and Public Policy*, 18: 347-352.

Nelson R., Winter S. 1982. *An Evolutionary Theory of Economic Change*, Harvard Press: Cambridge.

Nlk Consulting 1992. *The Way Ahead for Environmentally Driven Papers*, London.

Norberg-Bohm V., Rossi M. 1998. The Power of Incrementalism: Environmental Regulation and Technological Change in Pulp and Paper Bleaching in the US, *Technology Analysis & Strategic Management*, 10: 225-245.

Nyström E. 1998. Interview, Swedish Environmental Protection Agency, Stockholm.

Oecd 2001. *OECD Environmental Outlook*, Oecd: Paris, 327 p.

Oecd 1999a. *Case Study on the Pulp and Paper Sector – Part One*, Oecd: Paris, 101 p.

Oecd 1999b. *Environmental Requirements for Industrial Permitting, Vol. 1 – Approaches and Instruments*, Oecd: Paris, 99 p.

Parson EA., Clark WC. 1997. Learning to manage global environmental change: a review of relevant theory, *Summer Symposium on the Innovation of Environmental Policy*, University of Bologna, 41 p.

Phillips RB. 2000. Research and Development in the P&P Industry, *TAPPI Journal*, 83: 42-46.

Porter ME., Linde C. 1995. Towards a new conception of the environment-competitiveness relationship, *Journal of Economic Perspectives*, 6: 119-132.

Ppi 1999. Annual Review, *Pulp & Paper International*, www.pponline.com.

Ppi 1997. *Pulp and Paper International Price and Fact Book.*

Rajotte A., 2002. Pulp production technology and environmental performance in Sweden and Finland: policy, science and market share, *Society & Natural Resources* (under press).

Rajotte A. 2000. Case study on chlorine policies in the pulp and paper sector in Finland, France and Sweden, *Technology and Environmental Policy (TEP)*, 4th Framework Programme of DG XII, European Commission, 105 p.

Rajotte A. 2000a. Pulp and Paper Industry, background document for the *OECD Environmental Outlook*, Oecd: Paris, 73 p.

Rajotte A. 2000b. Steel Industry, background document for the *OECD Environmental Outlook*, Oecd: Paris, 47 p.

Rajotte A., Smith A. 2001. When markets meet socio-politics: the introduction of chlorine-free bleaching in the Swedish pulp and paper industry, in *Technology and the Market – Demand, Users and Innovation*, Coombs R. , Green K., Richards A., Walsh V. (eds.) Edward Elgar: London, 136-155.

Raumolin J. 1985. The impact of forest sector on economic development in Finland and Eastern Canada, *FENNIA*, 163: 396-437.

Reilame I. 1998. Interview, Metsä-Bothnia Ab, Helsinki.

Rosenberg N., Ince P., Skog K., Plantinga A. 1990. Understanding the adoption of new technology in the forest products industry, *Forest Products Journal*, 10: 233-249.

Salter L., Hawkins R. 1990. Problem areas in the management of technology: Standards and standards-writing in Canada, in *Managing Technology – Social Science Perspectives*, Salter L., Wolfe D. (eds), Garamont Press: Toronto.

Skea J. 1995. Environmental Technology, in *Principles of Environmental and Resource Economics. A Guide for Students and Business Makers*, Folmer H., Gabel L., Opschoor H. (eds.), Edward Elgar Publishing: London, 389-412.

Silverberg G. 1990. Adoption and diffusion of technology as a collective evolutionary process, in *New Explorations in the Economics of Technological Change*, Freeman C., Soete L. (eds), Pinter Publishers: London, 177-192.

Simons Consulting Group, 1994. Forestry Sector Benchmarking Initiative – A Case Study in Environmental Regulations, *Canadian Forest Service & Industry Canada*, 111 p.

Simpson AE., MANGAN E. 1997. The Effects of Government Environmental Policy on Costs and Competitiveness – Iron and Steel Sector, DSTI, *OECD*: Paris, 56 p.

Sinclair WF. 1990. *Controlling Pollution from Canadian P&P Manufacturers: A Canadian Perspective*, Environment Canada, 360 p.

Siro M. 1998. Interview, UPM Kymmene, Helsinki.

STEP 1997. Innovation Activities in Pulp, Paper and Paper Products in Europe, *STEP*: Norway, 148 p.

Tana J., Lehtinen KJ. 1996. The Aquatic Environmental Impact of Pulping and Bleaching Operations – An Overview, *Finnish Environment Institute*: Helsinki, 103 p.

Tarnvik, 1998. Interview, Svenska Cellulose Ab, Stockholm.

Tietenberg GT. 1996. *Environmental and Natural Resource Economics* (4th Edition), Harper Collins College Publishers: United States, 614 p.

Usepa 1995. *Profile of the Pulp and Paper Industry – Sector Notebook Project*, Office of Compliance, Washington, EPA 310-R-95-015, 128 p.

Wheeler D., Martin P. 1992. Prices, policies and the international diffusion of clean technology: The case of wood pulp production, in *International Trade and the Environment*, P. Low (eds), World Bank: Washington, 197-224.

REFERENCES

1 The analysis draws upon the author's work in Chapter 18 "The Pulp and Paper Industry" from the *OECD Environmental Outlook to 2020*.

2 Statistics from the US Department of Commerce indicate that, since the late 1980s, the share of pollution abatement costs attributed to products and process changes is increasing at the expense of end-of-pipe measures (Johnstone, 2001). Yet pollution control techniques still account for the largest share. According to a study of *Recherche Développement International*, the shares of end-of-pipe means in environmental equipment for 1987 were 80% in Belgium, 82% in Western Germany and 87% in France (Skea, 1995).

3 The absolute load, in terms of biochemical oxygen demand (BOD) substances and total suspended solids (TSS), is today a mere 2% of what is was in 1970 and, since P&P production has doubled during the same period, the specific load is thought to be only one hundredth of the 1970 levels (Gullichsen, 1998). Since 1980, the discharge of chlorinated organic compounds has been reduced by about 90% while emissions of dioxins and furans has decreased by 99% in the Canadian and European P&P industries (CEPI, 1998; CPPA, 1999).

4 These figures are extrapolated from the OECD Reference Scenario, which forecasts annual average world growth rates of 2.3% between 1995 and 2020 (OECD, 2001).

5 Thus, the development of the Finnish forest cluster is often connected to the economic constraints posed by the fierce competition in the main export markets and the war debts imposed by the Allied, which consisted mainly in natural resources (wood) and engineering and industrial equipment to be paid to the Soviet Union. These conditions promoted innovation through resource efficiency and recycling as a way to intensify productivity. In contrast, the Canadian industry has long benefited from a relatively easy operational environment, with its enormous wood and hydropower resources and easy access to the large American paper market (Raumolin, 1985). Yet, the Canadian industry has lagged behind in developing technology, while progressively losing its ownership to foreign investments (MEB, 1993).

6 In 1992, the sector ranked third among major industries with a capital intensity averaging 1.3 as measured by total assets to sales ratio (STEP, 1997). About 15% of sales revenues are spent on capital expenditures, more than double the average 6% of all other manufacturing sectors (McDonough, 1998).

7 Technical advances have thus been mostly directed at increasing the size and speed of production rather than inducing radical changes (Laestadius, 1998). Yet increasing speed of paper machines from 60km/h to over 90km/h was made possible through improving the physical properties of pulp and paper (FEI, 1996).

8 Given the sharp upswings and downswings of the cyclical paper markets, firms often suffer from over-capacity, leading to strong fluctuations of pulp prices, weakening bargaining power with consumers, falling profitability and increasing debt. Econometric analyses over the past 30 years show that there were 18 periods of more or less 2 years between severe recessions and 4-5 periods of more or less 1 year between expansions (STEP, 1997).

9 In the US, the share of pulp and paper mills with annual capacity of more than 450,000 tonnes increased from 40 to 58% and from 23 to 42%, respectively, between 1980 and 1990. Differences between developed and developing countries are significant. The average capacity of Asian mills is 9,000 tonnes/year, far below the average 200,000 tonnes/year produced by mills in the European Union (Rajotte, 2000a).

10 Already in the 1980s, 7 of the top 10 OECD-based firms were involved in mergers and acquisitions, while following the trend of acquiring or operating joint ventures with firms of the Southern Hemisphere (PPI, 1999).

11 The perception has been reinforced by a traditional reliance on outside sources of technical development, a reported low research intensity, and science & technology indicators ranking the sector at the bottom of the OECD listing of technology levels of industries. In fact, unaccounted R&D costs and co-operation among members of the forest cluster is the norm rather than the exception in this sector (Laestadius, 1998).

12 Pulp production involves extracting fibre (50-60% of wood) by removing non-cellulosic components: bark, lignin, hemicellulose and extractives. This is done by either

mechanical or chemical means, or a mix of both. Both hardwood and softwood are suitable for pulp production. Hardwoods contain more fibres of higher initial brightness, but of shorter length (0.05 inch), while softwoods contain more lignin, but longer fibres (up to 0.2 inch) that provide greater strength. Hardwood is generally ill suited to mechanical force that reduces fibre length. With wood accounting for 55% of production costs, mechanical pulp has an apparent economic advantage, converting 90-95% of the wood as pulp. But its high energy requirement offsets this effect. It also damages the cellulose, producing short fibres (lower strength) and leaving much lignin in the pulp, making it unsuitable for certain end-use. In contrast, chemical pulping produces brighter and stronger fibres that meet the desired properties of higher grade products. But it leads to higher capital and operating costs, lower yields (about 45% of pulp as wood) and more environmentally complex effluents. Papermakers most commonly mix different pulps to meet product specifications, while minimising manufacturing costs.

13 The kraft process has not fundamentally changed since its patent in 1884, but has been significantly refined into a stepwise progression of chemical reaction, evolving from a single stage hypochlorite (H) treatment to a multi-stage process, involving chlorine (Cl_2), chlorine dioxide (ClO_2), and sodium hydroxide (E), leading to the conventional CEDED bleaching sequence. The introduction of Cl_2 bleaching made it possible to use kraft pulp in information grades. This breakthrough was strengthened with the use of ClO_2, which made it possible to bleach pulp to a very high final brightness. The pulp could then be used in the most demanding grades. Concurrently, the problems of extractives in hardwood pulp, which were harmful in papermaking, were solved and birch kraft pulp became the dominant source for fine paper production (USEPA, 1995).

14 Higher costs of chemical recovery in the sulphite process were eventually the deciding factor for the industry-wide shift to kraft pulping. In Finland, analyses comparing the cost of recovery systems between sulphite and sulphate pulp production always came out in favour of switching to kraft pulping (FEI, 1996).

15 A modern bleached kraft mill, with an average capacity of about 500,000 tonnes/year, can cost in excess of US$1 billion, or more than US$1 million per employee, the likely sales of the plant over 3 years.

16 Econometric models show that there is more adoption of new technologies in major industrial nations, given the higher number of domestic firms and technological spill-over in line with agglomeration economies (Wheeler and Martin, 1992).

17 Thus, Stone Groundwood is the cleanest technology, but does not meet most contemporary quality standards.

18 A dynamics similar to that of the iron and steel industry, where the mini-mill concept flourishes, given its lower capital and labor costs, and increased production flexibility (Rajotte, 2000b).

19 Thus, the preamble of the 1972 United States' Water Act called for the elimination of "the discharge of pollutants into the navigable waters (…) by 1985" (Tietenberg, 1996).

20 BOD measures the oxygen consumed by bacteria feeding on the biodegradable components in the effluent. Thus, it is particularly suitable to establish limits for effluents discharged to water bodies with low dissolved oxygen content. COD is a better indicator of total contaminants, measuring all components, including those recalcitrant to bacteria. Since external treatment is better fit to control organic matters of the final effluent, it is not very much efficient in removing COD. Under tight COD standards, internal measures are necessary to detoxify the primary effluent upstream of P&P operations (SIMONS, 1994).

21 In 1980, USEPA estimated it to US$1.4 billion in capital expenditures and $430 million in operating costs (MEB, 1993). Environmental investments cannot normally exceed 15-25% of total capital costs without affecting the affordability and profitability of pulp manufacturing (Jaakko Pöyry, 1997).

22 Prospective research on Cl_2 began in the late 1960s and intensified from the 1970s to the 1990s through joint work involving P&P firms, such as Stora and Södra, equipment and chemical suppliers, such as EKA, Kvaerner, Sunds and Kamyr, as well as research institutes (Axegård, 1998).

[23] Although the 1977 amendments to the US Clean Water Act were to relax control over conventional pollutants to allow more cost-effective, in plant methods against secondary treatment on a case-by-case basis, the ensuing interpretation of BAT kept being based on end-of-pipe control (SIMONS, 1994)

[24] Richard Phillips, senior vice-president at International Paper, suggests that the failure to anticipate the degree at which environmental concerns about the biological impacts of pulp mill effluents may impact on the sector is partly explained by the demarcation between the industry and its equipment suppliers. In such a context, there is little cross-fertilisation between compliance and production technology, and end-of-pipe control techniques tend to be the dominant response (Ashford, 1994).

[25] Albrecht (1998) explains the shortcomings by the fact that nations with diversified export patterns can only suffer marginal losses from stricter regulations. He suggests that the relationship between competitiveness and environmental regulation may be more measurable at the level of final products.

[26] The most influential action came in 1991with the release of a false copy of *Der Spiegel* (*Das Plagiat*) by Greenpeace, in Germany. The TCF-paper printed magazine contained information on cleaner technologies and mills that produced such paper. The action had a profound effect on the public opinion in Germany, a country where the lobbyist and consumers carried a great influence on paper specifiers, purchasers, and also on publishers when it came to the choice of paper. Soon enough, many publishers notified their suppliers that they would require TCF paper at the earliest possible. In a three-month interval, all tissue products in Germany, Austria and Switzerland switched to TCF pulp or recycled fibres (NLK, 1992).

[27] Mölnlycke, a subsidiary of Sweden's Cellulosa AB (SCA) and owner of a major baby diaper producer in Europe, Peaudouce of France, had first exploited the issue by warning the public that dioxins as by-products of Cl2 bleaching could transit through baby skin via conventional diapers. Interestingly enough, the French pulp producers launched a lawsuit against SÖDRA for deceiving the consumers. Conversely, their Finnish competitors considered the move as a simple matter of competition, which reflected their acknowledgement of the shift towards Cl_2-free products on the Northern European markets (Reilame, 1998).

Paper 2 –

LIMITS AND INCONSISTENCIES OF ENVIRONMENTAL REGULATION OF INDUSTRIAL POINT SOURCES: THE CHALLENGE OF INTEGRATION

Introduction

The evolution of environmental regulation testifies to governmental will to ensure a high level of environmental protection by imposing emission limit values (ELVs) based on the concept of best available technology (BAT). Implicitly, adopting the precautionary principle[1], in response to the increasing awareness of irreversible effects that can result from human activities, has helped give the BAT concept its present importance in the decision-making process. In so doing, the pollution prevention and control paradigm has established technological assessment as the best way of ensuring that potential risks are addressed and that the levels of environmental compliance evolve in accordance with technological progress.

The BAT concept has quickly become a cornerstone of environmental policy across member countries of the Organization for Economic Co-operation and Development (OECD). The Clean Water Act of 1972 in the United States has established the concept under a variety of applications, among others, the Best Available Control Technology (BACT). Since 1987, the United Kingdom has been setting discharge limits in terms of Best Available Technology Not Entailing Excessive Costs (BATNEEC). The French Environment Ministry uses this principle when establishing emission standards and has been instrumental in persuading the European Union (EU) to develop BAT guidelines for various industrial sectors within the framework of its Integrated Pollution Prevention and Control (IPPC) directive (Wallace, 1995; Lesser and Dodds 1997; OECD 1999c).

From the 1970s onwards, the BAT approach has imposed major investments into environmental measures to reduce industrial pollution. Yet, it appeared that a technology-based strategy only offers a short-term response and not a lasting solution to environmental problems. Within single-media regulations, BAT requirements did not prevent pollution transfer from one media to another. Thus, although technology-based standards have increased the level of public health and environmental protection, they did not reduce the rates of cancer caused by exposition to chemical products in the United States (Travis and Hester, 1991).

The hopes founded in the BAT approach to shift technological progress towards a more sustainable pathway have also been dispelled. Neither conventional economics (i.e. internalizing externalities), nor command-and-control regulations and ambient-based standards have elicited the type of technological dynamism needed to alter the current patterns of ordered change in manufacturing technologies. Environmental considerations remain marginal and amalgamated to the main technical and economic criteria that shape technological innovations (Wheeler and Martin, 1992)[2]. Continuous improvements in process technologies and control equipment have progressively untied the traditional relationship linking production growth and pollution increase in a number of industrial sectors (Rajotte, 2001a; 2001b). Yet the aggregate effects of world production and consumption increases continue to outweigh some of the cumulative environmental benefits of technological change (OECD, 2001). Economic growth and the intensification of international competition contribute to the development of more productive technologies that pose a threat to ecological resilience, as illustrated by overfishing at sea and the unbridled growth of cars worldwide (Munro *et al.*, 2001; Wiederkehr, 2001). Preliminary estimates foresee that expanding economic activities will push the limits of ecological systems further. In the long run, the continuous destabilization of ecosystems threatens both ecological integrity and economic development, urging the need for developing ways of harmonizing economic growth and environmental quality (Ring, 1997).

In this context, environmental policy appears at a turning point. The potential risks of ever-increasing imbalance between economic and ecological systems call for a significant shift in environmental policy, from merely requiring compliance measures to encouraging radical technological change in order to achieve major advances towards sustainable patterns of development. The issue brings forth the need to address limits, inconsistencies and contradictions in environmental approaches impeding the harmonization and co-optimization of economic growth and ecological integrity.

This paper draws on the results of the OECD's four-year, multi-country study on the use of BAT and environmental quality objectives (EQOs) in industrial permitting[3]. Particular attention is paid to the role of technological, ambient-based and economic considerations in the standard-setting procedure. A number of issues are identified within the framework of standard-setting and permitting procedures. An historical perspective is used to illustrate the structural and cognitive effects linking economic and ecological systems. It is argued that regulatory change must be understood in filiation, not in rupture, with the contradictions inherent to different paradigms driving the relation between economic development and environmental protection.

The evolution of regulatory paradigms: at arm's length

The discussion on the use of BAT-based requirements and environmental quality objectives/standards (EQOs/EQSs) has often been held in an antinomic perspective. As such, these policy instruments are perceived as mutually exclusive:

- An all-EQO approach linking the actual quality of a given environment with the sources emitting polluting substances into this particular environment can be the ideal system to avoid "unnecessary" costs resulting from overly stringent regulations;
- An all-BAT approach is the most appropriate system to avoid the problems posed by scientific uncertainty about the risks of pollutants to humans and the environment.

Yet, the issue is not as clear-cut. The evolution of environmental policy shows that regulatory authorities have progressively attempted to reduce *areas* of uncertainty by integrating ecological, economic and technological considerations in decision-making. By focusing on three interrelated constituencies of environmental policy, it is possible to understand how some specific approaches and instruments came to serve a central position across OECD countries[4]:

- Up to the 1970s, utilitarian views justified the 'throughput society'. Regulations reflected a lack of legislative authority, as well as substantial industry influence over standards setting (Ashford, 1994). Ill-adapted, ambient-based standards helped provide a "free-ticket" to operators discharging pollutants. The approach fitted well with the prevailing notion that unused environmental resources are economically wasteful (Frederick, 1994). Adverse impacts caused by 'dilute and disperse' policies were then viewed as mere externalities, solvable given the right set of regulatory and economic signals to restore economic equilibrium;
- From the 1970s onwards, environmental awareness increased as people experienced the adverse environmental and social impacts of permissive ambient-based policies. In 1972, the United States adopted the Clean Water Act, which introduced a permitting procedure imposing on major industrial sources the implementation of environmental protection measures based on the best environmental control technology. The change represented a radical departure from earlier policies since it precluded the importance of ambient-based standards in setting requirements (Tietenberg, 1996);
- In the 1980s, authorities realized that pollution prevention and control was far more complicated than previously believed and required substantial financial and human commitments. National technology-based standards imposed major costs and, in some cases, led to no net environmental and social benefits in a majority of sites for some sectors (Luken and Clark, 1991). The industry used its expertise to force delay and impose on authorities justification of large expenditures. It became clear that decision-making was to be grounded in an epistemology that could confer legitimacy based on both environmental improvements and the cost-effectiveness of measures.

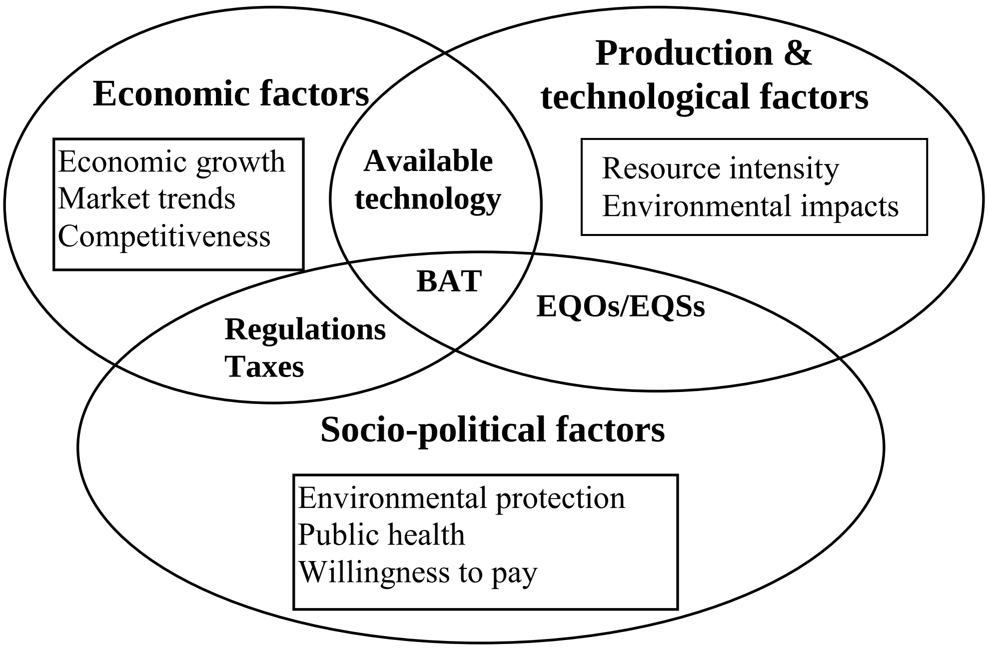
This basic summary suggests that the adoption of an all-BAT-based approach was driven by the inference that ambient-based policies were fully responsible for past failures. Early confidence in the BAT approach rested on the belief that pollution could be more easily delineated, controlled or prevented at the *end-of-the-pipe*, without any recourse to costly environmental cross-checking. Mandating "zero-discharge" through BAT-based standards had also the appearance of political toughness, wished for by a worried public opinion.

However, the lack of any connection to ambient-based standards turned out to be shortsighted, both from an environmental and political standpoint. Implementing "zero-discharge", with no distinction as to the nature of polluting substances, was economically questionable. Quickly, the industry took advantage of the absence of cost-benefit cross-checking to discredit the drive towards tougher technology-based standards. They argued that overly stringent regulations threatened economic growth and stalled productivity, while diverting resources away from business innovation (Skea, 1994). The absence of compliance deadlines for "zero-discharge" in the American legislation shows that the authorities quickly understood that it was politically inoperative (Tietenberg, 1996). In a way, the shortcomings of an all-BAT approach provided some political leeway to proponents of cost-benefit analysis as a means to subject environmental regulations to the requirement of economic viability[5].

Moreover, a technology-based approach cannot guarantee the prevention of pollution (Portmann and Lloyd, 1986). The evidence is that we can hardly assess changes affecting the environment subjected to various stresses without a broader understanding of ecosystems. Technology-based standards led to a significant reduction of industrial pollution, but the overall result was ambiguous. Increasing chronic and global problems (dioxin, acid rain, global warming, etc.) provided evidence of shortcomings, in particular the inability to account for pollution transfer across media and toxicity eluding detection.

Thus, the swing of the pendulum between environmental and technological considerations resulted from their respective shortcomings. Defining problems and prescribing solutions through linear cause-and-effect relationships proved inadequate and restrictive, as well as inappropriate for neither integrating different options and instruments, nor adapting new information as issues were evolving. Fundamentally, it ran counter to the dynamics and complexity of both ecosystems and social systems. Figure 1 illustrates how regulatory settings are tributaries of a confluence of economic, technological and socio-political factors. The intrinsic complexity at the interface of ecological and social systems, and information asymmetries among stakeholders require to go beyond static balancing of considerations towards a more dynamic and complex concept of policy, where risk and uncertainty (economic, environmental, political) can be viewed as a function of decision.

Figure 1 – Interplay between economic, environmental and political factors

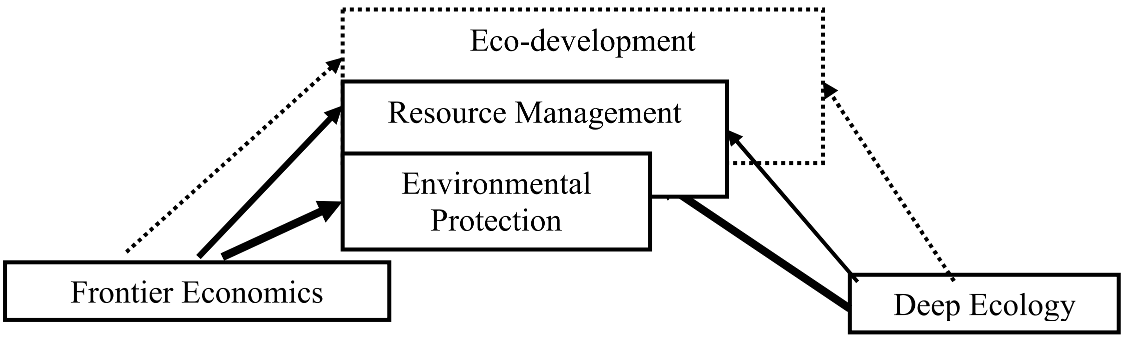


(Adapted from OECD, 1999a)

In that frame of analysis, factors driving decisions (e.g. economics, politics, science, technology, etc.) cannot be held as a constant factor of policy but as variables subjected to the specifics of the problem under review, its institutional locus and local settings. What matters then to understand policy changes is the knowledge actually used in decisions, and not necessarily if this knowledge is scientifically validated nor plausible for a particular group of actors; even more so since environmental issues have proven plastic over time.

History teaches us that policy changes often came in response to dramatic experiences associated with environmental pollution, e.g. Seveso, Love Canal, Bhopal, Schweizerhalle, etc. Thus, the dynamics of change may be construed as organizational responses to observed gaps between observed outcomes and aspiration objectives (Levitt and March, 1988). Paradigmatic upheavals affecting what should be economically viable, ecologically necessary and politically realistic appear as such much more as a social dynamics, rather than the result of rational, cumulative and systematic attempts at introducing comprehensive strategies and means. Borrowing from Lakatos's view, an analogy can be drawn between the competition among regulatory paradigms and the one among research programs in science (Majone, 1980). In a way, the paradigmatic overlaps among different environmental management approaches reflect not only the competition among various schools of thoughts, but also the conflicts of interest for the primacy of decisions inherent to policy settings. In so doing, the regulatory dynamics give rise to a continuous development of the different concepts and instrument, and consequently to a transformation of each of the paradigms (Colby, 1991). Figure 2 provides an illustration of the co-evolutionary process that characterizes paradigmatic change in environmental management within OECD countries. Developments over time suggest that OECD countries have progressed incrementally in adapting and developing institutional and organizational approaches to better manage the contradictions linking economic development and environmental integrity. Evolving trends in approaches and instruments, and their effects on industrial responses, are summarized in Table 1. Outlooks beyond 2000 are included to show ongoing developments.

Figure 2 - Evolution of environmental management paradigms



(Source: Colby, 1991)

The diagram attempts to illustrate the non-linearity of environmental management evolution. The vertical scale indicates the progression over time from one paradigm to the next, going upwards; the horizontal scale, the position of the paradigms between the diametrically opposed views of frontier economics and deep ecology. The size of the boxes suggests the different degrees of inclusiveness and integration of the different factors affecting the human/nature relationships. Non-solid lines indicate the hypothesized future (Colby, 1991).

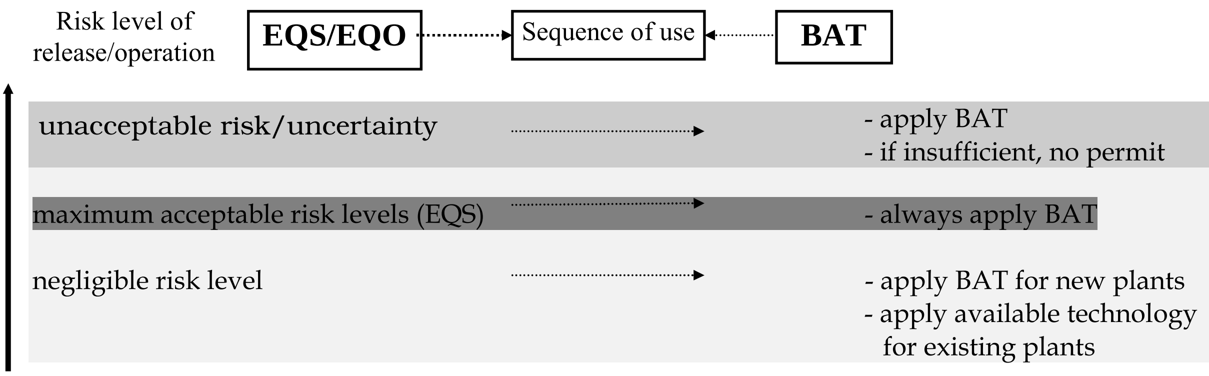
Table 1 – Regulatory approaches and industrial response in OECD countries

	Prevailing Regulatory Paradigm	Industrial Response
1945 – 1970	Assimilative capacity Ambient-based standards based on intended uses and environmental classification of sites	Pollution control techniques "Dilute and disperse" strategies
1970 – 1980	Pollution control Single media-specific approaches Focus on releases/by-products Few environmental quality standards End-of-pipe control requirements	Primary end-of-pipe treatment Waste treatment management Improving process/product yield
1980 – 1990	Pollution prevention and control Ecosystem approach Environmental quality standards Combinations of regulatory and economic instruments with focus on detoxification Trends towards integrated approaches Environmental impact assessment Public information system	Pollution prevention at source Implementation of '3Rs' (reduce, reuse, recycle) Secondary and tertiary end-of-pipe treatment and integrated technologies Improving process and product yield while reducing impacts
Beyond 2000	Eco-efficiency/de-materialization strategies Resource productivity Life cycle management Environmental cost accounting Combining environmental permitting with voluntary agreements Long-term goals Regulatory approaches for products and services	Closed-loop technologies Environmental management systems Reduction of total material intensity Eco-efficiency concepts for production Benchmarking of activities Provision of services rather than physical products

(Adapted from OECD, 1999a)

Lessons learned through the shortcomings and benefits of regulatory approaches have contributed to the displays of different combination between BAT and EQOs/EQSs in the decision-making process, with economic considerations generally playing a buffering role. BAT-based standards are considered key to the implementation of an environmental level playing field as it rewards the best environmental performers by eliminating some undesirable dimensions of competition. A commonly agreed procedure has evolved in which BAT is first applied, regardless of environmental considerations, in order to require the most optimal achievable environmental option; EQOs/EQSs are then used as a reference to confirm compliance with some agreed level of environmental quality. Where EQSs are exceeded, further reductions must be required beyond levels achievable by BAT-based measures. This may lead to closures or denied authorizations of process expansion or modification of existing sources. The relationships and sequence of use are illustrated in Figure 3.

Figure 3 - Sequence of the combined use of BAT and EQOs/EQSs



(OECD, 1999a)

The combined use of technological and environmental considerations in decision-making reflects a relative degree of integration of different environmental management paradigms. These developments constitute a response to the shortcomings resulting from a mutually exclusive use of ambient-based and technology-based approaches. Yet, these approaches carry ambiguities and contradictions that the environmental regulation claims to resolve.

Economics and BAT: reconciling industrial growth and environmental protection

Economic methodologies for devising appropriate environmental conditions for major point sources are a matter of contention between stakeholders. The industry seeks to keep control over regulatory forecasting by subjecting it to traditional investment cycle analyses. Regulatory authorities have adopted a technology-based approach to avoid bias or otherwise inadequate instrumental perspectives that either neglect or exaggerate economic or environmental factors. The industry acknowledges the concept of a *best* environmentally wise technological level, but considers that economic considerations are open to interpretations because the notion lacks a clear and practical definition (Welford and Gouldson 1993).

While definitions and administrative procedures may vary among countries, the concept of best available technology is used according to similar principles:

- *Best* usually refers to environmental performance achieved by the average best 10-15% plants of the particular sector of concern worldwide;
- *Available* implies that regulatory requirements be based on well proven, commercialized techniques and practices; and
- *Techniques* includes production and pollution control techniques, plant and process design, housekeeping and training in preventing/reducing/controlling environmental impacts.

As a rule, the incorporation of economic considerations is subjected to the nature of polluting releases under review. OECD countries have gradually applied a principle according to which releases of hazardous substances (e.g. persistent, bio-accumulative, carcinogenic pollutants) are ineligible for review or waiver on economic grounds. The control of conventional pollutants are subjected to more flexibility, taking into account the assimilative capacity of local environments, although loosening BAT limits is generally the exception confirming the rule.

Approaches towards economic considerations may also differ whether limits will be established on a case-by-case basis within the framework of environmental permitting (e.g. Nordic countries) or via nationally-set standards that provide floor requirements at the permitting level (e.g. United States, Germany). Most countries apply general criteria to determine the economic impacts of measures they impose. These criteria usually refer to an average plant operated by an average, financially sound firm of the particular sector of concern. Thus, the economic situation of an industrial sector will be taken into account against such a yardstick, but the cash flow situation of a particular firm should, in principle, be disregarded.

Policy wisdom calls for harmonizing economic parameters at the national and even international level in order to avoid economic distortions and unduly burden on competitiveness. However, across-the-board parameters are likely to introduce inefficiencies in resource allocations and/or inadequate conditions at the local level, which runs counter to the proclaimed objective of taking economics into consideration. It is quite revealing to observe the manner in which countries resolve the tension between the need for a regulatory harmonized economic level playing field, on the one hand, and local environmental conditions for maintaining environmental quality, on the other hand. One seems to be at the expense of the other. Either specific conditions of the receiving environment are paramount, in which case they induce distortions between similar process operating in vastly different environments. Alternatively, local conditions are not taken into account to avoid economic distortion, in which case the requirements are patterned after a set level of across-the-line environmental parameters that may be either too low or too high. This issue was constitutive of the debate that took place within the EU during the proposition for the IPPC directive. Policymakers have not brought the issue to a close. Article 9 of the directive indicates that the physical setting of a facility, as well as the conditions of its receiving environment must be taken into account in setting ELVs, which gives discretionary power to the permitting authorities.

When comparing regulatory approaches between jurisdictions, the evidence suggests that, although policy principles may appear straightforward, practice often diverge from proclaimed best approaches or commitments. Thus many, if not all, countries allow standards weaker than BAT to be applied. Among noteworthy examples taken from the study:

- South Korean authorities indicate that technological assessment is a determining factor, yet concentration-based parameters are still used in setting environmental requirements, although dilution can be used as a means of compliance (Hatch Associates, 1995; OECD, 1999d);
- End-of-pipe requirements may be a most important factor whether industrial processes are validated or dismissed as BAT. Sinter operations in steelworks have been shutdown in Sweden, while retained in the United Kingdom with the inclusion of end-of-pipe devices in setting BAT limits. Priority risk ranking and interpretation of assimilative capacity have been influential in such decisions (OECD, 1999a); and
- Finland, Canada, and the United States have focused on biological oxygen demand (BOD) when establishing BAT limits for pulp and paper plants. Using the high dilution conferred by the Baltic Sea, Sweden has loosened its BOD limits because it acts as an economic disincentive to the implementation of in-plant measures detoxifying the primary effluent (Rajotte, 2001c; Rajotte and Smith, 2001).

The review of permits within the framework of the OECD's project on industrial permitting indicates a trend towards a combined use of BAT and EQSs/EQOs in setting environmental requirements. But the reasons underlying this trend reflect national differences in priority ranking and economic considerations, rather than convergence. Obviously, risk priority of industrial pollution cannot be generalized given that different cause-and-effect relationships are, in part, a function of differences relative to local contexts, e.g. production siting, cultural and political traits, etc. Yet, these differences are reinforced by the ambiguous economic criteria in the BAT definition. On the one hand, the notion of economic viability establishes pollution as inherent to industrial production by juxtaposing economic and environmental considerations in the standard-setting procedure. On the other hand, the lack of a clear and practical definition of economic considerations increases the discretionary power of authorities. In the end, the BAT concept leads to a more or less sophisticated procedure that imposes on industry to integrate environmental protection within its economic limits (Lascoumes, 1994). Despite the displayed objective of constraining industrial activities to sustainable development, the BAT approach reconciles, at best, economic development and environmental protection, illustrating the difficulty of fully integrating economic and environmental considerations into a sustainable pathway.

The idea that environmental needs are constrained by some level of existing technological performance appears odd, given the ongoing contradiction between economic and ecological systems. If the notion of economic feasibility is incorporated in both technology-based requirements and EQSs, BAT may lead to a relative level of technological *status quo*. Although regulations tend towards greater stringency, BAT-based limits are typically based on existing technology. Obviously, this problem raises the critical issue of the impact of regulations on technological change. Too much certainty in the means to attain compliance is not likely to result in changes beyond those complying with the requirements (Ashford, 1994). In this context the BAT approach appears more suitable for technological diffusion than technological innovation and does not provide for the much-needed environmentally oriented technological dynamism[6].

EQOs/EQSs, a necessary counterpoise to the notion of economic viability

The review of regulatory practices among OECD countries confirms the difficulty of establishing a correlation between ELVs and EQSs (OECD, 1999a)[7]. There are still EQOs that set up threshold limits for certain pollutants according to a classification of particular usage of specific areas (e.g. protected ecological zones, recreational areas, industrial zones, etc.). Yet, these usually act as guidance and do not have force of law. Despite the deficiencies of an all BAT-based approach as a regulatory fundament, we can only remark that the development of EQOs and EQSs remain rather limited. The fact that EQOs/EQSs are science-intensive, yet uncertain, except in the case of some pollutants for which threshold limits are well known, may explain why this development does not appear to be a political priority. Table 2 provides an overview of EQOs and EQSs in some countries that suggests their limited scope within the regulatory process.

Table 2: EQOs and EQSs Criteria in some OECD Countries

	EQO Criteria	**EQS Levels**
CANADA	- Quantitative and qualitative terms to support and maintain particular uses of the environment	– EQS for water, sediment, soil, biota tissue, drinking water – EQS according to media, resource use and ecosystem
FINLAND	- Few EQOs - Air target limits - Water classification scheme	– Decided at licensing stage
FRANCE	- EQOs dependent on actual quality of the media	– Purpose is to have optimal water quality everywhere in country – Binding air EQSs – Regions can adopt more stringent levels
GERMANY	- Effects on the environment which affect humans, animals, plants, soil, water, atmosphere, cultural assets and other material goods	– Emission values
JAPAN		– Standards set for each category of waters (river, lake, marsh, sea areas) – Standard parameters = pH, BOD, SS, DO, number of coliform groups
HOLLAND	- Available scientific/technical data - Available information on state of environment - Expected developments - Options for restricting risk - EQOs set below Maximum Permissible Concentration (MPC) but no lower than Negligible Concentration (NC)	– Air Quality Standards for SO_2, black smoke, NO_2, CO, lead, benzene – Guide values for 24 substances (e.g. VOCs, PM_{10}, ozone, asbestos) – Air quality objectives for NO_2, SO_2, benzene

SWEDEN	- Ensure the survival of healthy, balanced populations of naturally occurring species	– National air quality standards on SO_2 and NO_2 – Local limits on noise, vibration, light
UNITED KINGDOM	- Maintaining and improving the quality of receiving environment	– Classification of controlled waters, statutory objectives replacing administrative strategies – National air quality standards developed = air quality standards that represent no or minimal risk of health effects to the public = benzene, 1,3 butadiene, CO, Pb, NO_2, O_3, PM, SO_2
UNITED STATES	- Air: Protecting public health and the environment from pollutants - Water: Protecting the designated use of water bodies - Waste: Protecting public health and environment from release of hazardous constituents in the wastes	– Air: National Ambient Air Quality Standards (NAAQS) for CO, Pb, NO_2, O_3, PM_{10}, SO_x; National Emission Standards for HAPs (189) - Water: Water quality standards + development of specific national recommended criteria for protection of aquatic life and human health

(Source: OECD, 1999a)

The influence of economics can only be reinforced by the limited place taken by EQOs/EQSs in decision-making. Though EQOs/EQSs are essentially scientifically driven and immune, in principle, from the financial considerations of management policy, costs may vary considerably for meeting standards from area to area. Local environmental conditions affect the permit requirements that are set for individual facilities. Thus, if a facility is in a "non-attainment area"[8], ELVs will be stricter and economic costs higher. If not, the available assimilative capacity of the environment can be used and will be a reason to argue that BAT limits are expendable. Economic considerations thus become a determining factor of environmental quality.

Conclusion

Despite a clear desire for a complementary use of economic and environmental factors into decision-making, regulatory approaches within OECD countries address the problem of integration rather than resolve it.

The BAT approach does not solve the conflict of interest that drives the relationship between economic development and environmental protection. By downgrading the importance of EQSs/EQOs in decision-making and reinforcing the discretionary power of local authorities through loosely defined economic criteria, the BAT approach subordinates, in part, the setting of environmental measures to the hazards of economic progress.

Obviously, neither technological, economic nor scientific assessments are capable by themselves of eliciting the type of social dynamism needed to shift economic development towards sustainable patterns. Solving environmental problems underlines the importance of social learning in adapting and developing policies and methodologies capable of dealing with the inherent complexity at the interface between economic growth and environmental quality.

To this end, environmental permitting systems are of strategic importance. Strengthening the connection between EQSs/EQOs and BAT-based limits in order to bridge short- and longer-term environmental goals is key to ensure that continuous signals and incentives for structural change are integrated into economic development. These tasks illustrate the case-by-case nature of environmental permitting and stress that regulatory decisions are fundamentally political.

It thus appears that solving the conflicts of interest between economic growth and environmental protection within a sustainable development perspective is tributary of the broadening of the decision-making process to all of the stakeholders.

BIBLIOGRAPHY

Ashford NA. 1999. An Innovation-Based Strategy for the Environment, in *Worst Things First?,* A. Finkel (ed.), RFF, WOC, 275-314.

Colby, ME. 1991. Environmental Management in Development: the Evolution of Paradigm, *Ecological Economics*, 3: 193-213.

Frederick KD. 1994. Environmental Values and Water Use, *Resource*, Fall: 19-23.

Hatch Associates Ltd. 1995. Releases and Control of Priority and Other Substances of Concern from the Iron and Steel Industry in Canada, Ottawa: *Environment Canada*.

Jackson, T. 1993. *Clean Production Strategies*, London: Lewis Publishers.

Kneese A., Schultze C. 1975. *Pollution, Prices and Public Policy*, Washington: Brookings Institute.

Kourilsky P. 2002. *Du bon usage du principe de précaution*, Paris: Odile Jacob.

Lascoumes, P. 1994. *L'éco-pouvoir, environnements et politiques*, Paris: La Découverte.

Lesser JA., Dodds DE. 1997. *Environmental Economics and Policy*, Reading: Addison-Wesley.

Levitt B., March JG. 1988. Organisational Learning, *Annual Review of Sociology*, 14: 319-340.

Luken RA., Clark L. 1991. How Efficient Are National Environmental Standards? A Benefit-Cost Analysis of the United States Experience, *Environmental and Resource Economics*, 1: 385-413.

Majone G. 1980. Policies as Theories, *Omega*, 8: 151-162.

Munro G., Bertuzzi C., Chung C. 2001. Fisheries Trends: A Background Report, Background document for the *OECD Environmental Outlook*, Paris: OECD.

Organisation for Economic Co-operation and Development 2001. *OECD Environmental Outlook*, Paris: OECD.

OECD 1999a. *Environmental Requirements for Industrial Permitting – Vol. 1 – Approaches and Instruments*, Paris: OECD.

OECD 1999b. *Environmental Requirements for Industrial Permitting – Vol. 2 – OECD Workshop on the Use of Best Available Technologies and Environmental Quality Objectives*, Paris: OECD.

OECD 1999c. *Environmental Requirements for Industrial Permitting – Vol. 3 – Regulatory Approaches in OECD Countries*, Paris: OECD.

OECD 1999d. *Environmental Requirements for Industrial Permitting – Case Study on the Iron and Steel Industry*, Paris: OECD.

Portmann JE., Lloyd R. 1986. Safe Use of the Assimilative Capacity of the Marine Environment for Waste Disposal – Is it Feasible?, *Water Science Technology*, 18: 233-244.

Rajotte A. 2001a. Pulp and Paper Industry, Background document for the *OECD Environmental Outlook*, Paris: OECD.

Rajotte A. 2001b. "Iron and Steel Industry", Background document for the *OECD Environmental Outlook*, Paris: OECD.

Rajotte A. 2001c. Case Study on Chlorine Policies in the Pulp and Paper Sector in Finland, France and Sweden, Technology and Environmental Policy (TEP), Brussels: *European Commission*.

Rajotte A., Smith A. 2001. When Markets Meet Socio-Politics: the Introduction of Chlorine-free Bleaching in the Swedish Pulp and Paper Industry, in *Technology and the Market – Demand, Users and Innovation*, Coombs R., Green K., Richards A., Walsh V. (eds.), London: Edward Elgar, 136-155.

Ring I. 1997. Evolutionary Strategies in Environmental Policy, *Ecological Economics*, 23: 237-249.

Simpson AE., Mangan E. 1997. The Effects of Government Environmental Policy on Costs and Competitiveness – Iron and Steel Sector, Paris: *OECD*.

Skea J. 1994. Environmental Issues and Innovation, in *The Handbook of Industrial Innovation*, Dodgson M., Rothwell R. (eds.), London: Edward Elgar, 421-431.

Sowell T. 1996. *Knowledge and Decisions* (2nd edition), New York: Basic Books.

Tietenberg T. 1996. *Environmental and Natural Resource Economics* (4th edition), Cambridge: Harper Collins.

Travis CC., Hester ST. 1991. Global Chemical Pollution, *Environmental Science & Technology*, 5: 815-818.

Wallace D. 1995. *Environmental Policy and Industrial Innovation Strategies in Europe, the US and Japan*, London: Earthscan,.

Welford R., Gouldson A. 1993. *Environmental Management and Business Strategy*, London: Pitman Publishing.

Wheeler D., Martin P. 1992. Prices, Policies and the International Diffusion of Clean Technology: The Case of Wood Pulp Production, in *International Trade and the Environment*, Low P. (ed.), Washington: World Bank, 197-224.

Wiederkehr P. 2001. Environmental Outlook to 2020 for Transport, Background document for the *OECD Environmental Outlook*, Paris: OECD.

REFERENCES

[1] Originally developed in Germany, the 'precautionary principle' was introduced at the international level at the First International Conference on the Protection of the North Sea in 1984 (Jackson, 1993). Publicly praised at the Earth Summit in Rio in 1992, it was adopted the same year in the Maastricht Treaty. Its definition remains open to different interpretations. For some, it basically means that one should refrain from doing something for which doubts exist about its ultimate environmental consequences. For others, it should be read instead that, in cases of scientific uncertainty, the best thing might be to refrain a given activity, or else to take the best means to minimize the potential risks to an acceptable levels (Kourilsky, 2002).

[2] Environmental costs represent merely 1 to 5 % of overall production costs across OECD economies (Simpson and Mangan, 1997).

[3] The project on Environmental Requirements for Industrial Permitting was launched in late 1993. It involved three distinct phases: (i) a survey of permitting legislation, regulations and practices in OECD countries; (ii) case studies in four industrial sectors (pulp and paper, iron and steel, metal finishing, and oil refining); and (iii) an international workshop on environmental permitting of industrial facilities, which was held in May 1996. The project publications come in three volumes covering each of these phases (OECD, 1999a; 1999b; 1999c).

[4] The following discussion draws mainly on the United States' experience, although it provides a good illustration of similar developments across OECD countries.

[5] It culminated into the adoption of the Levin Thompson Regulatory Improvement Act in the United States in 1997, which reinforces the obligation for public agencies to submit their legal requirements to an economic assessment.

[6] In the mid-1970s, experts were already stressing that the capacity to reorient the course of technological development towards more environmentally benign and resource-efficient processes was probably the most important single criterion to judge the performance of environmental regulation (Kneese and Schultze, 1975).

[7] Thus, Japanese authorities explicitly recognize that the BAT concept is used, although their legislation do not legally stipulate the concept because of the difficulty of defining limits based on carrying capacity of receiving environments (OECD, 1999d).

[8] Areas with measured violations of EQSs and areas that contribute to violations of EQSs are defined as "non-attainments areas" in the American legislation (OECD, 1999c).

PAPER 3 –

WHEN MARKETS MEET SOCIO-POLITICS -
THE INTRODUCTION OF CHLORINE-FREE BLEACHING IN THE SWEDISH PULP AND PAPER INDUSTRY

1 Introduction

This paper seeks to illustrate how situating events in their social and political context can improve our understanding of cleaner technology innovation and diffusion.[1] The paper discusses the shift to non-chlorine bleaching technologies in the pulp industry after discharges from traditional chlorine bleaching were found to be causing environmental damage. The case study is apt because green market demand is widely credited with bringing forth cleaner, non-chlorine technology in the industry. Sweden is recognised as having led the way in the new green market for non-chlorine pulp which emerged at the end of the 1980s, and is the main focus of this paper (though the outlook will be international where necessary). The paper suggests socio-political factors can be particularly useful when explaining green market demand and technological responses to that market demand.

The study also touches upon how technology choices stabilise, since the best replacement for the traditional chlorine process was by no means clear. Identifying the rich confluence of social, political, scientific, technological and market processes and how these positioned Sweden in the vanguard of non-chlorine technology requires a reconsideration of the chlorine bleaching story.

Important processes in the case are introduced after the following section has elaborated the event being studied, namely the switch away from chlorine bleaching, and the features that make the case so interesting. Following this, section three discusses the regulatory culture and processes in Sweden, where firms appeared best suited to meeting the chlorine challenge. The section argues that it is this regulatory culture which ensured technologies important for the rapid switch away from chlorine were already in place in many firms. Section four introduces the role regulatory science played in initially framing the chlorine issue. Section five explains how Sweden put that issue on the international political agenda and the activities of environmental groups in pushing the issue up the European public agenda. This section concludes with the dispute between pulp firms over which of the alternative non-chlorine technologies best addressed the chlorine problem. Section six brings the case up to date, with the stabilisation of bleaching technology around the cheaper technique, before the paper draws a few conclusions from the case study.

2 Switching away from chlorine bleaching in the pulp industry

The Kraft sulphate process is one of the key techniques for manufacturing wood pulp for papermaking. Kraft chemical pulping produces strong pulp fibres that are brown in colour and thus have to be bleached for many paper applications. The technological trajectory for Kraft pulping is rooted in the last century, and chlorine has been the conventional bleaching agent since the 1940s. The bleaching sequence widely practised in the early 1980s, where this case study begins, was established in the 1960s and involved bleaching first with chlorine, and then with chlorine dioxide.

Like many mature process industries, bleached Kraft pulp production is capital intense and large in scale. A modern bleached Kraft pulp mill can have a capacity of 500,000 tons per year - which means world production in 1995 could have been achieved with only 144 modern mills. A new mill can cost in excess of US$1000 million, i.e. more than US$1 million of capital per employee. Consequently, Kraft pulp tends to be bought from the market by papermakers rather than vertically integrated into production (which is the case with mechanically produced pulp, the other dominant fibre source for paper products).

Despite this scale and capital intensity, there was a rapid switch away from chlorine bleaching in the late 1980s and early 1990s, when it was discovered that the process discharged dioxins and other chlorinated organic compounds of environmental concern. Within five years chlorine bleaching was all but eliminated in European countries (Collins, 1994). Sweden was in the vanguard, and a number of alternative bleaching processes were introduced. The alternatives fell broadly into two categories - elemental chlorine free (ECF) pulp and totally chlorine free (TCF) pulp. ECF pulp eliminates chlorine but maintains chlorine dioxide as a bleaching agent, whilst TCF replaces chlorine and chlorine dioxide with non-chlorine bleaching agents (e.g. hydrogen peroxide, ozone, peracetic acid). Both ECF and TCF processes are capable of meeting the discharge limits for chlorinated organic compounds introduced by regulators in the late 1980s and early 1990s.

ECF proved an easier and cheaper transition for pulp producers, and it produces a pulp with physical properties not too dissimilar to those prized under chlorine bleaching (notably high brightness and strength). Switching to TCF was a more difficult and costly exercise for many of the world's pulp producers - either in terms of capital or in terms of operating cost (depending upon the TCF strategy taken).[2] Estimates for annual operating costs of ECF bleaching compared to TCF bleaching in 1998 for a 1500 metric tonne/day bleaching facility are ECU10-12 million compared to ECU18-21 million respectively (European Integrated Pollution Prevention and Control Bureau, 1998).[3] In the early 1990s, TCF pulp was also inferior compared to ECF pulp in terms of brightness and strength (though the differences have subsequently narrowed).[4]

Despite these disadvantages relative to ECF, TCF pulp capacity was installed in the early 1990s, particularly in Sweden, and a global market for TCF pulp has established. Indeed, the paper industry in the late 1980s and early 1990s was deeply divided over the issue of which technology should replace conventional chlorine bleaching. Today, an industry and regulatory consensus maintains that ECF and TCF discharges are environmentally equivalent, and only a few pulp mills solely manufacture TCF pulp – though many European mills are in a position to manufacture both. The explanation for why costly and inferior TCF capacity was installed ahead of clear regulatory demand (which in the event never materialised) attributes it to a straightforward case of green market demand (Simons, 1994; Auer, 1996; OECD, 1999). However, whilst transient green market demand was indeed a significant trigger, it masks a complex confluence of factors underpinning this episode in technical change and raises more questions than it answers:

- What generated this market demand?
- Why was such a capital intense, mature process industry able to respond so rapidly?
- Why were Swedish firms in the vanguard, and why did some firms move beyond ECF into more costly and inferior TCF bleaching?
- How has the choice between ECF and TCF bleaching technologies stabilised?

Answering these questions is instructive for analyses of market demand, particularly the green variety. The case study illustrates how the market greening phenomena is a result of interacting processes in regulation, regulatory science, politics, and markets. In this case study, green market demand was, ironically, promoted by regulation in two ways:

1. The science informing regulatory processes suggested a problem with chlorine bleaching, and this suspicion was forged into tangible public concern and thence market demand by political processes; and
2. Earlier, non-chlorine regulatory practices in Sweden positioned firms favourably with regard to adopting TCF techniques.

3 Regulatory culture in Sweden

To understand Sweden's vanguard position in the dechlorination story, and the ability of firms to switch away from elemental chlorine so rapidly, we need to appreciate prior regulatory practice in Sweden. Kraft pulp mill discharges are regulated under a licensing system first created under the 1969 Environmental Protection Act: a national licensing board establishes limits in a license, which is reviewed every 10 years. The system's integrated permitting approach emphasises prevention over control through a more thorough assessment of cross-media considerations. Other regulatory considerations include the 'substituting principle', requiring operators to substitute less-benign materials and compounds than the ones used when available (Act on Chemical Products, 1973), and the concept of best available technology as the starting point for permit limits (Rajotte and Renevier, 1999). Prior to the chlorine scare only conventional pollution parameters were regulated: Biological Oxygen Demand(BOD), Chemical Oxygen Demand (COD), Total Suspended Soids (TSS), colour, pH. Sweden was by no means unique in this regard, and was regulating parameters typical amongst Western industrial nations.

Less conventional was the means the Swedish regulator and industry sought for meeting these parameter limits. Whilst other countries (e.g. Finland, US and Canada) relied on waste water treatment plant to control discharge parameters (the classic end-of-pipe measure), Swedish authorities and firms pursued discharge improvements at many mills through internal modifications to the Kraft pulping process (akin to a cleaner technology strategy). This was made easier by the forgiving coastal location of many mills, where organic discharges like BOD and TSS could be dispersed and degraded in coastal waters. The uniform discharge performance associated with wastewater treatment plant was not considered so vital at such locations. Requirements like BOD limits in Sweden were much less restrictive, at 8-17 kg BOD/metric tonne (m.t.) of pulp, compared with the US 4-8 kg BOD/m.t. (Simons, 1994), on the understanding that internal process measures would be taken to improve environmental performance overall. This long-standing consensus remains between Swedish authorities and the industry, whereby efforts concentrate upon process change in addressing the overall environmental harm of plant operations (OECD, 1996).

Process changes such as improved washing techniques, modifications to the pulping stage, and the installation of an oxygen delignification process between the pulping stage and the bleaching stage have all helped reduce the organic load discharged by bleached Kraft pulp mills. Significantly, these were changes which also reduced the quantity of chemicals needed in the bleaching stage, making it easier to switch away from chlorine bleaching and use alternatives.

So one feature of the dechlorination story is that technologies facilitating the elimination of chlorine bleaching were already available and, in the case of Sweden, were in place with operational experience. Oxygen delignification, for instance, had first been introduced in 1970 at a South African mill where low water availability made the technology attractive. Oxygen delignification allows more of the process stream normally wasted to be recycled back to the pulping process, which also means around 50% fewer organic contaminants are passed through to the bleaching stage.[5] It was this latter potential to reduce organic pollution which influenced promotion and diffusion of the technology through Sweden in the 1970s and 1980s. Only later were the benefits for controlling chlorinated organic compounds realised. Fewer organic contaminants meant fewer chlorinated organic compounds were discharged after reacting with the chlorine bleaching agent. Other pre-bleaching steps, such as improved washing and screening, and extended cooking were also encouraged by authorities on similar grounds. The technologies also led to a significant reduction bleaching chemical inputs and volume of wastewater, and they avoided the costly secondary treatment required in other countries. Economic savings sweetened regulatory requirements. These changes would later provided a competitive edge to Swedish manufacturers when chlorine regulations and burgeoning TCF markets emerged. Reductions in the quantity of bleaching chemical allowed the removal of chlorine and made it easier to avoid chlorine dioxide too, i.e. switch to TCF.

So innovation in pulp bleaching did not rest solely on green market pressures. Important preconditions were facilitated by the style of the environmental permitting system in Sweden for conventional pollutants. The development and diffusion of TCF bleaching techniques was eased by practice of addressing environmental disturbances at source. These institutional dispositions played an important role in favourably positioning Swedish industry when international environmental concern did turn to chlorine bleaching. It provided Swedish mills with a first mover advantage to capture the burgeoning green market and the price premium for totally-chlorine free (TFC) papers and paper products.

Thanks to their process know-how, and mill retrofitting experience, the equipment and chemical suppliers in Sweden also benefited from increased world wide export markets. What appeared innovative chlorine-free pulping and bleaching techniques had actually been under long development and improvement through use in Sweden. Two Scandinavian firms, Sunds Defibrator AB and Kamyr AB, were involved in important innovations in extended cooking and oxygen delignification. Their commercialisation was the result of long years of research, starting in the 1960s. At the outset, these innovations were motivated by both economic and conventional environmental concerns, i.e. chemical cost and organic effluent load reduction. Green market demand - fuelled by the chlorine politics of the late 1980s (see below) - led to a tremendous surge in world-wide purchases of this equipment. Swedish pulp firms had important shares in these industries up until the 1990s, when capital deregulation led to their selling to foreign investments.

In summary, the integration of economic and conventional environmental objectives, as well as the style and concerns of Swedish environmental policy, were significant factors in positioning its industry in the vanguard of chlorine-free bleaching. However, whilst this provides an explanation for the rapidity of the response from a capital intense mature process industry, it does not say much about what triggered the switch away from chlorine. What generated the market demand for chlorine free pulp, particularly TCF? And was it purely fortuitous that Swedish approaches and technology to conventional pollutants were also suited to chlorine free bleaching?

4 The environmental problem with chlorine bleaching

The problems associated with persistent, mand-made toxic compounds were not new to the 1980s. Rachel Carson's 1962 book, Silent Spring, popularised concern about chlorinated pesiticides and was a seminal piece of environmentalism. Research into discharges of chlorinated organic compounds had been conducted in Sweden in the 1970s, by the industry as well as the authorities, and some claim this work can be traced back as far as the 1960s (Södra, 1996). But it was in the 1980s that Swedish policy-makers really began addressing the impacts of man-made toxics. Policy processes culminated in the 1988 Act, 'Environmental Policy for the 1990s'. There was concern that reliance on the assimilative capacity of the environment, implied in controls for traditional organic pollutants, could not be continued for persistent toxic compounds. Research into the environmental and technological implications of these substances began under the context of policy to reduce environmental releases of persistent toxic compounds. To this end, public funding for scientific and technological research was secured, as well as economic incentives for R&D

projects aiming at cleaner technologies and products. In the course of this work, it was soon found that Kraft pulp bleaching mills were a major source of chlorinated organic compounds.

Early research associated with this broad policy included a project to assess environmental risk from bleached Kraft mill effluents. The Environment/Cellulose I project was run by the Swedish National Environmental Protection Agency, as the exclusive funding source, and began in 1982 (Södergren *et al*., 1988). It aimed exclusively at possible links between chlorinated organic compounds and adverse environmental effects.[6] Within a year, Swedish officials were submitting evidence to the Helsinki Commission (HELCOM) implicating chlorinated organic compounds from pulp mills in the declining health of Swedish coastal waters (Helsinki Commission, 1983, cited in Auer, 1996).[7] HELCOM was the body responsible for overseeing the negotiation and implementation of marine environmental agreements between Baltic nation states. It was to become an important focus for chlorine politics (see later).

An important piece of Swedish scientific investigation was conducted in 1984-85 at the Norrsundet Kraft mill, located in the Gulf of Bothnia, and at a non-bleach Kraft mill which acted as a control. Researchers found evidence of altered fish populations, deformed eggs, reproductive disturbances, physiological anomalies, skin diseases and skeletal deformities, as well as high levels of chlorinated organic compounds in sediments in the vicinity of the bleached Kraft mill.

Although no direct cause-and-effect between chlorinated organic compounds and environmental damage could be demonstrated unequivocally, members of the project team expressed alarm over the toxic potential of the compounds, and the prospect of irreversible damage and costly remedial measures. A correlation between bleached Kraft mill effluent and documented environmental effects was underscored by a lack of damage to fish exposed to the control site effluents (i.e. from the non-bleached Kraft pulp mill). The finger of suspicion pointed at chlorine bleaching. The 1985 discovery of dioxins in the effluent of a bleached Kraft pulp mill in the US reinforced concerns (dioxins are a family of chlorinated organic compounds, some member substances being extremely toxic). Pulp mill effluents began to be reassessed in a new, toxicological and bioaccumulative light (Kringstad and Lindström, 1984; Paasavirta, 1988). The effects of many of the chlorinated compounds were unknown, though feared to be non-biodegradable, accumulative, and hazardous to life.

The findings were soon influencing regulatory negotiations over bleached Kraft mill license reviews. The Aspa Bruk mill in Sweden began negotiating its licence review in 1985, and chlorinated organic compounds in the discharge were introduced as an issue. The licence, finally settled after three years of debate, set a limit of 3kg of adsorbable organic halogen (AOX)[8] per m.t. pulp and required the firm to investigate the feasibility for reducing the discharge to 0.5 kg AOX/m.t. pulp by July 1990 (O'Brian, 1996). Similar requirements had been introduced at Södra's Kraft pulp mill at Mönsterås in 1986. The issue was institutionalised in a Swedish Parliamentary decree, adopted in June 1988, which stated that effluent discharges were to be cut to 1.5 kg total organically bound chlorine (TOCl) per m.t. pulp by 31st December 1992. Contemporary discharges were estimated to lie in the range 3.5-4 kg TOCl/m.t. pulp, which compared with 1974 levels of 7-8 kg/m.t. pulp (an indication of incidental gains already made through internal process measures to control traditional parameter discharges) (Fallenius, 1988).

Regulatory pressure was thus forcing firms to address the problems of chlorine bleaching. Although risk assessment remained tentative, comparative studies by the industry trade association (Skogsindustrierna, project SSVL-1985) provided additional evidence that conventional chlorine bleaching processes exhibited more severe environmental impacts than other types of bleaching chemistry (Fallenius, 1988). Later monitoring of Swedish mills confirmed that chlorine-free (ECF) schemes were outperforming conventional bleached mills in terms of environmental quality.

Mills began working with suppliers to eliminate elemental chlorine from their bleaching process. The Aspa Bruk mill carried out a joint research project with Swedish chemicals firm Eka Nobel. The latter launched a high brightness ECF process in 1989 (O'Brian, 1996). By 1991, 12 out of 15 Swedish bleached pulping mills complied with the Parliamentary decree, mainly by doing away with chlorine and relying upon hydrogen peroxide and chlorine dioxide in the bleaching process (i.e. ECF processes). However, whilst ECF removed highly chlorinated compounds, over which there was some concern, residual chlorinated organic compounds remained in discharges from the mills. A modern ECF bleaching plant in 1998 can discharge in the range of 0.2-1.0 kg AOX/m.t pulp and have a capacity of 1500 m.t. pulp/day (EIPPB, 1998, 74), which implies 110-550 m.t. AOX per annum. The sufficiency of this pollution reduction became an important issue in the market demand for TCF pulp – TCF processes promised no chlorinated organic discharges because chlorine/chlorine dioxide was eliminated completely.

Some of the mills which had responded to the chlorine scare with an initial switch away from chlorine bleaching to ECF (chlorine dioxide) were soon in a position to move beyond this and substitute for chlorine dioxide too - thanks to improved process measures such as extended cooking and oxygen delignification. The Aspa Bruk mill began to explore the market for a TCF pulp (bleached using only hydrogen peroxide) in 1989.[9] Though not as bright as ECF pulp, some customers were keen to buy pulp without any attendant chlorine problems amidst growing public concern over the chlorine issue and its international politicisation (see below).

However, the ecological necessity of this extra step into TCF was by no means clear to all pulp firms nor was the science persuasive to all governments, particularly in countries where costly investments had already been sunk into end-of-pipe waste water treatment measures (e.g. Finland). The Swedish idiosyncrasy might not have mattered had it only been of domestic concern. Both Swedish authorities and firms had been working on chlorine bleaching issues, and they began pushing this agenda abroad in the late 1980s. Swedish authorities were promoting measures like oxygen delignification in international negotiations over the best available technologies for controlling pollution in the Baltic Sea (negotiations which they had initiated). Moreover, those Swedish firms practising TCF became a thorn in the side for the rest of the industry, since the former demonstrated that commercial TCF was possible; which provided a stick for environmental NGOs to bash non-TCF pulp producers in the politicisation of chlorine. Chlorine bleaching became an international political issue, and the debate over eliminating chlorine rapidly became reframed as whether ECF or TCF was the best replacement.

5 The politics of chlorine in the Scandinavian pulp industry

As already mentioned, Sweden was proceeding toward a more precautionary approach to suspected toxic chemicals in the 1980s. The mere detection of accumulated levels of chlorinated compounds in sediments, wildlife, consumer products and humans became by itself an indicator of toxicity, and thereby justified the view that continued discharges of chlorinated organic compounds would be troublesome. Chlorine compounds had proved harmful elsewhere, e.g. ozone depletion, agent orange, the Seveso fire, and these experiences were being generalised into a suspicion that chlorinated materials could be harmful to biological life.[10] Even without conclusive evidence of a relationship between specific compounds in mill discharges and adverse effects in aquatic communities, the precautionary approach prompted calls for preventative measures. This tendency is captured in this quote from A. Södergren, co-ordinator of the Swedish studies:

> *Despite the fact that no specific chlorinated organic compounds were possible to relate with observed effects in the receiving water, their mere presence are a matter of concern, above all considering what is previously known about chlorinated compounds with similar properties.* (Södergren *et al*., 1988)

Other countries were reluctant to take regulatory action and regulate discharges of chlorinated organic compounds in the absence of more science, desiring proof of causal links between the compounds and aquatic damage. Unfortunately, no scientific consensus could fill the void and satisfy the exigencies of policy-makers (precisely one of the arguments for a precautionary approach, but more traditionally used as a reason for policy inaction). Although industry and regulatory experts were well aware of chlorinated discharges in aquatic environments, what came as a surprise was the highly toxic potential of some of these compounds. Until the dioxin scare, environmental pulp and paper regulations in both Europe and North America had concentrated on the control of conventional pollutants and properties, i.e. BOD, COD, TSS, colour, and pH. As little as 15% of the thousands of chemical components in a bleached Kraft pulp mill discharge had been clearly identified (Ontario Ministry of the Environment, undated). Accordingly, most studies prior to the 1980s did not dissociate biological impacts caused by toxic compounds from those related to other effluent characteristics (Tana and Lehtinen, 1996). Seldom documented, there were few records for scientists to test correlations between exposure to chlorinated organic compounds and adverse effects on fish (Carey *et al.*, 1993). Sub-lethal effects of such effluent constituents were poorly understood and became a matter for international debate.

5.1 International dispute over a chlorine phaseout

Having taken unilateral action to regulate chlorinated organic compounds in 1988, Swedish authorities proposed, under the auspices of HELCOM that same year, discharge limits from bleached Kraft mills in all Baltic States. Finland and Sweden were by far the major dischargers, and the former rejected the latter's proposals. Remember, Finnish pulp firms used waste water treatment plant to treat their discharges, and so had not invested in the process technologies which formed the basis for limits proposed by Sweden. Swedish proposals were again rejected at a meeting of Nordic Ministries in November 1988. Matthew Auer (1996) has described the highly contested negotiating process between Finland and Sweden, which finally led to a HELCOM agreement in January 1990 to limit discharges to 1.4 kg AOX/ m.t. pulp by 1995. What is important for the purposes of this paper is how the dispute over the science and risks from discharges fed into and reflected wider social disputes - even Finnish environmental groups were at odds with Swedish NGOs - and that some pulp firms promoted TCF even when ECF met the limits negotiated.

Finland questioned the interpretations being made by Swedish authorities over the risk from discharges. Conflicting interpretations of risk assessments often led to disagreement and latent suspicion between countries: Sweden accused Finland of a Third World approach to environmental policy, whilst Finland considered Sweden's approach to be motivated purely by a desire to raise its market share in pulp by framing regulations which already favoured its industry (Auer, 1996). Both Sweden and Finland are major pulp exporters, with Germany, France and the UK being key markets. The two countries engaged in a round of bitter negotiations over environmental prescriptions and appropriate technologies for tackling chlorinated discharges to the Baltic Sea. Opponents argued cost-effective measures should be based upon the old nostrum of sound science. Swedish moves were consequently premature and misguided.

Finland finally agreed to discharge limits when a study by independent paper industry consultants,[11] sponsored by the Nordic Council of Ministers, concluded acceptable discharges of chlorinated organic compounds could be achieved with the waste water treatment plant used by its industry (Nordic Council of Ministers, 1989). More significantly, Finland had also become concerned over the negative publicity it was attracting internationally in the chlorine debate, and that this might harm the commercial interests of its export-oriented pulp industry. Sure enough, the discharge limits agreed in 1990 soon became redundant as green market demand escalated with the rise in public concern over chlorinated organic compounds. The scientific disputes and public declarations around HELCOM had contributed to this public concern. Pulp firms across Europe were forced to switch away from chlorine and install ECF pulping. So green market demand in the early 1990s leapfrogged the regulatory debate and forced firms to switch to ECF anyway, and convinced a number of firms to go beyond this to TCF pulp.

5.2 Public concern and environmentalist lobbying on the chlorine issue

Green market demand was the product of scientific uncertainty and fervent, high profile campaigns from environmental NGOs. According to Renate Kroesa, international pulp and paper campaign co-ordinator at Greenpeace, it was not until August 1987, when the group leaked the US Environmental Protection Agency discovery of dioxins in discharges (Greenpeace, 1987), that the international pulp industry took real notice (Kroesa, 1990).

Soon after this US EPA disclosure, Greenpeace leaked internal industry documents which led to the conclusion that paper products themselves might be contaminated with dioxin (Kroesa, 1990). Greenpeace had protested at a number of pulp mills in Sweden, Germany and Austria over chlorinated discharges in the mid-1980s. Activists distributed sandwiches containing contaminated crab, caught locally, during the public hearing for the license renewal at Södra's mill in Varö, Sweden in 1986. There were similar protests at other Swedish pulp mill license hearings, with significant public support strengthened by interventions from political parties hoping to win votes in the 1988 election (O'Brian, 1996). Environmental issues featured highly in the 1988 election and the ruling Socialists joined environmentalists in the chlorine debate hoping this would clip the wings of a Green Party in the ascendant (Auer, 1996). All these events were influencing domestic regulatory processes in Sweden and the position of the authorities in international negotiations (see above).

Greenpeace organised a panel discussion in Stockholm, 'Nordic Scientists Hearing on Organochlorines', in which experts were invited to give their views on the appropriate measures to be taken; the group also talked directly with pulp and paper producers.

For Greenpeace, the total elimination of chlorine in the international pulp industry was part of a wider and ongoing campaign against the use or creation of persistent toxic compounds (which now has a focus in the PVC phaseout campaign). Other environmental NGOs were active in the fray, such as the Women's Environment Network - which campaigned in the UK for chlorine free sanitary products - and the Environmental Defence Fund in the US. Public and media attention in the UK in 1988 focused on the risk to health from possible dioxins in milk cartons, tea bags and so forth. In the absence of scientific consensus over the risks, public perception became the driving force (Collins, 1994).

To groups like Greenpeace, ECF bleaching was insufficient, only TCF could really solve the perceived problem of residual discharges of chlorinated organic compounds. Compounding concerns about pollution, made graphic with images of seal deaths in the media, were peoples concerns about chlorine compounds in their coffee filters, toilet tissues, magazines, sanitary towels, milk cartons, and so forth. The conditions for green market demand were set. Soon pulp customers in Germany, the UK and France also wanted TCF pulp. The environmentalists' chlorine campaign in Europe had focused on both producers and users of bleached Kraft pulp, and as exporters Swedish firms had to respond to public concerns in their important markets in addition to domestic pressure.

5.3 *Pulp friction: ECF or TCF?*

The scientific and technical studies of the mid-1980s were deemed sufficient for Sweden, and eventually other countries, to take action over chlorine bleaching and set limits for discharges of chlorinated organic compounds. Attention shifted to studies into the precise harm caused by residual discharges of chlorinated compounds from ECF mills. The ensuing scientific controversy provided a site with space for a variety of interests to interpret the issue and press for their particular policy advocacy. The debate crystallised into a battle between advocates of a total phase-out of chlorine bleaching (requiring TCF measures) and advocates of ECF, who thought that this provided sufficient reductions in discharges of chlorinated organic compounds (particularly dioxins).

Some pulp producers were quick to address growing public concern about chlorine. They promoted TCF in a way that fed off public concern and initiated a TCF domino effect through parts of the industry. Firms which had invested in oxygen delignification, improved washing and other process modifications in the past were at an advantage here. Mölnlycke, a subsidiary of Swedish firm Svenska Cellulosa AB (SCA) and owner of a major baby diaper producer in Europe, Peaudouce of France, first exploited the issue by warning the public that dioxins as by-products of chlorine bleaching could be transmitted through babies' skin via conventional diapers. Mölnlycke and Peaudouce diapers were produced with pulp bleached with hydrogen peroxide (i.e. TCF pulp) and promoted as free from harm. A key competitor, Procter & Gamble, had responded to the chlorine issue by switching away from chlorine to chlorine dioxide (ECF) bleached pulp, claiming that the switch virtually eliminated dioxins. Such was public concern and perceived market pressure that eventually Proctor & Gamble were forced to introduce TCF diapers in Europe. In 1989, Swedish pulp firm Aspa Bruk began selling TCF pulp to a UK manufacturer of tea bags who wanted assurance that no traces of AOX would be found in the product or in discharges from its manufacture (O'Brian, 1996).
It was the German pulp market, however, which became an important driver for TCF products. Tengelmann, a leading toilet tissue manufacturer, announced

in 1989 that it had abandoned the use of both chlorine and chlorine dioxide bleached pulp in its products. Within three months, all tissue products in Germany, Austria and Switzerland had switched from elemental chlorine or ECF to TCF pulp or de-inked secondary fibres. In both cases, environmental groups, particularly Greenpeace, were extremely active in pushing the issues in the public arena. In both cases, a major supplier to the market was ready to exploit a perceived environmental advantage (NLK Consultants, 1992).

Arguably the most influential action took place in Germany in 1991 with the Greenpeace publication of a spoof issue of the magazine *Der Spiegel*, called the *Das Plagiat* (The Plagiarist). The magazine was printed on TCF paper, contained information on cleaner TCF-related technologies, and mentioned the Aspa Bruk mill in Sweden which produced the TCF pulp in the magazine. It included a reply card addressed to publishers Spiegel-Verlag inviting readers to request future copies of *Der Spiegel* printed on TCF paper. The action had a profound effect on public opinion in Germany.[12] Following this action, many publishers notified their suppliers that they would require TCF paper as soon as possible:

> *At this stage, only one softwood Kraft pulp producer, Aspa Bruk of Sweden, was able to supply a TCF [pulp] grade for LWC production [i.e. magazine paper], and this grade would not normally have been selected for such an exacting product. The success of this campaign in the mechanical paper sector span off in other advertising and office papers. One by one, the integrated and market sulphite pulp producers switched to TCF operations and this quickly led to the launch of many ranges of TCF woodfree papers for letterheadings, copier papers, business forms, high quality advertising, greetings cards and other end uses.*
> (NLK Consultants, 1992; see also Collins, 1992)

Swedish pulp firm Södra furthered the diffusion of TCF in 1992 'with the start of its enormously successful promotion campaign for its Z pulp' (O'Brian, 1996). This campaign publicised firm discussions with Greenpeace, embraced the goal of zero discharges (hence the brand name, 'Z' pulp), and borrowed rhetoric from the political debate by suggesting brilliant white paper (necessitating ECF) may be poisoning its user (Södra, 1996). Such was the impact of Z pulp that Södra is regarded to have started the TCF ball rolling (O'Brian, 1996).

For a period TCF pulp enjoyed a premium price sufficiently high to encourage other pulp firms to make the extra investment in TCF capacity. However, it is important to remember that innovations in TCF bleaching and modifications to the pulp process had really occurred years before the market greening of the early 1990s. Oxygen delignification was used at around 50% of Swedish pulp mills in 1980, compared to none in Finland and North America; by the mid-1990s over 90% of Swedish mills had the technology, compared to around half of Finnish mills and one quarter of mills in North America (interview evidence).

The pulp firms in a position to take advantage of the market demand were those that had already invested in the development and implementation of such ECF and TCF assisting technologies, and here Sweden was at a particular advantage. In 1995 ECF pulp had 40% of the global market in bleached chemical pulp (Auer, 1996) and dominated the European market.

In a nutshell, market greening really prompted technology diffusion more than innovation (though as is often the case with these processes, the distinction is blurred); and whilst market greening persuaded some firms to go beyond ECF into TCF, the processes that facilitated this had not all been market mechanisms.

6 Stabilisation around ECF pulp

Whilst demand for TCF boomed in the early 1990s, it has nevertheless remained the case that ECF processes dominate modern bleaching technology (Table 1). Not every pulp producer and user felt obliged to make the transition beyond ECF during the disputes of the early 1990s despite environmentalist pressure to tilt markets and regulations in favour of the latter.

Table1: diffusion of oxygen delignification, ECF and TCF technology.

Capacity ('000 tons)	1970	1975	1980	1985	1990	1995
O_2 delignification	300	1500	4000	8400	22800	53200
ECF	-	-	-	-	3200	34400
TCF	-	-	-	-	500	5200

Source: Sunds Defibrator.

The zenith of environmental pressure on bleached pulp has since been replaced with a new consensus on the equivalence of ECF and TCF amongst regulators (see below). As environmental pressure in this area has subsided, so decisions between ECF and TCF have come to be driven more exclusively by industrial economics. Political pressure and regulatory debate no longer shape decisions in this area of the industry as they once did. Demand for TCF pulp has not increased in recent years and only a few mills are solely manufacturing TCF pulp. Instead, many mills in Europe are now in a position where they can make TCF in separate production campaigns instead of their standard ECF product, should the market demand (European Integrated Pollution Prevention and Control Bureau, 1998).

Scientific and technical reviews have raised doubts about the benefits of a total shift towards TCF bleaching. More studies into the environmental impacts of bleached Kraft mill discharges have been undertaken. Efforts have been aimed at verifying the correlation drawn between chlorinated organic compounds and observed malformations in fish. The correlation between residual chlorinated organic compounds and observed effects has became problematic due to the complexities of both historic and current mill discharges and their influence upon specific local ecosystems. Some of the areas studied have had a history of exposure to other process discharges, such as black liquor, washing losses, residual acid and contaminated sludge. Adverse environmental effects could have been caused by these substances from other operations. Doubts were further raised when a Canadian study, comparing effluents between pulp mills with and without chlorine-based bleaching, showed that similar environmental damage occurred in both cases (Carey *et al.*, 1993). Something other than chlorinated organic compounds might be responsible for the adverse effects observed in aquatic communities (Peck and Daley, 1994). Finnish studies furnished similar results (Tana and Lehtinen, 1996). The latter concluded that policies in Sweden were, "mainly driven by a series of scientific rebounds, such as over-interpretation and, in some cases, misinterpretations of the scientific material" (Tana and Lehtinen, 1996).

Given the significant impacts now suspected from other aspects of conventional bleached Kraft mill discharges, there was no guarantee that moving to TCF would bring maximum environmental benefit. Perhaps attention could be applied more cost-effectively elsewhere? Scientific uncertainty over the best course of action was increased by studies into chlorinated organic compounds. Whilst information about many chlorinated organic compounds remained unknown some scientific work was showing that not all chlorinated organic compounds were alien to biological life (Asplund and Grimvall, 1991), and that some were regarded by a number of experts as harmless and degradable by natural processes.[13] All of this uncertainty was grist for the mill to advocates of the ECF sufficiency policy position.

The position of pro-TCF firms came to be viewed, in the eyes of critics, as speculative and controversial. For others though, such as environmental NGOs, the scientific uncertainty was precisely the reason for TCF and further closure of the bleach plant such that *all* discharges become minimised and contaminant free. Closure is easier to achieve with TCF than ECF because liquid streams are free of corrosive chlorates (European Integrated Pollution Prevention and Control Bureau, 1998). Greenpeace continues to campaign for TCF on these grounds.

The scientific debate appears recently to have reached some form of closure: recent work suggesting ECF and TCF give a comparable environmental performance (Swedish Environmental Protection Agency/Swedish Forest Industries Water and Air Pollution Foundation, 1997; Finnish Ministry of the Environment, 1997).[14] The consensus belatedly confirms the earlier compromise reached between countries and within the industry for environmental performance-based standards allowing both ECF and TCF as means of compliance (e.g. the HELCOM discharge limits). This equivalence is reflected in draft guidance on Best Available Techniques for the pulp and paper industry, under the European Commission 1996 Directive on the Integrated Pollution Prevention and Control (European Integrated Pollution Prevention and Control Bureau, 1998). However, reaching this consensus has taken a long time (nearly a decade), and parallel events had already forced the diffusion of TCF technology in the industry (see above).

However, whilst a stabilisation in technical change appears to have been reached for now, it is by no means clear that ECF will enjoy a long equilibrium in the manner of chlorine bleaching. Continued scientific consensus on ECF and TCF cannot be guaranteed. One recent report, which concluded discharges from the two processes were broadly equivalent environmentally, also called for further detailed research to improve understanding on the effects of discharges from mills, which it noted were very site-specific (Swedish Environmental Protection Agency/Swedish Forest Industries Water and Air Pollution Foundation, 1997). Growing scientific awareness and concern over endocrine disrupting substances (colloquially known as gender bending substances) is including residual ECF chlorinated organic compounds amongst the list of suspects (Hilleman, 1991; Colborn, 1992; Environment Agency, 1998). Overcoming discharge problems once and for all, by closing water loops in the bleached Kraft pulp mill, is discussed in pulp industry circles even if little serious investment has followed (Lockie, 1997). Greenpeace has latched onto this and are now campaigning along these lines, an added arrow in their quiver to phase chlorine out of industrial economies. So it appears technical change in the bleached Kraft pulp industry is enjoying a respite, and that further changes are possible. Recent history suggests this will depend upon the degree of public and regulatory pressure which is brought to bear directly upon pulp producers and, possibly, reinforced via rejuvenated green markets.

7 Conclusion

This paper has explored what was ostensibly a case of 'market demand' technical change. Earlier studies have certainly attributed the rapid switch away from chlorine bleaching in the pulp industry to market demand (Simons, 1994; Auer, 1996; OECD, 1999). However, by positioning this event in its social and political context, this paper suggests the transition to chlorine free bleaching arose from a confluence of processes, not all of them market based.

The chlorine issue emerged when some scientists pointed the finger of blame for the very real damage found near pulp mills at chlorinated organic compounds discharged from the bleach plant. A regulatory culture which was precautionary and process focused (rather than end-of-pipe) placed Swedish authorities and pulp firms in a good position to address the perceived problem. This contrasted with the 'sound science' and end-of-pipe culture of regulation in other countries, for whom the chlorine issue consequently posed a bigger challenge. Nevertheless, technologies facilitating a switch away from chlorine were available.

Swedish authorities took the issue to the international stage in proposing international controls on discharges of chlorinated organic compounds. Authorities in other nations, e.g. Finland, interpreted the scientific uncertainty in a different way to Sweden. If the exact cause was unknown, it seemed unwise to take action to eliminate chlorine bleaching. End-of-pipe measures could reduce discharges of chlorinated organic compounds. Switching away from chlorine may not bring further benefits and would not therefore be cost-effective. Unfortunately for them, such action was too limited to satisfy public concern and customer demands. The authorities were not the sole protagonists. Environmental groups, particularly Greenpeace, were successful in publicly implicating chlorine bleaching, leaking US EPA and industry evidence and bringing scientists together to discuss the issue. Environmental groups also skilfully exploited images which played well in the media and raised and disseminated public concern. Pulp firms were forced to scrap chlorine bleaching, even if end-of-pipe measures could meet regulatory limits, and some firms introduced TCF and happily exploited public concern to their commercial advantage.

However, there was by no means a scientific consensus over the benefits of TCF compared to ECF. A consensus has emerged only recently, and considers discharges from the two processes to be environmentally equivalent, though endocrine risks may rupture that consensus. Significantly, however, the technologies which made such a rapid switch possible already existed in this mature process industry. Public pressure led to market demand which acted as a trigger for the diffusion of technologies which had been developed to meet prior regulatory requirements, and which facilitated chlorine free bleaching with relatively straightforward modification.

Certainly, this case suggests the role played by markets in the innovation and diffusion of cleaner technologies can be contingent on other factors. Had prior technologies not been available for the rapid transition away from chlorine bleaching, it is unclear whether Sweden would have acted so forcefully, [15] and latent green market demand might not have materialised through pioneer pulp firms identifying a niche. Supply would not have been as elastic and it is likely that public concern would have had to rely upon regulation to encourage cleaner innovation and assuage fears. What does our case study tell us about market greening generally? Basically, that there are a lot of regulatory and political pressures which precede greening and then often act to reinforce market greening. Understanding cleaner technology change requires analyses that capture the broader shaping environment and do so from a historical perspective. Moreover, it is the mixture of policy and market measures that is critical, not whether one is more important than any other. Other studies of market greening would be well-advised to lengthen and broaden their analytical frames accordingly.

BIBLIOGRAPHY

Asplund G., Grimvall A. 1991. Organohalogens in Nature – More widespread than previously assumed, *Environmental Science and Technology*, 25(8): 1346-1350.

Auer M. 1996. Negotiating Toxic Risks: A Case from the Nordic Countries, *Environmental Politics*, 5(4): 687-699.

Auer M. 1996a. *Krafting An Agreement: Negotiations To Reduce Pollution From The Nordic Pulp Industry*, PhD Dissertation, Yale University, United States

Carey JH., Hodson P., Munkittrick K., Servos M. 1993. *Recent Canadian Studies on the Physiological Effects of Pulp Mill Effluent on Fish*, Ottawa: Environment Canada.

Charles River Associates (CRA), 1993. *Assessment of the Economic Benefits of Chlor-Alkali Chemicals to the United States and Canadian Economics*, The Chlorine Institute, Washington DC.

Colborn T. 1992. *Chemically induced alterations in sexual and functional development: the wildlife/human connection*, Princeton: Princeton Scientific Publishing.

Collins L. 1992. Environment versus industry: a case study of how the pulp and paper industry is responding to changing attitudes to the environment, *Business Strategy and the Environment*, 1(4): 29-36.

Collins L. 1994. Environmental performance and technological innovation: the pulp and paper industry as a case in point, *Technology in Society*, 16(4): 427-446.

Ek et al., 1994. "The Role of Metal Ions in TCF Bleaching of Softwood Kraft Pulps", *Proceedings of TAPPI Pulping Conference*. Quoted from Alliance for Environmental Technology, 1999. http://www.aet.org/facts/.

Environment Agency. 1998. *Endocrine-disrupting substances in the environment: what is to be done?*, Bristol: Environment Agency.

European Integrated Pollution Prevention and Control Bureau. 1998. Pulp and paper industry BAT reference document – draft. Sevilla: EIPPCB.

Fallenius, UB. 1988. Environmental matters concerning the pulp and paper industry in Sweden, Unpublished Swedish Environmental Protection Board memo.

Finnish Ministry of the Environment. 1997. *The Finnish Background Report for the EC Documentation of Best Available Techniques for the Pulp and Paper Industry*, Helsinki: Ministry of the Environment.

Følke J., Männistö E., 1993. Chlorine Dioxide in Pulp Bleaching – Environmental Influence on Future Use, Working Document, Helsinki.

Greenpeace International. 1987. *No margin of safety*, Vancouver: Greenpeace International.

Hilleman B. 1991. Call to regulate reproductive effects of chemicals, *Chemical & Engineering News*, 7th October: 4.

GRIMVALL, A. et al., 1991. Organohalogens of natural and industrial origin in large recipients of bleached plant effluents, *Water Science Technology*, No. 24, 373-383.

Helsinki Commission. 1983. Reductions of discharges of harmful substances from the kraft pulp and industry. Agenda item of the ad hoc working group on criteria and standards for discharges of harmful substances into the Baltic Sea area. Helsinki: Helsinkin Commission.

Kroesa R. 1990. *The pulp industry's progress on pollution*, Vancouver: Greenpeace International.

Kringstad K., Lindström K. 1984. Spent liquors from pulp bleaching, *Environmental Science and Technology*, 18: 236-248.

Lancaster et al., 1993. "The Effects of Alternative Pulping and Bleaching Processes on Product Performance – Economic and Environmental Concerns", *Proceedings of EPA International Symposium on Pollution Prevention in the Manufacture of Pulp and Paper*. Quoted from Alliance for Environmental Technology, 1999. http://www.aet.org/facts/.

Lockie M. 1997. Pulp producers: losing metal or resolve?. *Pulp and Paper International*, 39(12): 44-49.

Massachusetts Institute of Technology (MIT) 1993. *Dimensions of Managing Chlorine in the Environment*, Report of the M.I.T./Norwegian Chlorine Policy Study, Cambridge.

NLK Consultants. 1992. *The Way Ahead for Environmentally Driven Papers*, NLK Consultants Ltd, London.

O'Brian H. 1996. TCF: It all started here at Aspa Bruk, *Pulp and Paper International*, October: 19-22.

OECD. 1996. *Environmental performance reviews – Sweden*, Paris: OECD.

OECD. 1999. *Case study on the use of Best Available Technology (BAT) and Environmental Quality Objectives (EQOs) in the environmental permitting of bleached chemical pulp and paper mills*, Paris: OECD.

Ontario Ministry of the Environment. Undated. Kraft Mill Effluents in Ontario, Unpublished internal note.

Paarsvirta J. 1988. Organochlorine compounds in the environment, *Water Science and Technology*, 20(2): 119-129.

Peck V., Daley R. 1994. Toward a Greener Pulp and Paper Industry, *Environmental Science and Technology*, 28(12): 524-527.

Rajotte A., Renevier L. 1999. Environmental requirements for industrial permitting – regulatory approaches in OECD countries (draft). Paris: OECD.

SEPA and SSVL. 1997. *Environmental impact of pulp and paper mill effluents*, SEPA/SSVL Report 4785.

Simons Consulting Group. 1994. 'Forestry sector benchmarking initiative – a case study in environmental regulations', Simons Consulting Group.

Södra. 1996. *The book about Z. Södra*, Växjö, Sweden.

Södergren A., Bengtsson BE., Jonsson J., Lagergren S., Larsson Å., Olsson M., Renberg L. 1988. 'Summary results from Swedish project Environment/Cellulose', *Water Science Technology*, 20: 49-60.

Swedish Environmental Protection Agency/Swedish Forest Industries Water and Air Pollution Research Foundation. 1997. *Environmental impact of pulp and paper mill effluents: a strategy for future environmental risk assessments*, Stockholm: Swedish Environmental Protection Agency.

Tana J., Lehtinen KJ. 1996. *The aquatic environmental impact of pulping and bleaching operations – an overview*, Helsinki: Finnish Environment Institute.

REFERENCES

1 This paper draws upon research from two projects funded by DGXII of the European Commission under the Framework IV Climate and Environment Programme: 'Technology and Environment Policy' (PL970779); and 'Sustainability, Competitiveness and Technical Change in Mature Process Industries' (ENV4CT960342).

2 Mills planning to switch to ECF can find different implementation routes, depending on local circumstances. Over-capacity in $Cl0_2$ generation plant can allow bleaching at 100% $Cl0_2$-substitution without extended cooking and/or oxygen bleaching. If reduction in COD and chronic toxicity are required, oxygen bleaching and extended cooking may be better options. General cost comparisons between TCF and ECF bleaching on a mill-by-mill basis are impossible because of there are so many factors involved, such as investment in ozone generation and bleaching equipment, additional investment in cooking and oxygen bleaching, potential utilisation of residual oxygen from the generation of ozone to reduce running costs for oxygen recovery, power prices, environmental regulations (Følke and Männistö, 1993).

3 Differences in investment cost between ECF and TCF vary. Lancaster et al. (1993) has estimated that the switch from bleaching at 50% $Cl0_2$-substitution (**base**) to ECF amounted to 19 $ millions in investment costs plus approximately 10 $ millions in annual operating costs; from **base** to ECF bleaching with oxygen bleaching to 104 $ millions in investment costs plus approximately 4 $ millions in annual operating costs; and from **base** to TCF, 144 $ million in investment costs plus approximately 14 $ millions in annual operating costs.

4 According to Ek et al. (1994), "the TCF bleached pulps were found to have a 5-10% lower tear strength at a given tensile index compared to the ECF-bleached and oxygen delignified pulps. The TCF pulps also had a lower fiber strength."

5 The high corrosive nature of chlorinated material in bleached kraft pulp mills impedes current attempts to cycle wastewater back into the process because it would lead to a rapid deterioration of equipment. Improved water recyclability is an advantage of TCF techniques.

6 SNV outlined the criteria for selection of the field site and topics for study: the primary area was to be localised in the Gulf of Bothnia, where over 50% of the Swedish chemical pulp mill's AOX loads were discharged; the studies were to be focused on kraft mills and on the bleached effluents of the selected mills.

7 "The Baltic Marine Environment Protection Commission (HELCOM) was established under article 12 of the Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention) (13 I.L.M. 544). The convention was drafted after many months of negotiations between countries with conflicting political ideologies and divergent economic policies. […]The "Convention Area" encompassed the "marine environment of the Baltic Sea Area," including the water body, sea-bed and living resources of the sea (§4.1). The legality of the convention in territorial seas and internal waters of member states was more opaque. Article four ordered contracting parties to implement the terms of the regime within said areas, but "without prejudice to the sovereign rights" of each state (§4.2;4.3). Article one, however, stated explicitly that internal waters were not part of the convention area. The renewed Helsinki Convention (1992) clarified that internal waters and territorial waters were part of the Baltic Sea Area (§1), formalising in statutory language what was already common practice among Germany, Denmark, Sweden and Finland […]. As is true of other treaties governing common property resources, the contracting parties to the Helsinki Convention established an international organisation to oversee implementation of the agreement. This entity, the Helsinki Commission (HELCOM), was assigned several duties under the agreement, including: reviewing the contents of the convention and proposing (to member states) changes to the convention's main body and annexes; defining pollution control criteria and objectives for reducing pollution; promoting cooperation between member states; receiving, processing and disseminating to member states relevant scientific, technological and statistical information; and consulting and cooperating with outside experts on relevant activities pertinent to the convention (§13). […] HELCOM was directed "to make recommendations on measures relating to the purposes" of the

convention (§13.b). The duty to "make recommendations" represents one of HELCOM's most important and time-consuming tasks […]. Since coming into force, member states have signed between four and fifteen new recommendations annually […], including Recommendation 9/6 (1988) "Restriction of Discharges form the Pulp and Paper Industry […] and Recommendation 11/4 (1990) "Restriction of Discharges from the Kraft Pulp Industry" […]." Quoted from Auer (1996a, 16-17).

8 The AOX parameter was adopted as a regulatory parameter in most countries because it is easier and cheaper to conduct. Yet the parameter is controversial because, though it provides a measure of total chlorinated content in the effluent, it does not discriminate between its toxic and benign fractions.

9 The pioneering move by the mill can be explained by the fact that it was there that the issue of chlorinated discharges was first discussed within the framework of its permit renewal in 1985, though the agreement was reached in 1988 (O'Brian, 1996).

10 The issue whether chlorinated chemicals were judged on properties or reputation has been at the core of the many controversies that have plagued this family of compounds. Some misconceptions have even achieved the status of myths. Here are some of those: Myth 1 (an agent of death): Chlorinated compounds can be lethal, but chlorine disinfection provides potable water for millions of people. Some 85% of pharmaceuticals contain or are manufactured using chlorine, including products to treat AIDs, allergies, arthritis, cancer, depression, diabetes, heart diseases, etc. Chlorine-containing compounds are an important intermediary in the manufacture of vitamine C. Add three chlorine atoms to sucrose and you have a low calorie sweetener, not a health hazard; Myth 2 (all chlorinated compounds have the same potential): Each organochlorine has unique properties determined by the molecular structure, not by the simple presence of chlorine; Myth 3 (all are toxic): Not all substances rich in chlorine are highly toxic; Myth 4 (all bioaccumulate): An organochlorine's ability to bioaccumulate depends on its level of water solubility. Certain chlorinated hydrocarbons such as PCBs and DDT bioaccumulate as a result of their low water solubility, not their chlorine content; Myth 5 (all are persistent): Most chlorinated organic matter in pulp mill effluent naturally degrade in the ecosystems and has been found to have a half life of 10 days depending on exposure to the sun; Myth 6 (organochlorines are alien to nature): Over 2000 different organohalogen compouds have been reported to be found in nature, produced by natural fires, ocean, and fungal activities. See MIT (1993), CRA (1993), Grimvall (1991).

11 The Finnish firm, Jaakko Poyry, was responsible for the study. The objective of the study was to assess and compare differences in chlorine-based policies and technological responses between Finland and Sweden, in particular the activated sludge treatment techniques in Finland versus oxygen-based techniques in Sweden. Finland was suspicious of oxygen-based techniques of being a 'Swedish technology', while Sweden criticised Finland for sticking to an end-of-pipe approach at the expense of the Baltic Sea. The report concluded that both approaches allowed acceptable and comparable environmental performance. See Jaakko Poyry, Reduction of Chloro-organic Discharge in the Nordic Pulp Industry. Nordic Council of Ministers, Environment Report 1989.

12 The European survey conducted by NLK Consultants found that paper brightness no longer plays such an important role in paper specification in Germany (NLK Consultants, 1992).

13 Nearly 30% of chlorinated compounds in bleached Kraft mill effluents are of a low molecular weight and may entail harmful impacts. There are disagreements between experts over the environmental risk of high molecular material, e.g. whether synergistic effects or their degradation by natural processes would detrimentally change their composition. Regarding dioxins, there are 210 different types of the family that have been identified and 17 of them are considered harmful. In 'Is Bleached Paper Dangerous? – Seven experts give their views', *Skogsindustrierna*, Stockholm.

14 As shown by empirical work in both countries. See among others: The Finnish Background Report for the EC Documentation of Best Available Techniques for the Pulp and Paper Industry. Ministry of the Environment, Helsinki, 1997.

15 It is worth pointing out that the positions of Sweden and Finland are reversed over the issue of eutrophying discharges (Auer, 1996a).

Paper 4 –

PAPER PRODUCTION TECHNOLOGY AND ENVIRONMENTAL PERFORMANCE IN SWEDEN AND FINLAND: POLICY, SCIENCE AND MARKET SHARE

Introduction

In the mid-1980s, Sweden introduced regulations affecting paper production in response to alleged environmental risks of chlorine (Cl_2) bleaching of pulp. Sweden defended its policy within the international community based on both environmental quality considerations and technological availability for Cl_2-free technology. Since the majority of chlorinated compounds were unknown and held the prospect of being hazardous, precaution was defensible as a basis for policy. Industry experts and policy analysts have questioned the wisdom of the major process change. In their views, the changes have been based on suspicions and over-interpretations of facts, and were market-driven rather than justified by ecological concerns (Følke *et al.*, 1993; SIMONS, 1994; Tana and Lehtinen, 1996). The overwhelming influence of market forces precluded the continuation of protracted discussion. Despite uncertainty, there was a rapid decrease in Cl_2 bleaching. By the end of 1999, elemental chlorine-free (ECF) techniques captured about 60% of the world bleached pulp market, while totally chlorine-free (TCF) schemes secured a market niche of about 6% (AET 1999).

This paper argues that attributing changes to variables such as politics or markets can be misleading. Claiming the importance of 'market pull' typically overlooks the intricacies of technological change, including technical feasibility, economic viability, market response, regulatory change, etc. (Kline and Rosenberg, 1986). Clearly, *ex post* 'market pull' cannot be a cause, but rather a condition of *ex ante* interplay between different kinds of issues and decision-making units. Correlating sub-optimal research with obstructive politics carries the strong view that science should "speak truth to power", *ex ante* of decisions, overriding the evidence that knowledge formation is deeply embedded in social contexts (Jasanoff, 1996).

The question remains as to why the paper industry came full circle from introducing Cl_2 as the most efficient and affordable bleaching agent in the 1940s to virtually phasing it out by the end of the 20th century. This case study illustrates how these decisions were reached within the scope of economic and environmental issues affecting the industry during that time. The analysis is based on a review of historical records and interviews conducted in 1998 with key decision-makers among Swedish and Finnish industry, along with governmental and non-governmental organisations. By examining factors linking economic growth and change in bleached pulp production, it is argued that the Cl_2 bleaching controversy resulted from differences in perceived benefits and costs of the low predictability of risk estimates linking chlorinated effluents to adverse effects of bleached Kraft mill effluents (BKMEs). By comparing developments in Sweden and Finland, it is shown that these differences are historically tied to specific mill siting that led to differences in causal inferences linking BKMEs, downstream environmental effects, and the perception of risk as equivalent. It is concluded that the validity of risk estimates may be seen as socially constructed through a complex dynamic of knowledge authentication tied to the political economy of paper production.

Growth and change in the P&P sector: when economics meets the environment

In today's modern economies, paper performs a range of core functions, ranging from communications to packaging, hygienic and household uses. Paper products are produced from wood pulp and wastepaper that generate large quantities of organic waste generated by the techniques used to separate the fibrous and non-fibrous material from wood fibre. If untreated, the effluents from these operations, which contain persistent toxic compounds and wood-related hazardous products, may significantly impair waterways.

Given the rapidly evolving technologies, there are no simple relationships among production costs, effluent quality, and the type of paper produced. Environmental impacts and costs are a function of the intended end-use of pulp and manufacturing processes used. Economic factors play a major role in determining the environmental performance of the industry. Up to the 1970s, there was a strong correlation between production growth and pollution increase. As continuous economic growth led to increased production of paper and board (P&B), pulp mills became a source of excessive discharges, oxygen depletion of waterways, dramatic fish kills, and loss of potable water and fishing grounds (OECD 1973). World discharges of total suspended solids (TSS) and biochemical oxygen demanding (BOD) substances reached 4 and 6 million tonnes respectively in 1970, with pulp mills accounting for 70% of total industrial and domestic water withdrawal. Concurrently, since World War II, the growing market drive for stronger, brighter and more versatile paper products has led to contradictory developments. Better quality pulp meant higher earnings, but increased production costs and pollutants (Table 1).

The 1970s witnessed unprecedented regulatory activities across the Organization for Economic Co-operation and Development (OECD) countries to ensure better control of industrial pollution. Of particular interest to the P&P industry, the environmental reform introduced the concept of Best Available Technology to set discharge limits of TSS and BOD. Together with rising costs of tightening regulations, the price increases affected the competitive position of the different technologies and the search for alternatives (Wheeler and Martin, 1992)[1].

Early on, the industry and authorities envisioned a combination of external measures and in-plant changes to ensure environmental protection. Replacing small, uneconomical and environmentally-obsolete units with more energy- and resource-efficient larger mills provided a cost-effective means of reducing discharges per production ratio (and a source of political leverage in permit negotiations), without deviating from the business inclination to seek productivity gains through expansion. Approaches differed whether the focus was on the primary effluent, i.e. in-plant measures, or on the final effluent, i.e. external treatment, which suggests that the transition to more efficient operations was influenced by local contexts. In most cases, oxygen depletion of waterways required the rapid adoption of stringent BOD limits, locking industry into end-of-pipe measures (OECD 1973). Yet, the simultaneity of industry growth along with tightening regulations offered some leeway in optimising technological change for production and environmental purposes.

Table 1 – Production and environmental effects of market trends

Trends	Requirements	Solutions	Consequences
Improved images - Multicolour - Resolution - Combined advertising and packaging	Brightness	- Bleaching of pulp - Increased use of bright additives	- Lower yield and higher pollutant generation - Higher energy consumption - Lower strength and stiffness of chemical pulp - Less fibre in end-product and higher solid waste generation in recycling
	Opacity	- Additives - Maximum use of mechanical pulps	- No change - Increased use of external energy
	Smoothness, gloss, strength	- Increased pulp refining - Increased coating	- Increased use of energy - Potentially higher polluting loads
Lower basis weight (raw material and investment efficiency, reduced handling fees)	Strength	- Stronger chemical pulps	- Lower overall yield through more selective raw material usage - More complex processes
	Stiffness	- Increased use of mechanical pulps - Increased additives - Multilayer forming	- Increased use of external energy - Higher pollution load - More complex machinery

(Modified from FEI, 1997)

Comparing Sweden and Finland: similar goals, different means

Finland and Sweden are representative of the factors and issues that have shaped the political economy of the industry over time. Both are among the top ten world P&P producers, as well as leaders in process and environmental technologies.

In Finland, discussions about P&P mill pollution started in the 1960s as production expansion increased water quality problems. Starting with the Water Act of 1961, when appropriate controls were lacking and public protests were increasing, the Finnish authorities had to address oxygen depletion of the many small and shallow Finnish rivers (Ruonala, 1998). Tightening BOD and TSS limits brought the industry to implement various forms of biological and physico-chemical treatments. Activated sludge treatment eventually became the flagship of the Finnish industry and, as a result, the release of organic substances is now less than 1/10 of the 1970s levels, while production has doubled during that time (Gullichsen, 1998).

Until the 1970s, Sweden faced a similar environmental challenge as pulp mill effluents were routinely discharged into waterways without secondary treatment (Jirvall, 1998). Authorities first imposed black liquor recovery as a minimum requirement. Following the rapid reduction of BOD and TSS, it was considered that the problem of oxygen depletion had been sufficiently addressed and chemical oxygen demand (COD) was substituted for BOD as the leading parameter to favour internal measures over external treatment (Nyström, 1998).[2] Improved washing and screening, substitution of chlorine dioxide (elemental chlorine free bleaching) and oxygen-based (O_2) agents to Cl_2, as well as development of extended cooking and O_2 delignification led to drastic COD reduction by nearly 90% between 1960 and 1995.

Obviously, the evolving differences in risk posture and instrumental perspective were connected to the different mill sites. Most Finnish mills are located near small, inland water bodies with limited dilution capacity and a shallow coastline with small assimilative capacity, while 80% of Swedish mills are within 50 km of the Baltic sea (Enckell, 1998). It is therefore no coincidence that Finland concentrated on ecological effects of effluent in the immediate environment, while Sweden shifted its focus on environmental impacts over a wider range of space and time (Nyström, 1998; Myreen, 1998). However, less apparent was the role that these differences played in shaping differing causal inferences linking BKMEs and downstream environmental effects. These soon became apparent through the Cl_2 bleaching controversy.

The Cl_2 controversy: a case of bureaucratic focus or differences in building capacities?

The introduction of limits restricting the use of Cl_2 as a bleaching agent may be related to the Project Environment/Cellulose (PE/C), sponsored by the Swedish Environment Protection Agency (SEPA). Its conclusions linked the presence and accumulation of chlorinated compounds in sediments with a series of documented effects on plants and fish near the *Norrsundet* bleached Kraft pulp mill. Altered fish populations, deformed eggs, reproductive disturbances, physiological anomalies, skin diseases and skeletal deformities were reported, as well as high levels of chlorinated compounds in sediments in the vicinity of the mill. Although the report failed to establish specific cause-and-effect relationships, the PE/C team suspected a link between chlorinated compounds and observed adverse effects. The assumption was reinforced by the fact that fish exposed to unbleached effluents of the control site did not show any of the effects for the parameters surveyed (Södergren *et al.*, 1988). In addition, dioxins were detected in effluents, sludge and pulp, as well as in fish collected downstream from American bleached pulp mills in 1985.[3] Although accounting for a tiny fraction of the chlorinated effluent, the toxicity of dioxins along with the history of adverse effects of substances such as PCB and DDT spread a perception that all chlorinated compounds discharged from bleached pulp mills were potentially toxic (McDonough, 1998), shifting the PE/C team to a more protection-prone attitude.

The documented effects prompted SEPA to impose limits restricting the use and discharge of chlorinated compounds. The decision was controversial and challenging because it was not proven whether Cl_2 was the cause of the adverse impacts, nor if compliance could be reached with available measures (Axegård, 1998). The first TOCl[4] limit was adopted in *Södra*'s *Mönsterås* Kraft pulp mill's permit in 1986. Despite opposition from industry and some local authorities, the adoption of Bill 1988 confirmed the backing of the Swedish parliament.[5] The decree included short- and long-term reduction targets. In the long term, chlorinated discharges were to be eliminated. TOCl/AOX limits were gradually incorporated in remaining permits from 1988 onward (Lagergren and Nyström, 1991).

At the same time, Sweden sought a multilateral initiative to reduce chlorinated effluents from pulp mills within the framework of the Helsinki Commission on the Protection of the Baltic Sea (HELCOM) and the Paris Commission for the Protection of the North Sea and the North East Atlantic (PARCOM), which was met with fierce resistance. The fact that O_2-based techniques were required by the Swedish delegation to ensure reduction of potential risks was particularly objected to, as it meant phasing out Cl_2 without conclusive proof of cause-and-effect relationships (Nyström, 1998). Obviously, the debate about Cl_2 bleaching risks was tied to the differences in environmental impacts and technical skills between jurisdictions.

Targeting Cl_2: a Swedish "science"?

Requesting controls further upstream in the bleaching process crystallized the knowledge gaps in the link between BKMEs and downstream environmental effects, including the lack of information or misinformation already in current regulations. Yet, in retrospect, Sweden's decision to target Cl_2 bleaching reflected a long-standing regulatory trend favouring in-plant measures to end-of-pipe control. It was consistent with a policy plan aiming at the elimination of persistent organic pollutants (POPs). Persistence of adverse impacts near bleached pulp mills posed a regulatory dilemma. Considering the large volume of chlorinated material discharged and its accumulation in marine environments, these were readily suspected[6].

The PE/C team sought to augment scientific knowledge about the role of POPs by including environmental impacts of BKMEs. Experts suspected that excessive BOD discharges over the 1945-1970 period were probably *hiding* more subtle effects of other contaminants in the effluent. Up to the 1980s, only about 10% of BKME components had been identified and many had never been investigated (Bengtsson, 1998). The low molecular weight portion of chlorinated organic matter, as well as resins and fatty acids, were probably responsible for some of the adverse effects. Swedish experts guessed that these low molecular weight materials probably accounted for about 20% of the chlorinated content of effluent. Benchmarking conducted by the Swedish Forest Industries Association indicated that O_2 pre-bleaching stages and modern bleaching techniques reduced both non-chlorinated and chlorinated compounds. Monitoring from authorities confirmed that these techniques outperformed conventional processes from the perspective of environmental protection (Fallenius, 1988). Thus, despite a lack of evidence, precautionary actions appeared justified based upon a systematic technology assessment and policy analysis that also led to greater efficiency of industrial operations.

Finnish policy: environmentally lax or rational?

Evidence submitted by Sweden at HELCOM had taken Finnish officials by surprise. They were unfamiliar with the methods and results emerging from Sweden documenting eco-toxicological effects of BKMEs. Although Finnish authorities acknowledged the risk of some chlorinated compounds, secondary wastewater treatment had seemingly addressed the problem (Ruonala, 1998). Lacking adequate knowledge, Finnish officials requested industry assistance in the HELCOM discussions, a decision that outraged the Swedish delegation. The deliberations rapidly deteriorated into mutual accusations of environmental wrongdoings to the Baltic Sea (Auer, 1997). The Swedish delegation sought to undermine the credibility of Finnish arguments by presenting data comparing primary effluents among jurisdictions (Myreen, 1998). This was a disadvantage for Finland as they had focused on the final effluent. Finnish experts were suspicious that the Swedish position was tainted by a political bias as a series of methodological flaws of the PE/C became known. The Swedish control site had lower production and BOD loading than typical plants and greater flushing and effluent dilution in the receiving water (CAREY *et al.*, 1993). Moreover, the *Norrsundet* mill had experienced severe problems at start-up, such as heavy losses of black liquor, washing waters, spent acids and contaminated sludge, all conditions that could have caused the reported effects. At the same time, Canadian and Finnish field studies comparing environmental impacts of bleach plants with or without chlorine bleaching showed that similar effects in fish could be detected under both effluent conditions. These results suggested that something else, maybe some natural constituents in wood, could be responsible for most of the acute toxicity of BKMEs.

Resolving the conflict: expertise as a social learning process

The policy dispute revealed how differences in instrumental perspective predisposed Swedish and Finnish authorities to respond differently to gaps in knowledge regarding the link between BKMEs and downstream environmental effects:

- In Sweden, where the evidence correlating Cl_2 bleaching and the documented adverse effects was inconclusive, its use was environmentally suspicious and an obstacle to further effluent closure given its corrosiveness (Axegård, 1998). Requiring long-term scientific studies made policymakers face the risk of failing to protect the environment in a timely fashion, while slowing down environmentally-promising innovations.
- In Finland, policymakers did not want to introduce changes without proven environmental benefits (Ruonala, 1998). This was environmentally unwise and economically wasteful, given the significant costs already involved in external treatment. The 'safe until proven otherwise' paradigm represented a rational response in addressing unproven risks.

What is quite certain is that Swedish and Finnish authorities did not face the same dilemma of scientific rigor or policy relevance in addressing information gaps to link BKMEs with downstream environmental effects. These differences carried different prerequisites by which causal inferences could be made valid. This case study illustrates the hazards inherent in assumptions of validity in controversial contexts. If we accept that causal inferences are seldom fully confirmed, then *plausibility* must be distinguished from *validity* in examining linkages between knowledge and operational decisions (Schon, 1995). Targeting Cl_2 bleaching suggests an overt preference by Swedish authorities for a causal inference more susceptible of future actions and optimization of environmental performance. Conversely, Finland showed scientific scepticism and sought additional expertise rather than relying upon the anecdotal evidence that contradicted the scientific fundamentals of its policy.

However, the overwhelming influence of market forces precluded protracted discussions and required a compromise among Baltic Sea countries to overcome their disagreements. Sweden and Finland being, by far, the main P&P producing nations among contracting parties to HELCOM, both were mandated by the Commission to resolve the dispute and to submit recommendations. To overcome political polarization, countries agreed to reach consensus through a bi-lateral working group mandated by the Nordic Council of Environment Ministers.[7] The group was mediated by a Finnish engineering consulting firm, chosen for its expertise in the sector and recognition in both countries. New scientific information brought a turning point to the discussions. Studies indicated the low molecular weight materials represented only 5% of the total AOX constituents, far from the 20% previously suggested by Swedish regulators (Myreen, 1998). Existing control techniques, such as activated sludge treatment, were efficient in addressing the toxicity of effluent at those low levels. The debate reached closure as technological benchmarking demonstrated that both ECF (i.e. substituting COl_2 to Cl_2) and TCF techniques were achieving comparable environmental performance. On 15 June 1989, the working group recommended that BKMEs should, as an average for each contracting parties to both HELCOM and PARCOM, be limited to 2 kg AOX/tonne of coniferous pulp and 1 kg AOX/tonne of deciduous pulp, or 1.4 kg AOX/tonne of bleached Kraft pulp, by the end of 1995. Sweden and Finland endorsed the proposal, which was later adopted as official guidelines of the Nordic Council of Ministers in 1990. [8]

Risk assessment qua decision-making: reconciling facts and values

In retrospect, the case study revealed how decisions were actually an exercise in dealing with various, contradictory types of information, suggesting that different kinds of decisions were constrained by different kinds of risk, as well as inherent conflict of interests built into the regulatory process. It illustrated how linkages between knowledge and decision were shaped out of intellectual premises and resources in ways that were context-dependent. Both countries differed markedly with respect to the perceived potential benefits and diffused costs of low predictability of risk estimates. Consequently, the dynamics shaping the political economy of pulp production interacted differently in the respective jurisdictions, in particular:

- market forces, which induced different correlation between environmental risks and financial risks at different points and time of the regulatory process; and
- technological developments at mills, responding to market expectations and political pressures, inducing authorities to capture improvements in environmental performances through national regulations and/or permitting requirements.

What makes the case so interesting is how economic and environmental factors coincided in providing a competitive edge to the Swedish industry, allowing them to charge premium prices for Cl_2-free product. The emergence of market niches in the late 1980s, triggered by the detection of dioxins throughout the papermaking cycle, eased acceptance of lower quality chlorine-free products, which increased the diffusion of O_2-based delignification techniques. Yet, the fact remains that the Swedish industry had been carrying out projects on the economic and environmental significance of Cl_2 bleaching well ahead of regulatory and market pressures. The situation showed an industry/authority consensus in shifting emphasis from proven risks to seek co-optimization of economic and environmental considerations through prospective techniques and anticipation of environmental issues associated with synthetic chemicals. Conversely, the late decision by Finland in adopting a national AOX policy in 1989 reflected that it had been out of sync with environmental issues affecting pulp and papermaking, reflecting a general trend across the industry in OECD countries (Phillips, 2000). This condition, combined with the conventional focus towards BOD and end-of-pipe compliance, explained why decisions were delayed. Relying on market signals was then a rational response to changing conditions, rather than conservatism. The decision later proved wise as comparative assessment of processes substituting to conventional Cl_2 bleaching showed an environmental equivalence. This information gradually switched market demands back towards traditional economics of product quality specifications. As a result, premium prices on Cl_2-free products fell and ClO_2 bleaching soon became the fastest growing segment of chemical pulp. In the end, Finland was able to retain its competitiveness, while fine-tuning regulations accordingly.

Conclusion

It is awareness of the knowledge influencing the decision-making process that constitutes the main factor in understanding policy changes, and not necessarily whether this knowledge is scientifically validated. Through the examination of the policy dispute involving Sweden and Finland, local factors have been shown to induce differences in risk posture and instrumental perspective between the jurisdictions. Claims about the importance of 'market pull' or 'policy push' are as such superficial since each country faced different contexts, and every changing conditions led to differing sets of constraints and opportunities affecting the competitive and regulatory situation of their industry. This type of environmental controversy is symptomatic of the knowledge gap linking the aspiration objective of sustainable development and regulatory demands placed by local authorities. International consensus over sustainable development paths is likely to be dependent on resolving this type of issues. In this perspective, knowledge-based analyses are a necessary counterpoise to power and interest in order to understand the processes that shape the knowledge guiding social changes.

BIBLIOGRAPHY

Alliance for Environment Technology (AET). 1999: www.aet.org/facts/rippleAd.htm .

Auer M. 1997. Negotiating Toxic Risks: A Case from the Nordic Countries, *Environmental Politics*, 5: 687-699.

Auer M. 1996. Negotiating Toxic Risks: A Case from the Nordic Countries, *Environmental Politics*, 5(4): 687-699.

Axegård P. 1998. Interview, Former Expert with the Swedish firm, Eka Chemical.

Carey J., Hodson P., Munkittrick KR., Servos MR. 1993. *Recent Canadian Studies on the Physiological Effects of Pulp Mill Effluent on Fish*, Ottawa: Environment Canada.

Enckell E. 1998. Interview, Permit Writer and Finnish Delegate at HELCOM.

Fallenius UB. 1988. Environmental Matters Concerning Pulp and Paper Industry in Sweden, Helsinki Commission, 18 October.

Finnish Environment Institute 1997. *The Finnish Background Report for the EC Documentation of Best Available Techniques for P&P Industry*, Helsinki: FEI.

Følke J., Männistö E., Lehtinen KJ., McCubbin N. 1993. *Chlorine Dioxide in Pulp Bleaching – Technical Aspects and Environmental Effects*, Brussels: CEFIC.

Gullichsen J. 1998. Interview, Helsinki University of Technology.

Jasanoff S. 1996. Science and Norms in Global Environmental Regimes, in *Earthly Goods – Environmental Change and Social Justice*, Hampson FO., Reppy J. (eds.), Ithaca: Cornell University Press 173-197.

Jirvall N. 1998. Interview, Chairman of the Swedish Forest Industries Association.

Kline SJ., Rosenberg N. 1986. An Overview of Innovation, In *The positive Sum Strategy*, Landau R., Rosenberg N. (eds.), Washington: National Academy of Science, 275-305.

Lagergren S., Nyström E. 1991. Trends in Pollution Control in the Swedish Pulp and Paper Industry, *Water Science Technology*, 24: 3-4.

McDonough TJ. 1998. Foreword, in *Chlorine and Chlorine Compounds in the Paper Industry*, Turosky V. (ed.), Madison: Ann Arbor Press.

Myreen B. 1998. Interview, Jaakko Pöyry Oy.

Nyström E. 1998. Interview, Swedish Delegates at HELCOM and PARCOM.

Organisation for Economic Co-operation and Development 1973. *Pollution by P&P Industry – Present Situation and Trends*, Paris: OECD.

Phillips RB. 2000. Research and Development in the P&P Industry: Year 2000 and Beyond, *TAPPI Journal*, 83: 42-46.

Pulp and Paper International. 1999. Statistics, www.pponline.com.

Ruonala S. 1998. Interview, Finnish Delegates at HELCOM.

Schon, DA. 1995. Causality and Causal Inference in the Study of Organisations, in *Rethinking Knowledge – Reflections Across the Disciplines*, Goodman RF., Fisher WR. (eds.), New York: State University Press, 69-101.

SIMONS Consulting. 1994. *Forestry Sector Benchmarking Initiative – A Case Study in Environmental Regulations*, Ottawa: Canadian Forest Service & Industry Canada.

Tana J., Lehtinen KJ. 1996. *The Aquatic Environmental Impact of Pulping and Bleaching Operations – An Overview*, Helsinki: Finnish Environment Institute.

Wheeler D., Martin P. 1992. Prices, Policies, and the International Diffusion of Clean Technology: the Case of Wood Pulp Production, in *International Trade and the Environment*, P. Low (eds), World Bank: Washington, 197-224.

REFERENCES

1 The industry-wide shift from sulphite to Kraft pulp production was driven by operating cost considerations. Comparing cost of spent liquor recovery between sulphite and Kraft production always came out in favour of switching to Kraft pulping (FEI, 1997). The 50% cost increase in energy and base chemicals in the mid 1970s, which was partly regulatory driven, also improved the competitive position of advanced mechanical pulping techniques, i.e. Thermomechanical Pulping (TMP), against chemical pulping, though higher energy costs of mechanical pulping offset this advantage (Wheeler and Martin, 1992). Bleached Kraft and TMP are the grades responsible for the recent growth of world wood pulp supply (Tana and Lehtinen, 1996).

2 As a result, BOD limits in Sweden became less restrictive at 8-17 kg BOD/tonne of pulp compared to the American limit of 4-8 kg BOD/tonne. In 1980, compliance with BOD limits in the United States amounted to about $1.4 billion in capital expenditures and $430 million annually in operating costs (SIMONS, 1994).

3 Sampling at the same locations two years earlier had failed to detect dioxins. Advances in analytical methodology later enabled detection in parts per quadrillion and trillion range (McDonough, 1998).

4 **T**otal **O**rganically-bound **Cl**orine provides a measure of chlorinated materials in the effluent. Introduced in Sweden, it was later replaced by an alternative method, absorbable organic halide (AOX), because of its experimental complexity and low accuracy.

5 SEPA required the support of the Environment Ministry, which upheld its demand for stringent TOCl limits against reluctant local permitting authorities (Nyström, 1998).

6 Using the **E**xtractable **O**rganic **C**hlorine (EOCl) as a tracer of bleached plant effluent, Nordic studies conducted in the early 1990s have shown that some 21,000 tonnes of EOCl had been discharged in the Gulf of Bothnia since the onset of large-scale chlorine bleaching in the 1940s. The EOCl fraction represents 0.5-2% of the chlorinated effluent, but it contains the ecotoxicologically important class of chloroorganic compounds (Jonsson *et al.*, 1996).

7 "The five Nordic countries, Iceland, Denmark, Noway, Sweden and Finland established the Nordic Council in 1953 to serve as an advisory body to Nordic parliaments and governments. Eighteen years later, the Nordic Council of Ministers was founded in response to growing differences among Nordic countries over the prospect of each nation's membership to the European Economic Community. […] Whereas the Nordic Council was largely a consultative body with no legal authority, the Nordic Council of Ministers possessed at least minimal authority to impose rules on member states. In 1988, Swedish and Finnish delegates to HELCOM obtained funding from the Nordic Council of Ministers to evaluate state-of-the-art technologies to reduce AOX. In addition, the Council of Ministers provided financial support for a new round of multilateral negotiations outside of the HELCOM setting. These meetings took place between 1988 and 1989." Quoted from Auer (1996, 18-19).

8 Finland adopted its Decision on the matter of chlorinated organic compounds on 22 June 1989. The proposal led to HELCOM and PARCOM recommendations on 15 February and 14 June 1990 respectively.

Paper 5

SCIENCE AND EXPERTISE IN ENVIRONMENTAL POLICYMAKING: A SOCIO-POLITICAL PERSPECTIVE

Introduction: science, expertise and policymaking

Forecasts indicate that continuous economic growth and demographic expansion will push the limits of ecological systems further (OECD, 2001). With human activities increasingly threatening life-support systems, economic development is likely to be limited, in return, by resource depletion and degradation, as opposed to limits inherent to human knowledge (Ring, 1997). The interdependence of economics and ecology is increasingly central to policymaking (Colby, 1991), while environmental awareness and public commitment to science are becoming chief attributes of sustainable development (Cohen, 1998).

There is great expectations put on science to help foresee current and future societal issues in the face of increasing complexity and uncertainty that characterise our understanding of global environmental risks. However, several assumptions underlie this statement. First, science is assumed to provide objective data in a way that improves decision-making. Second, policy improvement seems to require that research develop better predictive tools. Third, scientific expertise is considered as a prerequisite to grasp scientifically related issues. Yet, as each of these interrelated assumptions are examined more closely, we quickly understand that the link between science and decisions is neither straightforward nor well understood:

- First, in decision-making contexts fraught with uncertainty and controversy, *objectivity* is hard to come by while it is easy to find experts for the pros and the cons. As politics finds its sources not only in power but also in uncertainty (Heclo, 1974), expert knowledge is inevitably mixed up with political power and interests, producing claims liable to social interpretation (Wynne, 1993). More research does not resolve such dead-ends. A debate that is not scientific to begin with cannot be resolved by expert arguments, however powerful they may be (Allen, 1987).
- Second, many environmental risks facing policymakers require science, yet go beyond its limits (Weinberg, 1976). Moreover, the belief in the puzzle-solving and predictive power of science is out-of-sync with most decision-making contexts in which facts are uncertain, even unpredictable, and where stakes are high and values in dispute (Funtowicz and Ravetz, 1990; Brunner and Ascher, 1992). Scientific prediction exposes the uncertainty; it does not solve it. Power structures turn this trend into a positive effect. Scientific scepticism often leads to a tacit *collusion* in which those interested in delaying decisions or defending the *status quo* always find scientists supporting claims for better prediction and its inherent research funding (Mukherji, 1989).
- Third, science is seen as indispensable in facing environmental risks. Yet it can be inoperative if objectivity is the prerequisite. The search for objectivity most often leads to political inaction. Though objectivity must be a constant goal in policymaking, it cannot be taken for granted. Data take their meaning from the context of human values in which mandated science operates. Values in dispute are resolved through successful politics, not science (Majone, 1977).[1] Furthermore, the problem is often not so much a lack of knowledge, but whether it is practical, comprehensible, timely, or profitable.

Obviously, scientific expertise is paramount to policymaking. Incomplete and inadequate knowledge is indeed one of the most severe constraint facing human beings in making all kinds of decisions (Sowell, 1980). What needs to be recognised, however, is that both expertise and policymaking must change if there is to be a better synergy between science and politics (Weinberg, 1976; Funtowicz and Ravetz, 1990; Mayo, 1991; Wynne, 1993).

This articles analyses the socially constructed nature of scientific evidence about environmental impacts of bleached pulp mill effluents and, in so doing, links previous work on the social construction of science for policy[2] with the interest-based model in sociological studies of science. The paper begins with a discussion of the systematic ambiguity running through the large and diverse literature on the role of expertise and science in policymaking. The ambiguity concerns the forensic context in which experts appear as both fact seekers and defenders of particular interests. Science is next addressed as a special case of professional thinking to examine whether the resultant knowledge may be seen as more *objective* and less liable to social interests and determination. Through an examination of the controversy surrounding risk assessment of chlorine bleaching, the paper then illustrates an explicit link between science and policymaking designed to explain differences among countries within a single explanatory framework.

Expertise in policymaking: a dual process

The link between expertise and policy is somewhat of a paradox. The recourse to expert knowledge has been continuously growing, yet much of it is known to be useless, dismissed, or left for non-substantive purposes (Clark and Majone, 1985). When an issue turns out to be controversial, the interventions of experts merely expose the political polarisation, manipulative schemes and conflicts of interests that are built into the policymaking process (Benveniste, 1972; Nelkin, 1975; Marshall, 1983; 1989). In messy decision-making environments, where goals and interests are multiple and contradictory, experts are guns for hire and the resultant knowledge clearly liable to social bias.

Understood as the encounter between an expert knowledge and a forensic context, the nature of expertise appears equivocal (Restier-Melleray, 1990). Either the competence of experts refers to some knowledge category, in which case the relation between competence and expert knowledge becomes tautological; or it refers to a performance, in which case the competence is reduced to a set of individual acts in interactive decision-making contexts. The link between knowledge and performance remains elusive, yet the competence of experts includes both (Merchiers and Pharo, 1992). We may better grasp the ambiguity by comparing how scientists and experts behave in contexts where facts are uncertain, decisions depend on research and stakes are high. For the scientist, the latter consideration should have no influence to the validation of facts. For the expert, strengthening his position by using scientific scepticism against opponents' work reflect a concern "less for the (contested) "facts" than for [his client] threatened interests" (Funtowicz and Ravetz 1990). In such a context, the counter-expertise appears as the very denial of the idea of expertise

(Paradeise, 1985). It is therefore not surprising that the expertise is often seen as validated through social trust, interest and authority, rather than by the sceptical testing suggested by the scientific tenet (Smith and Wynne, 1989).[3]

Beyond bureaucratic capture, it can be argued that the shortcomings of expertise are rooted into some unrealistic expectations about what actually happens in a decision-making process. Much of the beliefs about the role of expert knowledge in policymaking still bear the imprints of the old dream of substituting *the administration of things to the government of men*.[4] Thus, the positivist view continues to hold much influence on decision-makers, a prevalence that is obviously rooted in its historical and political significance (Torgerson, 1986). Historically, the rhetoric of legitimacy underlying the positive role of science in society has driven the social organisation of professional disciplines.[5] The rise and diffusion of professional expertise and policy analysis can be seen as co-extensive of such rhetoric.[6] Politically, the façade of objectivity conferred by expert knowledge appears to provide a sure rock against which stakeholders can anchor their commitments. Turning issues over to a particular groups of experts invariably involves the imposition of particular values and interests on others (Sowell, 1980). Despite the counter-expertise, the decision-making unit in which protracted discussions are prolonged may even use the deadlock to raise itself as the instance of arbitrage. Thus, the bureaucratic capture of scientific practice can be seen as *engineered* through its inclusion in social settings (Duclos, 1991).

Assuming that decisions flow organically from the expertise, in the sense of disinterested experts educating policymakers to improve decisions, is a caricature. Perhaps this can be turned around. It may be more relevant to look at it as a collective learning process, shaped through social accommodation among stakeholders, including the sciences, which set the boundary conditions for the efficacy of individual experts (Jasanoff, 1990; Limoges 1993). Thus, the issue is not so much the substance of decision, but rather how the design and representation of the process influence the validation of knowledge in support of decisions (Majone, 1977). Inasmuch as the expertise is socially determined, then it cannot he held as a constant factor of policy, but as a variable shaped by the constraints, incentives and feedback mechanisms of its particular locus and problems under review (Sowell, 1980).

Science in environmental policy context: a risky business

Science may represent a particular case of professional thinking. Traditionally, it was granted a special place because its method was believed to make the resultant facts more objective and less liable to social interpretation. The importance attached to science in policy matters, notably in environmental policymaking, suggests that the notion remains influential. In the United States, for example, virtually all the R&D funding devoted to the administration of environmental issues has been attributed to hard sciences (Alm, 1992). Since ambient and technology-based standards make up the core instruments of regulatory systems, this is understandable. The undertaking of problems, such as bio-diversity, water quality and climate change, would also be hardly thinkable without resorting to scientific research. The question, therefore, is not whether science is required, obviously it is, but whether it is framed towards addressing the hard issues facing decision-makers. [7]

Yet it is not all clear that science implies wisdom in environmental policymaking. Where there is radical uncertainty, scientific expertise cannot provide reliable answers and decision-makers often wander (Adams, 1997). Ill-founded scientific predictions clearly misled policymakers when it was early assumed that the protection of the environment and public health increased proportionally to the height of industrial stacks and the capacity of water flow in rivers and estuaries in which pollutants were discharged. When negligible effects are subsequently monitored in ecosystems, which have been subjected to pollution over long periods, the data may turn out to be an ill-informed legacy of past neglects, leading scientists to misread the lesser sensitivity of remaining organisms with the upper limits of tolerance beyond which signs of distress may appear (Dethlefsen *et al*., 1993).

Knowledge gaps between the positive (the production and validation of knowledge) and the normative (the relationship between the public, expert and political authority) in decision-making raise the epistemological issue whether the universe of facts must be seen as pre-existing our coming to it, or whether it is socially constructed, a character that can only be revealed through subsequent counter-evidence.[8] Implicit to this is the practical question "whether the empirical, scientific, and technical questions in estimating environmental risks either can or should be separated (conceptually or institutionally) from the social, political, and ethical questions of how the risks should be managed" (Mayo, 1991). The classic (positivist) answer to that question assumes that a sharp distinction between science and policy is a prerequisite to immunize the objectivity of scientific practice from the subjective ends of policymaking. Since the 1970s, this view has been challenged on both practical and epistemological grounds of either the possibility or desirability of separating scientific risk assessment from the context of human values inherent to risk management.[9]

The problem with the positivist view is that people are lead to believe that a consensus can be reached through science solving the disputed facts in a way that positively influence decision-making. Yet, instead of the old image of science solving nature's enigmas, the reality is rather one of coping with the uncertainty and complexity that characterise our understanding of global environmental risks (Funtowicz and Ravetz, 1990; Wynne, 1993). In such a decision-making context, political expediency or the recourse to delays appears as a more appropriate description of how uncertainty is dealt with than enlightened politics. Claims for better prediction through more research reflect by themselves a bias about the role of science, often cutting off decision-making from direct feedback and turning into a *conspiracy* against the laity (Anon, 1992).[10] These postures are seen by many as threatening public trust in science to the extent that it serves self-interests and their scientific allies at the expense of the general public and good science (Weinberg, 1976).[11]

The structuring of interests and knowledge authentication

Current studies in the sociology of knowledge have sought to develop a coherent theoretical framework aimed at understanding science as a socially determined phenomenon. The resultant analytical frameworks can be broadly divided into two camps: a focus on the concept of interests and knowledge authentication as a process of attribution (Bowden, 1985). On the one hand, the sociology of interest analyses the behaviour of actors within a '*satisficer*' model (Simon, 1978), thus clearly borrowing from the paradigm of the neo-classical economics (Caillé, 1981). Implicit to the analytical framework is the view that actors carry some rational understanding of world states, underlying the coherence of their choices, in seeking the greatest possible 'want satisfaction'. Knowledge of particular time and place is thus analysed through the structuring of individual and collective interests, evolving through perceived gaps between outcomes and aspirations, and (re)assessment of decision situations.[12] On the other hand, the concept of attribution does not exclude the notion of interests, but sees it as coincidental or *ex post* to science *in the making*. Drawing on ethnomethodology, the analytical focus here is on the series of local acts constituting facts as valid, following a logic of symmetry in which people, things, beliefs, and interests are *networking*, i.e. a social construct (e.g., Brannigan, 1981; Callon, 1986; Latour and Woolgar, 1986).

The record of social studies of science suggests that interests play a larger role when an issue is new, fragmentary, and with unclear implications for existing methods and theories (Laudan, 1977). As rational understanding develop, the room for social determination become more limited. The distinction suggests that a historical perspective may be warranted, following a methodology of first trying to account for scientific claims on the ground of rational success and only seeking social explanations when results are weak. In allowing objective grounds for criticism, such an approach may circumscribe the dualism between objectivism and subjectivism, which haunts most sociological accounts in the study of science (Mayo, 1991).

The case study used in the paper illustrates an explicit link between structural interests and knowledge authentication suggesting local contextual factors inducing differences in risk estimates of bleached kraft mill effluent (BKME). These differences became visible when policymaking turned to the preventive paradigm, substituting technology-based approaches to the previous environmental management approach which was based on the principle of assimilative capacity of the environment. The chlorine bleaching controversy can be seen as an epiphenomenon of the paradigm shift causing turmoil and changes in the political economy of the sector. But before getting to the case, it is first necessary to examine more closely the implications of the precautionary principle on environmental decision-making.

The science and politics of the precautionary principle

It can be argued that the most significant change that arose since the 1970s environmental reform came with the formulation of the precautionary principle.[13] The 'better safe than sorry' principle was itself a response to past failures of environmental management approaches based on a permissive interpretation of the assimilative capacity of the environment. Activities were deemed 'safe until proven otherwise' and scientific scepticism most often ended up as a way to legitimate even more control over natural environments (Jackson *et al.*, 1993). The precautionary principle turned this situation around by explicitly recognising that legislative actions could be required even in the absence of conclusive proofs of harm.[14] Shifting the burden of proof towards polluters and away from nature involved more than a new epistemology, changing quite drastically the nature and direction of risk assessment (e.g. Colby, 1991; Wynne, 1993).

So far as natural systems were thought to be linear and gradually modified without discontinuity, predicting responses to various stresses rested on an understanding of their structures and functions. These criteria allowed controlled and reproducible experiments to be conducted by establishing threshold limits below which pollution could be avoided (Portmann and Lloyd, 1986). Increasing environmental deterioration, together with advances in geo-physiology, the chaos theory and *Gaia* hypothesis (Lovelock, 1979), later showed the precariousness of such a view. Natural ecosystems are basically non-linear and stochastic, involving a complex set of homeostatic (stabilising and destabilising) feedback mechanisms. Understanding these functions appears therefore critical to establishing limits within which the system components can either conceal the disturbance or, in cases where the adverse effect decreases, bring the whole to its original backgrounds (SEPA, 1997).

The foregoing development clearly raised doubts about the possibility of establishing a limiting assimilative capacity of natural systems upon which previous environmental management approaches were based. In such a framework, identifying no adverse effects of specific pollutants rests on being able to prove the absence of harmful effects. Yet no finite number of empirical verification can do this, inasmuch as some pathways are overlooked (for administrative reasons, scientific limits or other reasons). If it is impossible to ensure unequivocal cause-and-effect relationships, then leaving environmental protection to the principle of environmental capacity alone appears dubious (Dethlefsen *et al.*, 1993).

Thus, the burden of proof in regulation is a matter of debates and controversies in policy (Funtowicz and Ravetz, 1990). The tension comes both the legislation, which requires accountable and affordable evidence in making all kind of decisions, and from science, which aims to scientifically-validated the factual basis of decisions (Smith and Wynne, 1989). Despite efforts towards improving the science-policy relationships through procedural innovations, differing processes of validation most often conflict, while ignorance and uncertainty remain the typical characteristics of environmental policy contexts (Wynne, 1993).

This regulatory dilemma explains by itself the swing of the pendulum that has characterised the evolution of principles and instruments upon which environmental policies have been formulated since the 1970s (Rajotte, 2003). Early on, the best available technology (BAT) concept was explicitly substituted to ambient quality standards to avoid the problems posed by scientific uncertainty about the risks of pollutants to public health and the environment. Quite rapidly though, emerging problems, e.g. ozone depletion, climate change, along with advances in analytical instrumentation, e.g. the detection of dioxin, showed that technology-based approaches alone cannot guarantee a pollution-free environment (Portmann and Lloyd, 1986; Tietenberg, 1996). The respective limitations of single sources of environmental prescription led to the ongoing consensus regarding the need for complementary approaches. Positively, it helped rehabilitate the assimilative capacity concept as an essential tool of environmental management. In moving away from misinterpretations based on the 'dilute-and-disperse' philosophy, the uptake of environmental quality factors has been useful in risk evaluation and cost effectiveness issues associated with regional pollution scale, e.g. the critical load concept in defining long-range transboundary pollution goals among jurisdictions. Together with BAT benchmarking, environmental quality standards and objectives clearly help orient the available resources, while adapting developments with cost efficiency (OECD, 1999).

Paradigm shifts and overlaps in environmental management must be seen as evolutionary, with new approaches competing with each others and prevailing practices, and with winners and losers determined in actual contest through selective incentives and constraints. A fuller consideration of knowledge in decision-making requires a recognition of these different principles and instruments, including their scientific, economic and policy dimensions. The issue, therefore, is not merely the type of knowledge, but *who* drives the decisions, under what constraints and feedback mechanisms (Sowell, 1980).

Science in controversy: the case of chlorine bleaching of pulp

Environmental concerns turning to chlorine (Cl_2) bleaching of pulp are usually associated with two, coincidental, scientific events that subsequently led to policy and technological changes internationally:

- The Project Environment/Cellulose (PEC), sponsored by the Swedish Environmental Protection Agency (SEPA) that documented changes in plants and fish around the *Norrsundet* bleached kraft pulp mill, located in the Gulf of Bothnia. The field studies were made in 1984-1985 and the results published in 1988. Altered fish populations, deformed eggs, enlarged livers and other subtle effects were documented, as well as chloro-organics, widely distributed around the mill, notably dioxins and furans. The conclusion drawn was that high discharge and accumulation of chlorinated materials was a cause for concern, considering the harmful effects observed and the history of adverse effects associated with these compounds (Södergren *et al.*, 1988); and
- The detection of dioxins in effluent, sludge and fish downstream from bleach pulp mills in the United States (US) in the mid-1980s. The findings led to closure of many fishing grounds. Risk perception increased when subsequent studies revealed that dioxins could be found in consumer goods such as milk containers, coffee filters, sanitary and paper products (USEPA, 1990; Greenpeace, 1990).

Industry and regulatory authorities were aware of chlorinated compounds being discharged in aquatic environments,[15] but what came as a surprise was the highly toxic potential of some of them, in particular the dioxins. PEC results prompted Swedish authorities to take actions despite the fact that no specific links could be made between chlorinated effluents and downstream environmental effects (Södergren *et al., 1988*). TOCl/AOX-based limits[16] were incorporated in Swedish permits from 1986 onward (Lagergren and Nyström, 1991).[17]

The international debate really started when Sweden requested HELCOM and PARCOM to adopt a recommendation restricting Cl_2 bleaching and discharges, while mandating oxygen (O_2) delignification as a compliance measure. The demand was controversial and challenging because it was not proven whether Cl_2 was the cause of adverse impacts, nor if compliance could be reached with available techniques. The proposal sparked a bitter debate among major pulp and paper producing countries, in particular between Finland and Sweden in the context of HELCOM discussions. At the onset, the adoption of Cl_2-free policies clearly favoured the Swedish P&P industry and equipment supplier industry, given their leading edge in Cl_2-free bleaching equipment and pre-step techniques, such as O_2 delignification, and modified and extended cooking. Obviously, it gave the appearance that the Swedish recommendations were influenced by extra-scientific considerations.

Scepticism from the opposition increased as a series of methodological flaws became known. No specific attempts were made by PEC scientists to connect some of the observed effects to exposure to one or several chlorinated organic compounds (Tana and Lehtinen, 1996). The control mill using Cl_2-free bleaching was very different in capacity and location, "having a lower pulp production and a lower [biological oxygen demand] BOD loading, combined with greater flushing and effluent dilution in the receiving water" (Carey *et al.*, 1993). Worst, start-up operations at the *Norrsundet* mill led to heavy losses of black liquor, washing waters, spent acids and contaminated sludge, all conditions known as potential cause of the reported effects. Thus, the neglect to explore alternate explanations, in particular studies linking the observed effects to natural wood constituents in effluent,[18] suggested that the results drawn by PEC scientists were dubious. Furthermore, Canadian and Finnish field studies comparing environmental impacts of bleach mills using both Cl_2 and Cl_2-free technologies could not find a correlation between AOX and effects. In fact, similar adverse impacts were detected under both effluent conditions, suggesting that something else than chlorinated compounds was responsible (Peck and Daley, 1994).

The search for the faulty compounds was becoming both a policy and trade issue since a growing number of individuals and groups were calling for a Cl_2 phase-out. Demands for the phase-out of chlorine were not only coming from environmental groups. In 1992, the International Joint Commission on the North American Great Lakes concluded that chlorine and chlorine-containing compounds in the Great Lakes basin should be banned (NLK, 1993). The prospect of a complete phase-out of Cl_2 industrial chemistry was also a result of the succession of major environmental controversies associated with chlorinated compounds. Thus, the environmental crisis in the aftermath of the massive spreading of chlorinated pesticides, such as DDT, was a landmark step in the rise of the environmental movement and the creation of the federal environmental authority in the United States (Bastian, 1986).[19] Concerns regarding the persistency and bio-accumulation of chlorinated substances in the environment increased as a growing body of scientific work documented reproduction failures and extinction of species, contamination of groundwater, long range atmospheric deposition in remote areas, depletion of the ozone layer, and the likes.[20] The lessons of history were obviously dragging risk perception on the side of precaution.

The overwhelming influence of public pressures, notably through increasing demands for chlorine-free products on the North European markets, soon precluded protracted discussions, compelling other countries to adopt policies restricting chlorinated discharges.[21] For many industry experts and regulatory authorities abroad, the decision appeared as an uncritical combination of the precautionary principle and the concept of BAT (Følke *et al.*, 1993). It compromised *good* science to the rhetoric of the Greens.[22] As it is commonly the case, the controversy revealed the existence of conflicting arguments, "suggesting that different conclusions [were] reached because of different paradigmatic perspectives" (Eijndhoven and Groenewegen, 1991).[23] Clearly, the bone of contention concerned the relationship of the precautionary principle to the scientific interpretation made by Swedish authorities about what was still perceived by opponents as a virtual risk.

Those involved soon became aware that the debate was more about controlling industrial discharges in the environment than about the pulp-bleaching chemical itself. Lost in the controversy, however, was an understanding of how science and politics reached a measure of reconciliation in spite of differences of goals and interests among stakeholders, and quasi-independent local contexts shaping risk assessment of BKME.

Half-truths make sense, almost[24]

Consider the paradox: on the one hand, critics of Cl_2-free policies argue that "the rapid transformation of the pulp bleaching process technology during the last decade was, in fact, mainly driven by a series of scientific rebounds, such as over-interpretation and, in some cases, misinterpretation of the scientific material regarding environmental impacts". On the other hand, the same detractors conclude that eliminating "chlorine as a bleach chemical in the pulp industry has brought about a positive environmental effect [allowing] a closure of the mill system and recycling of the bleach plant effluent back to chemical recovery system. Thereby, also the unchlorinated toxic compounds can be withdrawn from the discharges" (Tana and Lehtinen, 1996). If this *ex post* paradoxical conclusion were rooted in *ex ante* different local contextual factors among jurisdictions, then it would be pointless to try to compare them by using either science or technology as the litmus test. In short, the assumption proceeds on the premise that those local contextual factors are not a constant but a variable, yet it is a crucial variable from the standpoint of the effectiveness of knowledge in particulars of time and space.

Policy analysis can be very misleading by ignoring the different kinds of incentive structures and constraints facing experts and decision makers in dealing with a particular issue, yet in taking place in quasi-independent local contexts. When does research improve policy in such a perspective? There are no straightforward answers to the question, though it is preferably dealt with on a case-by-case basis. Research designed to investigate a specific policy need – BAT to reduce certain pollutant discharges, for example – is very different from scientific investigation into reproductive failures of fish communities exposed to specific pollutant streams. Yet they can be equally effective in achieving the objective being sought. In instances where facts are uncertain, interests in dispute and decision stakes are high, decision makers most often seek to fill the limitations of various sources of investigations through their combined use (Rajotte, 2003).

Obviously, investigating further upstream in the pulp bleaching process exposed more of the uncertainty about downstream environmental effects. Yet the uncertainty was already there, but "black-boxed" in previous policies. Untreated BKMEs were known to include large amounts of toxic substances. Up to the 1980s, only about 10% of BKME constituents had been identified and many had never been investigated (Bengtsson and Renberg, 1986). It is estimated that there are perhaps 2000 chemicals in chemical pulp mill effluent (Strauss, 1993). Past studies had a tendency to measure only the acute lethality of effluents, while using sum parameters to establish threshold limits for conventional pollutants and properties, e.g. dissolved oxygen caused by decomposition of organic substance, suspended solids, pH, etc. Although seldom documented, no correlation had been established between AOX exposure and effects on aquatic communities (Carey *et al.*, 1993).[25] Experts suspected that excessive BOD discharges over the period 1945-1970 were probably *hiding* more subtle toxic effects of other contaminants in the effluent. They were convinced that the low molecular weight portion of chlorinated organic matter, as well as resins and fatty acids, were probably responsible for some of the adverse effects. It was estimated that about 75-80% of the organically-bound chlorine in the effluent consists of high molecular weight compounds which have proven difficult to identify and characterise.[26] However, most were thought to be harmless due to the size of their molecules, with about half readily biodegradable and disappearing during effluent treatment.

Such was the state-of-the-art risk assessment of BKMEs when dioxin detection and the Swedish initiatives following PEC turned environmental concerns to Cl_2 bleaching. The environmental level playing field was still focussing on BOD, and external treatment was BAT in most countries. Only Sweden had differentiated itself by substituting chemical oxygen demand (COD) to BOD limits in order to favour pollution prevention against pollution control. The high dilution capacity conferred by its mills siting on the Baltic Sea clearly provided a safety margin with respect to oxygen depletion that other countries did not have. The immediate results from these internal measures were more modest in the final effluent than what could be achieved through external treatment. But preventive measures at source was more likely to anticipate on emerging issues since continuous detoxification of pulping and bleaching operations allowed the primary effluent to be recycled back to chemical recovery systems. Conversely, in the remaining P&P producing countries, BAT regulations still reflected the old pollution control paradigm. In spite of the tightening up of regulations, BOD-based limits had no direct effect on compliance strategies. Pollution control was the end of the matter and the result end-of-pipe techniques.

Something else differentiated Sweden from other countries in environmental terms. Its consensual and co-operative style of policy development, along with a strong environmental awareness and public commitment to science, placed the country as a frontrunner of green competitiveness, both at the local and international levels (Lundqvist, 1998; Cohen, 1998). It can be argued that the paradigm shift towards the precautionary principle provided the opportunity for Sweden to take advantage of its unique regulatory features and leading edge in pulping and bleaching technologies. Thus, PEC results were scientifically worthy because the precautionary principle had momentum within a growing international public opinion frustrated by decades of environmental senseless economic development. This had been most explicitly the case with the P&P industry, in particular during the 1945-1970 era (Tana and Lehtinen, 1996). Scientific objectivity became useless to Swedish authorities since Cl_2-free policies clearly provided a competitive edge on the Northern European P&P markets and to its P&P industry and equipment supplier industry, while improving the environmental performance of mills overall. In contrast, countries that had focussed on external treatment could not find any economic advantages to new investments in Cl_2-free equipment, except to the extent of potential losses of market shares. External treatment complied with prevailing environmental standards and any changes were to be met by the industry's counter-expertise.

Yet another important but little noted paradox was that the breakage of the chlorine connection through counter-expertise, if a good news for the environment (given the irreversibility of effects associated with these substances), was publicly revealing that the faulty chemical X causing the adverse effects remained unknown (Strauss, 1993). Consequently, the debate took a new turn, forcing the protagonists to reach a consensus on which measures to use in order to address the problem in spite of scientific uncertainties and differing risk perception. Science could only play second fiddles to a social process reconciling values and interests in paper manufacturing into environmental terms.

Conclusion

Expert knowledge is a prerequisite in support of effective environmental decision-making. Yet social studies of the role of science in policymaking have shown that the context is still fraught with unrealistic expectations, inherited from a positivist past, about what science can actually achieve. In particular, these studies have stressed the precariousness of operating a sharp distinction between them. Science and expertise cannot escape the normative tension induced by multiple interests and values in a forensic context. Mandated knowledge is a product of negotiation; the more it is studied, the more its premise is revealed to be socially determined. Only history can subsequently partition claims between those proving successfully rational from those socially constructed.

The case study used in this paper illustrates an explicit link between risk assessment and risk management of BKME designed to explain changes and conflicts in risk estimates within a single explanatory framework. The early attribution of statuses of validity to measured risks was based on the principle of assimilative capacity of the environment. Up to the 1970s, the undisputed principle led to repeated flaws with respect to environmental protection, given its permissive interpretation, i.e. the dilute-and-disperse fallacy, and misinterpretation of the dynamics of a natural ecosystem. Regulations focussed on the *visible* part of pollution, in particular oxygen depletion of water bodies. From the 1970s onward, the paradigms of environmental management changed in response to the failures of the previous approach with the adoption of the precautionary principle. The 'safe until proven otherwise' paradigm was out-of-sync with the reality of natural ecosystems, which science advisors and policymakers increasingly regarded as stochastic and unpredictable. The new paradigm significantly shifted the political economy of regulated industrial sectors. In particular, it turned the relationship between science and policy around, legitimating regulatory actions in spite of inconclusive science about potential risks.

The controversy surrounding the alleged environmental impacts of chlorine bleaching illustrates a case in which scientific knowledge was new, incomplete with limited connection to more mature lines of risk assessment of pulp mill effluent. In such a context, social factors played an important role in attributing validity to knowledge having force to guide decisions. Sweden took the leads on the issue because it was an environmental frontrunner in pollution prevention policies and technologies in this sector. In spite of inconclusive science, its early focus on pollution prevention measures at sources, combined with increasing market demand for chlorine-free products, made the recourse to the precautionary principle a matter of both good politics and competitiveness. Though the chlorine connection remains unclear, while the cause of adverse effects would appear to be related to natural wood constituents, the Swedish policies turned out to be beneficial because compliance was directed towards continuous detoxification of manufacturing processes and further closure of mill effluents. Conversely, the remaining countries had to catch up through additional investments, in spite of the contested facts. Somewhat the perceived *bad* science in Sweden turned out to be good policy.

BIBLIOGRAPHY

Adams J. 1997. Virtual Risk and the Management of Uncertainty. *Royal Society on Science, Policy and Risk*.
Allen GE. 1987. The Role of Experts in the Scientific Controversy, in *Scientific Controversies*, Engelhardt HT., Caplan AL. (eds.), Cambridge: Cambridge University Press, 169-202.
Alm AL. 1992. Science, social science, and the new paradigm, *Environmental Science & Technology*, 26(6): 1123.
Anon. 1992. Whistleblower prize for O'Toole, *Science*, 257: 27.
Auer M. 1996. Negotiating Toxic Risks: A Case from the Nordic Countries, *Environmental Politics*, 5(4): 687-699.
Bastian K. 1986. Biotechnology and the United States Department of Agriculture: Problems of Regulation in a Promotional Agency, *Ecological Law Quarterly*, (17): 413-446.
Benveniste G. 1972. *The Politics of Expertise*, Glendessary Press: Berkeley.
Bernstein RJ. 1983. *Beyond Objectivism and Relativism - Science, Hermeneutics and Praxis*, United States: University of Pennsylvania Press.
Bowden G. 1985. The Social Construction of Validity in Estimates of US Crude Oil Reserves, *Social Studies of Science*, 15: 207:240.
Brannigan A. 1981. *The social basis of scientific discoveries*, Cambridge: Cambridge University Press.
Brunner RD., Ascher W. 1992. Science and Social Responsibility, *Policy Sciences*, 25/3: 295-332.
Caillé A. 1981. La sociologie de l'intérêt est-elle intéressante?, *Sociologie du Travail*, 3: 257-274.
Callon M. 1986. Some elements of a sociology of translation – domestication of the scallops and the fishermen of St Brieuc Bay, in *Power, Action and Belief: a New Sociology of Knowledge*, Law J. (ed.) Sociological Review Monograph 32: Toutledge.
Carey J., Hodson P., Munkittrick K., Servos M., 1993. *Recent Canadian Studies on the Physiological Effects of Pulp Mill Effluent on Fish*, Ottawa: Environment Canada.
Carson R. 1962. *Silent Spring*, Boston: Houghton Mifflin.
Clark WC., Majone G. 1985. The Critical Appraisal of Scientific Inquiries with Policy Implications, *Science, Technology, and Human Values*, 10/3: 6-19.
Cohen M. 1998. Science and the environment: assessing cultural capacity for ecological modernisation, *Public Understanding of Science*, 7: 1-19.
Colby ME. 1991. Environmental management in development: the evolution of paradigm, *Ecological Economics*, 3: 193-213.
Dethlefsen V., Jackson T., Taylor P. 1993. The Precautionary Principle – towards anticipatory environmental management, in *Clean Production Strategies*, Jackson T. (ed.), London: Lewis Publishers.
Douglas M., Wildavsky A. 1982. *Risk and Culture*, Berkeley: University of California Press.

Duclos D. 1991. *L'homme face au risque technique*, Paris: L'Harmattan.

Eijndhoven J., Groenewegen P. 1991. The Construction of Expert Advice on Health Risks, *Social Studies of Science*, 21: 257-278.

Fallenius UB. 1988. Environmental Matters Concerning Pulp and Paper Industry in Sweden, Swedish Delegation Room Document, *HELCOM*, 18 October.

Faucheux S., Nöel JF. 1990. *Les menaces globales sur l'environnement*, Paris: La Découverte.

Fisher F. 1992. Reconstructing policy analysis: A postpositivist perspective, *Policy Sciences*, 25: 333.

Funtowicz S., Ravetz J. 1990. *Global Environmental Issues and the Emergence of Second Order Science*, Brussels: Commission of the European Communities.

Følke J., Männistö E., Lehtinen KJ., McCubbin N., 1993. *Chlorine Dioxide in Pulp Bleaching – Technical Aspects and Environmental Effects*, Brussels: CEFIC.

Green J. 1989. Industrial ill health, expertise, and the law, in *Expert Evidence: Interpreting Science in the Law*, Smith R., Wynne B. (eds.), London: Routledge.

Greenpeace, 1990. *Toward a Chlorine-Free P&P Industry*, Greenpeace Canada.

Heclo H. 1974. *Modern Social Politics in Britain and Sweden: From Relief to Income Maintenance*, United States: Yale University Press.

Henschler D. 1984. Exposure Limits: History, Philosophy, Future Developments, *Ann. Occ. Hyg.*, 28: 79-92.

Hilleman B. 1992. Cancer risk found from water chlorination, *Chemical & Engineering News*, 13 July: 7-8.

Jackson T., Costanza R., Overcash M. and W. Rees 1993. The 'Biophysical' Economy – aspects of the interaction between economy and environment, In *Clean Production Strategies*, Jackson T. (ed.), London: Lewis Publishers.

Jackson W. 1990. Third World Agricultural Tragedies, *Chemical & Engineering News*, December issue.

Jasanoff S. 1996. Science and Norms in Global Environmental Regimes, in *Earthly Goods*, Hampson, F. O., Reppy, J. (eds.), Ithaca: Cornell University Press, 173-197.

Jasanoff S. 1992. Science, Politics, and the Renegotiation of Expertise at EPA, *Osiris*, 2nd Series, 7: 195-217.

Jasanoff S. 1990. *The Fifth Branch: Science Advisors as Policymakers*, Cambridge: Harvard University Press.

Jonsson P., Grimvall A., Cederlöf M., Hildèn M. 1996. Pollution Threats to the Gulf of Bothnia, *Ambio*, 8: 21-26.

Kuhn T. 1970. *The Structure of Scientific Revolution* (2nd ed.), Chicago: University of Chicago Press.

Lagergren S., Nyström E., 1991. Trends in Pollution Control in the Swedish Pulp and Paper Industry, *Water Science Technology*, 24: 3-4.

Lakatos I. 1970. Falsification and the Methodology of Scientific Research Programmes, In *Criticism and the Growth of Knowledge*, Lakatos I., Musgrave M. (eds.), Cambridge: Cambridge University Press.

Latour B., Woolgar S. 1986. *Laboratory Life: The Construction of Scientific Facts*, Princeton: Princeton University Press.
Laudan L. 1977. *Progress and its Problems: Toward a Theory of Scientific Growth*, Berkeley: University of California Press.
Limoges C. 1993. Expert knowledge and decision-making in controversy contexts, *Public Understanding of Science*, 2: 417-426.
Lovelock JE. 1979. Gaia, *A New Look at Life on Earth*, Oxford: Oxford University Press.
Lundqvist L. 1998. Capacity Building or Social Construction? Explaining Sweden's Shift Towards Ecological Modernisation, *Proceedings of the International Workshop on Ecological Modernisation*, Helsinki: University of Helsinki.
Lyotard JF. 1979. *La condition postmoderne*, Paris: Minuit.
Maddox J. 1987. Half-truths make sense (almost), *Nature*, 236: 637.
Majone G. 1977. Technology assessment and policy analysis, *Policy Sciences*, 8: 173-175.
Marshall E. 1989. Science Advisers Need Advice, *Science*, 245.
Marshall E. 1983. Hit List at EPA?, *Science*, 1303.
Mayo DG. 1991. Sociological Versus Metascientific Views of Risk Assessment, in *Acceptable Evidence*, Mayo DG., Hollander RD. (eds.), New York: Oxford University Press, 249-279.
Merchiers J., Pharo P. 1992. Éléments pour un modèle sociologique de la compétence d'experts, *Sociologie du travail*, 34(1): 47-63.
Molina M., Rowland FS. 1974. Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom Catalysed Destruction of Ozone, *Nature,* 249(5460): 10-12.
Mukherji C. 1989. *A Fragile Power: Scientists and the State*, Princeton: Princeton University Press.
Mulkay M. 1979. *Science and the Sociology of Knowledge*, Controversies in Sociology Series 8: London.
Nelkin D. 1975. The Political Impact of Technical Expertise, *Social Studies of Science*, 35-54.
NLK Consultants 1993. *Totally Chlorine-Free Pulp and Paper – European Supply and Demand Trends*, London.
NLK Consultants 1991. *Impacts of Environmental Legislation on the Pulp and Paper Industry in the 1990s*, London.
Norberg-Bohm V., Rossi M., 1998. The Power of Incrementalism: Environmental Regulation and Technological Change in P&P Bleaching in the US, *Technology Analysis & Strategic Management*, 10(2): 225-245.
O'Brian H., 1996. TCF: It all started here at Aspa Bruk, *Pulp & Paper International*, October: 19-22.
Organisation for Economic Co-operation and Development 2001. *OECD Environmental Outlook*, Paris: OECD.
OECD 1999. *Environmental Requirements for Industrial Permitting – Approaches and Instruments*, Paris: OECD.
Paradeise C. 1985. Rhétorique professionnelle et expertise, *Sociologie du Travail*, 1: 17-31.

Peck V., Daley R., 1994. Toward a "Greener" P&P Industry, *Environmental Science & Technology*, 28(12): 524-527.

Popper KR. 1973. *La logique de la découverte scientifique*, Paris: Payot.

Portmann JE., Lloyd R. 1986. Safe Use of the Assimilative Capacity of the Marine Environment for Waste Disposal – Is It Feasible ?, *Water Science Technology*, 18: 233-244.

Rajotte A. 2003 (forthcoming). Évolution de la réglementation environnementale des secteurs industriels: les ambiguïtés d'une stratégie réglementaire de développement durable, in *Sociologie, Économie et Environnement*, Gendron C., Rajotte A. (eds.), Presses universitaires du Québec.

Restier-Melleray C. 1990. Experts et expertise scientifique – Le cas de la France, *RSFP*, 40(4): 546-585.

Ring I. 1997. Evolutionary strategies in environmental policy, *Ecological Economics*, 23: 237-249.

Roqueplo P. 1993. *Climat sous surveillance*, Paris: Economica.

Simon H. 1978. Rationality as Process and as Product of Thought, *American Economic Review*, 68(2): 1-15.

Smith R., Wynne B. (eds.) 1989. *Expert Evidence: Interpreting Science in the Law*, London: Routledge.

Sowell T. 1980. *Knowledge and Decisions* (2nd ed.), New York: Basic Books.

Strauss S. 1993. Why effect of pulp mills on environment is complex, *The Globe and Mail*, Toronto, February 2: A15.

Swedish Environmental Protection Agency (SEPA). 1997. *Environmental impact of pulp and paper mill effluents* (Report 4785), Stockholm: Swedish Environmental Protection Agency.

Södergren A., Bengtsson BE., Jonsson J., Lagergren S., Larsson Å., Olsson M., Renberg L. 1988. Summary of results from Swedish project Environment/Cellulose, *Water Science Technology*, 20(2): 49-60.

Tana J., Lehtinen KJ., 1996. *The aquatic environmental impact of pulping and bleaching operations – an overview*, Helsinki: Finnish Environmental Institute.

Tietenberg T. 1996. *Environmental and Natural Resource Economics* (4th ed.), New York: Harper Collins.

Torgerson D. 1986. Between knowledge and politics: Three faces of policy analysis, *Policy Sciences*, 19: 33-59.

Travis C., Hester S. 1991. Global Chemical Pollution, *Environmental Science & Technology*, 25(5): 815-818.

Ullmo J. 1969. *La pensée scientifique moderne*, Paris: Flammarion.

United States Environmental Protection Agency (USEPA). 1990. National Dioxin Study Released, *Environmental News*, 24 September.

Weber M. 1971. *Économie et Société* (tome 1), Paris: Plon.

Weinberg A., 1976. Science in the Public Forum: Keeping it Honest, *Science*, 30(191): 4225.

Woolgar S., Pawluch D. 1985. How shall we move beyond constructivism? *Social Problems*, 33(2): 159-162.

Wynne B. 1993. Uncertainty and environmental learning, in *Clean Production Strategies*, Jackson T. (ed.), London: Lewis Publishers, 63-83.

Wynne B. 1982. Institutional Mythologies and Dual Societies in the Management of Risks, in *The Risk Analysis Controversy: An Institutional Perspective*, Kunreuther HC., Ley EV. (eds.), Berlin: Springer-Verlag, 63-83.

REFERENCES

1 Issues, such as ozone depletion and climate change, illustrate the point. Negotiations have been mostly driven through compromises, while the open texture of scientific claims provided the pretext for contesting the point of view of the other side and delaying decisions (Faucheux and Nöel, 1990; Roqueplo, 1993).

2 Two influential papers shaping the analysis in this paper are Wynne (1993) and Jasanoff (1996).

3 Occupational health issues illustrate the point. Problem solving is above all driven by the reasonability of its undertaking (Green, 1989). The presumption of risks is mainly sized up through incomplete data, limited clinical observation of workers and poor knowledge of the working place. In 1984, West German authorities concluded that less than 10% of threshold limit values adopted as workplace exposure standards were based on sufficient animal tests and/or filed experience (Henschler, 1984).

4 The postulate was derived from Frederick Engels, but was clearly inspired by Saint-Simon, the father of positivism (Torgerson, 1986). The belief in the power of science to distinguish objectively between the lawful orders of nature and those of society goes back as far as the Enlightenment. Interventions of experts in public matters can be traced back as far as 17th century France and England (Smith and Wynne, 1989). French sociologist Auguste Comte substantiated positivism by further developing its theoretical and methodological foundations (Bernstein, 1983). In the wake of Modernity, Karl Marx and Max Weber reasserted the tenet, each in their own terms. “The basis (*grundpfeiler*) of production and wealth […] stems from the intelligibility and mastery of nature through men as social body [such that] the general social knowledge […] becomes direct forces of productivity.” Marx quoted in Lyotard (1979). “Without rational calculus, the foundation of economy, in other words without a set of concrete circumstances linked to the history of economy, instrumental rationality would have never been borne (Weber, 1971).” Although refuted as a theory of science, positivism still provides the foundations of the methodological conditions of empirical enquiry (Ullmo, 1969).

5 As the sociology of work teaches us, the social organisation of professional categories has invariably involved a rhetoric underlying three premises: (i) society’s need for the specific knowledge category; (ii) its confirmed scientific value; and (iii) the competence of the applicants as a group. The logical inference is the need for the discipline and the privileges that founds it (Paradeise, 1985).

6 Scientific management was seen as a response to the early turmoil of industrialisation. The belief that the methods from the hard sciences could solve social calamities, such as illiteracy and poverty, also gained prominence among social scientists, particularly in the 1950s and 1960s (Torgerson, 1986). Programs such as Roosevelt’s *New Deal* were typical of such beliefs (Fisher, 1992). The *Green Revolution*, the widespread of chemical insecticides, pesticides and fertilisers, was also driven by a belief of the benevolence of techno-science and economics (Jackson, 1990). The mismatch between the “zero-discharge” goal and the concept of best available technologies (BAT) in the early phases of environmental regulations can also be associated with a technocratic view, in which pollution was primarily viewed as easily solvable, given the appropriate incentives, investments and technologies (Tietenberg, 1996). The implementation gaps provided the opportunity to industry to turn the scepticism of science to positive effect by requiring authorities to substantiate scientifically the targeted effects of industrial practices. Positivism was again sneaking in through the back door of science and policy interface.

7 Interestingly enough, the larger share of environmental funding to hard sciences appears ambiguous, in the context of widespread consensus among decision-makers over the need to shift from a command-and-control to a voluntary approach in better coping with the multifaceted issues associated with environmental problems. Indeed, if the use of a broader range of instruments and complementary approaches is advocated through voluntary initiatives, “then the paucity of social science research is a limitation” (Alm, 1992).

8 This tension between objectivism and relativism runs through much of the literature about the role of science in society, and in policymaking in particular, since the last half of

the 20th century. Up to the 1970s, the social structures in which hard sciences operate were seen as fair ground for the behavioural sciences, not their scientific content (Mulkay, 1979). This notion was progressively challenged by raising issues of cognitive versus social factors: first, by showing that science progresses through conjectures, falsification and rectification, and is therefore cumulative (Popper, 1973); next by arguing that particular theories and practices are bounded to macro-theories (paradigms) coming into existence as a result of social consensus, which may be overruled through increasing counter-evidence (Kuhn, 1970); finally, by acknowledging that different, even conflicting, paradigms can coexist and evolve over time (Lakatos, 1970). Within the new sociology of knowledge ('social constructivism'), attempts have been made, sometimes persuasively, to construe the existence of particular scientific theory or evidence within actor-network theories. In such a framework, individual and collective meanings, and things and artefacts are seen as co-evolving symmetrically, i.e. a social construct (e.g. Callon, 1986; Latour and Woolgar, 1986). The hypothesis has formed the basis for two sociological variants: either the social factors are seen to fill in for the knowledge gaps revealed in the course of scientific inquiry, i.e. social relativism (e.g. Wynne, 1982); or all cognition are seen as socially determined, whatever the facts, since the normative assumptions and moral judgement always structure the context in which science operates, i.e. social reductionism (e.g. Douglas and Wildavsky, 1982). Two concerns have been raised against these views. First, assuming the subordination of science to coalition alignments leads to a liberal deadlock, with not much objective grounds for criticism (e.g. Mayo, 1991). Second, if all cognition is claimed as socially determined, then the constructivist rhetoric turns paradoxically into an objectivist view of reality, eluding refutation (Woolgar and Pawluch, 1985). A compromise has been suggested on the grounds that social factors usually play a larger role when issues are uncertain and incomplete, but a more limited role in mature fields of scientific investigation (Laudan, 1977).

9 Thus, history has witnessed that the legitimacy of science has been oriented toward the optimisation of the system performance, a normative value considered a logical point of departure for empirical enquiry (Lyotard, 1979). Yet, taken in different decision contexts (e.g. economic efficiency, environmental integrity), individuals obviously do not share the same opinion over the legitimacy of this value.

10 Over-reliance on expertise often means that other forms of knowledge, such as based on lay experience, are neglected or disputed. As Sowell (1980) points out, "this feedback is not only additional knowledge, but knowledge of a different kind. It is direct knowledge of particulars of time and place, as distinguished from the second-hand generalities known as "expertise." […] Certainly expertise it not sufficient in itself without the additional direct knowledge of results obtainable closer at hand, and at lower cost, by great numbers of individuals who acquire no personal distinction from possession of that kind of knowledge."

11 Paradoxically, a strong public commitment to science in environmental policy and awareness of issues are seen as a cultural prerequisite to set the stage for ecological modernisation of economies (Cohen, 1998).

12 Raymond Boudon, Michel Crozier and Pierre Bourdieu represent this view in the French sociology. For a counter-view, see Caillé (1981). For a review of English representatives, see Bowden (1985).

13 Developed in Germany and introduced at the international level at the First International Conference on the Protection of the North Sea in 1984, the precautionary principle has subsequently gained acceptance across OECD countries (Dethlefsen *et al.*, 1993). The widespread adoption of the concept of BAT as a core means of legislative actions can be seen as one of its most significant policy consequences (OECD, 1999).

14 Though this notion had been recognised prior to the adoption of the precautionary principle. Thus, the Court of Appeals for Washington DC concluded, in a landmark case held in 1976, that certainty of harm was not a prerequisite for legislative actions (Jasanoff, 1992).

15 Conventional processes used around 90 kg of Cl_2 per ton of pulp produced up to the 1980s. Bleached pulp mill effluents were known to be responsible for large input of chlorinated organic compounds in marine environments. In the 1990s, Nordic studies showed that elevated concentrations of **E**xtractable **O**rganic **Chl**orine (EOCl) – the

fraction representing about 0.5-2% of the chlorinated content of the effluent, but the ecotoxicologically important class of chloro-organic compounds – were present in surficial sediments in the vicinity of bleached mills, as well as in more remote areas of the Baltic Proper. The amount of EOCl accumulated in top sediments in the Bothnian Bay, Bothnian Sea and Baltic Proper were estimated to be about 500, 5000 and 7000 tonnes, respectively. It was further estimated that some 21 000 tonnes of EOCl had been discharged since the onset of large-scale chlorine bleaching in the 1940s (Jonsson *et al.*, 1996).

16 The absorbable organic halide (AOX) parameter was substituted to total organically bound chlorine (TOCl) because it is easier and cheaper to conduct. Yet the parameter is controversial because it does not discriminate between the toxic and benign fractions of the chlorinated content of the effluent.

17 The issue was first discussed within the framework of the permit renewal of the Aspa mill in 1985, though the agreement was reached in 1988 (O'Brian, 1996). The first TOCl limit was adopted in the *Södra*'s *Mönsterås* kraft pulp mill permit in 1986. Despite opposition from industry and some local authorities, the adoption of Bill 1988 confirmed the backing of the Swedish parliament. The decree stated that chlorinated discharges were to be initially cut by 60-70%, while measures were to be undertaken to reduce them further to 1.5 kg TOCl/ton of pulp by 31 December 1992. In the long term, discharges were to be entirely eliminated. The 1992 target was stringent since the discharges at that time was estimated at about 3.5-4 kg TOCl/ton, down from 7-8 kg TOCl/ton in 1974 (Fallenius, 1988).

18 In 1982, the results of Finnish studies comparing the effects of unbleached and bleached pulp effluents strongly suggested that many of the effects reported by PEC, e.g. liver dysfunction and other physiological effects in fish, could be caused by resin acids (Tana and Lehtinen, 1996).

19 In particular, the publication by Rachel Carson of *Silent Spring* in 1962 marked the rise of the American environmentalist movement. It sparked a political campaign that eventually led President Kennedy to create the Environmental Protection Agency (EPA).

20 On chlorinated pesticides, see Carson (1962); on ozone depletion, see Molina and Rowland (1974); on global pollution, see Travis and Hester (1991); on water pollution, see Hilleman (1992).

21 In Europe, most countries adopted AOX as the lead parameter. The United States Environmental Protection Agency (USEPA) focussed pollution control on dioxin water quality standards, as did Environment Canada, though some of the provincial jurisdictions used AOX as a basis for regulation, e.g. British Columbia and Quebec. Whatever the case, the adopted regulations resulted in a significant shift away from Cl_2 bleaching, either substituting either or both chlorine dioxide (ClO_2) or non-chlorinated compounds, such as ozone, hydrogen peroxide and oxygen (Norberg-Bohm and Rossi, 1998).

22 "[T]he possibly largest industrial process restructuring performed in a short time within the Swedish industry – and followed by the Finnish and North American industry – largely was done on the basis of unproven suspicions" (Tana and Lehtinen, 1996). Thus, "a Finnish expert, Karl-Johan Lehtinen, questions whether it was worth all the efforts by scientists, as the results are largely neglected or misinterpreted in discussions on which kind of emissions should be reduced or which processes should be used for pulp production". (NLK, 1993).

23 The protracted discussions were fed by a series of mutual accusations among stakeholders of either under-reacting or overreacting about the risks involved, thereby misleading public interest. The debate involving Finland and Sweden at the HELCOM was particularly bitter. At some point, Swedish delegates accused their Finnish counterparts of acting as a 'developing country' on environmental matters and with respect to their national and international obligations on water quality (Auer, 1996).

24 The title is borrowed from Maddox (1987).

25 A correlation between Cl_2 bleaching and discharges of toxic chloro-phenol compounds was later well established by comparing bleach plant effluents at various degree of ClO_2 substitution to Cl_2, thereby enabling the prevention of their generation (NLK, 1991).

[26] The guessed estimate led Swedish authorities to argue that the remaining fraction, suspected of being carcinogenic and mutagenic, probably accounted for 20% of the chlorinated content of effluent The misinterpretation proved a turning point in the debate at HELCOM when it was later shown that the low molecular weight materials represented only 5% of the total AOX constituents. The new finding implied that existing control techniques, such as activated sludge treatment, were efficient in addressing the toxicity of effluent at those low levels.

Section 4 -

CONCLUSION

4 SUMMARY AND RECOMMENDATIONS

The writing of the dissertation papers has been somewhat inspired by my aversion to pervasive arguments that connect social changes to single causes, whether market, political or scientific incentives. To my mind, these blinker and sterile views perpetuate the cynical conclusion that the end justifies the means. Not only is this anecdotal view of social change a fallacy of what actually happens when social institutions and processes interact in coming to term with environmental problems, but it offers no perspectives to improvement, nor means of overcoming political expediency. These *deus ex machina* explanations merely end up empowering those already in power, while failing to live up to the requirements of accountability, fairness and democracy that should be the hallmarks of efficient policies. In contrast, the idea that knowledge formation and utilisation could yield better explanations of social change recognises the complexity, uncertainty and contingency inherent to social institutions and processes by which scattered pieces of different, even contradictory, forms of knowledge are coordinate in ultimately making society works (Sowell, 1980).

Yet, I was not entirely aware of the many theoretical and methodological obstacles waiting ahead in dealing with an issue that is fundamentally multidisciplinary. Nor had I thoroughly evaluated whether an article-based dissertation concept was the best fit. In truth, as it should probably be the case, the questions, framing and conceptualisation of the dissertation work shaped up throughout the drafting of the articles and subsequent puzzling about how to integrate the whole exercise. To use the expression much cherished by 'social constructivists', the dissertation took form *in the making*.

The theoretical significance of this dissertation lies more in the way it investigates and cross-fertilises different disciplinary fields – sociology, comparative policy research, political science, philosophy, evolutionary economics, management science, environmental studies, science and technology studies – than in a deepening of a particular approach. Its contribution can be seen as twofold:

- First, it provides a review of different theories, methodologies, and empirical material that focus on the role of knowledge as a key and under-addressed issue, with a view to identifying how this vast and rich literature can inform proper conceptualisation of the problem at issue in environmental contexts;
- Second, it tests different theoretical and methodological concepts empirically by focussing on different interactive decision settings.

One problem in examining the link between knowledge and decision is that the preoccupation of many commentators is often with the end results rather than with the process of choice. Moreover, the implicit notions of rationalistic and/or behavioural components are usually 'black-boxed' in the analysis. We must then interpret what exactly underlies the commentator's position when arguing against some decision or others. Drawing on my interviews with top governmental officials, decision-makers in industry, and consultants and experts, I noticed that many of their positions seem to be influenced by a definition of rationality – the utility maximiser – which is clearly inspired by economics. Yet, this does not reflect, by any means, all human behaviours, nor does economics limits itself to this narrower definition (Simon, 1978). I was astonished by how otherwise clever experts and scientists exhibited a positivist attachment to the idea of truth, which prevented them from understanding that both science and politics are "deeply embedded in politics and culture" (Jasanoff, 1996, 173). This social rigidity, together with the political polarisation and conflicts of interests built in policymaking, is partly the cause of the apparent mismatch between science and politics, notably because it reflects the uneasiness with which scientists and experts behave in messy decision contexts.

The link between knowledge and decisions can be simplified by the chicken and egg analogy. What comes first? Changes in behaviours? Values? Science? Policies? Technologies? Who decides what? Policymakers? Scientists and Experts? Industry? Markets? The answer to this enigma probably lies more in the recognition that a social interplay must occur and mature, both *ex ante* and *ex post*, towards some forms of consensus over what needs to be changed if the new development is to be meaningful. The world is full of brilliant ideas that were solely of interest to their promoters, that would have been superior to existing practices, yet now sleep on the shelf. New social configurations must logically follow some shifts in costs and benefits (not only in economic terms) among individuals and social aggregates. Thus, in attempting to link some change to particular knowledge and/or stimulus, and particular decisions, the analyst must examine the changing relations by which the interplay between cognitive, technical, and normative processes shifts the established consensus incrementally or radically.

The subjectivity and context-specific nature of knowledge in multiparty decision contexts require an analytical symmetry between the knowledge driving decision and social closure. As Jasanoff (1996) rightly suggests, it is the political organisation of such a process which is a relevant explanatory variable, not some sort of externalised scientific, social or economic factors revealing optimality in 'speaking truth to power'.

4.1 Results

Four dynamics, which have been well identified in social science studies of knowledge and comparative research studies of environmental policy, are central to understanding the link between knowledge and decisions through the evolution of environmental regulations of BKMEs:

1. Historical developments of political culture, industrial economics and environmental characteristics of P&P producing nations – prior to the 1970s environmental reform – are essential to understanding contemporary policy and technological constraints, as well as the features and mechanisms subject to variation among national constituencies;
2. Policy-relevant knowledge is socially constructed through institutional and administrative procedures, as well as ad hoc mechanisms, e.g. markets;
3. Differences in treatment of facts and values can be attributable in large part to variations in the distribution of power, costs and benefits among parties and countries, making the available evidence vulnerable to criticism in decision-making contexts; and
4. Political closure is dependent on a process of social accommodation among stakeholders (including scientists and experts) which is tied to the political economy of the sector.

Though these four determinants clearly reflect the dominance of politics on adopted developments, there is still much opportunity for learning in this dynamics. Indeed, the very rapid evolution of market, technologies, science and policy affecting bleached kraft pulp production suggests that various forms of meaningful learning have occurred at all level of society with a marked effect, in return, on the whole political economy of the sector:

- Industry learned that environmental concerns about the biological impacts of pulp mill effluent, even as unproven risk perception, could impact significantly on policies and competitiveness (Phillips, 2000). There was an increasing awareness that the old credo of 'safe until proven otherwise' had the potential of being politically and economically harmful in view of the competitive implications of regulatory changes and the greening of markets. Although returning profits to shareholders justifies the existence of companies, properly anticipating the future requires the uptake of societal values affecting paper demands beyond those of traditional product quality specifications, significantly based on price (Nlk, 1992). The industry learned that "[…] the ability of the marketplace to punish rather than to reward [had] an equal, if not greater, impact on a firm's strategy" (Lundan, 1996, iii). Not surprisingly, in their study of investments in the P&P industry, Moilanen and Martin (1996, 86) found that "the perceived strategic nature of the investment in chlorine-free bleaching of pulp meant that calculations for other investment options were not made.";
- Environmental pressure groups, e.g. Greenpeace, learned that one of its typical foes, growth market, could be turned into positive effects by substituting green market demands to regulatory forces by inciting cleaner technologies and products. The emphasis shifted the strategy from adversarial pressures to collaboration with national segments or individual firms in creating market niches for chlorine-free paper products;
- Policy developments in Sweden and Finland reflected substantial changes and apprenticeship among governmental officials, allowing authorities to deal with uncertainty about environmental risks. In Finland, environmental authorities acknowledged their lateness in keeping abreast of the interplay between BAT and environmental quality objectives (EQOs) and, consequently, in setting the environmental level playing field (Interview, Finnish National Board of Water and

Environment, 1998). Swedish authorities eventually recognised that technological assessment cannot entirely substitute scientifically-based water pollution assessment, in particular in the case of toxicity associated with natural wood components in effluent (Interview, Swedish Environmental Protection Board, 1997). Distinctive interactions between the concepts of BAT and EQOs gave rise to differing environmental strategies and path dependency in compliance technologies. Though these differences were shown to be tied to variations of local contexts, they were clearly revealed through paradigm shifts in environmental management, in particular the implementation of the precautionary principle.

- Scientists and experts learned that closure of policy-relevant scientific debates do not correspond to the standards of normal science procedures. What the chlorine bleaching controversy revealed was that past national regulations based on biological oxygen demand parameters concealed many elements of uncertainty, indeterminacy or plain ignorance. Whether the validated evidence – and its inherent element of ignorance and indeterminacy –constitute an appropriate scientific basis for policy is a normative administrative choice, not an independent scientific decision (Wynne, 1993);

Taken together, the five papers map out the economic, regulatory, scientific and technological context affecting knowledge and decisions in the P&P industry. The papers show how each kinds of particular issues and decision-making units shaped, while also being shaped by the broader political economic context. The changing correlation between the perception of environmental risks and that of organisational risks has been a central explanatory variable. It shows that risk perception and the validation of knowledge guiding decisions vary in accordance with the particular incentives and constraints associated with each of the particular decision settings surveyed (e.g. competitiveness, national security, political influence, public interests, etc.).

4.2 Recommendations for future research

This dissertation is largely based on field work and empirical case studies. Many of the analyses have been inspired by different disciplinary fields, with a view to increasing understanding of the link between knowledge and decisions in environmental contexts. It provides a useful beginning to develop a proper theorisation and conceptualisation of the problematic. Beyond the diversity and overlap of situations explored throughout the articles, there has been a progression: from a critique of conventional hypotheses of neo classical economics and conflict-related theories that overly subordinated knowledge to power and interests; then, to a more positive view of the link between knowledge and decision, in particular how differences in building capacities impact on the economic competition and environmental performance among national segments of the industry; and, finally, by showing the connection between structural interests and the attribution of status of validity in the process of knowledge formation. In sum, though knowledge remained a decision variable, the analyses showed it was a crucial variable from the point of view of timing and the advantages it may confer in specific local context shaping, although shaped by an increasingly changing, global and risky world.

Studies of social changes would be well-advised to broaden their analytical framework accordingly.

In his review of comparative environmental policy studies, Vogel (1987) has identified a series of weaknesses: a lack of understanding of industry role in making and implementing environmental policies; a lack of understanding the role of scientific uncertainty in the environmental decision-making process; the need to pay attention to historical developments that occurred before the 1970s environmental reforms in order to improve the understanding of recent phenomenon. We hope that this dissertation has help filled up some of these weaknesses and shortcomings. However, to the extent that this task depends on a broad set of theories, methodologies and analytical focus, more theoretically-oriented research will be needed, together with an increase in the stock of empirical case studies in this area.

4.3 Policy and business implications

An ever-increasing challenge for human societies in the coming decades will be to improve management capacity in the face of increasing uncertainty and complexity that now characterise our understanding of global environmental risks. One conclusion of this dissertation is obviously that the distinction between science, professional expertise and other forms of knowledge is a distinction of procedures, not of end results. The logical inference is that, in order to increase policy efficiency, it is better to understand them as communicating vessels, rather than competing epistemology. Policymakers and industrialists most often fail to recognise the degree at which social stimuli and other forms of knowledge, outside the realm of normal science and professional expertise, can impact, positively or negatively, on social developments.

A striking aspect of environmental issues is that, in many cases, social response to environmental risks did not bring about new technology or products. Rather, it substituted old ones or on-the-shelf techniques, as with oxygen-based delignification. This is clearly illustrated by the ozone depletion issue or pest control (Zurer, 1993; Ashford, 1994). Neo-Schumpetarian economics uses the term 'selection-environment', instead of market, to describe the process by which organisations select the most appropriate options regarding their competitiveness or pain survival. The term 'selection-environment' is meant to include factors *ex ante* and *ex post*, e.g. market, institutions, geo-politics, which have a bearing on the competitive environment (Schot, 1989). This distinction is of interest when considering the increasing consensus that the 'command-and-control' approach is too rigid to elicit the type of technological dynamism needed to spur the next major advances required to ensure sustainable growth. The implicit idea, indeed attractive, is that agreeing on goals and risk sharing among concerned parties, *ex ante* of regulatory changes, is more susceptible to creating the incentives, e.g. market, subsidy, R&D, standards, etc., easing *ex post* greening of behaviours, technologies and products, while avoiding the adversarial pressures of command-and-control. Somewhat less apparent is the implementation gaps between calls for integrated actions and the actual commitments of governments to environmental administration. Virtually all of environmental R&D budget, whether in public administrations or academic bodies, is directed to hard sciences rather than behavioural sciences. As long as regulations are based on technology- and ambient-based standards, this might be understandable. However, if policymakers are serious about *engineering* sustainable development through multiparty consensus, then the paucity of social science research is clearly a limitation (Alm, 1992).

This dissertation is obviously a plea to develop and increase procedural innovations that will work towards the implication of all stakeholders in developing appropriate economic level playing field for a sustainable future. This implies tasks both *ex ante* and *ex post* of perceived and yet-to-come issues. One obvious issue is the harmonisation of environmental parameters enabling fair and accountable comparison of performance among countries. It also means that the relationships should be one in which stakeholders accept to jump into the fray as rhetoricians and persuaders of truth. By reconciling the different worlds of relevance, the obstacles and necessary adjustments to new social consensus can be eased and made more manageable.

It is my profound conviction that, although science is needed to guide environmental policy, the key to sustainable development lies is the reshaping of social consensus among individuals, communities and countries. The solution is undoubtedly political and requires mutual respect and recognition of the interdependence of nations vis-à-vis the future of the planet.

ANNEX 1

ENVIRONMENTAL REGULATIONS AFFECTING BLEACHED KRAFT PULP MILLS IN SWEDEN AND FINLAND - AN OVERVIEW

TABLE OF CONTENT

FIGURES

TABLES

Introduction

The object of this annex is to provide an understanding of the regulatory context and the factors underlying differential responses of the Finnish and Swedish pulp and paper industry to environmental risks. In order to narrow the scope of investigations, the report focuses on the regulation of bleached kraft pulp mill effluents (BKMEs). The industry faces numerous environmental issues, e.g. forest management, eco-labelling, fibre recycling, greenhouse gases emissions, solid waste disposal, etc. It must be emphasised, therefore, that BKMEs are but one part of the overall regulatory concern impacting on the industry. Thus, the results of this report must be understood within the broader context of the full range of regulatory issues affecting the industry in the selected jurisdictions and abroad.

Paper manufacturing has long been a focus of environmental concern. Pulping and bleaching operations have accounted by far for most of the pollution associated with this industry. Until the 1970s, the sector was weakly regulated, leading to some of the worst industrial pollution. Following the tightening regulations in the early 1970s, the most urgent and obvious problems (e.g. oxygen depletion, odour, aesthetic, etc.) were successfully tackled through the development of better control techniques and more efficient process innovation. In the 1980s, pulp bleaching became the focus of environmental concern, following the detection of dioxin throughout the entire production lifecycle. Concurrently, studies conducted by the Swedish Environmental Protection Board in the mid-1980s found mutations and other adverse effects in fish communities living in the vicinity of a kraft pulp mill, which discharged chlorinated effluents into the Baltic. The conclusion then drawn was that chlorine was a probable culprit. A combination of regulatory pressures and greening market demands then became the driving force behind developments in pulp bleaching, leading to a virtual phase-out of chlorine. Yet, under radical uncertainty about the precise cause-and-effect relationship, policy and technological changes differed among countries. These differences have had a significant effect on the competitiveness of the sector.

Finland and Sweden are well representatives of the wide range of factors, issues and strategies that have shaped developments in the political economy of bleached kraft pulp production. Both are world leaders in process and environmental technologies, and have thus played an active role in enhancing the environmental level playing field of the industry in Europe and abroad. There is much commonality in the policy process regulating BKMEs in Finland and Sweden. As neighbouring countries, the jurisdictions surveyed share many historical, cultural and political traits. With respect to regulatory regime, they both favour a case-by-case approach in delivering permit conditions, while retaining the use of the concept of best available technology (BAT) as a decision-making principle. Yet the objective of this study is not to highlight similarities but rather to identify factors underlying differences in policy and technological responses to environmental risks associated with bleached kraft pulp production.

The information provided in this report has been collected through interviews with key decision-makers and experts from industries, trade associations and environmental agencies, as well as by reviewing consultant reports, regulatory surveys, and individual permits when available. The list of interviewees is provided as an appendix to the annex. Section 2 describes briefly the Kraft technology, including the economic, environmental, and regulatory trends that have affected developments. Section 3 describes the policy process regulating the sector in the countries under review. Section 4 benchmarks regulations and discharge limits addressing bleached Kraft mill effluent, including a review of regulatory and institutional factors affecting discharge limits, technological development and environmental performance at source. Finally, section 5 provides a chronological overview of policy formulation and implementation of regulations and measures addressing more specifically the discharge of chlorinated effluents, and how the Finnish and Swedish industries responded to the requirements. Some conclusive remarks close up the report.

1 Technological, economic and environmental backgrounds

1.1 Bleached kraft pulp development: an overview

Chemical Kraft pulp is produced by cooking wood chips in aqueous solutions of caustic soda and sodium sulphide (i.e. the white liquor) to separate the cellulose and hemicellulose as fibre from the lignin. Additional oxygen- or hydrogen peroxide-based delignification may be added to reinforce the extracting operation. After cooking and washing, the Kraft pulp is brown in colour because the cooking of the lignin leads to the formation of coloured groups in the pulp. Depending on pulping process conditions, 90-95% of the lignin can be removed from the wood in Kraft pulping. The residual lignin content in the unbleached pulp is measured by the Kappa number. Typical Kappa values for unbleached softwood Kraft pulps range from 25 to 35, whereas those for hardwood Kraft pulps from 12 to 20. The unbleached pulp may be used for the manufacture of packaging materials, whereas writing and printing papers normally require pulp bleaching to increase brightness.

The purpose of bleaching is to dissolve and remove the lignin from wood to bring the pulp to a desired brigthness level. Bleaching is carried out in a multi-stage process that alternate delignification and dissolved material extracting stages. Washing operations are used to purge the unbleached pulp from the spent white liquor and the dissolved lignin and wood extractives, the so-called black liquor. The black liquor is then evaporated, concentrated and burned in a recovery boiler to recycle its calorific value and the inorganic material in the form of sodium carbonate. The recovered liquid, the green liquor, is continuously converted to white liquor so that the inorganic portion of the black liquor is recycled in a closed loop at high efficiency. The remaining portion of the black liquor which is incinerated provides the process with steam and energy from the boiler.

Up to the 1930s when it started losing market shares to kraft pulping, the sulphite process (1866) was the dominant technique. The competitive situation first changed between the sulphite process and the kraft process because of the latter versatility in using various wood species. The second major change came with the tightening of environmental regulations, which forced sulphite mills into chemical recovery.[1] Together with Chemi-Thermo-Mechanical Pulp (CTMP), the brighter, stronger, and more versatile kraft pulp has been the net beneficiary of the growth in higher grades supply and its dominance is predicted to continue well into the next century (Tana and Lehtinen, 1996).

Since its introduction at the turn of the century, chemical Kraft bleaching has been refined into a stepwise progression of chemical reaction, evolving from a single-stage hypochlorite (H) treatment to a multi-stage process, involving chlorine (Cl_2), chlorine dioxide (ClO_2), hydrogen peroxide (P) and ozone (O_3). Bleaching operations have evolved since the conventional CEHDED sequence and now involve different combinations with or without chlorine containing chemicals. The common compounds used, together with their letter symbols are listed in table 1. The introduction of Cl_2 and ClO_2 in the 1930s and early 1940s, respectively, increased markedly the efficiency of the bleaching process. Being much more reactive and selective than H, Cl_2 had less tendency to attack the cellulose and other carbohydrate components of wood, producing much higher pulp strength. Although it did not brighten the pulp as H, it extensively degraded the lignin, allowing much of it to be washed out and removed with the spent liquor by subsequent alkaline extraction. The resulting brownish pulp required additional bleaching to increase brightness, which led to the development of the multi-stage process. ClO_2, a more powerful brightening agent than H, brought the Kraft process efficiency one step further. Table 2 details different considerations that have affected the development and use of the main bleaching chemicals over time. The information contained in the table provides an overview of economic and product quality considerations associated with pulp bleaching techniques and chemicals.

Table 1 - Bleaching chemicals used

Symbol	Chemical	Symbol	Chemical
C	Chlorine	Z	Ozone
D	Chlorine dioxide	E	Sodium hydroxide
H	Hypochlorite	X	Enzymes
O	Oxygen	Q	Chelating agents
P	Hydrogen peroxide	A	Acid

Source: Tana and Lehtinen, 1996.

[1] The higher costs of chemical recovery in the sulphite process was eventually the deciding factor for the industry-wide shift to kraft pulping.

Over the last 30 years, the industry response to regulatory requirements and public demands have led to a significant de-coupling of production growth and pollutant outputs, as well as reduced need for bleaching chemical, fresh fibre (wood), energy and water volume. Significant portions of capital expenditures have been devoted to environmental measures in the 1970s, following the adoption of control regulations of biochemical oxygen demanding (BOD) substances and total suspended solids (TSS) across the Organisation for Economic Co-operation and Development (OECD) countries. These were mainly directed towards the implementation of secondary treatment, although some countries chose to concentrate on in-plant measures to reduce pulp mill effluent. Environmental investments cooled off in the early to mid-1980s, but increased again by the end of the 1980s to address the problem of dioxin and persistent chlorinated compounds. On average, environmental spending has been in the range of 10-25% of new capital invested (Nlk, 1991).

Under tightening regulations and market demands for chlorine-free products, the industry accelerated the implementation of elemental chlorine free processes (ECF), which substitute $Cl0_2$ to Cl_2, and totally-chlorine free (TCF) processes, which substitute oxygen-based chemicals to chlorinated compounds, although the timing and scale of these changes have varied between regions. The series of incremental and radical innovations increased the efficiency of pulping and bleaching operations, while reducing significantly their environmental impacts. The development of O_2 delignification, modified and extended cooking, the improvement of operation controls (e.g. improved pulp and chemical mixing, multiple split chlorine additions, and pH adjustments) increased the economics of the process, while leading to significant reduction of wastewater. Increased substitution of ClO_2 to Cl_2 brought down significantly the generation and release of harmful chlorinated organic compounds. The implementation of modified cooking and oxygen-based delignification impacted on the entire process by lowering the kappa number of the pulp prior to bleaching, thereby reducing further the amount of bleaching chemicals needed.

Table 2 - Economic and technological implications of bleaching agents

Oxidant symbol	Code/form	Function	Advantages	Disadvantages
C	Cl_2 Gas	Oxidize and chlorinate lignin.	Effective, economical.	Can cause loss of pulp strength.
O	O_2 Gas used with NaOH solution.	Oxidize and solubilize lignin.	Low chemical cost, provide chloride-free effluent for recovery.	Large amount required expensive equipment, can cause loss of pulp strength.
H	$Ca(OCl)_2$ or NaOCl	Oxidize, brighten and solubilize lignin.	Easy to make and use.	Can cause loss of pulp strength if used improperly, expensive.
D	ClO_2	Oxidize, brighten and solubilize lignin.	Achieves high brightness without pulp degradation, good particle bleaching.	Expensive, must be made on-site
P	Na_2O_2 2-5% solution	Oxidize and brighten lignin.	Easy to use, high yield and low capital cost.	Expensive, poor particle bleaching
Z	O_3 Gas	Oxidize, brighten and solubilize lignin.	Effective, provides chlorine-free effluent for recovery	Expensive, poor particle bleaching
E	NaOH 5-10% solution	Hydrolyze and solubilize lignin	Effective and economical.	Darkens pulp.

Source: Nlk, 1991.

Technological developments over time indicate that the industry has been able to reverse its predominant image as a heavy polluter in one in which it is perceived as producing and using resources that are reusable, recyclable, bio-degradable and cleanly convertible to energy. Nowadays, the estimated total loads of BOD and TSS are a mere 2% of the 1970s' levels, while pulp and paper production has doubled over the period (Gullichsen, 1998). Concurrently, the generation of dioxins have been virtually eliminated.

1.2 *Regulating BKMEs – Development, convergence and differences*

Owing to the nature and scale of operations, bleached kraft mill effluents (BKMEs) have accounted by far for the greatest environmental impacts associated with water pollution from P&P mills. Since only one part, barely half, of the timber is retained for paper manufacturing (the fibrous content), techniques used to separate the fibrous and non-fibrous materials from wood have typically required large amount of process water with corresponding large quantities of organic waste. The nature and quantity of pollutants normally correlate with the lignin content (measured with the index Kappa) and the carry-over of dissolved organic substances with the pulp processed to the bleaching stage.

If untreated, chemical pulp mill discharges have high biological and chemical oxygen demand (BOD and COD), with potential to cause lethal and chronic effects in aquatic life, as well as severe eutrophication of aquatic ecosystems. Between 1945 and the 1960-1970s, pulping and bleaching operations often translated into excessive discharges, leading to oxygen depletion of water courses, dramatic fish kills, and loss of potable water and fishing grounds (Tana and Lehtinen, 1996). In 1970, world discharges of total suspended solids (TSS) and BOD were estimated at about 3.8 million tonnes and 6 million tonnes respectively. Pulp mills accounted then for about 70% of the total industrial and domestic water withdrawal, and respectively 90% and 75% of the total industrial discharge of BOD and TSS in some countries (Oecd, 1973). Sulphite and semichemical mills accounted for about half of the total BOD load. According to a 1987 report on water pollution in Finland and Sweden, discharges of BOD_7 from unbleached pulp production in Sweden and from the overall pulp and paper production in Finland were as high as 150 kg/tonne of pulp produced in the mid-1950s.[2] The multiplication of dramatic impacts caused by pulp and paper operations over the period 1945-1970 eventually acted as a catalyst of public protests against the industry and public authorities across OECD. Under mounting pressures, international and national meetings were organised in which environmental problems were discussed.[3] These regulatory concerns occurred in the wake of the environmental reform of the 1970s, which led to the adoption of environmental laws and/or the setting of national environmental protection agencies across OECD countries. The reform was then driven by a strong belief that pollution could be clearly delineated and addressed, being mere externalities of unwise past policies and patterns of development. Thus, the preamble of the landmark's 1972 United States' Water Act called for the elimination of "the discharge of pollutants into the navigable waters (…) by 1985".[4] The objective represented a major departure from past policies, substituting technology-based limits (the best available technology (BAT) approach) for the prevailing ambient quality standards, considered then a free ticket for dilute-and-disperse strategy. Implementing more severe standards and appropriate techniques appeared a proper answer for what was thought to be reversible problems within realistic time and investments. With respect to conventional pollutant discharges from pulp and paper mills, more exacting regulations were adopted in most OECD countries from the 1970s onward, in which BAT-based limit values were set for conventional parameters, e.g. BOD, TSS, toxicity, colour, etc. In most cases, the

---

2 SNV, 1987. "Water Pollution Problems of Pulp and Paper Industries in Finland and Sweden", Report of the Special Working Group, Committee for the Gulf of Bothnia, Report 3348.

3 Water pollution was a major item of discussion at the 7th session of the Advisory Committee on P&P in November 1996 under the auspices of the Food and Agriculture Organisation (FAO). Several other meetings were held to further discuss problems and options to address effluent disposal problems in the P&P industry, including the Canadian National Conference on Pollution and Our Environment (Montreal, 1966), the Economic Commission for Europe (ECE)'s Ad Hoc Meeting of Experts for the Study of Economic Aspects of Water Pollution Control Problems (Geneva, 1966), the third P&P Industry Air and Stream Improvement Conference (Vancouver, 1967), and the International Conference on Water Pollution (New York, 1967).

4 Tietenberg, T., *Environmental and Natural Resource Economics*, Harper Collins, Boston, 1996, p. 434.

attainment of policy objectives led to an industry-wide implementation of secondary treatment and end-of-pipe techniques to prevent direct discharge of effluent in waterways.

But the unexpected finding, in 1985, that fish collected downstream from bleached kraft mills contained detectable levels of dioxins, led to a second wave of stringent regulations affecting pulp and paper mills. Regulatory concerns and public fear were reinforced by existing knowledge on adverse impacts of notorious chlorinated compounds such as PCBs, Agent Orange, and DDT. The issue worsened when subsequent studies revealed that trace levels of dioxin could be found in paper products such as milk containers, coffee filters, and sanitary products.[5] Increasing citizen suits and political actions from environmental groups prompted policymakers and industrialists to undertake actions.[6] Chlorinated compounds were also suspected of being linked to a chain of events in which communities of marine mammals, such as dolphins, seal, and whales experienced wide-scale die-off. Although risk uncertainty and disagreements within and between countries remained, market reactions and intervention on the part of national and international regulatory bodies eventually forced pulp mills to install technologies to eliminate, prevent and/or control the discharge of chlorinated compounds.

The legalistic and adversarial nature of the North American institutional framework contributed in part to the United States Environmental Protection Agency (USEPA) emphasis on dioxin as the main culprit of adverse effects of chlorinated effluents. Yet the strong North American domestic market partly insulated its industry from the influence of European politics.[7] In Europe, national regulations were modelled on the basis of international and regional developments. Recommendations from marine conventions influenced significantly the establishment of national policies and standards, in particular from the Helsinki Commission on the Protection of the Baltic Sea (Helcom) and the Paris Commission for the Protection of the North Sea and the North East Atlantic (Parcom). These discussions took place under the leadership of Sweden, which acted as a lead country on the P&P sector in both conventions. The debate between Sweden and Finland at Helcom provided a benchmark for policies and environmental measures world-wide. Yet these negotiations were characterised by an overt conflict over risk assessment of BKMEs. A compromise was eventually reached and the resulting agreement has influenced significantly developments world-wide.

---

5 See “National Dioxin Study Released”, *Environmental News*, United States Environmental Protection Agency, 24 September 1990; “Toward a Chlorine-Free P&P Industry”, *Greenpeace Canada*, 1990.

6 For example, a paper company was accused of not warning the public about possible dioxin contamination and ended up having to pay one million dollars to a man who had suited them for 100 millions dollars. In “Impact of Environmental Legislation on the P&P Industry in the 1990s”, *Nlk*, 1991, p. 110.

7 However, the German market accounts for one third of market pulp export for the Canadian P&P industry and therefore it plays a significant influence on the strategic decisions of the Canadian industry.

Counter-expertise now suggests the adverse effects previously correlated with chlorinated discharges would be caused by natural compounds contained wood (Peck and Daley, 1994). Yet concerns over endocrine disrupting substances also include residual chlorinated compounds contained in effluents from pulping and bleaching operations (Colborn, 1992). Regulatory concerns associated with endocrine disruptors and natural toxic substances contained in wood are thus among the factors bringing industry to work on the progressive closer of effluent, ahead of regulatory demands and public pressures across OECD.

1.3 Economic and technological trends

Causes and factors underlying policy and technological development are better understood when considering key economic drivers and environmental considerations affecting kraft bleached pulp production growth and changes over time. Thus, two factors have had significant influence over the period 1950-1985: the ever growing market demands for brighter and stronger paper products, requiring process changes and production growth of higher grades pulp; and the increasing production and environmental costs associated with the above. These trends carried an element of contradiction. On the one hand, the drive of consumers for stronger, versatile, and brighter paper products had a major long-term influence on product diversification and technological development. From the 1960s onwards, these trends led to significant growth in better quality, high-priced pulp and higher earnings for the industry. But on the other hand, producing higher grades pulp requires more material inputs and process refinements, increasing production costs and the generation of more environmentally-disruptive effluents (Sinclair, 1990; FEI, 1997). This contradictory development has provided incentives for enhancing resource productivity through improved management, raw materials and chemicals substitution, and the development of more cost-efficient processes. Although this has not been a straightforward, continuous improvements in environmental performance also suggest that industry has tended to integrate production and environmental cost considerations in its strategic planning. This is exemplified by the industry-wide shift from the sulphite process to Kraft pulping over the past 20 years. Higher costs of implementing and operating a spent liquor recovery system in the sulphite process have been the deciding factor as such.[8]

The simultaneity of kraft bleaching production growth and tightening regulatory controls over pulp mill effluents over the period 1970-1980 is a key element when analysing the relationship between regulatory and technological changes. The need for additional production capacity obviously provided the industry with an opportunity to co-optimise environmental issues within its

[8] In Finland, analyses comparing recovery systems costs between sulphite and kraft pulp always came out in favour of switching to the latter. In FEI, 1997. "The Finnish Background Report for the EC Documentation of Best Available Techniques for Pulp and Paper Industry", Helsinki, ISN 952-11-0123-7.

business strategy. Trends over that period show that different options were implemented to comply with tightening regulatory controls:

- The closure of uneconomical, small scale operations;
- Increasing cost-effectiveness of chemical recovery systems by substituting kraft-based to sulphite-based production;
- Increasing economies of scale through bigger, state-of-the-art production units;
- Implementing state-of-the-art external treatment; and/or
- Investing in new in-plant processes, e.g. O_2 delignification, modified cooking, etc.

This margin of manoeuvre is important considering the ranges of investment costs between retrofitting existing mills and building a new site. The first option is usually more predictable and makes it easier to optimise capital and operating costs through optimal design. Table 3 compared the estimated costs in bringing both options to BATs.

Table 3 - Investment costs for different measures for a kraft pulp mill

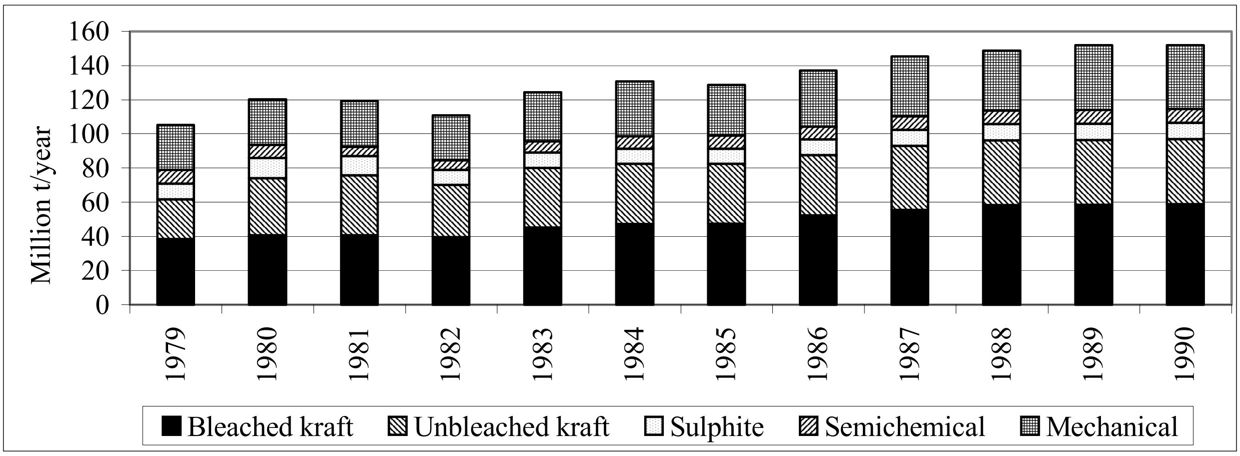
	Investment costs (Finnish Mark, million)
Dry debarking and modern chip-handling	
– A new complete plant	180-190
– Modernisation of existing plant	30-90
Extended cooking (batch/continuous)	
– A new complete plant (batch – cont.)	230-300
– Modification of existing conventional plant to extended cooking (cont. – batch)	80-200
Brown stock washing	
– A new complete washing plant	80-140
– Additional washing stage in existing washing plant	20-60
– CO_2-washing	0.1
Oxygen delignification before bleaching	
– 1-stage delignification	80-90
– 2-stage delignification	90-100
Enzyme treatment	0.5-1
Bleaching	
– A new complete TCF bleaching plant (with peroxide – with ozone stage)	220-300
Additional bleaching stage	
– Chelating stage	35-55
– Pressurised EOP stage	50-60
– Ozone stage	70-90
Evaporation of bleached liquor	
– A new complete plant	100-120
– Additional high-density concentrator	20
Handling system for malodorous gases	
– Strong gases	25-35
– Weak gases	15-20

Source: FEI, 1997

The kraft process is the principal technology used in industry today (around 70% of world production), accounting for the most recent growth in world wood pulp supply. In spite of increasing regulatory pressures, the dominance of the Kraft process is predicted to continue well into the next century. Developments are shown in figure 1.

Figure 1 – World development in wood pulp supply

Source: Tana and Lehtinen, 1996



The last 20 years of developments in the Kraft technology has been remarkable. Despite the production scale and capital intensity of Kraft mills,[9] the industry has been able to come full circle from using Cl_2 as the most widely used bleaching chemical since the 1940s to virtually phasing it out in the course of the last 20 years. ECF and TCF bleaching schemes have continuously increased their world share of chemical bleached pulp production, with ECF now accounting for nearly 50% of world production capacity. Regional shares of ECF and TCF in world chemical pulp production in 1996 are illustrated in figure 2, which further suggest the dominant role played by the Nordic countries in the TCF versus ECF debate. As the environmental fervour for chlorine-free products eventually lost momentum, TCF pulp has eventually stagnated at around 6% since 1994, following a steady growth in the early 1990s. Though markets moved against Cl_2, paper specifiers have become unwilling to pay the price premiums or accept the lower quality of TCF pulp.[10] Responding to market signals, the industry has therefore switched to ECF bleaching cycles.

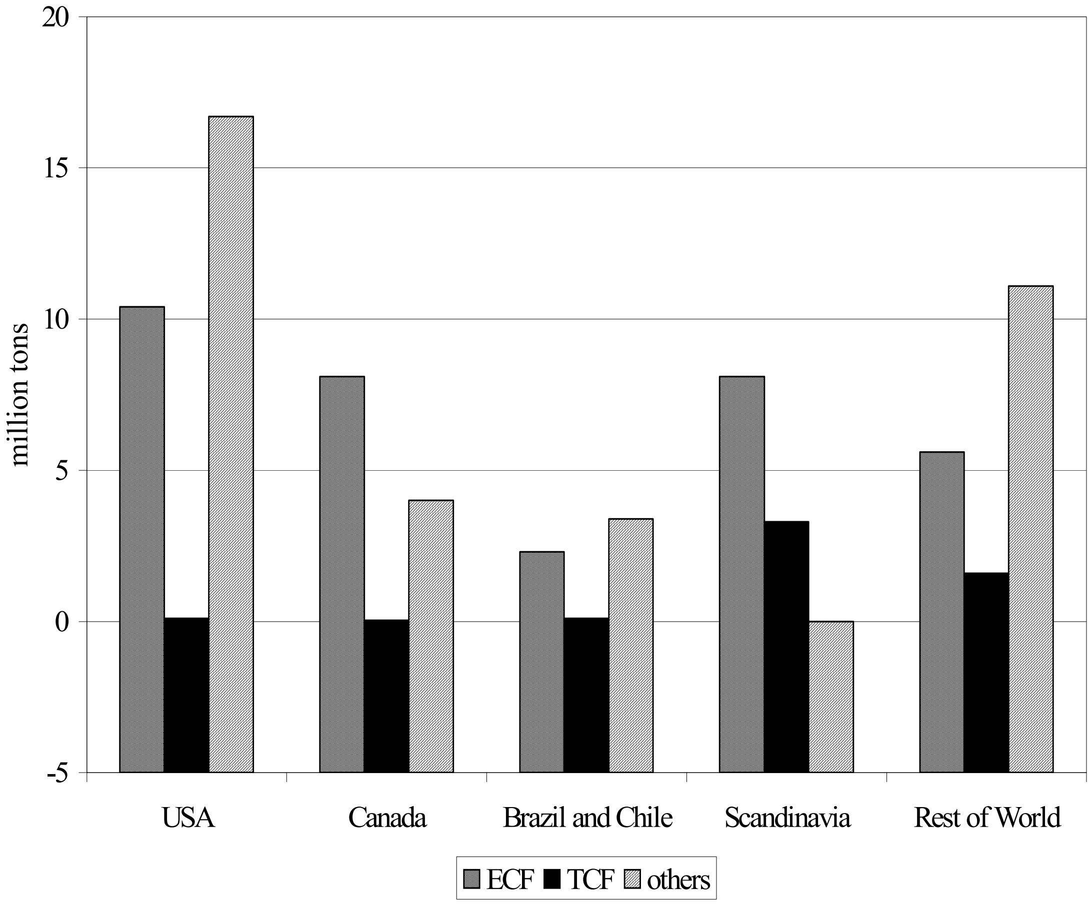
---

9 Like many mature industries, bleached kraft pulp production is capital intensive and requires large economies of scale to remain competitive. A modern kraft mill, with a capacity of 500,000 tonnes/year, can cost over US$ 1 billion, more than US$ 1 million per employee. As a result, kraft pulp is mainly purchased from the market by papermakers rather than being vertically integrated into production (STEP, 1997).

10 ECF is the preferred method in terms of product quality, e.g. brightness, although TCF pulp is closing the gap. Production costs for TCF pulp remain slightly higher than ECF pulp (Swedish Licensing Board, 1999).

Figure 2 - Share of ECF and TCF pulp in market pulp between countries, 1996

Source : Alliance for Environmental Technology



The continuing growth of ECF sequences (and to a lesser extent of TCF) in total share of world production of chemical bleach pulp will continue world-wide (Aet, 1999), bringing down the total effluent loading, while reducing investment and operating costs through increasing economies of scale of both equipment and chlorine-free chemical supply. Studies on ECF and TCF processes indicate that effluents exhibit no or only weak toxic effects in marine environments, although a certain effect remains with respect to fish reproduction and growth. It is assumed that low kappa ECF and TCF bleaching lead to very low emissions of chlorinated compounds and non-detectable level of high-chlorinated phenolic substances. In addition, the chlorine content in high-molecular materials contained in effluent from modern low kappa ECF mill is only slightly higher or on a level comparable with concentrations in naturally chlorinated humic substances. The amount of other substances of concern, fatty acids, resin acids and sterols in effluent from modern mills are affected more by the raw material, i.e. from the pulping stage rather than the bleaching stage(SNV, 1997).

In advanced countries, sub-lethal effects of pulping and bleaching effluents will continue to provide incentives for continuing research aiming at the closed-cycle mill, i.e. the totally effluent-free (TEF) mill. Since the 1990s, the use of complexing agents, which use significantly increased with the implementation of new pulp bleaching methods using hydrogen peroxide or ozone, are not affected by secondary treatment. Their discharges have been associated with eutrophication effects and long range dispersion of metals (Tana and Lehtinen, 1996). Effective secondary treatment systems will increasingly become necessary to ensure appropriate control of degradable organic matter and low chlorinated phenolic compounds (SNV, 1997).

1.4 Industry profile in the selected jurisdictions

1.4.1 Finland

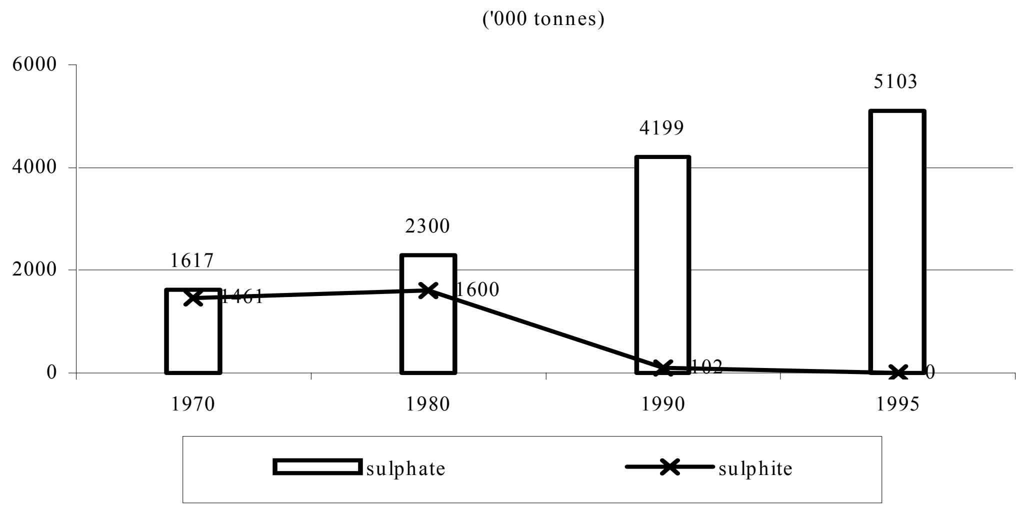
Finland ranks respectively fifth and sixth in world leading pulp, and paper and board production. In 1995, the production of chemical pulp was nearly 6 million tonnes and of paper and board 11 million tonnes (Ppi, 1997). The sector is of utmost importance to the Finnish economy, showing the largest net trade balance of trade. About 80% of total production is exported to Europe and 10% used domestically. As a major exporter of pulp and paper products, the Finnish industry is an important source of virgin fibres in Europe. Combined with associated engineering work, and the chemical, machinery and control equipment suppliers, the industry is the heart of the forest industry cluster, by far the most important in the Finnish economy. As such, Finland is considered a world leader in process technology, and production of advanced-quality magazine paper grades and coated woodfree grades.

The most significant trends that have affected the industry over time include:

- Increasing capacity of production units and closure of old mills;
- Phasing-out of Cl_2 as bleaching agent;
- Phasing-out of the sulphite process; and
- Developments in improved and specialised papers and advanced production technology.

Finland has a total of 16 integrated and non-integrated kraft pulp mills. Two of these mills produce unbleached pulp and the other 14 mills, bleached pulp (almost 90% of the pulp is bleached). All but five mills are integrated to paper or board producing plants. The number of kraft mills have remained unchanged since 1965 (16), but the production units have increased markedly, largely off-setting the closure of sulphite-based capacity. The number of sulphite mills decreased from 19 to 3 between 1965 and 1985. The last sulphite-based operations was shut down in 1991. Developments in the respective share of chemical bleached pulp between sulphite-based and kraft production are illustrated in figure 3.

Figure 3 – Developments in chemical pulp bleaching technologies in Finland



Source: Oecd, 1973; Ppi, 1997

Discussions with respect to environmental impacts of P&P production started in the mid-1960s as the rapid expansion of production was leading to growing pollution of waterways and public protests. The Water Act was still in its infancy and appropriate controls were lacking. Environmental protest against P&P mills reached its peak at the end of the 1960s (National Board of Waters and Environment, 1998). BOD and waste loads were significant as the Finnish industry then lagged behind most producing nations in developing cleaner technologies (Konttinen, 1998). Authorities had but little choice to tighten discharge limits on BOD and suspended solids and to require effluent treatment in all pulp mills. Finland announced its intention to require both external treatment and in-plant measures via chemical treatment to reduce the BOD and dissolved substance discharges in waste waters. At first, environmental authorities did not expect to impose secondary treatment prior to 1980 (Oecd, 1973). However, they found it necessary to move quickly on BOD limits to address the oxygen depletion of the many small and shallow rivers. In addition, while about 40% of Finnish mills are to be found near the Baltic Sea, the coast line is shallower than in Sweden (Finnish permitting authorities, 1998), therefore having small dilution capacity. Regulatory emphasis on BOD discharges and suspended solids was thus tied to the topography of waterways, leading to the rapid implementation of secondary treatment at all Finnish mill sites. Table 4 reflects this situation by listing the different wastewater treatment methods implemented by pulp and paper mills in Finland up to 1995.

In 1993, all but one of the pulp mills had biological treatment systems for their effluent or had them under construction. Cl_2 was phased out as a pulp bleaching chemical in 1993, whereas the use of hypochlorite was abandoned before that. The first O_2 delignification system was implemented in Finland in 1988 and, by the end of 1995, most mills had followed suit. Today, 80% of the kraft pulp is being delignified with O_2. Since 1995, all kraft mills have implemented ECF bleaching, while seven mills can produce TCF pulp. Other changes include the use of enzyme treatment before bleaching.

Table 4 - Wastewater treatment methods in use in Finland in 1995

	AS	AL	AN+AL	C	M
Integrated mills (paper production and kraft and/or	4	1	1		1
mechanical pulp)	7*	2			
Bleached kraft pulp mills	2		1		
Semi-mechanical mills	11			4	
Wood-containing paper and board and mechanical pulp mills	3			4	3
Woodfree paper and board mills					

AS = activated sludge plant
AL = aerated lagoon
AN+AL = anaerobic filtration and aerated lagoon
C = chemical precipitation
M = mechanical sedimentation

Note: The number of treatment plants exceeds the number of mills because some sites have two treatment plants. In one case, a treatment plant is used jointly by two mills.

Source: FEI, 1997

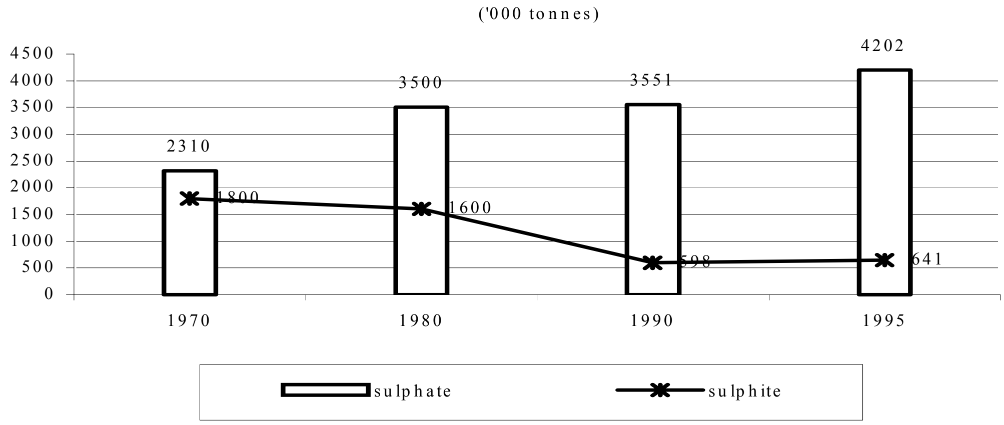
1.4.2 Sweden

Sweden is respectively the sixth and seventh largest world pulp, and paper and board producer. In 1998, the production of chemical pulp was nearly 8,5 million tonnes and of paper and board nearly 10 million tonnes (Swedish Forest Industries Association, 1998). The pulp and paper industry is an important asset to the national economy, contributing significantly to the balance of trade. The export of forest industry products amounted to 93 billion Swedish Kronor (SEK) in 1998, registering a trade surplus of 75 billion SEK. Sweden is a world leader in process and environmental technology for the sector. As a major exporter, the Swedish industry is also an important source of virgin fibres in Europe.

The pulp and paper mills are primarily located along the Baltic Sea shoreline and to lake Vänern. There are 7 sulphite mills, 26 kraft mills, 15 of them with bleach plants, and 23 mills producing mechanical and semi-mechanical pulp. Shares of chemical bleached kraft and sulphite-based pulp production over time are shown in figure 4.

Figure 4 - Developments in chemical pulp bleaching technologies in Sweden

Source: Oecd, 1973; Ppi, 1997



Pulp mill effluents were routinely discharged into waterways without secondary treatment prior to the 1970s, while only a few mills had black liquor recovery systems (Oecd, 1973; Swedish Forest Industries Association, 1998). Black liquor recovery was first imposed as a minimal requirement, which led to the closure of older, small mills. Sweden then announced its intention to reduce pollutant loads from pulp and paper mills by means of COD discharge limits rather than the BOD focus (Oecd, 1973). Swedish authorities and industry thus agreed to divert efforts from end-of-pipe measures toward process change in addressing the overall toxicity of plan operations.[11] Sweden based its approach on a balancing of assimilative capacity and technology-based considerations, which translated into less stringent BOD requirements on short-term, easing the implementation of O_2 delignification and recovery of wastewater to reduce COD loads. Swedish authorities took advantage of the assimilative capacity conferred by the siting of its mills nearby the Baltic Sea to give a 'regulatory break' to its industry on BOD limits. BOD requirements were much less restrictive at 8-17 kg BOD/metric tonne of pulp, compared with the American limit of 4-8 kg BOD/Mt (Simons, 1994). The Swedish approach prevented its industry from investing into costly secondary treatment of effluents, while widening the range of measures allowing reduction of discharges by internal measures.[12] The Swedish industry focused on the development of measures, such as improved washing and screening, extended cooking and O_2 delignification in order to reduce the amount of chlorine used and to ease recycling of bleached filtrates. The Aspa and Gruvön mills were largely

11 "(…) It is the right approach to aim for all emissions to be brought down to non-injurious levels. This means that society will be obliged to tolerate very modest emissions, which are within the bounds of what Nature can withstand and satisfactorily deal with." Nils Jirvall, *Skogsindustrierna*, quoted in Simons, *Op. cit.*: p. 52.

12 "Secondary water treatment systems required the greatest capital expenditures to reach compliance. In 1980, the EPA estimated that compliance with the regulation would require $1.4 billion in capital expenditures and $430 million annually in operating costs." In "Competitive Implications of Environmental Regulations – Case Study Drafts", *The Management Institute for Environment and Business*, US, 1994: p. 36.

responsible for the technological breakthrough of O_2 delignification in 1973, although the first pilot trials had previously taken place at a Modo mill. Overall, these technical developments increased energy efficiency, reduced chemicals and waste treatment costs, and allowed non-chlorinated wastewater to be cycled back to the recovery boiler.[13] These changes later provided a technological edge when the Cl_2 bleaching issue sparked.

In 1992, all Swedish mills applied O_2 delignification, with most of them using modified cooking systems (Skogsindustrierna, 1995). Södra Cell AB was the first company to switch all of its production to TCF and its Mönsterås mill was benchmarked world-wide for its environmental performance and product quality (Swedish Licensing Board, 1998). However, Sweden lags behind most major pulp producing countries with respect to secondary treatment plants. Only eight of the fifteen mills had installed aerated stabilisation basins in 1993, while none had activated sludge treatment plants (Simons, 1994).

2 The policy process regulating BKMEs in Finland and Sweden

2.1 FINLAND

2.1.1 Environmental legislation

Environmental control in Finland is implemented under a series of media-specific acts and administrative laws, which establish the provisions for the administration, co-ordination, and direction of environmental protection:

- Air Pollution Control Act.
- Chemical Act.
- Environmental Permit Procedure Act.
- Noise Abatement Act.
- Public Health Act.
- Public Water and Sewerage Systems Act.
- Waste Management Act.
- Water Act.

As a party to several international agreements, the process by which Finland adopts its positions in international negotiations influences also the establishment of environmental requirements at the domestic level. Thus, the following agreements have had a significant influence on the formulation and implementation of environmental control in the country:

- Accession to the Economic Communities.
- Convention on the Long Range Transport of Air Pollution (Lrtap).

[13] The high corrosive nature of chlorinated material in BKMEs impedes to cycle back wastewater to recovery boilers because it would lead to a rapid deterioration of equipment.

- Convention on the Protection and Use of Transboundary Watercourses and International Lakes.
- Convention on the Protection of the Marine Environment of the Baltic Sea (Helcom).
- Convention on the Protection of the Marine Environment of the Northeast Atlantic (Parcom).

2.1.2 Permitting procedure and requirements

The basis for regulating point sources discharging in water courses is a permitting system that was developed as a provision of the Water Act (1962). The issuance of permits was an administrative responsibility delegated at the national level until 1990. The process was then put under the responsibility of 13 Regional Environmental Centres located throughout the country.[14] A system of notification exists for minor polluting sources, which is under the responsibility of local authorities.

Water Courts are the administrative unit responsible for conducting public hearing and setting permit conditions on a case-by-case basis. There are three Courts, each representing a geographical area. Their board is usually composed of three members, a lawyer, an engineer, and an ecologist. The concept of BAT is a guiding principle in setting conditions and discharge limits. It was legally stipulated in recent amendments to the Water Act (1995), although it has been put in practice since the 1980s. The concept is meant to cover production and environmental techniques, housekeeping, control systems, or any other means that will optimise pollution prevention and control. The new Waste Management Act has also introduced an efficiency criterion which stipulate that an operator shall save materials and reuse waste instead of raw material, whenever possible. There are few environmental quality standards (EQSs) in Finland, but local consideration of environmental quality is an important consideration affecting decision-making on a case-by-case basis. In addition, water quality and water pollution guidelines developed by the Ministry of the Environment and international obligations binding on Finland are other important factors shaping permitting outcomes. The permitting procedure comprises the following steps:

- The operator must submit an application containing information on releases by process units, on production techniques and control measures, on the fate and effects of compounds used in production, on the efficiency of treatment measures, as well as risk assessment of water-related releases;
- The application and related recommendations for permit conditions are then submitted to an evaluation by independent experts;

---

14 The Regional Environmental Centres were put in place in 1995 to take over the overall responsibilities in environmental protection that was previously dealt by thirteen Water and Environment District Offices for water pollution control and twelve provincial governments for regional air and solid waste control.

- The ensuing documents are available for public review and comments;
- The permitting authority establishes permit limits and other conditions;
- The applicant and other concerned stakeholders are granted a right to appeal of the permitting authority's decision;
- Amendments are made to the proposed permit as appropriate.

The permit must legally include a deadline for revision. In practice, the duration varies between three and ten years

2.2 *SWEDEN*

2.2.1 Environmental legislation

Up until the major environmental reform in 1999,[15] environmental protection in Sweden was implemented under four main acts:

– The Nature Conservation Act (1964).
– The Environmental Protection Act (1969, 1981, 1987, 1989).
– The Act on Chemical Products (1973, 1985).
– The Act on the Management of Natural Resources (1987).

With respect to environmental control of point sources, the Environmental Protection Act has been the main piece of legislation. It stipulates the list of activities requiring permits (under the 1989 Environmental Protection Ordinance), and the principles and administrative means by which limits and other conditions are set. The Ministry of the environment oversees environmental matters. The Environmental Protection Agency (SNV – *Statens naturvårdsverk*) is the central authority for environmental protection, responsible for implementing the decisions of the Parliament and the government. One of its principal responsibilities is to assist the relevant authorities in day-to-day pollution control activities, which include environment permitting and monitoring of point sources.

2.2.2 Permitting procedure and requirements

Permitting requirements are established on a case-by-case basis by the National Licensing Board for Environmental Protection, a central administrative unit that is autonomous and has a status similar to that of a court. Board members are appointed by the government and are experts in industrial engineering, environmental science, legal matters, etc.

---

[15] The reform introduced an Environmental Code which integrated the fifteen previous environmental laws into a single piece of legislation. With respect to licensing and supervision of point sources, related decisions must integrated the different objectives of the overall environmental legislation in Sweden.

Sweden has been a pioneering country in implementing an integrated permitting system that considers together releases to air, water, and land, as well as other nuisances, when defining limits and other conditions. BAT is the starting point for defining permitting conditions, although economic feasibility and environmental impacts of the installation are important considerations in setting requirements. Thus, limits may be relaxed to allow more flexibility to the operator in implementing more lasting, preventative measures instead of more stringent, end-of-pipe techniques. Permits often include both discharge limits, which cannot be exceeded, and guide values, usually based on historic record of discharges, which, if exceeded, must lead to measures leading to compliance, after agreement with permitting authorities. As an active participant to international agreements, Sweden implement the decisions from these conventions when considering an individual case.
When applying for a permit, the applicant must take the following steps:

– The application must provide information on current and future environmental releases, generation and disposal of waste and noise, a description control measures and their costs, and an environmental impact assessment;
– An evaluation is made by SNV, which then prepares a draft permit;
– The licensing board is appointed by the government to prepare the final permit. The board is responsible for conducting public hearing on the proposed permit;
– Decisions by the licensing board can be appealed by SNV, the company, or any other entity concerned by the decision. The government then decides on the validity of the appeal and render the final decision;
– The permittee may apply for amendments, if he is unable to meet the requirements. The request will be judged by the same administrative unit reviewing the permit, with guidance from SNV. At this stage, the public cannot appeal of the decision.

Permits are normally good for ten years, unless an increase in production or major modifications to existing installations will require a review.

3 Finnish and Swedish regulations affecting BKMEs

3.1 FINLAND

3.1.1 National standards and guidelines

There are no industry-wide standards regulating BKMEs. However, national guidelines and objectives have been developed to provide guidance to relevant authorities. In addition, recommendations from Helcom and the Nordic

Council of Ministers of the Environment are important input in identifying environmental issues of concern and devising measures, which are then incorporated into the permitting structure.
With respect to pulp and paper effluents, two national programmes have been established which provide emission targets and objectives for the pulp and paper sector:

– A Water Protection Programmes to 1995 (1988).
– Decision taken on the Reduction of Discharges of Chlorinated Organic Compounds for the Pulp and Paper industry (1989).

The 1988 Decision-in-Principle by the Finnish Council of State on the Water Protection Programmes provides specific indication as for the direction and overall objectives of environmental protection, as well as specific targets with respect to pulp and paper effluents. These includes the following:

– Improving the quality and prevent the further deterioration of waters in Finland, using the best available, economically feasible, technology;
– Prioritising discharges and compounds causing the most harm;
– Focussing on bleached pulp mill effluents and the discharge of chlorinated organic compounds as a regulatory issue, and supporting the development and implementation of alternative techniques and measures;
– Mandating the Ministry of the Environment to set target values for total discharges by the pulp and paper industry by 1992; and
– Implementing the recommendations from Helcom to reduce the specific loads of COD_{cr}, phosphorus, and BOD_7 to respectively 65 kg/ADt of pulp, 60 g/t of pulp, and 160 t/day.

The Finnish Ministry of Environment quickly followed the publication of the Decision-in-principle on Water Protection Programmes by announcing its Decision on the matter of chlorinated organic compounds on 22 June 1989. The issue is further discussed in the next section on AOX policies. Taken together, the national guidelines provided the following targets for the pulp and paper industry up to 1995:

– AOX: 1.4/ADt
– BOD_7: 160 tonne/day
– COD_{cr}: 65 kg/ADt
– Phosphorus: 60 g/ADt

During 1992-1993, a Nordic Council's working group issued further recommendations for the environmental control of pulp and paper mills, which included BAT-based targets to be reached by the end of the century.[16] These are provided in table 5 for new and existing bleached kraft pulp mills. The Finnish industry has expressed some reservations with respect to the desirability of these goals, stressing the need for further environmental impact assessment (Oecd, 1999a). Although these targets have yet to be adopted as a Council of State Decisions, they do provide guidance in setting BAT-based limits in permits.

In 1997, Finland has published a report on the sector, which provides a review of environmental impacts and benchmarks BAT-based techniques and performance for different process units.[17] A second report on BAT classification was expected to be forwarded to the EU in 1998.

Table 5 - Guidelines for new and existing mills by the Nordic Council of Ministers

	kg/tonne on annual average			
Bleached kraft pulp	**AOX**	**COD_{cr}**	**Total – P**	**Total – N***
Existing mill	0.4	30	0.04	0.2
New mill	0.2	15	0.02	0.15

* Nitrogen discharges associated with the use of complexing agents should be added to the figure for total nitrogen.

Source: Oecd, 1999a

3.1.2 Permitting requirements and environmental performance at kraft mills

Discharge limits, compliance monitoring, and plans for decreasing pollution are established through the permitting procedure. Limits are defined as performance-based numerical values, leaving the choice of compliance measures to the applicant. The parameters regulating BKMEs are BOD_7, COD_{cr}, absorbable organic halides (AOX), and total phosphorus (P-tot). Limits are usually specified in quantity per day and set on a 3-month moving average, although recent permits have used a 1-month period (Simons, 1994).

The review of permits reflect the changes in environmental targets and control parameters which took place over the past 20 years. Finland first found it necessary to address quickly the problem of oxygen depletion by imposing stringent BOD limits in the 1970-1980s. Since 1989, COD limits are increasingly used as a complement to BOD to favour both in-plant measures and external effluent treatment to control the amount of fast and slowly decomposing organic material in the final effluent. The COD measures all oxydizable

---

16 The document, "Study on Nordic Pulp and Paper Industry and the Environment", was published by the Nordic Council of Ministers of the Environment in 1993.

17 "The Finnish Background Report for the EC Documentation of Best Available Techniques for Pulp and Paper Industry", *Finnish Ministry of the Environment,* Helsinki, 1997, ISBN 952-11-0123-7.

materials (both organic and inorganic), putting incentives on internal measures. The control and large scale measurements of AOX discharges were introduced in 1989. The limits for P-tot address the problem of eutrophication, which came about as the result of secdondary treatment plant expansion. COD measurement and the implementation of activated sludge treatment plants render obsolete the measurement of TSS as an indicator of progress. [18]

Tables 6, 7, 8 and 9 provide discharge limits for BOD, COD, TSS and P-tot issued in permits for non-integrated bleached kraft mills in Finland. Estimated annual discharges for the year 1993 have been included to monitor mills' performance with permit limits. It indicates that most mills operated well below compliance levels. Two mills, Sunila and Kemijärvi, were either exceeding or operating very close to BOD_7 and COD_{cr} discharge limits, though the permit conditions did not come into effect until January and September 1994 respectively. Both mills were taking measures to reach compliance in the course of that year. In the case of phosphorous, three of the five non-integrated mills were meeting the Helcom guidelines in 1993 (60 g/ADt), while the remaining two mills were taking steps to reach compliance within their permit deadline.

Table 6 - BOD_7 limits in Finnish permits for bleached kraft pulp mills

Mill	Date of compliance or Permit d.m.y	Reference production, t/y (from permit)	Permitted BOD_7 limit, t/d		Actual annual average BOD_7 discharge in 1993, t/d
			3-month moving average	1-month average	
ENOCELL	01.01.94	560,000	-	3.0	0.5
JOUTSENO	01.01.94	550,000	6.0	-	3.8
	01.01.96	550,000	-	6.0	-
KASKINEN	26.06.94[1]	420,000	5.0	-	3.3
	01.01.96	420,000	3.5[2]	3.5	
KEMIJÄRVI	02.11.94[1]	210,000	7.0	-	5.9
	01.01.97	210,000	5.0	-	
SUNILA	01.01.94	300,000	4.5	-	15.1

1. This permit was appealed to the Supreme Water Court.
2. 3-month moving average was in effect until 30 June 1996. Thereafter, the one month average became effective.

[18] Finnish authorities indicated that the COD is derived from suspended particulate contained in the effluent, thereby mills must consider solid losses when choosing options to meet COD limits (OECD, 1999a).

Table 7 - COD_{cr} limits in Finnish permits for bleached kraft pulp mills

Mill	Date of compliance or Permit d.m.y	Reference production, t/y (from permit)	Permitted COD_{cr} limit, t/d		Actual annual average COD_{cr} discharge in 1993, t/d
			3 month moving average	1 month average	
ENOCELL	01.01.94	560,000	-	50	17
JOUTSENO	01.01.94	550,000	85	-	47
	01.01.96	550,000	-	70	-
KASKINEN	26.06.94[1]	420,000	50	-	39
	01.01.96	420,000	35[2]	35	
KEMIJÄRVI	02.11.94[1]	210,000	50	-	46
	01.01.97	210,000	45	-	
SUNILA	01.01.94	300,000	50	-	55

1. This permit was appealed to the Supreme Water Court.
2. 3-month moving average was in effect until 30 June 1996. Thereafter, the one month average became effective.

Over the past three decades, the absolute load, in terms of BOD and TSS, has been reduced to a mere two percent of the1970s levels. Since production doubles over the period, the load is one hundredth of what is was in 1970 (Nordicum, 1998). Figure 5 shows the steady reduction of TSS, BOD and COD discharges. Obviously, mills have been able to *break* the traditional relationship between production and discharge growth.

Table 8 -TSS limits in Finnish permits for bleached kraft pulp mills

Mill	Date of compliance or Permit d.m.y	Reference production, t/y (from permit)	Permitted TSS limit, t/d		Actual annual average TSS discharge in 1993, t/d
			3-month moving average	1-month average	
ENOCELL	01.01.94	560,000	-	3.0	0.5
JOUTSENO	01.01.94	550,000	6.0	-	3.8
	01.01.96	550,000	-	6.0	-
KASKINEN	26.06.94[1]	420,000	5.0	-	3.3
	01.01.96	420,000	3.5[2]	3.5	
KEMIJÄRVI	02.11.94[1]	210,000	7.0	-	5.9
	01.01.97	210,000	5.0	-	
SUNILA	01.01.94	300,000	4.5	-	15.1

1. This permit was appealed to the Supreme Water Court.
2. 3-month moving average was in effect until 30 June 1996. Thereafter, the one month average became effective.

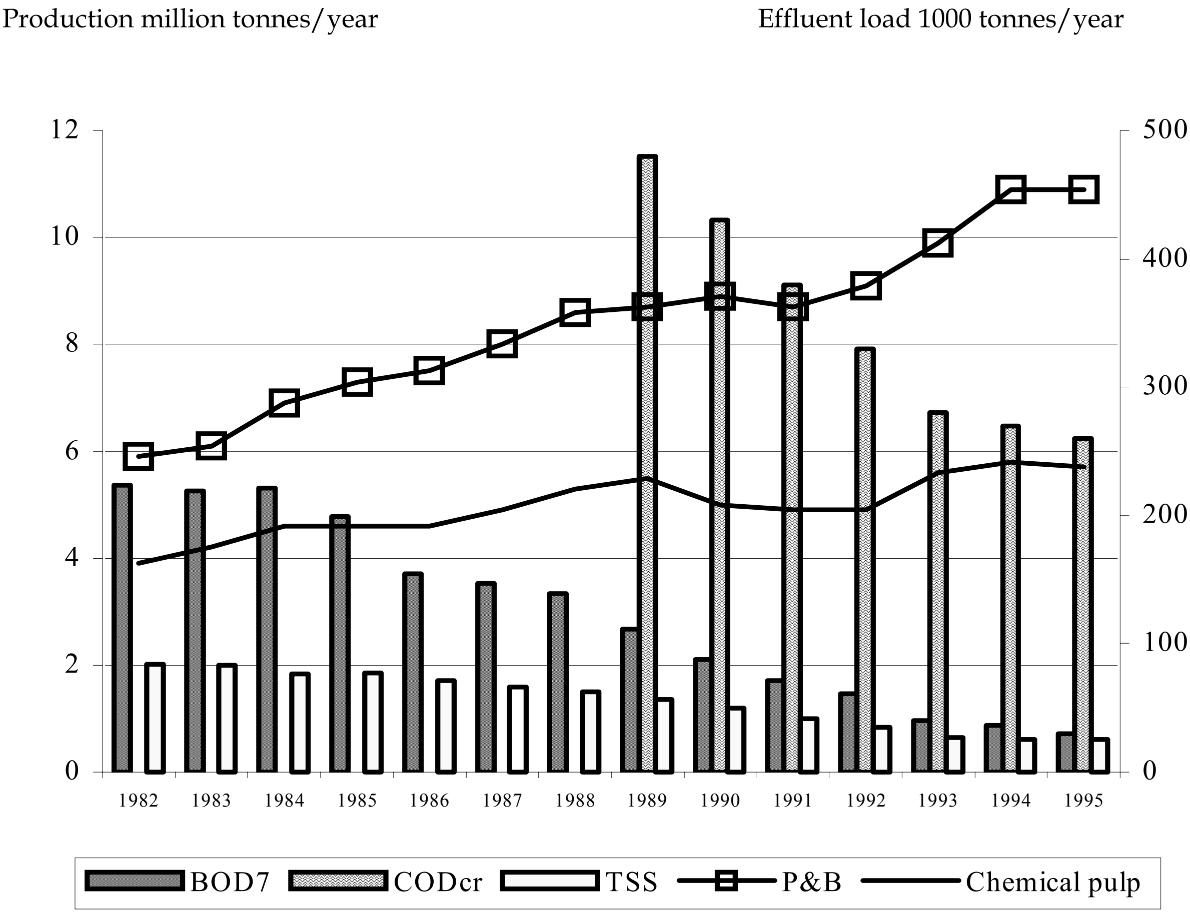
Table 9 - Phosphorous limits in Finnish permits for bleached kraft pulp mills

Mill	Date of compliance or Permit d.m.y	Reference production, t/y (from permit)	Permitted P-tot limit, kg/d		Actual annual average P-tot discharge in 1993, kg/d
			3-month moving average	1-month average	
ENOCELL	01.01.94	560,000	-	75	8.6
JOUTSENO	01.01.94	550,000	100	-	43
	01.01.96	550,000	70	-	-
KASKINEN	26.06.94[1]	420,000	80	-	78
	01.01.96	420,000	50[2]	50	
KEMIJÄRVI	02.11.94[1]	210,000	80	-	69
	01.01.97	210,000	60	-	-
SUNILA	01.01.94	300,000	-	70-	46

1. This permit was appealed to the Supreme Water Court.
2. 3-month moving average was in effect until 30 June 1996. Thereafter, the one month average became effective.

Tables 6, 7, 8 and 9: Adapted from Simons, 1994

Figure 5 - Production and discharge from the Finnish pulp and paper mills



Source: FEI, 1997

3.2 *SWEDEN*

3.2.1 National standards and guidelines

There are no national standards covering pulp and paper operations, although various policy documents have been issued by national authorities to provide guidance to the National Licensing Board in setting discharge limits. The government Bill 1988 set up the Action Plan against Marine Pollution which included short and long term environmental goals for bleached pulp mills.[19] This is further discussed in the section on AOX policies. The Swedish Parliament followed with an environmental bill in 1991 that expanded the range of substances and environmental impacts caused by industrial activities that should be targeted for further reductions, including non-chlorinated substances, nutrients, metals, and chemical compounds used in production.[20] The Bill included the following points, which concerned specifically the pulp and paper sector:

– The objective is to limit discharges by the year 2000 to such a level that no noticeable effects in marine environments may be measured.
– BAT should be used.
– The pulp and paper industry should be given priority in the revision of permits.
– All parameters of importance should be considered.

The Action Plan against Marine Pollution had been effective in stimulating environmentally-driven technical developments. Dry bark removal, modified cooking, O_2 bleaching, substituting ClO_2 to Cl_2, effective washing and purification, as well as in-site recycling of condensates and well developed systems for collection of spillage have been implemented in response to tightening discharge limits affecting bleached pulp mills. These developments were gradually classified as BATs and diffused nationally (Lagergren and Nyström, 1991). Bill 1991 counted on the ongoing and foreseeable technological development to require more stringent measures on both short- and long-term, including the totally chlorine-free (TCF) route. Table 10 benchmarks the technological developments since the 1980s by comparing conventional techniques with BAT-based levels, including current expectations from foreseeable developments.

---

19 Government Bill 1987/1988:85 – "Environmental Policy for the 1990s".
20 *A Living Environment, Main Proposal*. The Swedish Government Bill 1990/1991:90.

Table 10 - Relationship between technology and discharges, 1990-1998

Kraft mills	**AOX**	**COD**	**P-tot**	**N-tot**
Up to 1990				
Normal level	2.5-3.5	50-60	0.1	0.3
BAT	1.5	35	0.05-0.1	0.2-03
Before external treatment				
Current normal level	0.3-1	35-70	0.05-0.1	0.2-0.4
Current BAT	0^{x}-0.3	35-40	0.05	0.2
Development potential	0^{x}-0.1	10-15	0.02	0.2
After external treatment, BAT				
	0^{x}-0.2	10-15	0.01-0.02	0.1-0.2

[x] Totally Chlorine-Free pulp (TCF-pulp)

Source: Lagergren and Nyström, 1991; SNV, 1997

The results suggest that comparable environmental performance can be achieved through either internal and external treatment measures, although it is unclear whether 'development potential' includes the latter. In any cases, Sweden recognise that new knowledge about the toxicity of natural substances contained in wood (e.g. resin acids) could justify the need for external measures in the future (Lagergren and Nyström, 1991).

3.2.2 Permitting requirements and environmental performance of kraft mills

Environmental requirements for point sources are set on a case-by-case basis within the framework of the permitting system. Permits often contain both binding limits and guide values that are made about 20% more stringent and are usually based on historic trends of reduction of discharges (Nlk, 1991). Discharge limits are usually specified for the parameters TSS, COD, AOX, N, and P-tot, with BOD_7 being increasingly phased-out as a control parameter. In some cases, limits are included for chlorate discharges, which are associated with the increasing use of ClO_2. The total organically-bound chlorine (TOCl) parameter is still in use, but is being gradually replaced by the AOX parameter as the permits are renewed. Discharge limits for either TOCl or AOX are expressed in kg/t, while COD, BOD_7 and TSS limits are provided as t/d. Only four of the 15 bleached kraft mills are imposed with BOD_7 discharge limits, expressed as t/d. Converted to kg/ADT, annual and monthly average BOD limits in Swedish permits range between 9.4 and 12.7, and 11.3 and 17.9 kg/ADt, respectively. COD and TSS limits for the eight non-integrated bleached kraft pulp mills are given in tables 11 and 12.

Limits converted in kg/ADt are included to provide an estimation of each mill's compliance against their permit limits. Annual average discharge of mills are estimated assuming a 350 operating days. In the 1960s and 1970s, the main objective was to reduce oxygen depletion of water bodies caused by pulp mill effluent by limiting BOD and TSS discharges. From the late 1970s onward, Swedish authorities considered that both parameters were being addressed effectively by industry and shifted the regulatory focus towards the long-term effects of pulp mill effluent (SNV, 1998). Since then, COD_{cr} has been increasingly substituted for BOD_7 to favour internal measures over external treatment for reducing both the toxicity and quantity of discharges.

The industrial response to tightening limits over the past decades has resulted in steep reduction of discharges. Table 13 summarises the limits, goals, and actual discharges of Mönsterås mill to provide an illustration of ongoing environmental performance in Sweden.

Table 11 - COD discharge limits for non-integrated bleached kraft mills in Sweden

Mill	Date of compliance of permit d.m.y.	Reference production, t/y (from permit)	Permitted COD limit, t/d		Estimated COD limit, kg/ADT		Actual annual average COD discharge in 1993 kg/ADt
			Annual average	Month average	Annual average	Month average	
ASPA	09.04.90	140,000	-	-	-	-	49
HUSUM	04.07.91	550,000	105	-	67	-	50
MÖNSTERÅS	08.04.86	335,000	-	35	-	37	21
MÖRRUM	30.11.92	375,000	60	-	56		45
NORRSUNDET	09.12.86	290,000	40	50	49	61	30
SKUTSKÄR	03.04.87 03.04.87	450,000 500,000	65 70	75 80	51 49	58 56	44
VALLVIK	01.11.88	220,000	35	38[1]	56	61[1]	58
VÄRÖ	01.01.89 01.01.90	300,000 300,000	- -	88 60	-	103 70	45
NOTES: 1. This value is a target, not a limit.							

Table 12 - TSS discharge limits for non-integrated bleached kraft mills in Sweden

Mill	Date of compliance of permit d.m.y.	Reference production, t/y (from permit)	Permitted TSS limit[1], t/d		Estimated TSS limit, kg/ADT		Actual annual average TSS discharge in 1993 kg/ADt
			Annual average	Month average	Annual average	Month average	
ASPA	09.04.90	140,000	1.9[2,3]	-	4.8[2]	-	2.1[2]
HUSUM	30.12.88 30.12.88	550,000 600,000	4.5 5.0	6.0 6.5	2.9 2.9	3.8 3.8	 2.6
MÖNSTERÅS	08.04.86	335,000	-	0.3	-	0.31	1.3[2]
MÖRRUM	30.11.92	375,000	1.2 1.0[4]	-	56	1.1 0.93[4]	0.33
NORRSUNDET	09.12.86	290,000	2.5	3.0	1.3	1.6	2.3[2]
SKUTSKÄR	03.04.87	450,000	5[2]	6[2,4]	3.9	4.7[4]	2.9[2]
VALLVIK	01.11.88	220,000	1.5	2.0[2]	0.78	1.0[4]	1.2[2]
VÄRÖ	01.01.90 01.07.92	300,000 300,000	2.0 1.5	- -	0.72 0.54	- -	1.2
1. All discharge limits and results are based on test procedures using a 70 µm filter. 2. These discharge limits and results are based on test procedures using a glass filter (10 µm). 3. TSS should not exceed 2.2 t/d for more than 5% of any monthly period. 4. Target value.							

Tables 11 and 12: Adapted from Simons, 1994

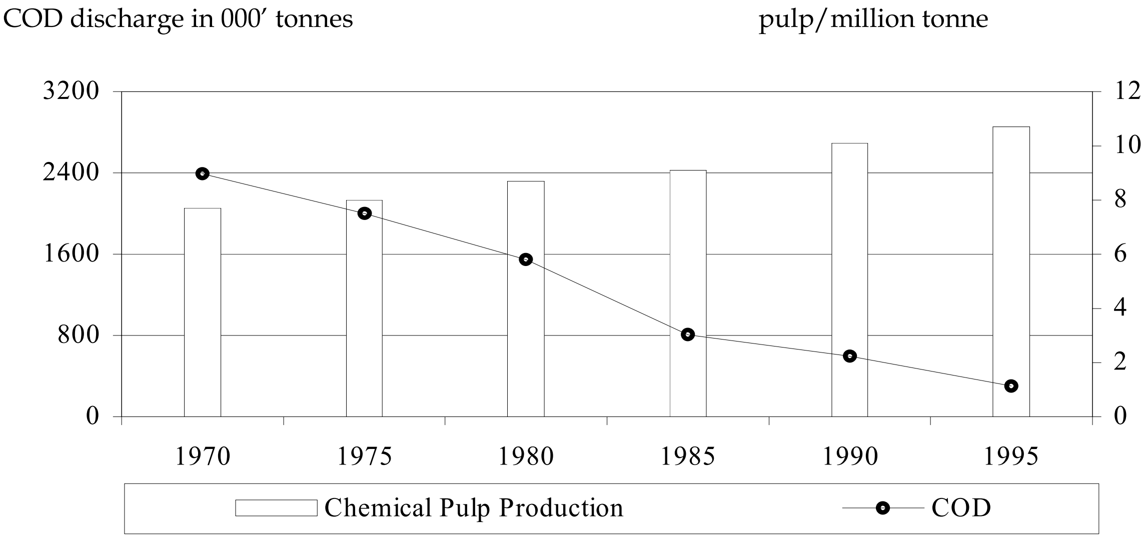
Table 13 - BAT-based limits and technological response at Södra's Mönsterås mill

	COD	AOX	N	P
Permit, August 1998				
– **Conditions**	~9	0,15	0,3	0,03
– **Goals**	6	-	0,2	0,02
Discharges, October 1998	12,6	0	0,29	0,28

Source: Swedish Forest Industries Association, 1998

The industry estimates that COD discharges have been reduced by nearly 90% since 1960, as illustrated in figure 6.

Figure 6 - Pulp production and COD discharges in Sweden, 1970-1995



Source: Swedish Forest Industries Association, 1998

4 AOX regulations and discharge limits in the selected jurisdictions

4.1 *Environmental and regulatory backgrounds*

Up to the mid-1980s, regulatory focus for the pulp and paper industry had been the control of conventional pollutants, i.e. BOD, COD and TSS. Regulatory concerns over the use of Cl2 as a pulp bleaching agent emerged following the detection of dioxins and furans[21] in fishes collected downstream from bleaching

[21] Dioxin is the generic term for the group of polychlorinated dibenzo-p-dioxins (PCDD) containing 75 isomers. Dioxin is considered the most potent carcinogen ever tested on animals. Often associated with dioxins is a related group of 135 isomers classified as polychlorinated dibenzofurans (PCDF), which potency is estimated at one tenth of that of

mills in the United States, as well as in effluents, sludge and pulp in 1985[22]; and the results of the project Environment/Cellulose – sponsored by the Swedish Environment Protection Agency (SNV) – that correlated adverse effects observed in fishes with chlorinated discharges by a bleached kraft mill.

The correlation between chlorine bleaching and dioxins sent a series of shock waves across the industry and regulatory authorities. Industry and authorities were well aware of the presence and accumulation of chlorinated materials in aquatic environments, but the highly toxic potential of some of these compounds and the high public profile of the issue took them by surprise.[23] Public concerns grew even more when dioxins were later detected at trace levels in consumer goods, such as milk containers, coffee filters, sanitary and paper products.[24] Many fisheries had to be shut down in areas where chlorine bleached pulp mills discharged. In September 1990, there were at least 31 State-issued fishing advisories or bans in effect due to dioxin discharges from bleaching mills in the United States (Prothro, 1991). Since the late 1988, the Canadian government had shut down shellfish harvesting over hundreds of kilometres of British Columbia's coastline because of contamination by dioxins and furans (Oecd, 1999c). Similar situations occurred in Europe.

But dioxins represented only a small amount of the chlorinated by-products contained in chlorinated pulp mill effluent. When Swedish experts alleged a connection between chlorinated compounds discharged by pulp mills and deformities of fishes and other adverse effects in marine ecosystems, the regulatory focus suddenly switched towards the whole group of chlorinated substances. Although Swedish studies were subsequently contested,[25] market reactions and interventions of national and international regulatory bodies led to a significant reduction of chlorine use and discharges into marine environments. SNV paved the way by incorporating discharge limits on TOCl in permits from 1986 onward.[26] Although its position was justified on the principle of precaution, the demand sparked a controversy as it was not proven that Cl_2 was the direct cause of adverse environmental impacts associated with pulp bleaching, nor if it was possible to achieve compliance with available measures, even without the use of chlorine gas (Axegård, 1998).

2,3,7,8-TCDD. The principal dioxin and furan found in bleached kraft mill samples were 2,3,7,8-TCDD and 2,3,7,8-TCDF (Nlk, 1991).

22 The results came from the 1988's joint USEPA – Industry survey of 104 bleached pulp mills. The findings was rendered possible thanks to advances in analytical methodology enabling the detection of dioxins in parts per quadrillion and trillion range. Indeed, sampling at the same locations two years earlier had failed to detect dioxins with the then parts per billion analytical range (McDonough, 1998).

23 Already in the 1970's, chlorinated phenols had been scrutinised by regulatory authorities. The first field work on chlorinated compounds in Finland can be traced back as far as the early 30s. Interview with Jaakko Paasivirta, Department of chemistry, University of Jyväskylä, April 1998.

24 USEPA, 1990. "National Dioxin Study Released", *Environmental News*, 24 September.

25 Carey, J., Hodson, P., Munkittrick, K. and M. Servos, 1993. "Recent Canadian Studies on the Physiological Effects of Pulp Mill Effluent on Fish", *Environment Canada*.

26 On average, AOX values are estimated at about 30% higher than TOCl (Simons, 1994).

Uncertainty over the value of AOX parameter in measuring toxicity contributed to the range of regulations and discharge limits adopted across OECD countries. Nevertheless, major European producing countries adopted AOX policies to control chlorinated effluents from bleached plants. In North America, the potential human health risk of dioxins provided a stronger legal basis for regulating this isomer than other chlorinated compounds (Oecd, 1999c). In any cases, stricter limits led to the high rate of ClO_2 substitution to Cl_2, as well as the introduction of O_2 delignification.

The following subsections review the Finnish and Swedish regulatory approaches, and their effects on technological development and environmental performance at point sources.

4.2 FINLAND

4.2.1 Regulatory approaches and requirements

Regulatory issues associated with chlorine use and discharge were first addressed within the framework of permit issuance to a Kemi Oy's pulp mill in 1972. Authorities recognised that some chlorinated compounds had the potential for harm, but then believed that secondary treatment were addressing the problem appropriately (National Board of Waters and Environment, 1998). Environmental impacts associated with chlorine use and discharge from pulp and paper mills had been investigated for some times, but BOD loads remained the focus of regulators. Measurement of AOX and COD started only on a large scale in 1989, although some measurement had been conducted since 1979. The situation was taken more seriously in the mid-1980s, when dioxins were detected in pulp mill effluents and sludge, and following Swedish demands for Helcom recommendations on TOCl discharges.

Finland lagged behind Sweden in addressing the issue. Still, the results from Sweden's Environment/Cellulose were largely covered by medias and had some repercussions in Finland, notably on the west coast where local fishermen were alarmed by news of difformed fish and contamination of fishing grounds. The permit renewal of the Kaskinen mill in 1984-85 was characterised by significant pressures from the local community to include limits on the discharge of chlorinated compounds. Representatives from the National Board for Environmental Protection, which came to assist at public hearings felt that the limits on chlorinated discharges suggested by the regional permitting authority were too tough (Regional Permitting Authorities, 1998). The situation showed an absence of consensus on the problems between the different level of environmental authorities.

Thus, when Sweden introduced the issue at Helcom, Finnish authorities were not prepared to enter discussions. The first discussions, which took place in 1984 at Helcom, testified of profound disagreements between the two neibourghing countries. At some point, the Finnish delegation invited representatives from the Finnish industry to assist them. The Swedish delegation interpreted the move as a resistance to policy changes. Some Swedish officials even accused publickly Finland of polluting the environment and refusing to take the appropriate measures to protect the Baltic Sea (Auer, 1997). Swedish regulators further attacked the credibility of Finnish authorities by comparing mill effluent after primary treatment, which obviously disadvantaged Finnish mills having invested mainly in secondary treatment over the past 20 years (Experts, 1998).

The issue eventually required the mediation of the Nordic Council of Ministers to overcome the dispute. A working group was established by the Nordic Council to study environmental problems associated with chlorinated discharges in the Bothnian Bay and to recommend measures to reach a compromise. Technical guidance was requested from a major and well respected consulting firm, Jaakko Pöyry. Consensus-building data were eventually gathered. The work, later published by the Nordic Council, showed that:

– the chlorinated compounds of concern (chlorinated aromatics) represented only 5% of total chlorinated materials (aliphatic material), far from what was previously believed by Swedish authorities;[27] and

– acceptable performance with respect to chlorinated discharges of concern could be met by both internal measures, e.g. O_2 delignification, various degree of ClO_2 substitution, and optimised external treatment, such as the activated sludge treatment plant.

On 15 June 1989, the working group recommended that the discharges of chlorinated organic substances from bleached kraft mills should, as an average for each contracting party to both Helcom and Parcom, be limited to 2 kg AOX/tonne of coniferous pulp and 1 kg AOX/tonne of deciduous pulp, or 1.4 kg AOX/tonne of bleached kraft pulp, by the end of 1995. Soon after, Finland adopted its Decision on the matter of chlorinated organic compounds, issued by the Ministry of Environment on 22 June 1989, that introduced an annual average discharge limit of 1.4 kg/ADT to be met by the pulp and paper industry by 1995. The Decision of 22 June 1989 clearly reflected the recommendations of the working group. Conditions aiming at this goal were to be introduced on a case-by-case basis within the framework of the permitting system, in accordance with the normal regulatory procedure. AOX discharge limits were gradually incorporated in permits. These are listed in table 14 for bleached kraft mills. The table includes the conversion of permit limits, specified as kg/day on 1-month and 3-month averages, in kg/ADt to allow comparison between countries under review. The table also includes AOX

---

27 According to a participant to the negotiation, the finding gave a severe blow to Sweden's effort to drive the Nordic Council to require oxygen-based bleaching as a minimal requirement. Indeed, a major argument as such was that the low molecular part corresponded to about 20% of the chlorinated organic matter, as indicated in a HELCOM room document from Sweden. In Fallenius, U.-B., "Environmental Matters Concerning Pulp and Paper Industry in Sweden", *Environmental Protection Board*, October 18, 1988.

discharge per mills in kg/ADt, as reported by the Finnish Forest Industries Federation for 1993. As the table indicates, Finland catched up fast as AOX limits and compliance measures at mills showed the same level of stringency and performance as those found in Sweden in 1993.

Table 14 - AOX discharge limits in Finnish permits for bleached kraft pulp mills

Mill	Date of compliance or Permit d.m.y.	Reference Production, t/y (from permit)	Permitted AOX limit, t/d		Estimated AOX limit in kg/ADt		Actual annual average AOX discharge in 1993, t/d
			3-month moving average	1-month average	3-month moving average	1-month average	
Enocell	25.11.92	560,000	1.7	-	1.06	-	0.1
Joutseno	01.01.94	550,000	3.0	-	1.91	-	0.6
	01.01.96	550,000	2.1	-	1.34	-	-
Imatra	01.01.95	940,000	-	2.9	-	1.08	0.6
Kaskinen	See note 1	420,000	1.0	-	0.8	-	0.4
	01.01.96	420,000	0.5[2]	0.5	N/C[3]	N/C[3]	
Kemijärvi	See note 1	210,000	0.9	-	1.5	-	1.2
Oulu	26.10.93	280,000	1.8	-	2.25	-	0.4
	01.01.97	280,000	-	1.4	-	1.75	-
Sunila		300,000	-	-	-	-	1.2
Varkaus	09.07.92	210,000	0.9	-	1.50	-	0.4
	01.01.97	210,000	-	0.7	-	1.17	-

1. This permit was appealed to the Supreme Water Court.
2. 3-month moving average was in effect until 30 June 1996. Thereafter, the one month average became effective.
3. N/C: not calculable.

Adapted from Simons, 1994

4.2.2 Industrial response

Since the late 1980s, Finnish mills have continued to drive down AOX discharges well below permit limits by implementing both in-plant measures and secondary treatment, in continuation of the strategies that had been developed in the early 1970s. The development also reflects the influence of market demands in driving non-chlorine bleaching technologies and products. The development are provided in figure 7.

In the 1960s, it was already assumed that external treatment measures removed some of the toxicity but not all of it. In the 1970s, the industry made recommendations regarding the quantity and proper use of Cl_2 in bleaching. One problem was that some mills used excessive amount of chlorine chemicals instead of investing in additional capacity to respond to growing market demand (Finnish Forest Industries Federation, 1998). Thus, the rapid reduction of AOX discharges was rendered possible by the gradual replacement of Cl_2 by ClO_2 and oxygen-based processes and chemicals in pulp bleaching. The use of ClO_2 was well known to industry people, being beneficial for pulp yield. ClO_2

had long been used earlier in a Rauma mill as an additive for quality reasons. It was then that industry found out about the advantage of substituting ClO_2 to Cl_2 in reducing the generation and discharge of toxic organochlorines (Finnish Forest Industries Federation, 1998).

Based on information contained in available reports from the Finnish Forest Industries Federation, the introduction of new pulp bleaching technologies, which took place over a period of 10 years, has been largely completed. Over the past 10 years, environmental investments in Finland reached nearly 6.5 billion FIM, with almost three quarters destined to water protection issues. For a long period, environmental investments have represented between 10 and 15% of total investments made by the industry (Finnish Forest Industries Federation, 1998).

Considering that Finland had somewhat lagged behind Sweden in responding to the chlorine issue, the industry showed a lot of determination and ingeniosity in developing meaures to comply with both regulatory requirements and demand trends. For instance, the Hanneskoski mill was put under a lot of pressures from all sectors to implement O_2–based bleaching, but resisted and eventually developed the activated sludge treatment and extended cooking as suitable measures reducing both AOX and BOD loads. The technical ideas that were later used for the TCF mill in Rauma was tested in the Kaskinen mill, where O_2 delignification was first implemented in Finland.

Figure 7 – Developments in AOX kg/tonne of bleached pulp in Finland

Source: Finnish Forest Industries Federation, 1997; 1998.

The Finnish industry capacity to respond to the regulatory and technical challenge was rendered possible by significant in-house expertise, as well as its closed relationship with the machine supplier industry (Finnish Forest Industries Federation, 1998). Likewise Sweden, the forest industries cluster was key in gathering the invesments and human resource needed to keep abreast of policy and market changes.

4.3 SWEDEN

4.3.1 Regulatory approaches and requirements

Swedish authorities used findings and conclusions from Environment/Cellulose I, as well as its own in-house monitoring, to require stringent measures to reduce chlorinated discharges in the primary and final effluent. In 1985, the permit renewal process at the Aspa mill provided a first opportunity to introduce measures on chlorinated discharges. After lengthy discussions, the permit was finally settled in 1988 and included a discharge limit of 3 kg AOX/tonne of pulp. The permit also imposed on the mill to undertake a research programme aiming at further reduction to 0.5 kg AOX/tonne.[28]

SNV's position gained significant support when the Swedish parliament followed with a Bill in June 1988 (*Environmental Policy for the 1990s)*, which included both short term targets and long term objectives with respect to the discharge of stable organic compounds. The decree stated that these releases were to be initially cut by 60-70% and measures initiated at mills to further reduce them to 1.5 kg TOCl before 31st December 1992. On the long term, discharges of chlorinated organics from the pulp and paper industry were to be eliminated. The short term target of 1.5 kg TOCl/tonne of pulp was stringent considering that the outlet of chlorinated substances was estimated at 3.5-4 kg TOCl/tonne in 1988, down from 7-8 kg TOCl/tonne in 1974.[29] SNV justified the need for stringent TOCl discharge limits for chemical bleached pulp mills on environmental quality considerations and technological availability for chlorine-free bleaching technology, in accordance with the guiding principles of environmental legislation.[30] The large scale distribution and irreversible effects associated with some of the chlorinated organic compounds argued for precautionary measures, even in the absence of certainty of harm.[31] Although risk assessment remained tentative, the results of comparative studies by the industry and ongoing monitoring of Swedish mills also suggested that chlorine gas-free schemes were outperforming conventional bleached mills in terms of environmental quality.[32]

---

28 O'Brian, H., "TCF: It all started here at Aspa Bruk", *Pulp & Paper International*, October 1996, pp. 19-22.

29 Fallenius, U. - B., "Environmental Matters Concerning Pulp and Paper Industry in Sweden", *SNV* (Helcom room document), 18 October 1988, p. 8.

30 "While reasonableness of costs is an important principle in decision making on environmental conditions and may sometimes contradicts the BAT concept, departure from the principle is possible and generally left to the professional judgement of the permitting authority. This is the case, for example, in the context of the continued presence of persistent and bio-accumulative toxic compounds, such as dioxins and heavy metals." In Rajotte, A., "Case Study on the Iron and Steel Sector", *OECD*, Paris, 1999b.

31 Södergren, A. et al., 1988. "Summary of results from Swedish project Environment/Cellulose", *Water Science Technology*, No. 20, pp. 49-60.

32 Fallenius, *Op. cit.*

In order to implement Bill 1988, a major action plan, known as the Action Plan against Marine Pollution (1987, amended in 1990), was introduced and included, among others, discharge targets for chlorinated organic substances.[33] These were to be implemented within the framework of a graduated schedule in permits, whereby TOCl discharges were to be reduced to 6,500 tonnes per year by 1992, 2,000 tonnes per year by 2005, and 500 tonnes per year by 2010, down from about 10,000 tonnes per year in 1988. SNV then established national discharge goals for AOX for chemical bleached pulp mills up to the year 2010. These are provided in table 15 as AOX kg/ADt for Kraft mills. SNV targets were introduced in a joint announcement with the Nordic Council of Ministers on the discharge of chlorinated organic compounds from the production of bleached pulp. The content was basically consistent with the recommendations of Helcom and Parcom.

Table 15 - SNV Targets for AOX Discharges from Kraft Mills

Kraft pulp	end-1992		end-1995		end-2000		end-2010
	kg/ADt	t/y	kg/ADt	t/y	kg/ADt	t/y	kg/ADt
Softwood	2	5,500	1	2,700	0.5	1,400	0.1
Hardwood	1	1,400	0.5	700	0.3	400	0.1

Source: SIMONS, 1994

Table 16 lists TOCl and AOX discharge limits for the 15 bleached kraft mills, as well as discharge performance for 1992 and 1993, as compiled by SNV. The table provides an overview of the regulatory approach taken by permitting authorities with respect to AOX discharge limits, as well as its effect on environmental performance at point sources:

- The first TOCl discharge limit was introduced in Södra’s Mönsterås kraft pulp mill’s permit in 1986, prior to the adoption of national targets and policies. From 1988 onward, TOCl limits were progressively incorporated in environmental permits for bleached pulp mills. By 1993, 14 of the 15 bleaching kraft mills had to comply with either TOCl or AOX discharge limits in environmental permits.[34]
- Permitting authorities made an extensive use of target limit values as a step-wise strategy to provide flexibility to the mills in complying with TOCl/AOX limits.
- Since late 1992, AOX rather than TOCl has been used to set discharge limits.
- Most mills are outperforming their permit limits, suggesting the role of market forces in driving chlorine-free technologies and products.

---

33 SNV, 1987. *Action Plan for Marine Pollution*, ISBN 91-620-1037-9.

34 Lagergren, S. and E. Nyström, 1991. “Trends in Pollution Control in the Swedish Pulp and Paper Industry”, *Water Science Technology*, vol. 24, no. 3-4, p. 13.

4.3.2 Industrial response

Regulatory requirements on TOCl discharges were first met with substantial resistance from industry. Lars Landner, a Swedish industry's expert, concluded that the changes were driven by "a series of scientific rebounds, as well as over-interpretation and misinterpretations of scientific material regarding environmental impact" (Tana and Lehtinen, 1996). There were tough debates and fights between the industry and regulators. According to an expert inteviewed, the industry was then sitting on the old paradigm, i.e, 'safe until proved otherwise' and senior staffs from SNV were explicitly targeted by industry. In some cases, one member of Environment/Cellulose was accused of going beyond its duties in challenging the industry in the media (Swedish experts, 1998). Eventually, both parties overcame their disagreements and technological measures started to be implemented at mills to meet the stringent TOCl discharge limits imposed by SNV.

Table 16 – TOCl/AOX limits in Swedish permits for 15 bleached kraft pulp mills

Mill	**Date of compliance or Date of permit d.m.y**	**Permitted TOCl or AOX limit kg/ADt bleached pulp**				**Actual annual average AOX discharge**	
		TOCl		AOX		In 1992[10] kg/ADt	In 1993[11] kg/ADt
		Annual average	Monthly average	Annual average	Monthly average		
Aspa	01.01.92	1.5	-	-	-	0.56	0.66
Gruvön	15.11.93	-	-	0.3	-	0.21	0.20
Husum	30.12.88	< 1.2[1]	-	-	-	0.70	0.49
Iggesund	01.07.93	1.5[2]	-	-	-	0.24	0.20
Karlsborg	01.01.91	1.5[3]	-	-	-	0.14	0.15
Korsnäs	01.01.91	1.5[4]	-	-	-	0.18	0.17
Mönsterås	08.04.86	1.5	-	-	-	0.84	0.54
Mörrum	30.11.92	-	-	1.3	-	1.2	0.97
Norrsundet	01.01.92	1.3[5]	-	-	-	1.2	0.30
Östrand	30.06.96[12]	-	-	0.3	-	0.8	0.66
Skärblacka	01.01.93	0.7[6]	-	-	-	0.34	0.25
Skoghall	28.08.91	See note 7	-	-	-	1.40	0.20
Skutskär	01.01.92	1.5[8]	-	-	-	0.49	0.30
Vallvik	01.11.88	1.5	-	-	-	0.64	0.62
Värö	01.07.92	1.5[9]	-	-	-	0.22	< 0.40

Notes:

1. TOCl annual average limit reduces to 0.5-0.8 when production capacity is increased to 690,000 t/y.
2. From 01.01.92 to 01.07.93 this was a target value; after 01.07.93 it was a limit.
3. Until 31.12.90 annual average target value was 2.0 kg3ADt.
4. Until 31.12.90 monthly average target value was 2.0 kg3ADt.
5. During 1990 and 1991 annual average TOCl limit was 1.44 kg/ADt.
6. During 1990, 1991 and 1992 annual average TOCl limit was 1.0 kg/ADt.
7. Annual average TOCl limit (kg/ADt) are as follows: 1992 – 2.0; 1993 – 1.7; 1994 – 1.5; 1995 – 1.0; 1996 – 0.8.
8. Annual average TOCl limit from 01.01.92 to 31.12.92 was 2.0 kg/ADt.
9. Annual average TOCl limit from 01.01.90 to 30.06.92 was 2.0 kg/ADt.
10. Data compiled by SNV. Discharges are reported as kg/ADt of bleached pulp.
11. Data compiled by SNV. Discharges are reported as kg/ADt of bleached pulp.
12. The compliance date for the Östrand mill is the date the new ozone bleaching system begins operation or June 30, 1996, whichever is sooner.

Source: Simons, 1994

The industry showed remarkable capacity to develop and implement techniques and measures, which eventually outperformed the tightening regulatory requirements. This was rendered possible by prior decades of research and investments in the development and implementation of environmentally-benign techniques and operating practices within the industry and in co-operation with its suppliers.[35] Industry's funding of environmental research and environmental investment's share of total investment over the past three decades are provided in table 17 and figure 8, which emphasise projects aimed specifically at environmentally-related developments in bleaching technology.

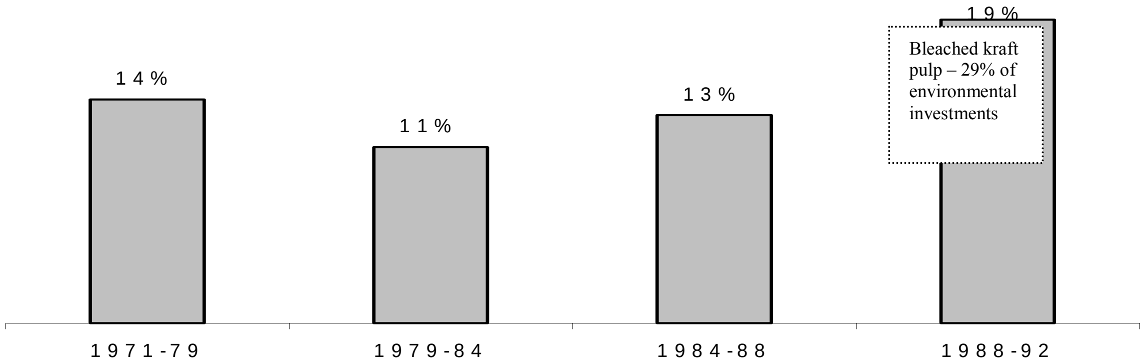
Table 17 - Environmental research projects by the Swedish pulp and paper industry

1970-73	The Environmental Care project	27	
1974-76	Chlorides in recovery system	4	
1975-78	Nordic Environment 80	12	
1977-81	Environmentally harmonised production of bleached	49	**Total**:
1974-75	pulp	14	
1980-85	Other SSVL projects	32	**535**
1986-90	SSVL –85	67	**million**
1989-93	Environment 90	70	**Swedish**
1993-94	Environment 93	4	**kronor**
1995-97	Environment 94	8	
1970-96	Environment 95/96	57	
1970-96	Grants to Swedish Environmental Research Institute, IVL	200	
	Grants to Swedish Pulp and Paper Research Institute, STFI		

35 EKA chemicals was active in increasing knowledge with respect to the use of alternative bleaching agents to Cl_2, such as ClO_2 (around 1983) and hydrogen peroxide (around 1990). When the dioxin issue exploded, it was already known that the problem could be solved if Cl_2 was replaced by ClO_2 (Axegård, 1998).

Figure 8 – Environment's share of total investments by the P&P industry in Sweden

Information for table 17 and figure 8: Swedish Forest Industries Association, 1998



In the course of this work, it was early assumed that the gradual reduction of sub-lethal effects, besides acute toxicity, correlated with the substitution of ClO_2 to Cl_2, as well as increasing delignification and cooking of pulp before bleaching. It was also recognised that external treatment was improving the situation. These views governed the introduction of environmental measures in both sulphite and kraft mills until the mid-1980s (Axegård, 1998). In the early 1970s, the introduction of O_2 delignification cut by nearly half the use of Cl_2 by lowering the lignin content of the pulp prior to the final bleaching stage. By the mid-1980s, O_2 delignification was widely used in Swedish mills, leading to a reduction to about 5 kg AOX/tonne of pulp, down from around 10 kg in the 1970s (Skogsindustrierna, 1995). ClO_2 was gradually substituted to Cl_2 during the 1980s to prevent the formation of highly chlorinated organic compounds. The introduction of reinforced and pressurised alkali stages in which hydrogen peroxide and O_2 can be used further reduced the need for chlorinated agents. Concurrently, the development of the concept of low multiple chlorination lowered the use of Cl_2 relative to the kappa number. These measures proved successful in preventing the formation of dioxins in the bleaching stage.

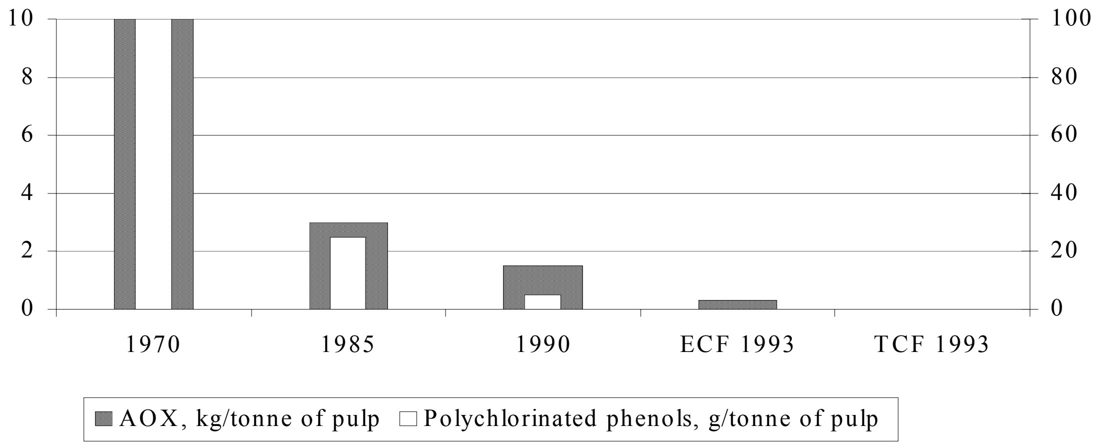
The investments required to develop these measures skyrocketed production costs, whereas "the cost of producing one tonne of pulp cost was 100-150 kronor more than in the main competing countries".[36] The forest cluster was active, with Sunds Defribator, then part of SCA, working on O_2 delignification, and Eka Chemical, developing techniques using hydrogen peroxide. But these projects required significant amount of fund and resources, and took at least 10 years to develop (Swedish Forest Industries Association, 1998).

Not surprisingly, when SNV decided to introduce even tighter TOCl discharge limits in the permit of Södra's Mönsterås mill, the industry had, to say the least, some reservations, as it was not known then if compliance could

36 *Skogsindustrierna*, 1995. "In balance with nature", Annual Publication, p. 14-15.

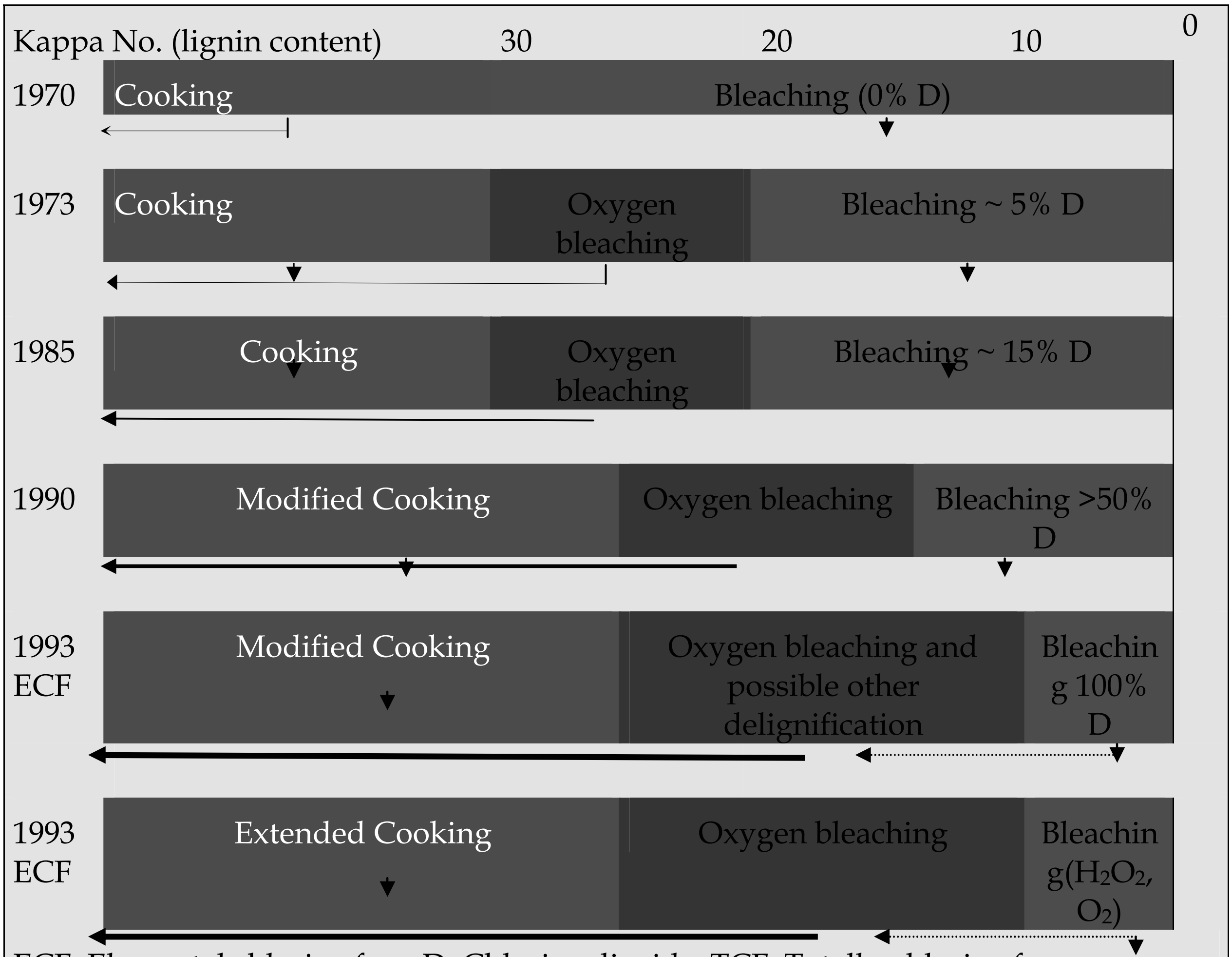
be achieve, even without the use of Cl_2. Moreover, the connection between chlorine bleaching and adverse effects in fishes established by the project Environment/Cellulose was contested by industry in Sweden and abroad. But increasing market demands for chlorine-free products provided significant momentum and economic justification to SNV's requirements. Industry followed suit and increased its effort in further development of bleaching techniques. Between the late 1980s and early 1990s, new processes were introduced which reduced further AOX discharges. The development in modified or extended cooking techniques allowed to cook the pulp to very low lignin content, while retaining strength and pulp yield. Cooking the pulp to lower kappa numbers reduced the amount of bleaching chemicals needed to achieve product requirements, allowed the introduction of less environmentally-harmful bleaching agents, such as ozone and peroxide, and the use of very small amount of ClO_2. Eventually, Cl_2 became needless. Since 1994, ECF and TCF processes have replaced the conventional kraft bleaching technology. Improvements in cooking and delignification techniques and the use of more environmentally-benign bleaching agents have reduced the toxicity and quantity of chlorinated compounds in the final effluent. As a result, discharges of chlorinated organic compounds have decreased by more than 90% since the 1970s (Skogsindustrierna, 1995), from about 10 kg/tonne of pulp in the 1970s to nearly non-detectable levels in the early 1990s. These developments are shown in figure 9. Figure 10 benchmarks technological developments in the bleaching of pulp since the 1970s, which eventually made it possible to abandon the use of chlorine gas and even substitute oxygen-based bleaching chemical to chlorine dioxide. As the figure suggests, industry has concentrated on improving the pre-bleaching stage, i.e. the cooking and delignification of pulp, which later eased the introduction of less-harmful bleaching chemicals.

Figure 9 – Emissions from bleaching of softwood kraft pulp at various techniques



Note: Polychlorinated phenols were undetected in ECF and TCF production in 1993

Figure 10 – Developments in Kraft bleaching technology in Sweden, 1970-1995



ECF: Elemental chlorine free; D: Chlorine dioxide; TCF: Totally-chlorine free

Source for figures 9 and 10: Swedish Forest Industries Association, 1998

Given the significant amount of research and investments that were necessary to comply with TOCl limits, it may be argued that SNV was under pressure, at some points, to push its regulatory strategy internationally so that competing producers abroad would have to comply with the same environmental level playing field than its domestic industry.

4.4 *International conventions*

Although their recommendations are not binding, recommendations and guidelines specified by Helcom and Parcom are normally incorporated by Finland and Sweden (Mickwitz, 1998). Thus, these conventions provided a policy forum in which Sweden could push its strategy at the international level. The adoption of Helcom and Parcom recommendations, with respect to BKMEs, took place respectively at the Helcom meeting of February 15, 1990 and the

Parcom meeting of June 1990.[37] Recommendations for bleach plants are summarised in tables 21 and 22. As mentioned previously, the Environment Ministers of Finland and Sweden had solved their disagreement over the issue and endorsed jointly the proposal made by the Nordic Council of Ministers' working group by the end of June 1989. The recommendations became official guidelines of the Nordic Council of Ministers in 1990. Helcom and Parcom recommendations are provided in tables 18 and 19.

The International Rhine Commission has also issued guidelines to limit discharges from pulp and paper mills in 1991, which covered the main parameters and specified that secondary treatment as a minimum requirement should be included in permits. These are provided in table 20.

Table 18 - AOX limits from HELCOM for new and existing kraft mills

Parameter (annual average)	Effective date	Bleached kraft[3]
AOX, kg/ADt	01.01.95	2/1[1,2]
– Higher number is for softwood; lower for hardwood. – Alternatively, each country may use a total AOX average of 1.4 kg/ADt. – New kraft pulp mills must meet the limits immediately.		

Table 19 - AOX discharge limits from PARCOM for existing and new mills

Parameter	Bleached pulp mill	
	Effective date	Limit
AOX, kg/t[3]		
Existing mills	01.01.96	1[1]
New mills[2]	01.01.93	1
Chlorine multiple		
Existing mills	01.01.96	< 0.15
New mills[2]	01.01.93	< 0.05
1. Except France accepts only 2 kg AOX/ADt and Portugal accepts only 1.5 kg AOX/ADt. 2. Includes modernised mills. 3. Air-dry tonne of pulp or machine-dry tonne paper.		

[37] Helcom recommendation on Restriction of discharges form the kraft and sulphite pulp industry, adopted on 15 February 1990, and Parcom Decision 90/1 on the reduction of discharges of chlorinated organic substances from the production of bleached kraft and sulphite pulp, adopted on 14 June 1990.

Table 20 - Limits for chemical pulp mills from the International Rhine Commission

kg/ADt

	BOD	COD	AOX
Chemical pulp mill	5	70	1

Source for tables 18, 19 and 20: Adapted from Simons, 1994

Conclusion

This report reviews the policy approach of Finland and Sweden in the issuance of environmental requirements controlling BKMEs. It shows that there are similarities in approaches and means taken to define the conditions necessary to meet the goals being sought. In both countries, environmental requirements are defined on a case-by-case basis by permitting authorities which balance technological and environmental considerations when making decisions, although these may vary in accordance with the local context under review. Economics are also taken into account. Both acknowledge the prime influence of the concept of best available technology (BAT) that they consider as a starting point to establish environmental conditions. In both cases, the issuance of environmental permit is under the responsibility of constituted bodies mandated by the government: the National Licensing Board in Sweden and the Regional Water Court in Finland.

But there are also significant differences between them. Sweden has always used an integrated approach balancing air, water and waste considerations in defining the most appropriate conditions for ensuring the maximum level of environmental protection at point sources. Finland has a two-tier approach, whereas water permitting is dealt separately from air and waste considerations. This difference highlights the distinctive context of mill sites, which distinguish both countries. In Finland, most mills are located near water bodies with low water flows, which makes it necessary to focus on water quality considerations. Conversely, in Sweden, most mills are along the Baltic seashore, which benefit from the high dilution capacity of marine environments.

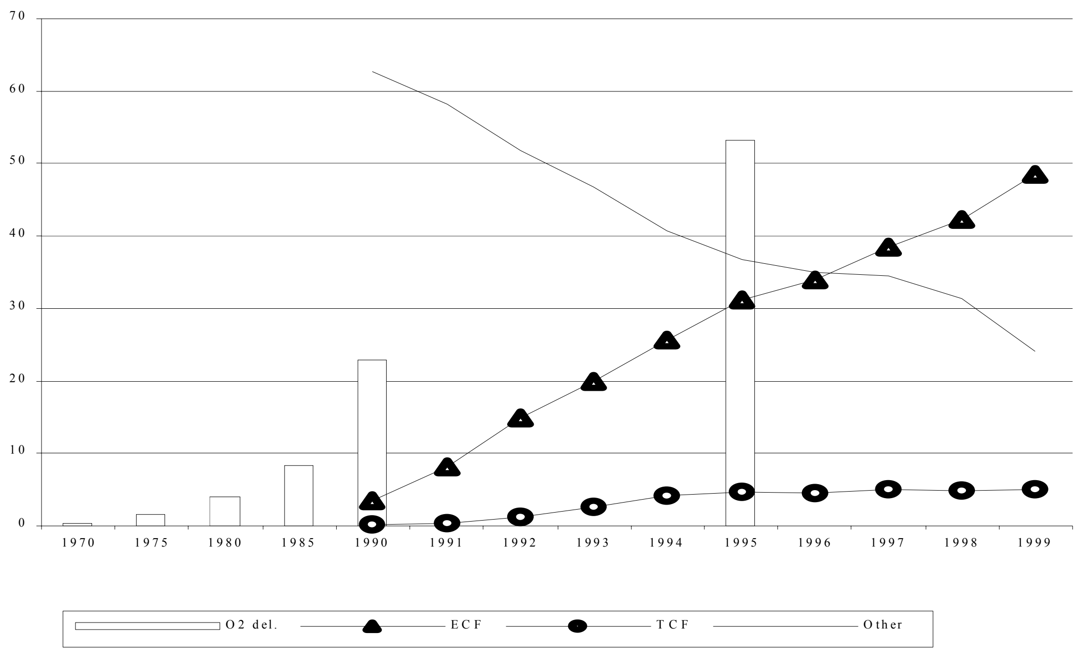
This condition helps explain another significant difference that distinguishes Sweden internationally. The regulatory focus in Sweden is on COD, whereas BOD limits are being progressively phased out as permits are renewed. Consequently, technological diffusion through performance-based standards has led to a differential response in Swedish mills compared to other countries. The selection of either BOD or COD as the lead parameter determines whether internal or external measures will be taken in complying with discharge limits. Secondary biological treatment is almost universal in those countries that have set stringent BOD limits. Thus, the activated sludge treatment technology has become the environmental flagship of the Finnish pulp and paper industry. In Sweden, the COD focus has led to internal measure aimed at the detoxification of wastewater and the progressive closure of effluents through chemical recovery. Thus, the implementation of oxygen-based bleaching in Swedish mills was almost completed five year ahead of other nations.

This *ex ante* difference in regulatory approach has been key when environmental concerns turned internationally to chlorine bleaching. Sweden was in a better position to influence the ensuing policy debate, while its industry could more easily made the necessary investments and marketing move to capture the market demands for chlorine-free paper products. Figure 11 indicates the connection between the implementation of oxygen-based delignification and the adoption of ECF and TCF technologies. Yet, the comparison of limit values and environmental monitoring at mills shows that both countries reached eventually similar performance in terms of BOD, COD and AOX discharges. The convergence is shown in table 7with respect to COD and AOX discharges.

The review of permitting conditions and environmental performance has also shown that many mills have been ahead of regulatory changes. It suggests that other forces were influencing the strategic reasoning of firms. Obviously, public concerns and market forces have been driving forces in the controversy and subsequent policy compromise concerning regulatory control of bleached kraft pulp production. On the one hand, marine conventions, such as Helcom and Parcom, were key in bringing countries, in particular Sweden and Finland, to agree on the appropriate environmental level playing field for the industry. On the other hand, market trends prompted some companies to produce either ECF or TCF pulp with a view to capture the emerging market niches. Thus, except for a short period when Sweden introduced its chlorine-free requirements, the discharge limits adopted by environmental authorities often followed the progressive improvements made by mills rather than challenging them to go further. In that frame of analysis, it is suggested that the perception of environmental risks has been clearly in correlation with that of financial risks.

Figure 11 – World trends in O_2delignification and chlorine-free bleaching capacity

Million tonnes



Source : Alliance for Environmental Technology.[38]

Table 21 - Technical development and environmental results in Kraft bleaching

	Bleaching Sequence	Secondary treatment	AOX kg/t	COD kg/t
1970	CEHDED	no	6-8	80-100
1980	O(C90+D10)EDED	no	3-4	50-60
1990	O(D50+C50)(EO)D(EP)D	yes	1.5-2	25-35
1993	Extended delignification - OD(EO)D(EP)DOQPP - OQZPP	yes	<0.2	20-25
1998	Further system closure	yes	<0.1	10-15

Chlorine(C); Sodium hydroxide (E); Hypochlorite (H); Chlorine dioxide (D); Oxygen (O); Hydrogen peroxide (P); Chelating agents (Q); Ozone (Z).

Source: TANA and LEHTINEN, 1996[39]

---

38 Figure for diffusion of O_2 delignification indicates total capacity, whereas figures for ECF and TCF account for annual production.

39 The data are based on a review of performance in Nordic countries.

BIBLIOGRAPHY

The Alliance for Environment Technology (AET), *ECF : Sending Ripples Around the World*, http://www.aet.org/facts/rippleAd.htm, 1998.

Auer, M., 1997. *Krafting an Agreement: Negotiations to Reduce Pollution from the Nordic Pulp and Paper Industry, 1985-1989*,UMI Dissertation Services.

Axegård,P., 1994. "Pulp bleaching and the environment – the situation in 1993", *Nordic Pulp and Paper Research Journal*, No. 4, pp. 365-378.

Carey, J., Hodson, P., Munkittrich, K. and M. Servos, 1993. "Recent Canadian Studies on the Physiological Effects of Pulp Mill Effluent on Fish", *Environment Canada*.

Colborn, T. 1992. *Chemically induced alterations in sexual and functional development: the wildlife/human connection*, Princeton: Princeton Scientific Publishing.

Fallenius, U. - B., "Environmental Matters Concerning Pulp and Paper Industry in Sweden", *Swedish Delegation* (HELCOM room document), 18 October 1998.

Finnish Environment Institute (FEI), 1997. *The Finnish Background Report for the EC Documentation of Best Available Techniques for Pulp and Paper Industry*, Helsinki, ISBN 952-11-0123-7.

Finnish Forest Industries Federation 1998. Environmental Report – Statistics for 1997, Helsinki.

Finnish Forest Industries Federation, 1997. *Facts and Figures – Statistics 1996*, Helsinki.

Greenpeace Canada, 1990. *Toward a Chlorine-Free P&P Industry*.

Gullichsen, J., 1998. "Bleaching Differences", *Nordicum*. 5, p. 44.

Konttinen, E., 1998. "Environmental Movements in Present-Day Finland", *ISA XIV World Congress of Sociology*, Montreal.

Lagergren, S. and E. Nyström, 1991. "Trends in Pollution Control in the Swedish Pulp and Paper Industry", *Water Science Technology*, vol. 24, no. 3-4.

Management Institute for Environment and Business (MEB), 1993. *Competitive Implications of Environmental Regulation in the Pulp and Paper Industry*, (DRAFT).

McDonough TJ. 1998. Foreword, in *Chlorine and Chlorine Compounds in the Paper Industry*, Turosky V. (ed.), Madison: Ann Arbor Press.

Mickwitz, P., 1998. "Implementation of Key Environmental Principles – Experiences from the Protection of the Baltic Sea", *Nordic Council of Ministers*, Copenhagen, ISBN 92-893-0142-2, 161 pages.

Nlk, 1991. *Impact of Environmental Legislation on the Pulp and Paper Industry in the 1990s*.

Nordic Council of Ministers, 1993. *Study on Nordic Pulp and Paper Industry and the Environment*, ISBN 0906-3668.

Nordicum, 1998. "Special Pulp & Paper Report", Helsinki, May.

O'Brian, H., TCF: "It all started here at Aspa Bruk", *Pulp & Paper International*, October 1996, pp. 19-22.

OECD, 1999a. *Environmental Requirements for Industrial Permitting, Case Study on the Pulp and Paper Sector – Part 1*, Paris, ENV/EPOC/PPC(99)8/FINAL/PART1.

OECD, 1999b. *Environmental Requirements for Industrial Permitting, Case Study on the Iron and Steel Sector*, Paris.

OECD, 1999c. *Environmental Requirements for Industrial Permitting, Volume 2 – OECD Workshop on the Use of Best Available Technologies and Environmental Quality Objectives*, Paris, ISBN 92-64-16193-7.

OECD, 1973. *Pollution by the pulp and paper industry – Present situation and trends*, Paris, ISBN 92-64-11117-4.

Peck, V. and R. Daley, 1994. "Toward a Greener Pulp and Paper Industry", *Environmental Science & Technology*, Vol. 28, No. 12.

Pulp & Paper International (PPI), 1997. *International Fact & Price Book 1997*.

Simons Consulting Group, 1994. "Forestry Sector Benchmarking Initiative - A Case Study in Environmental Regulations", *Canadian Forest Service & Industry Canada*.

Sinclair, W. F., 1990. "Controlling Pollution from Canadian Pulp and Paper Manufacturers: A Federal Perspectives", *Environment Canada.*, ISBN 0-660-13564-7, 360 pages.

Skogsindustrierna, 1997. *The Swedish Forest Industry - Facts and Figures 1997*.

Skogsindustrierna, 1995. *In balance with nature*, Annual Publication.

Södergren A., Bengtsson BE., Jonsson J., Lagergren S., Larsson Å., Olsson M., Renberg L. 1988. Summary of results from Swedish project Environment/Cellulose, *Water Science Technology*, 20(2): 49-60.

Statens Naturvårdsverk (SNV), 1997. *Environmental impact of pulp and paper effluents – a future for future environmental risk assessments*, Report 4785, Stockholm.

SNV, 1987. "Water Pollution Problems of Pulp and Paper Industries in Finland and Sweden", Report of the Special Working Group, Committee for the Gulf of Bothnia, Naturvardverket Rapport 3348, May 1987.

SNV, 1987. *Action Plan for Marine Pollution*, ISBN 91-620-1037-9.

Studies in Technology, Innovation and Economic Policy (STEP Group), 1997. *Innovation Activities in Pulp, Paper and Paper Products in Europe*, Norway.

Swedish Ministry of Environment, 1990. *A Living Environment, Main Proposal*. The Swedish Government Bill 1990/1991:90.

Swedish Ministry of Environment, 1988. *Environmental Policy for the 1990s*, Government Bill 1987/1988:85.

Tana, J. and K.-J. Lehtinen, 1996. "The Aquatic Environmental Impact of Pulping and Bleaching Operations - An Overview", *Finnish Environment Institute*, Helsinki.

Tietenberg, T., 1996. *Environmental and Natural Resource Economics*, Harper Collins College Publishers, Boston.

United States Environment Protection Agency (USEPA), 1990. "National Dioxin Study Released", *Environmental News*, 24 September.

Appendice I – List of interviewees

FINLAND

Ministry of the Environment:

Airi KARVONEN (OECD Delegation)

National Board of Waters and Environment:

Tuula LEPPÄNEN (former permit negotiator, now with Jaakko Pöyry)
Seppo RUONALA (HELCOM delegation)

Finnish Environment Institute:

Elina KARHU
Timo JOUTTIJÄRVI
Kaj FORSIUS

Regional permitting authorities:

Emelie ENCKELL-SARKOLA (Uusima Region and HELCOM delegation)
Liisa MARIA RAUTIO (West Finland Region)
Juhani ITKONEN (Lapland Region)
Antero LUONSI (Pirkanmaa Region)

Consultants and experts:

Karl-Johan LEHTINEN (Environment Research Group)
Johan GULLICHSEN (Helsinki University of Technology)
Jaakko PAASIVIRTA (University of Jyväskylä)
Myreen BERTEL (Jaakko Pöyry Oy)

Finnish Forest Industries Federation and mill representatives:

Pirkko MOLKENTIN-MATILAINEN (Finnish Forest Industries Federation)
Kari EBELING (director of corporate R&D - UPM-Kymmene Group)
Matti SIRO (technical director Pulp Steering - UPM-Kymmene Group)
Ismo REILAMA (director R&D, Metsä-Botnia Ab)
Timo MERIKALLIO (director R&D, Metsä-Rauma Ab)
Jyrki KEHEINEN (Oy Metsä-Serla Ab

SWEDEN

Environmental Protection Board (SNV)

Erik NŸSTROM (HELCOM Delegation, and chairman of PARCOM Point Sources)
Ulla-BRITTA FALLENIUS (HELCOM Delegation)

Licensing Boards

Ove ERIKSSON (Gävle Region)
D. LOVINS (Kälmar Region)

Consultants and experts

Bengt-Erik BENGTSSON (Institute of Applied Environmental Research)
Peter AXEGÅRD (STFI, former expert with Eka Chemical)

Trade Association and mills representatives

Nils JIRVALL (Sweden Forest Industries Association)
Gunnar TARNVIK (Svenska Cellulosa Ab)
Roland LÖVBLAD (Södra Cell Ab)