RISK COMMUNICATION
AND THE MANAGEMENT OF PCB RISK
IN CANADA

by

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RISK COMMUNICATION AND THE MANAGEMENT OF PCB RISK IN CANADA

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ABSTRACT

This study analyses current developments in risk communication research and their contribution to the public management of health and environmental risks. The analysis is supported by a case study which investigates how information concerning the risks of polychlorinated biphenyls (PCBs) has been produced and exchanged. The controversy over PCBs in Canada is a microcosm of the difficulties technical experts, regulators, and the general public typically encounter in communicating about health and environmental risks.

Part I of the thesis explores key concepts operative in risk communication research and articulates risk communication with the fields of risk assessment, risk management, and risk perception. Risk management activities are described as predicated upon two kinds of uncertainties: scientific, and institutional (or social) uncertainties. Several case studies of health and environmental controversies are reviewed and the methodological approach for studying the PCB controversy is outlined. The approach selected contrasts the expert and public views on risk and, in light of the differences observed, searches for ways to improve the effectiveness of present risk management practices.
Part II starts with a qualitative review of PCB scientific risk assessment and elicits the nature of expert knowledge regarding these compounds. An exposition of the regulatory, technical, and political dimensions of the PCB risk management problem follows. The press coverage of PCB-related events is then used to understand and represent the public perception of PCB risks.

The case-study shows that the information bases upon which the experts and the public respectively rely to pass judgment over the nature and extent of PCB risks have little in common. Further, this information leads to very different conclusions as to the environmental and health risks the compounds present and how they are managed. The study concludes that to be successful, future risk management strategies involving PCBs and similar kinds of potentially harmful compounds need to give priority and ongoing consideration to the careful management of risk communication processes.
DEDICATION

To my father Jean, my mother Solange, and my wife Sonya.
I would like to acknowledge the contributions of the scholars who participated in the development and completion of this dissertation.

Foremost I want to express my gratitude to my supervisory committee: William Leiss for introducing me to the stimulating field of risk research and for his expert guidance in the supervision of my doctoral work; Robert Anderson for his support during my studies at the School of Communication; Camille Limoges for his most effective and valued stewardship.

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This foreword presents a brief overview of the themes explored in the thesis, the articulation of the argument, and the main research findings.

Part I of the thesis introduces and discusses theoretical and methodological issues in risk communication and risk management. Part II presents a case-study which analyses how the information about PCB-risk has been produced and exchanged.

The essential claim of this thesis is that the public management of health and environmental risks can be improved by paying greater attention to the ways in which risk related information is communicated. Risk communication, it is argued, can contribute to a better fit between regulatory actions devised for making risk-benefit trade-offs on behalf of a society as a whole and that society's support for risk management actions.

Chapter 1 articulates the field of risk communication with risk assessment, risk management, and risk perception. The discussion treats risk communication as both a practice and a field of research and presents a critic of the psychometric paradigm to risk perception.
The main shortcoming of the psychometric paradigm is that it forces an artificial bracketing of the context in which responses to risk are actually formulated. Cultural approaches to risk selection and perception, on the other hand, focus on the broader societal environment in which a risk problem is constructed. For this reason, cultural approaches are viewed as more helpful to understand what needs to be communicated in the risk communication process.

The chapter concludes that future risk research should seek to draw together a variety of methodologies and disciplinary perspectives. In particular, the potential contribution of context sensitive disciplines (eg, history, comparative policy analysis, and so on) should not be undermined. Indeed, these disciplines often yield useful information which suggests ways in which existing risk communication processes can be modified to make the management of risk controversies more effective.

Chapter 2 contends that risk management activities must address two kinds of uncertainties: scientific uncertainties and institutional (or social) uncertainties.

The first section of the chapter focuses on "scientific uncertainty" and probes the implications attached to various views of the role of uncertainty in risk management science. The basic argument here is that scientific uncertainty is not a residual
category but is in fact a constitutive and inherent component of scientific knowledge. This section also emphasizes that risk management institutions have been too exclusively preoccupied by trying to minimize scientific uncertainties and have not spent enough resources and energies on the question of social uncertainties.

The second section reviews some practical problems involved with the use of various mechanisms used for managing public input and minimizing social uncertainty. An argument is made in favour of one specific mechanism, the multi-attribute utility technique (MAUT). The essential contribution of this technique is to facilitate the construction of an explicit and relatively comprehensive definition of the "risk problem" at stake. The chapter concludes that this type of information base developed and endorsed by both technical experts and stakeholder representatives can provide a sounder basis for the development of effective risk management strategies.

Chapter 3 reviews several recent case studies of health and environmental controversies in terms of their methodological tenets and introduces the PCB-case study. The analysis of the PCB controversy relies primarily on the methodological and conceptual approach developed by William Leiss and Daniel Krewski. Their approach presents an alternative to the traditional structuring of risk management activities in which risk assessment science
provides the main drive for risk management decisions. Instead, Leiss and Krewski frame the risk management problem as resulting from differences between the expert and the public views on risk. Problems in managing risk are seen as originating from inadequate communications between the domains of technical and perceived risk.

The PCB case-study thus, sequentially presents the expert and the public accounts of PCB risk. The development of the PCB controversy and subsequent difficulties in managing the PCB waste inventory are explained by the absence of adequate and sustained communication between these two constituencies.

There were several reasons for selecting the PCB controversy as the case-study of choice for a thesis on risk communication and risk management. First, since the controversy is well documented, there was sufficient empirical evidence available to present a relatively comprehensive account of the case. Second, despite the wealth of expert studies and press coverage on PCBs, the drawing together of the expert and public views on this issue had not yet been carried out.

Finally, the PCB controversy still constitutes a relatively problematic and troubled area of Canadian public policy. This is thus an area where research can produce practical and hopefully useful recommendations.
PART II describes and analyses the scientific assessment, regulatory management, and public perceptions of PCB risk.

PCBs are synthetic chemicals which were first manufactured in the 1930s and which for 40 years were widely used in consumer and industrial products. Their main use was as insulating and cooling fluids in electrical equipment.

PCBs' ubiquitous presence in the environment was first discovered in the late 1960s. It was subsequently established that they are very stable environmental contaminants with a tendency to bioaccumulate. Most people living in industrial nations have been found to have measurable concentrations of these chemicals in their body. PCB production stopped in the early 1970s and, starting in 1977, Canada subjected the chemical to a series of stringent requirements for handling and disposal.

Chapter 4 presents the scientific knowledge base on PCBs along with the data gaps and methodological problems present in PCB risk assessment. Exposure and toxicity data are examined sequentially and at two points in time: in the early 1970s, and in the late 1980s.

The main source of uncertainties in PCB risk assessment originates from the fact that "poly-chlorinated biphenyls" are not a single chemical but instead a family of 209 closely related but different
chemicals. In addition, the PCB fluids used in the electrical industry are generally mixtures containing 50-70 individual PCBs plus some organic solvents that further influence the chemical properties of the mixtures.

Although the environmental persistence and relative toxicity of PCBs varies depending on the precise chemical composition of the mixtures, much of the world data has been reported as "total PCBs" without taking into account this chemical complexity. For instance, the 1968 poisoning of 1200 Japanese people who had eaten PCB-contaminated cooking oil (the Yusho incident) was an important event in focusing scientific and public attention on these compounds. Yet it was later established that these people had been made sick not by PCBs but by other contaminants present in the mixture.

Other important sources of uncertainty in PCB risk assessment have to do with the wide range of sensitivity various animal species display when exposed to these chemicals. Another set of difficulties relates to the fact that laboratory studies are conducted with commercial PCBs which are different from the biologically altered PCBs to which humans and animals are exposed.

Overall, the risk assessment literature on PCBs indicates that these compounds have a depressive effects on the reproductive capacity of animals. It is important to keep in mind, however,
that most laboratory studies have focused upon the most toxic PCBs using the most sensitive animal species and have tended to emphasize the most sensitive responses in reporting results. There is little evidence that PCBs are carcinogenic in animals species.

With respect to human health effects, these chemicals have been observed to have two distinct actions on the body: a skin effect (chloracne) and a liver effect. Here again some caution applies. The range of effects observed in any given study is quite limited and not consistent across studies. In particular, there is an absence of a clear and consistent correlation between PCB human body burden and the health effects reported. No conclusive, direct relationship between cancer and human exposure has ever been established.

Scientists, in general, agree that there are few risks of developing acute illness from casual contact with PCBs -- except in the case of uncontrolled fire since the burning of PCBs can result in the production of dioxins and furans. The research continues and it remains contradictory in some areas and contentious in others especially in regard to the effects of long-term exposure to low concentrations.

There is, nevertheless, an apparent consensus on the relative health risk of PCBs: In comparison to other toxic substances, PCBs are not considered by scientists to be very toxic.
Three observations are inferred from the information presented in this chapter. Firstly, the numerical precision with which risk assessment data is expressed contrasts vividly with the broad assumptions and extensive extrapolations required to make such estimates possible in the first place. Secondly, progress in the scientific risk assessment knowledge between the early 1970s and the late 1980s do not seem to have resulted from new scientific findings per se but rather from the ongoing exchange of scientific information within the risk assessment community which led to a better qualitative appreciation of the data and accompanying uncertainties making up PCB risk assessment. Thirdly, this risk assessment is made of a series of interpretations and as such it is perhaps best described as an effort at synthesizing incomplete and sometimes contradictory evidence. In other words, the risk assessment of PCBs, far from speaking for itself, amounts to a cascade of expert judgments.

Chapter 5 focuses on the regulatory, technical and political dimensions of the PCB risk management problem. The most striking characteristic of the PCB regulatory framework is the great number and complexity of regulations and protective measures which govern the various aspects of PCB waste management at both the federal and provincial level. At the federal level only, over ten individual pieces of legislation specifically concern the use, handling, and disposal of PCBs.
The federal government response to the PCB waste problem has been formalized through its "PCB Destruction Program". This program is predicated upon an open endorsement of incineration as a technically and socially acceptable option for PCB destruction. The responsibility to authorize and implement PCB treatment and disposal facilities, however, has been left to the provinces.

Overall the Canadian regulatory framework appears to have been generally successful in preventing the ongoing release of PCBs into the environment and at controlling and limiting public exposure to these compounds. On the other hand, this complex patchwork of laws, regulations, and guidelines involving numerous levels of responsibility provides little incentives for seeking permanent disposal to the thousands of tonnes of PCB wastes stored across the country. This complex regulatory net also makes it difficult to convince the public that such highly regulated group of chemicals is not very hazardous. So far public opposition has largely prevented the siting of incinerators which, the government believes, could effectively and safely destroy PCBs.

The public perception of PCBs discussed in chapter 6 has been inferred from the press coverage on this issue. This is in keeping with recent findings which indicate that the mass media is the principal source of risk information for the general public.
In Canada, three events received extensive media coverage and became important "hooks" for the public discussion of PCBs: The 1985 Kenora spill, the 1988 St-Basile-le Grand fire in Quebec, and the 1989 sending of PCB wastes to Wales. Between 1977 and 1994, many other mini-controversies involving PCBs also took place throughout the country involving about every segment and organized group in Canadian society.

Two conclusions stand out in this chapter. First, the media's attempt to give a balanced treatment of PCB risks and to place these risks in perspective have been few. For instance, despite the absence of any definite proof that they may cause cancer in humans, the link of PCBs to cancer is a persistent and suggestive feature of PCB media coverage. The link to cancer, the association of PCBs with birth defects, or the label "highly-toxic" was observed in an overwhelming majority of the 1400 or so press articles reviewed.

The second conclusion is that the media's original tendency to dramatise the health risks of PCBs has progressively diminished over the years. The emphasis of media coverage has shifted to focus increasingly on the government's unsuccessful attempts at managing the PCB waste problem.
Chapter 7 concludes that it is the media rather than government agencies that have acted as the main channel for informing the public about PCBs. It is also the media which have provided the platform where PCB issues have been publicly discussed. Canadian risk management institutions gave very little consideration to the communication and exchange of PCB-related information with the public. Not surprisingly, the media filled that void.

The case study shows how the government’s reluctance to create circumstances for meaningful communication about PCBs seriously compromised the credibility of both its risk assessment and risk management activities. As of today, few PCB wastes have been destroyed and the "PCB Destruction Program" has been abundantly criticized for being motivated by criteria having to do more with political expediency and convenience than with the minimization of environmental and health impacts. The government disregard for public perceptions and its inability to address the concerns of the Canadian public in its risk management strategy are described as a determinant factor in the unfolding and persistence of the PCB controversy.

The government is now revising its siting strategy and is considering the offering of incentives for stimulating community acceptance of incinerators. The thesis concludes that any risk management strategy, whether predicated upon incineration or
incentives, is unlikely to succeed in the absence of adequate communication between the interested parties. Further, the main responsibility for creating the conditions under which such communication can be fostered lies with public authorities, not the media.

Finally, the management of risk communication processes is said to be critical to any risk management activity. For this reason risk communication should constitute a key element of any risk management strategy which expects to be successful in the long-run.
PART ONE: RISK COMMUNICATION AND RISK MANAGEMENT

THEORETICAL AND METHODOLOGICAL ISSUES
Chapter 1: RISK COMMUNICATION RESEARCH AND PRACTICE: PROGRESS, PROBLEMS, AND PROSPECTS

1. Introduction

The study of risk has grown out of the practical needs of modern societies to manage the effects of industrialized development and to protect their citizenry from hazards stemming from natural and technological causes. Over the last fifty years, the growth and professionalization of risk research produced ever greater levels of sophistication in ways of assessing and managing risks. More recently, rising public concern about environmental and health hazards have brought these activities to the foreground and stimulated interest from both the public and private sectors in risk perception and risk communication research. Today, the study of risk includes contributions from numerous disciplines in the natural and the social sciences and ranges from modelling the effects of chemical carcinogens to explaining social responses to health and environmental hazards. Positioned at the intersection of governmental, industrial, public, and academic interests, the field of risk studies has become increasingly interdisciplinary.
1.1 The Concept of Risk

The coming together of academic, regulatory, private and public energies on the question of "risk" would likely not have occurred had risk not been such a dynamic and powerful concept. The concept of risk is dynamic because, it draws its meaning by relation to its opposites "safety" and "benefit" and thus can hardly be invoked without reference to this tension. Risk is also a powerful concept because while it finds many applications in societal planning and public policy it is intuitively meaningful to the individual. Indeed, the question of 'how safe is safe enough?' is answered continually in private decisions and every-day behaviours. These two dimensions -- the risk-benefit dynamics and the macro-micro perspectives on risk -- are worth articulating, at least in a basic fashion.

Although we sometimes wish we could do without them, risks are involved in all human activities. Of course, it is possible to minimize some of the risks we face but avoiding all of them is simply impossible. In fact, most of the decisions we make involve trade-offs between different risks. Even doing nothing, in order to play it safe, means foregoing possible opportunities, and in that sense, at least, involves a degree of riskiness. In other words, to be alive is to be at risk.
Fortunately, while it is the negative connotation of the concept which stands out at first, there is also a brighter side to it since making choices, choosing between different options, taking certain risks as opposed to others is really what life is about. Viewed in this light, risks and benefits are inseparable and risks appear as acceptable stimuli rather than unacceptable threats. In short, individual risk taking is the essence of human striving.

In this more positive acceptation inherited from nineteenth century liberalism, risk invokes ideas of personal choice, free will, responsibility, and freedom. Elements of this perspective can readily be incorporated in the design of public health risk communication programs since, in modern societies, a great number of risks to human health can be mitigated by personal decisions about lifestyle choices. These include decisions not to smoke, to control one’s diet and exercise regimen, to wear seat-belts and avoid alcohol while driving, and so on.

The inescapable character of risks and the necessity to make trade-offs among them observed at the individual level are also encountered when risks are considered from a societal perspective. Much can be done at this level also, if not to avoid entirely, at least to minimize, citizens’ exposure to risks. For instance, governments and firms can reduce human health risks by implementing pollution controls, by requiring improved safety measures in industrial processes and consumer products, and by providing better
medicines. Of course, decisions regarding which risks to take and which risks to avoid are much more complex at this level -- especially in a pluralistic society. Nevertheless, there are some important similarities between the macro and micro perspectives on risk. First, the idea of zero-risk applies neither to the individual nor to society. And second, at both levels, trade-offs between risks and benefits as well as between different risks are unavoidable.

There are also important differences between the macro and micro perspectives on risk, essentially because, within any given society, risks are not evenly distributed. While most activities generate both risks and benefits it is often the case that some groups bear a disproportionate amount of the risks while others reap most of the benefits. Thus, at the societal level, the question of acceptable or tolerable risk often revolves not so much about the risks themselves but around distributional issues, that is around questions such as: Who or which group will be made better-off as a result of a particular decision on risk? At this level, conflicts will also arise from the different values and goals held by various participants to the risk debate.

1.2 Assessing and Managing Risk

Risk assessment, risk management, risk perception, and risk communication constitute the main headings that are used to
disentangle the mix of considerations at play with regard to health and environmental risks. In regulatory settings, responses to risks have been organized along the risk assessment-management axis.

The risk assessment and risk management processes correspond to a formally organized set of practices developed by regulatory agencies to manage, on an ongoing basis and in orderly ways, a bewildering array of responsibilities pertaining to the safety of modern industrial processes and products. Several models have been developed by national and international organizations to account for the risk assessment and management activities. Despite some conceptual differences and some overlaps in terminology, these models exhibit several basic similarities. In particular, they all essentially agree on the division of the scientific and societal aspects of the risk assessment and risk management process.¹

According to William Ruckelshaus, former administrator of the United States Environmental Protection Agency (USEPA):

"Risk assessment is the use of a base of scientific research to define the probability of some harm coming to an individual or a population as a result of exposure to a substance or a situation. Risk management, in contrast, is the public process of deciding what to do where risk has been determined to exist." (Rückelhaus, 1984: 160)
More specifically, the risk assessment process can be broken down in two distinct sets of activities: risk analysis and option evaluation. The aim of risk analysis -- itself the combination of a two steps process, hazard identification and risk estimation -- is to arrive at a numerical estimate of the risk. At this stage, disciplines in the natural sciences provide the primary source of information. Toxicologists, for instance, experimentally test a suspected substance on animals and extrapolate from the results obtained in an animal population its possible effects on humans. Epidemiologists complement these data by retrospectively seeking inferences about illnesses in the human population exposed to the same substance.

The final product of risk analysis is a number which reflects both the magnitude of the hazard (e.g., the potency of the toxic effects of the substance under investigation) and the magnitude of exposure to this hazard (the extent to which ecosystems, animals and humans may be exposed to it). In risk analysis then, risk is defined as a function of hazard and exposure.

The option evaluation stage which follows risk analysis and completes the risk assessment process involves developing and evaluating possible risk management strategies to respond to the risk identified at the preceding stage. Risk management options may include direct regulation, economic incentives or disincentives to reduce environmental pollution, the development and
implementation of technological system for pollution abatement or advisory recommendations to promote risk avoidance. The effectiveness of each strategy is susceptible to a host of factors including the degree and type of uncertainties involved in risk analysis, the technical feasibility of each strategy considered, the acceptability and public perception of the risks, and risk-benefit trade-offs. Several quantitative analytical decision-aiding approaches (e.g., cost-effectiveness, risk-benefit analysis) are available to assist agencies in the evaluation of the various options available to them.²

Finally, at the risk management stage, the results of risk assessment are integrated in a decision about environmental and health protection taken in light of more immediate social and political considerations. Thus, whereas risk analysis is clearly within the realm of science, option evaluation and risk management fall within the domain of public decision making.

In Canada,

"[t]wo main presuppositions govern this process: first, that risk is acceptable only in the light of demonstrable benefit; and second, that there ought to be a continuous striving to reduce the level of risk associated with hazardous materials or practices to a point that is 'as low as reasonably achievable'." (Leiss and Chociolko, 1994: 39)
2. Perceiving Risk

In the last fifteen years, the institutionally established activities of risk assessment and risk management have been complemented but also challenged by a series of findings produced in the areas of risk perception and risk communication. Developments in these relatively recent fields of inquiry have made substantial contributions to the understanding of risk and have become increasingly influential in decision making. The study of risk perception being the driving force behind the burgeoning research area of risk communication, this perspective is presented first. Initially, the systematic investigation of the qualitative characteristics of the perception of hazards was seen as a question for the psychologist. In particular, the psychological studies of risk perception were most actively pursued by researchers within the so-called 'psychometric' tradition.

2.1 The Psychological Paradigm: Psychometric Research and Cognitive Heuristics

The label psychometric derives from a method employed to study individual risk perceptions in which respondents are required to evaluate sets of pre-selected hazards according to a rating-scale or metrics. Analysts look for response patterns and relations
between hazards items, respondents' characteristics and rating scales using exploratory multivariate statistical techniques. This now well-established research tradition was initially pioneered by the Decision Research group in Oregon (Fischhoff et al. 1978). Many subsequent studies followed directly from their work.

The psychometric research on risk perception sketches a general framework in which the risk valuations resulting from individual perceptions are somewhat removed from the objective characterization of risk produced by risk analysis as estimated fatalities in some unit of time. Discrepancies between lay and expert's estimates are explained in terms of a set of qualitative attributes attached to risk events which are shown to influence the public's perceptions of risk (see for instance Table 1 in appendix A).

"Research has suggested that the primary correlates of public concern are not mortality or morbidity rates, but characteristics such as potentially catastrophic effects, lack of familiarity and understanding, involuntariness, scientific uncertainty, lack of personal control by the individual exposed, risks to future generations, unclear benefits and potentially irreversible effects. (....) Many of the most salient contemporary risks - nuclear power plant accidents, nuclear waste, airplane crashes, exposure to toxic chemicals, ozone depletion, exposure to
Thus, one of the most important findings to merge from the psychometric paradigm is that people take into consideration a large number of factors in evaluating the seriousness of a risk and that these factors are not readily captured by the quantitative and probabilistic models traditionally used in risk analysis (Slovic et al. 1980; Slovic, 1987; Covello, 1983, 1984).

In addition to these findings, another set of studies found that people tend to rely on intuitive reasoning in order to grapple with the complex probabilistic language in which the results of risk analysis are cast. These studies showed that while such short-cut judgment strategies called 'cognitive heuristics' help understand complex information, they also lead to predictable errors in assessing probabilities (Tversky et al., 1974; Kahneman et al., 1982).

For instance, people have been observed to estimate the probabilities of events by the ease with which instances of occurrences can be brought in mind. Recall depends on a number of factors including the personal salience of events which tend to systematically bias the estimates of relative probabilities. One study, for example, found that knowing someone who suffered flood
or earthquake loss was the single most important factor for distinguishing between purchasers and non purchasers of related insurance coverage (Kunreuter et al., 1978: 145-53).

Another interesting conclusion that has emerged from this line of research is that technically trained people themselves rely on similar intuitive judgments when they experience difficulties interpreting probabilistic information. One important correlate of heuristic research is that the way in which risk information is presented exerts a powerful influence on risk perception and selection.

2.2 Critique of the Psychological Research on Risk Perception

In several important ways, the psychological research paradigm has made a major contribution in enriching the risk problematic and many insights from this research tradition have been subsequently incorporated in risk communication research and practice. For one thing, this research has led to important questions regarding the paradoxical attempt of quantitative risk analysis to discard intuitive judgments while many daily individual decisions are made on precisely this basis. Yet, this approach displays some serious shortcomings. In particular, the segregation of psychological variables from broader social and cultural factors is probably the most vulnerable tenets of this research tradition.
Critics of the psychological research paradigm contend that people rarely perceive risk in isolation and that individual perceptions of risk depend in fact largely upon social and cultural variables. These include the institutional context of perception, organizational affiliations, community dynamics, media coverage, and social interactions with family, friends, co-workers and neighbours (Johnson et al., 1987). For instance, in a study of Perceptions of occupational risks, Michael Brown (1987) found that psychological factors cannot adequately explain why only some risks, and not others, are selected for attention by workers and managers. The author concluded that risk selection and perception in organizations appear to be rooted in social relationships and in the range of choices that workers perceive to be available to them within the specific organization and the wider society.

Other researchers have presented detailed empirical evidence showing that factors such as political ideology and world views can exacerbate or mute concerns about particular risks. Wildavsky and Dake (1990), in particular, have claimed that it is these factors (and not the qualitative aspects of technology or risk) which best account for patterns of risk perception. Still others have shown that experts are themselves culture bound and that organizational factors, for instance, can exert a strong influence on the judgments of risk experts. Lynn (1987), for example, points out that scientists working in different organizational settings diverge substantially in their beliefs about fundamental issues in

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risk assessment like the relevance of animal data for the identification and estimation of human risk and the existence of thresholds for human exposures to carcinogenic substances. Jasanoff (1987c), examining differences between the United States and Great Britain in how experts assess the risks of several toxic substances observes that, contrary to the British, American scientists assume, that i) a false positive is preferable to a false negative (i.e., it is preferable to err on the side of safety); and that ii) the existence of a significant health risk can be established by risk assessment procedures and does not need to be based on proof of actual harm (e.g., actual injuries or deaths).

In short, these critics all reinforce the claim that not all of the "cognitive biases" are cross-contextually valid nor universally distributed and that different institutional arrangements will shape their selection. The point is well taken by Harry Otway:

"In theory, there cannot even be a complete list of the salient attributes that underlie perceptions of technologies because people characterize a technology by whatever they have 'learned' to associate with it. (…) The factors that underlie perceptions, as well as their relative importance, depend on the characteristics of the technology, its history, whom you ask, the particular moment in time when you ask them, what psychometric
method you used, who designed the instrument, how the interviewing was done, how the data were analyzed and interpreted, and so on. The debates about cognitive dimensions have been useful in illustrating that risk perception is a complex, multidimensional concept, but one without fixed and universal dimensions."

(Otway, 1992: 224)

Another line of criticism has been directed to the fact that the psychological research on risk perception has often yield ambiguous evidence and incommensurable research findings.

For instance, in one of the largest survey reports coming from the United States (n = 1021), Gardner and Gould (1989) concluded that socio-demographic variables including political affiliation have only weak effects on risk perception as compared to the qualitative aspects of the technologies. However, in the wake of another large study (n = 1000) carried out in France, Bastide et al. (1989) reported that the different risk evaluations they observed did not just vary with the types of technologies surveyed but were also markedly affected by situational factors such as the social position and general feeling of security of the respondents. Elucidating whether these diverging conclusions stem from cultural differences in the two societies or from differences in methodological instrumentation does not seem to be possible (Pidgeon et al., 1992: 108, 110).
The important lesson to be drawn from all this is again put forward by Otway:

"The approaches used by different researchers, when viewed from a certain emotional and temporal distance, are more similar than dissimilar and have provided general insights that are largely consistent. In fact, the general findings, such as the multi-dimensionality of risk perception, are the important thing and, in principle, it would not even have been necessary to do empirical studies to get them - they could have been deduced anyway from long-established theoretical considerations. This makes arguments about the methods used to arrive at them seem a bit superfluous."

(Otway, 1992: 218)

Otway’s comment is most interesting since the major critique concerning the cultural approach to risk perception has hinged on precisely this argument, i.e., that cultural theory lacks the sound empirical basis and scientific armamentarium of psychological research to validate its theoretical propositions (Pidgeon et al., 1992: 124).
2.3 The Cultural Paradigm and the Grid-group Approach to Risk Selection and Perception

In contrast to the views held by risk analysts and psychologists, cultural theorists emphasize that risk is not an objective reality and that risk perception is first and foremost a social process. Cultural theorists underline that it would be impossible to attend to all the health and environmental risks that abound in the world and that, consequently, risk selection is necessary. Building on earlier anthropological work on beliefs about impurity, danger, pollution, and taboos, British social anthropologist Mary Douglas and American political scientist Aaron Wildavsky have claimed that the distinctive portfolio of risks each society believes to be worthy of attention can often be more accurately seen as ways of maintaining social solidarity than as reflecting health or environmental concerns (Douglas and Wildavsky, 1982).

The functional view of risk perception that cultural analysis supports, suggests that risk selection is used to defend preferred lifestyles and as a forensic resource to place blame on other groups.

"Cultural theory starts by assuming that a culture is a system of persons holding one another mutually accountable." (Douglas, 1990: 10)
Cultural theory analysis emphasizes how culture works as a means of accounting for actions, that is as a social control mechanism through which people convince and coerce each other to behave in certain ways, according to what is deemed possible, acceptable, natural or holy within a given society. In this view, the cultural coding of responsibility parallels the coding for perceiving risks. Whatever objective dangers may exist in the world, risks are minimised or exaggerated according to the social, cultural, and moral acceptability of the underlying activities.

Thus, cultural theories of risk see "risk" as a systemic phenomenon and our attitudes towards it as bound up in a broader system of beliefs and values. Risk perception and selection are inscribed in a stream of relationships and experiences and can only make sense against this larger socio-cultural background. Social interactions are responsible for our perceptual coding of risk and for the events and decisions we relate to risk issues. In short, what a given society labels risky is determined by cultural factors rather than by nature. Although anxiety and fear about risk are very real to those affected, "risk" conceived of in isolation does not really exist at all.

"According to cultural theory, institutional structure is the ultimate cause of risk perception; risk management is the proximate stimulus rather than its outcome."

(Rayner, 1992: 86)
To substantiate the claim that concerns about industrial risks cannot be understood by reference to scientific evidence nor by the culturally innocent perspective of individual psychology, some cultural analysts have attempted to link differences in risk perception to differences among institutionally embedded cultures. To this end, they have used a "grid-group approach" to cultural theory which accounts for cultural variations in terms of four cultural prototypes. The approach uses a two-by-two matrix of positions depending on how each institution draws its group boundary and how it regulates itself internally (Rayner, 1987, 1992). 6

The four major cultural categories (or cosmologies) identified consist of the following groupings: i) the entrepreneurs or individualists (for whom risk and opportunity go hand in hand); ii) the egalitarians (who accentuate the risks of technological development and economic growth so as to defend alternative lifestyles and attribute blame to those who hold different cosmologies); iii) the hierarchists (prepared to accept high risks so long as risk-decisions are made by experts or in other socially approved ways); and iv) the fatalists (who willy-nilly accept what is in store for them).

In some variants a fifth category, the hermits (a group made of autonomous individuals building multiple alliances) is added (Thompson, 1989b). In others, categories are regrouped so that the
main cleavage in attitudes towards societal risk-taking lies between the anti-risk stance of egalitarians (sometimes labelled sectarians or catastrophists) and the pro-risk stance shared by hierarchists and individualists (the cornucopians) (Douglas and Wildavsky, 1982; Wildavsky, 1989; Wildavsky and Drake, 1990).

The grid-group approach is not a psychological classification of personality types. Rather, "it is a social theory that sees institutions and social organizations as presenting patterns of opportunities and constraints for what can be said in a given social context" (Rayner, 1992: 107). Indeed, the main contribution of the grid-group approach has been to show how things are said differently in each cosmology, i.e., how each cultural regime validates different types of arguments about risk. Thus, Rayner notes, for instance, that appeals to authority have little effectiveness among egalitarians. Conversely, arguments about the common good are unlikely to carry much weight in the competitive world of the individualist; however, arguments about opportunities for individual advancement might do well with this group (idem).

Grid-group analysis has been criticized on several other grounds, the most serious of which being simply that partitioning culture in a four or five-fold typology oversimplifies complex shades of social differences. Whereas grid-group analysis argues that individuals think exclusively in terms constrained by one of the four or five possible cultural types, people in real life often
hold values that transcend cultural categories. For example, the value of equality is espoused by both individualists and egalitarians - although one group emphasizes equality of opportunity whereas the other insists upon equality of condition (Rayner, 1992: 114). It has also been argued that different kinds of environmentalism can arise from each of the four or five cosmologies of cultural theory (Johnson, 1987: 160).

Finally, critics arguing for a pluralism of cultural perspectives have underlined that, taken in isolation, each of the identified cultural bias is inherently limited and that a full-fledged account of our current social order can only be obtained from their combination.

"Individualists, for instance, need the hierarchists to enforce the law of contract, the hierarchists need the fatalists to sit on top of, the egalitarian excesses of the individualists and the hierarchists to criticize, and so on." (Schwarz and Thompson, 1990: 142)

In sum, if individuals can have affinities with several groups and if groups are mixtures of prototypes, the grid-group approach loses much of its explanatory power.

Notwithstanding the limits of this particular strand of cultural analysis, cultural approaches to risk have enriched the risk
Problematic by demystifying the assumption of the psychological approach that cultural bias is irrelevant for us at home, "that culture is something that starts with the Wogs, abroad" (Douglas, 1990: 10).

Overall, risk perception studies (cognitively and culturally based) can be credited for pointing to various factors shaping the perception of risk and for articulating how perspectives antithetical to the findings of risk assessment can emerge and endure. By suggesting a series of possible rationales for public reactions, risk perception research has provided substance and legitimacy to the public's views on risk. In turn, the acknowledgement of the perceptual dimension of the risk problem has had implications for risk management by suggesting ways to address the question of risk from a broader perspective.

3. Progress, Problems, and Prospects in Risk Communication

The question of how the main insights of risk perception research might be best incorporated in risk management practice is closely linked to recent work in risk communication.

"The study of risk communication relates theory and findings from basic risk perception studies to the
formulation of policy (for example for risk managers and regulators), to the currently evolving legislative frameworks for dealing with hazards, and to the key question of public involvement in decision making about hazards." (Pidgeon et al., 1992: 90)

On the one hand, government and private industry are under increasing legal and moral requirements to inform populations about the environmental, technological and health hazards to which they might be exposed (Otway and Wynne, 1989: 141; Pidgeon et al. 1992: 118-9). On the other hand, budgetary considerations, problems related to program implementation, and strongly held values regarding the rights of individuals and the limits of government have all converged to promote the use of information as preferred regulatory instrument. In this context, risk communication with its potential to contribute to the quality and effectiveness of public information processes, has become a central feature of risk management practices.

3.1 Risk Communication: The First Generation

Risk communication is generally preoccupied by building bridges between different views of risk. Discrepancies between the findings of risk analysis and risk saliency in the public mind provided the initial momentum for risk communication research. For instance risk managers and regulators became concerned that
while the dominant risks to health arise from cardiovascular disease, lung cancer, and automobile accidents, much public attention remained stubbornly focused on industrial chemicals and radiation. Initial discussions of risk communication assumed that improving risk information delivery would result in public acceptance for policies grounded in risk assessment methodologies.

Conceived according to a one-way transmission of risk messages from an expert constituency to a lay audience, the first generation of risk communication was designed along the line of the 'message transmission model' used in engineering communications. By drawing together the results of psychometric works and state of the art techniques of public communication, this approach was successful in summarizing the characteristics of the source, channel, message, and receiver that contribute to hinder the communication of risk information.

The identification of these problems provided the basis for a series of tactical frameworks for guiding the practice of risk communication. Vincent Covello, for example, compiled the following risk communication guidelines: i) accept and involve the public as a legitimate partner; ii) plan carefully and evaluate your efforts; iii) listen to your audience; iv) be honest, frank and open; v) coordinate and collaborate with other credible sources; vi) meet the needs of the media; vii) speak clearly and with compassion (1989: 13-16).
The problem with these kind of risk approaches to communicating risk lies not so much in what they says than in what they leave unsaid. For example, there are instances where confidentiality might be preferable to openness (e.g., in the case of medical information or when legal proceedings are underway) and others when disclosure should take priority over claims of privacy, but the guidelines make no provision to distinguish among them. Demands for public involvement may also vary from one situation to another. Furthermore, these guidelines do not seem to acknowledge that public demands for risk information may not really be about information per se or that risk messages are rarely unambiguous.

In sum, despite their common sensical and intuitive appeal, these types of communication recipes have been beset by problems of consistency which have compromised their effectiveness. While the general and universal character of these guidelines implies that risk communication is premised upon the context-free universalism of the natural sciences, experience in communicating risk information has clearly indicated that the relative success or failure of this activity is largely premised upon the abilities of risk communicators to understand and take into account the specificities of the societal context in which they intervene (Needleman, 1987; Krimsky and Plough, 1988, Wynne, 1987, 1989a, 1991).
Other problems associated with the earliest set of risk communication activities stemmed essentially from their narrow conceptualization of the nature of the "risk problem" in contemporary society and from their emphasis on a one-way, top-down approach to the communication of risk information. Some of the deficiencies inherent to this approach can be illustrated by its use of risk comparisons.

Because they speak a language that is intuitively meaningful, risk comparisons have been hailed as an effective means of expressing the low-probability numbers of macro risk assessments in terms that are familiar to most people. By comparing two risks (or more), or by ranking them on a scale, the relative magnitude of different risks can be placed in perspective and, in theory, help people make more informed judgment as to what should be done about these risks (Wilson and Crouch, 1987; Roth, 1990). However, since a given comparison, can only take into account a limited amount of the many dimensions of a risk, there is a danger that the risk comparison selected will promote a skewed representation of that risk.

For instance, the number summarizing the fatality risks associated with different modes of transportation (e.g., automobile, train or airplane travel) will vary depending on whether the calculation is based on fatalities per trip, per passenger miles, or per length of exposure. In addition, each estimate can vary depending on whether or not, factors such as the age, weight, and alcohol consumption of
the travellers, as well as the car sizes, roadway types, times of travel, and so on are taken into consideration (Evans et al., 1990). The point here is that illuminating some aspects of a risk necessarily obscures others, and that different measurements will support different conclusions regarding the riskiness of a particular activity or technology.

While in principle, an infinite amount of risk comparisons can be conducted, critics have observed that risk communicators have used risk comparisons to present the risks of modern life in a light that systematically minimizes the risks of unfamiliar and controversial technologies by comparing those risks to the generally accepted and familiar risks of every-day-life. For instance, Covello (1989: 25-49) displays a series of mortality tables used for risk communication purposes in which the risks associated with automobile accidents, cigarette smoking and firearms rank much higher in terms of lives lost than the risks related to nuclear power technology, radioactive waste disposals or toxic gases. The logical conclusion to be drawn from these tables is that public anxiety is misplaced and that there should be greater acceptance of the risks which, in statistical terms, are much smaller.

Yet, because they typically blend voluntary and involuntary risks and compare statistical averages when public concern is focused on the catastrophic potential of technology, these comparisons have
failed to express risk in a manner that reflects the qualitative criteria of risk that matter most to the public. Consequently, this approach to communicating risk information has rarely contributed to the public's endorsement of the experts' views on risk. Quite the contrary, the use of risk comparisons is now associated with attempts to mislead and manipulate the public for their use has triggered public reactions that often have been quite at odds with the goal they were originally set to achieve (Slovic et al., 1990).

In some ways, the shortcomings of risk communication guidelines and of risk comparisons are symptomatic of a critical tension within the discipline of risk communication which originates in it being both a practice and a field of study.

Since the stakes involved in societal decisions about risks are high, the communication of related risk information usually occurs within a conflictual environment. In this context, some have hoped that risk communication research would yield a set of readily applicable problem-solving techniques that would provide risk managers with the means to successfully steer protracted risk controversies towards closure. The use of risk comparisons described above is in keeping with this perspective.

Other risk researchers, less immediately embroiled in risk controversies, have looked at these conflicts not so much as
problems to be solved but rather as research questions requiring
dialogue and negotiation. In this view, risk communication is less
an applied science than a configuration of 'reflective theories' -
that is, theories by which a system becomes understandable for
those within it, as well as for others (Otway & Wynne, 1989: 144).

Viewed this way, risk comparisons may be used as a research tool
rather than as an instrument of persuasion. For instance, using
different parameters for measurements can help illustrate the
multifaceted character of risk. Encouraging various constituencies
to design their own comparisons can promote recognition of the many
possible perspectives which bear on risk valuation. Comparing the
risk reduction options preferred by different groups of experts and
non-experts, or the degree of uncertainty involved in arriving at
various risk estimates, can also help identify and clarify
diverging perceptions.

Conceived as heuristic tools, risk comparisons can serve to express
and communicate various views on risk and help broaden and enrich
the definition of the "risk problem" through an understanding of
the relative riskiness of various activities which prevails among
different member groups of society.

In this sense, risk comparisons can provide a valuable research
tool to gain insights as to what concerns the public most about
particular risks and help decision-makers develop options that are
more attune with the public will. At the same time, this approach could help the public develop a better appreciation of the difficulties involved in establishing tolerable standards of risk for public health and environmental protection.

In any case, risk comparisons do not offer a simple solution to the problem of incorporating different valuations of risk in the risk management process. Yet, when constructed in a way that incorporates various perspectives in their initial design, and when used to inform rather than to discredit or shift public opinion, risk comparisons can play a constructive role in improving communication about risks. But to be effective, risk comparisons themselves need to be placed in perspective. In other words, the assumptions, intents and limits of this instrument need to be exposed and the broader risk communication strategy of which it is a part clarified.

3.2 Risk Communication: The Second Generation

Risk communication activities of the first generation have been criticized mostly for relying too exclusively on the definitions of risk promoted by risk analysis and for their lack of attention to the societal context in which the communication of risk information does take place. The first generation of risk studies has been shown to devalue the perspectives and knowledge of the risk bearers (Brown P., 1987; Rappaport, 1988; De Marchi, 1991; Fisher, 1991;
Wynne, 1991) and to gloss over the political aspects of many of the risk conflicts in society (Krohn and Weingart, 1987; Otway, 1987; Fiorino, 1989; Nelkin, 1989). The overall critique is aptly summarized by Otway and Wynne.

"The risk communication paradigm rests on unexamined and unarticulated assumptions about who is communicating what, to whom, and in what context"
(Otway et al., 1989: 141)

In response to these critiques, the second generation of risk communication is moving away from the traditional views of risk promoted by the natural and cognitive sciences and towards new problem definitions that emphasize the cultural and socio-political aspects involved in the process of communicating risk information. The discipline is enlarging its focus of inquiry from a mere preoccupation with the formulation and delivery of effective risk messages to a broader concern with risk communication processes. In particular, the attention directed to the communication of risk information as an occasion for exercising political power, has resulted in a reformulation of the "expert-public" relationship over risk along lines that are in tune with the Jeffersonian ideal of democracy.
"I know of no safe depository of the ultimate powers of society but the people themselves; and if we think them not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it away from them, but to inform their discretion." (Thomas Jefferson, letter to William Charles Jarvis, September 28, 1820, quoted in National Research Council, 1989: 14)

More specifically, the second wave of risk communication studies tends to frame the risk communication problem in the following terms:

First, risk communication is now premised on a belief in the legitimacy of differing views on risk (loosely called "perceptions") each of which can be seen as logical and rational when considered in its own context of use (Krimsky and Plough, 1988; Leiss, 1989; Renn, 1992b). As a result, the communication of risk information is now conceived as a process of information exchange back and forth between interested parties.

"Risk communication is an interactive process of exchange of information and opinion among individuals, groups, and institutions." (NRC, 1989: 21)
Rather than conceiving successful risk communication in relation to the goals or purposes of the sender of the message (as in the engineering perspective) the new criteria for success lie with the recipients' evaluation of the risk communication efforts.

"Risk communication is successful only to the extent that it raises the level of understanding of relevant issues or actions and satisfies those involved that they are adequately informed within the limits of available knowledge." (NRC, 1989: 2, 21, 74)

Thus the crux of the new perspective lies in the belief that an adequately informed debate can assist citizens in making appropriate decisions (e.g., whether to protest, ignore, negotiate, or take protective action) regarding health and environmental risks. Rather than the provision of substantive guidelines for one-way messages, it is the establishment of a process of dialogue and criticism which is viewed as the best means to ensure that affected parties are provided with the decision-making ability needed to achieve an adequate level of concern over risks. Pragmatically, this new approach recognizes that gaps between different perceptions will not be narrowed by forcing change on the part of one constituency alone. Instead, the need to accommodate differing perceptions and values is acknowledged as the most effective pass towards balanced and robust public risk policy decisions.
Secondly, in addition to giving, as a matter of principle, equal legitimacy to expert and public views on risk, the new approach has sought to provide an account of these views by looking at the different interests, strategies, resources and cultural factors which contribute to their formation. Research carried out within the cultural theory and sociology of science traditions in particular, have sought to critically examine the genesis of diverging perspectives on risk in a spirit somewhat detached from a concern with the immediate impact their conclusions may have on the risk management process. The instrumental approach to risk communication straddled across the expert-public divide has been complemented by exploratory and explanatory endeavors that have attempted to account for the ways in which risk information is generated and communicated within each constituency (Brickmann et al., 1985; Cambrosio, 1991; Graham et al., 1988; Jasanoff, 1985, 1987a, 1987b, 1989a, 1990; Johnson et al., 1987; Latour, 1986; Limoges, 1992, 1993, Limoges et al. 1993; Salter 1988; Sprent, 1988; Wynne, 1987, 1989b). These in-depth analyses of the dynamics and institutional processes sustaining scientific and popular views on risk have thus complexified the risk problematic by extending the boundaries of the risk problem inward.

Finally, and perhaps most importantly, research carried within the second generation of risk studies aims at developing ways to establish long-term viable relationships between interested parties rather than at finding one-shot, short-term solutions to risk
controversies. In this perspective, risk problems are viewed as a series of interlocking political decisions instead of discrete, unrelated events. Risk management, rather than a mere succession of optimized decisions, is viewed as a dialectic endeavour involving ongoing relationships and a more open-ended concern for socially feasible and robust decisions. Pragmatically, this has translated in a search for institutional mechanisms capable of fostering this type of relationship (Allen, 1987; Edwards, 1987; Fiorino, 1990; Graham et al., 1988; Jasanoff, 1986; Kaspersion, 1986; Leiss, 1989, 1994; Limoges et al., 1993).

The need to develop and sustain more viable relationships between risk managers and the general public has been prompted by changing relations between the government and the governed, and a decline of faith and confidence in major institutions. The erosion of the social contract through which citizens consent to be governed over questions of risk, in particular, has generated much uncertainty and raised questions with respect to the purpose and effectiveness of risk communication activities (Laird, 1989; Slovic, 1991, 1992; Wynne, 1987). Indeed, the need to re-establish "trust" between risk-managing institutions and the public has been the main driving force behind the second generation of risk communication and is reflected, for instance, in the explicit consideration now given to the ethical dimensions of the endeavour and to the fine lines which separate attempts to inform, educate or persuade (De Marchi, 1991; NRC, 1989; Gregory, 1989; Morgan and Lave, 1990; Zimmerman, 1987).
Recently, the importance of the question of public trust in risk management processes has been reasserted and held as a major future research agenda for social science research into risk (Pidgeon et al., 1992: 122-124).

Obviously, the question of trust and credibility is a complex issue dependent on many variables. The establishment of a relationship of trust is dependent on personal experiences as well as specific to the social system involved. Being highly subjective and contextualized, the degree of trust in risk managing institutions is difficult to assess empirically. One might thus seriously wonder whether the issue of trust really is "a natural candidate for the psychometric paradigm" (Slovic, 1992: 152) and whether it can be adequately formulated and addressed using batteries of tests and questionnaires. In fact, as with risk perceptions, there is some basic and crucial ambivalence underlying the notion of trust that cannot be dealt with using the psychometric paradigm. Brian Wynne: "People may have to act as if they trust a social actor - a person, organization, or institutional complex - because they are, or see themselves to be, socially dependent on that actor (...) Thus alternative attitudes and beliefs may be held by the same person, as functions of alternative social identities reflecting a complex existence within different social networks."

(Wynne, 1992: 296)
The psychometric tradition has encouraged an artificially objective and decontextualized notion of risk perceptions and has been instrumental in promoting analyses of risk debates that are oblivious of the social, political and cultural context in which such debates occur. A key challenge to future risk research will be to engage seriously with the more complex perspectives associated with questions of trust and credibility. This will be difficult to achieve, however, without an analytical framework that tries to encompass the many variables that are influential in framing the social experience of risk.

3.3 Future Research

The first generation of risk communication research defines the risk communication problem as arising from a misfit between risk events and risk perceptions. This view of risk posits the existence of independent risk signals altered by psychological and social processes and is perhaps best illustrated by the metaphor of amplification (Kasperson, 1988). In this scheme, personal experiences, social group behaviour and institutional structures combine in an information system which, like a stereo receiver, amplifies or distorts risk signals coming from the objective world.

In keeping with this reified understanding of risk, a great deal of risk communication work has been inspired by technical scientists and behavioural analysts. Technical analysts, on the one hand,
seek to eliminate the noise (the psycho-sociological factors shaping public perceptions) and try to persuade everyone to understand probabilities and to choose between them rationally (e.g., Mayo, 1985). Behavioral scientists, on the other hand, urge risk managers to carefully listen to the noise, yet trivialize cultural factors by treating them as another variable in an experimentally derived technical framework. By reducing the complexity of cultural factors to a sum of distorted individual cognitions, these traditional approaches usually end up with the formulation of a series of templates which serve to promote truncated risk communication theories.

By contrast, the second generation of risk communication has proved more sensitive to the insights of cultural theory. Instead of focusing on risk events and risk signals emanating in a cultural vacuum the cultural analysis tradition considers the ways in which different societal arrangements direct attention towards different risks.

"The wrong way to think of the social factors that influence risk perception is to treat them as smudges which blur a telescope lens and distort the true image. (...) A better kind of analysis might treat such transformations of the image not as distortions but as improvements: the result of a sharper focus that assesses the society along with its assessments of risks."

(Douglas, 1985: 18)
Using risk as a lens for sharpening the focus on social arrangements reveals that so-called technical arguments about risks are often as moral as they are scientific and more often than not reflect arguments about how society should be organized. Research carried within the second generation tradition of risk communication has shown that the process by which risk is assessed and perceived reflects deep social, cultural, and political values.

Contrary to technical rationality which believes that risk can be studied independently of context, cultural approaches have emphasized that the choice of procedures and institutions used for dealing with risks are rooted in cultural and socio-political arrangements. It is those arrangements which need to be given priority in the analysis of the risk problem. The technical interpretations which ensue are those which support the given social organization. Yet, reification of risk is evident in the continued attempts to make sharp distinctions between risks and risk perceptions, facts and values, risk assessment and risk management.

For instance, national comparative analyses of risk regulation have highlighted how different countries which otherwise share a rational approach to policy formulation can differ in their preferred strategies for dealing with technological risk. Comparisons of regulations pertaining to pesticides, occupational hazards and food additives between the United States and European
countries (England, France and Germany) have revealed strikingly different strategies for dealing with toxic chemicals (Brickman et al., 1985). Differences in regulatory approach have been traced to specific political, legal and scientific traditions of decision-making which affect the configuration of power between government institutions and private parties. These traditions also shape the respective contributions that lawmakers, administrators, scientists, interest groups and the courts can make to the definitions of acceptable risk.

The examination of institutional arrangements that different nations or cultures privilege for dealing with risk can serve to highlight different approaches and expectations towards public authority. They can also provide important information for communicating risk effectively. Such analyses can, for instance, help decide the extent to which risk communication programs might profitably focus on the underlying causes of "risk perceptions" - such as the degrees and forms of confidence in risk management institutions - rather than on the facts regarding possible harms and the scientificity of hazard information.

In sum, political science, comparative cultural theories and other context sensitive disciplines need to be enlisted more systematically in risk research. Not only do these disciplines generate useful information regarding the propensities of various societies to acknowledge or discard specific kinds of risks, they
can also tell us about the type of strategies these societies privilege for dealing with the risks considered to be of importance. Yet in spite of its potential relevance, research on the culturally and institutionally defined frameworks within which risk perceptions are constituted is too often unavailable, unsystematic, or scattered around the risk literature. As a result, culturally-sensitive risk research is seldom used explicitly in decision making in comparison to the research produced in the risk analysis and behavioural science traditions.

Several examples can be used to buttress this point. There is, for instance, a wealth of information regarding the biomedical effects of tobacco and its burden on individual health and societies health care resources. Yet, the exclusive focus on risk (tobacco’s health effects) instead of people (smokers, snuffers and chewers) as the starting point of analysis has resulted in a paucity of data regarding the culture-dependent values which influence tobacco use (Edwards and MacMillan, 1990).

Sufficient evidence exists to indicate that the use of tobacco varies between different ethnic groups. Comparative data between France and Québec, for example, have shown that smoking rates appear to be roughly equivalent while a comparison of smoking rates between Quebec and the rest of Canada shows a significant difference. Despite evidence that lifestyle modification and tobacco cessation programs need to be culturally relevant to ensure
Successful outcomes (Flay, 1985), data on the relationship between cultural differences and tobacco use barely exist.12

Another example attesting to the scarcity of culturally relevant data in risk studies concerns the lack of research exploring the link between religious background and attitudes toward risk. As our use of medication illustrates, this might be an important oversight, even in the context of our modern and supposedly secular societies.

Recent analyses indicate a clear correlation between the percentage of Catholics in a country and that country’s number of medicines prescribed per capita annually. Protestant countries, by contrast, have been observed to consume less prescription drugs and to rely to a greater degree on the use of heterodox medicines (homeopathy, herbalism, naturopathy, etc.) and on self-medication (Griffin, 1989: 240-242).13 Several Canadian studies have confirmed these findings by showing, for instance, that people in Quebec, with a largely Catholic population, use fewer over the counter products overall and use them less frequently than people in other largely Protestant provinces. There is also evidence that region and primary language affect medication use (Science Council of Canada, 1990: 9).

These two examples simply underline further the role of cultural variables in moulding the perception, selection and construction of
risk. Yet, in both cases, a comprehensive review of the analyses undertaken to address the risk problem would show that the bulk of the analytical energy has been applied to the wrong units. On the one hand, technical analyses of the bio-chemical and psychological effects of tobacco and medication usage have resulted in a decontextualized, universal and reified understanding of the related "health" risks associated with these substances.

On the other hand, socio-psychological investigations of substance addiction or physicians prescribing habits have been essentially limited to the individual smoker, patient, or drug-prescriber's reactions to risk. By showing that, far from being solely dictated by medical considerations, medication taking and prescribing are affected by larger social and cultural processes, the latter example also points to the importance of cultural factors in influencing professional expertise.

3.4 The Cultural Approach Revisited

As mentioned in conclusion of section 2.2, the cultural approach to risk perception has been criticized for not producing empirically testable data. Another line of criticism has revolved around the self-serving use of "culture" of this approach. The critique is well formulated by anthropologist and Himalayan mountain climber Michael Thompson:
"Probably the greatest achievement of anthropology has been to shatter the convenient assumption that, in the same sort of situation people will tend to do the same sort of thing, and no sooner does an economist, a psychologist, a sociologist or a political scientist produce an elegant universal model of some aspect of human behaviour that an anthropologist will jump up to spoil his fun by adding the carping codicil: ‘in our culture’." (Thompson, 1980a: 280)

Thompson continues:

"Anthropologist have become so carried away by their spoilsport success that they have almost completely lost sight of the really interesting, and difficult question which is: ‘Granted that different people in the same sort of situation may do different things, why do they do the different things that they do?’ This is the question that a general theory of risk will have to answer." (idem)

Thompson’s first point - that the type of analysis that satisfies itself merely by pointing out the different ways in which people view and do things leaves half the job undone - is well taken. However, it can easily been shown that the research findings of the cultural traditions like those presented above can make a positive
and critical contribution when designing risk communication strategies.

Clearly we need to know more about the social groups we are addressing if we are to plan culturally relevant health promotion programs designed for the prevention and cessation of tobacco use. Similarly, it may be very wrong to accept medical data as absolutes. A sharper awareness of the influence played by cultural factors in the assessment of the relative risks and benefits of prescription drugs can help health practitioners and patients alike make more effective use of medications. The same holds true for the selection of medical technologies in the large.

In another context altogether, Rayner suggested that when dealing with the siting of noxious facilities, different social groups will require different incentive packages to accept a hazardous waste facility. Such incentives can include short-term cash rewards, land-value guarantees, investments in public works and/or community-controlled monitoring programs. Rayner showed how the social construction of risk perspective can help identify the components of such a package that are considered valuable by various groups (1987: 17-21). In short, many research findings from the cultural traditions amount to more than a series of quaint commentaries on our social arrangements observation. They have the potential to be of great practical utility in risk communication and risk management.
As for Thompson's second proposition - that a general theory of risk should elucidate why people act towards risk the way they do - it is perhaps a too tall order altogether, and it's immediate relevance perhaps not that crucial. What is really more pressing it seems, would be for general theories of risk to help design practical answers to the question of how, given people's proclivities to see the world differently, can their differences be accommodated in specific situations. At the minimum, this could lead to a better conceptualization of 'feasibility' in risk management by insuring that significant elements of the social, political, and cultural system in which communication takes place are not overlooked.

For instance, when the USEPA prepared its first risk communication program on radon, it relied on traditional methods, first asking experts what they thought people should be told and then packaging the scientists' suggestions in an attractive form. The end-product, EPA's brochure "Citizen's Guide to Radon", failed to take into account the fact that a sizable portion of the public assumed that radon contamination, like radiation contamination, is permanent and does not go away. This misconception, which had the potential to critically affect the EPA's strategy, was discovered only several years later after open-ended interviews were conducted with potentially affected home owners. As a consequence the EPA's strategy was revised so as to specifically address this misconception (Morgan, 1993: 40).
The premise of the cultural approach to risk is that risk communication cannot be understood in isolation. Rather, it is one component of complex social processes and this fuller context needs to be appraised before risk information can be effectively transmitted or received. As this last example illustrates, the provision of risk information needs to be preceded by an investigation of how people perceive the risk, that is by an examination of the beliefs and values they hold, the choices they face and of the risk-related information already in circulation (Morgan, 1992).

Pragmatically, cultural theory has shown that the minimal research commitment facing risk communicators is to empirically determine how much the parties involved know about a topic to begin with. In its most developed form, however, cultural theory could help recast cultural bias in risk perception as particular forms of expertise that together and in competition may contribute to resilient solutions to risk management problems.

So far, the cultural approach to risk studies has shifted analytical attention away from risk assessment as the exclusive true source of information about risk. This change in perspective has been supported by studies carried out in the sociology of science tradition that have examined regulatory science and its treatment of scientific uncertainty. These studies have unearthed the large number of intervening variables in risk analysis which
confound notions of specific causality and prevent a single authoritative reading of the evidence of the case. Although the risk number is still perceived, for a number of reasons discussed in the next chapter, as the main contribution of risk analysis, many risk researchers and practitioners now challenge the privileging of any particular referential discourse like science to uncover the underlying reality about risk. Far from being antiscientific, many culturally inspired treatments of risk do in fact acknowledge the positive role risk analysis can play in risk controversies and insist that there can be no substitute for that science (Jasanoff, 1987b, 1989; Graham et al., 1988; Krimsky, 1988; Leiss, 1994; Salter, 1988). However, the contribution that risk analysis can make in understanding and addressing the risk problem tends to be viewed in a different light. As Harry Otway suggests:

"The most valuable product of risk analysis is not the risk estimates generated, but what is learned about the system from the analytic process." (Otway, 1992: 222)

Thus, the second generation of risk studies participates in the search for a reformulation of the relationship between science and risk management, risk assessment and the formulation of risk policies. This new relationship which involves the inclusion of greater public input in risk management decisions is the subject of the next chapter.
This discussion starts by emphasizing that the practice of risk communication is about the provision of information aimed at enhancing both personal and societal decisions about risk. Sections 2 and 3 have introduced some of the major ways in which risk communication research supports this endeavour by advancing various understandings and formulations of the "risk problem". This section ends by pointing out that the practice of risk communication leads to questions concerning the appropriate role of science in risk management. In this sense, the discipline of risk communication also bears some responsibility for promoting an improved understanding of the respective contributions the technical and social sciences can make to the risk assessment and risk management processes.

4. Conclusion

In conclusion, it appears that the problem with the risk tradition is not so much that it provides potentially incompatible theoretical definitions of the risk problem nor that we are faced with competitive theoretical paradigms within and between the various disciplines that contribute to risk communication research. Quite the contrary, this diversity is inevitable and desirable given the potentially endless ramifications of the problems that are tackled and the possible repercussions that acting on health and environmental risk may have on other components of society.
What is problematic though, is that so far, the insights of context sensitive disciplines such as anthropology, comparative policy analysis, history and so on, have remained marginalized in decision-making as compared to the technical and psychological approaches of risk analysis and risk perception. What seems to be missing from the current body of research on risk is a more comprehensive and persuasive account of how perceptions and judgments arise from a host of complex factors at specific points in time and in specific places. For instance, propositions about the importance of factors such as the degree of public trust towards regulatory institutions need to be tested by researchers from a variety of disciplines including anthropology, economics, history, law, policy analysis, religious studies, and others.

Thus, in order to benefit risk communication most, future research would probably need to promote theoretical diversity yet, at the same time, force attention on the contributions particular research-findings may make to the management of risk controversies. In practice, this could mean seeking ways to counterbalance the disproportionate influence of cultural analysis at the rhetorical level relative to the extent of its empirical practice in risk management and public policy (Rayner, 1992: 113).

Several attempts have been made to organize in an integrative framework the different perspectives contributing to the analysis of risk experience and the prescription of risk policies (Renn,
1992a; 1992b; Kasperson, 1992; Hood et al., 1992). I would argue, however, that no grand synthesis for integrating those approaches is needed before the benefits of their respective contributions can become integrated in risk communication research and practice. On the contrary, diversity of perspectives and methods provides a freedom and a flexibility which, at this point, are much needed to address the multifaceted aspects of societal risk.

The presumption that, to be useful, each disciplinary contribution needs to fit neatly within the well-ordered categories and patterning of a given research program assumes that the nature of various disciplinary imports can be fully explicited before hand. Like the psychometricians' understanding of risk perception is limited by the type of relationships their statistical models allow them to investigate, such a programmatic approach may unduly restrict future potential contributions to the study of risk and further promote an already partial understanding of the risk problem. This would be ill-founded given the relative underdeveloped state of our present knowledge concerning the relationship between risk and society and the fact that much of the useful knowledge that has been gained so far has been obtained somewhat serendipitously and in the context of practice. What is needed, by contrast, is far more resolute efforts to integrate new disciplines within the mainstream of risk communication research. In turn, these perspectives can expect to become richer as a result of their preoccupation with risk.
Introduction

Over the last twenty years, the decline of public confidence and trust in government and industry has been recognized as a serious regulatory problem by many (Lowrance 1976; Averch, 1985; Leiss, 1994). During the same period, health and environmental protection from technologically incurred hazards has become a specific mandate for a growing number of regulatory bodies (Somers, 1990). In the process, the management of health and environmental risk has emerged as a substantial variable in the making of sound public policy. Once a well-circumscribed and exclusive domain of expertise, the management of health and environmental risk is now a highly visible and public activity which reflects a government’s overall ability to effectively perform its regulatory roles.
For citizens, risk management activities provide a testing ground for judging how responsive or cavalier governments are towards them. For social activists, the management (and mismanagement) of public risks provides opportunities for gaining political clout. For scientists in government, industry or academe, risk management endeavours constitute a source of research monies and of possible opportunities for professional and public recognition. For the administrators and those in public office, the risk management of health and environmental risks is a high stake, highly sensitive endeavour through which other battles may be won or lost. For social analysts, finally, regulatory risk management activities create a kind of microcosm through which the relationship between the governed and the governed can be scrutinized and general observations about the society at large inferred.

Although regulatory risk management may mean different things to different people, the importance the public now attaches to this activity is evidenced by the abundant and often colourful coverage it receives in the media. Concurrently, a large portion of the risk literature has attributed the current difficulties encountered by regulators in making risk decisions acceptable and implementable to risk management unwarranted and excessive reliance on scientific risk analysis and to its corresponding neglect of competing outlooks on the risk problem.

The development of the modern scientific world view has been
accompanied by an increased involvement of scientific knowledge in public decision making institutions. Since the end of World War II, science has been systematically enlisted as a regulatory ally. But the transition from modes of governance based on intuition, common sense and experience to decision-making processes informed by scientific information has not always been a smooth one. Governmental attempts to regulate technological and environmental health risks, in particular, are increasingly beset by controversies regarding the interpretation of scientific data.

"Yet the vision of science as a source of policy guidance retains extraordinary appeal, and science continues to play a central role in the public justification of risk management decisions. Indeed, a large part of the official effort to resolve risk controversies is directed toward the design of institutions and procedures that improve the scientific basis for regulatory actions."

(Jasanoff, 1986: 69)

With science establishing itself as the key source of justification for public decisions over risk, the adequacy of scientific knowledge has come to be viewed under a new and more intense light. Unresolved political conflicts over the content of scientific claims have encouraged critical scrutiny of the internal rules and practices by which that content is generated. In turn, the significance of scientific uncertainty has received increasing
attention for it mirrors, in the negative, the scope and strength of scientific knowledge used to legitimize regulatory decisions.

This chapter discusses the role of science in public decision making. The first section examines the ways in which uncertainty is part and parcel of scientific knowledge before turning to the risk management problem defined as a product of both scientific and social uncertainty. Uncertainty has always been a factor in public affairs but in our present regulatory context, it is increasingly science which mediates and is made responsible for managing uncertainty. The second section suggests that the most appropriate way for governments to manage the public’s volatile attitudes towards regulatory initiatives involves the incorporation of non-scientific framings of the risk problem into the process of regulatory risk management.

2. The Value of Scientific Uncertainty

2.1 The Conventional Character of Scientific Practice

The influential Mertonian and Popperian traditions in the sociology and philosophy of science contend that science’s essential modus operandi is to be uncertainty-seeking and that scientific knowledge is cumulative and convergent over time. In this ideal perspective,
Scientific progress is seen as taking place through the continuous testing and critical revision of science's own basic frameworks and premises. Contrary to this orderly image of consensual development, Kuhn (1962) has argued that science progresses through a series of crises. Furthermore, Kuhn emphasized that in practice, far from promoting total and ongoing scepticism, science's informal social processes limit the possibilities to critically examine and deconstruct the many components constitutive of a coherent scientific body of knowledge.

Recent studies in the sociology of science have outlined how, many issues which are normally thought of as technical matters within science, are in large part conventional and amenable to sociological analysis (Collins, 1981; Latour, 1979, 1987). Jasanoff (1989), for example, outlined that there is nothing inherently true or false about a scientific concept such as statistical significance. It is simply a convention adopted by scientists to distinguish between events they will treat as chance co-occurrences and those they will consider to be causally related. Comparative studies of toxic chemical regulations in Europe, Canada, and the U.S. have shown that not only technical regulations but basic normative definitions of what constitute science or scientific method can vary across national cultures and reflect different implicit models of what science is and where its boundaries with value questions lie (Brickmann et al., 1985; Ilgen, 1985; Jasanoff, 1989, 1990).
Scientific knowledge, in this view, appears as the outcome of a series of situated, context-bound decisions resulting from a process of negotiation among scientists. In turn, such understanding of scientific development suggests that the degree of certainty and reliability that can be attributed to a given scientific proposition may be, in itself, submitted to different perceptions, interpretations and presentations.

This insight from the sociology of scientific knowledge is important here for it explains how notions of "scientific proof" or of "adequate scientific evidence" can become fundamentally problematic in a context of unremitting scepticism. When science, as risk analysis, enters the public domain as justification for risk management activities the scientific debate over particular scientific conclusions is reopened. When applied scepticism is most systematic and severe - as in legal or quasi-legal settings, the criteria and models of proper and adequate science are subsumed to a continuous deconstruction / reconstruction process and the conventional character of scientific knowledge forced in the open.

"As a result, every new regulatory proceeding threatens to expose the absence of consensus within science and to underscore the subjective and socially constructed character of knowledge claims on which regulators finally rest their decisions." (Jasanoff, 1989b: 153)
Repeated deconstruction of scientific knowledge in the public policy arena have made closure over controversial scientific issues difficult to achieve and exposed the whole scientific edifice as a network of social-cognitive commitments. In recent years, the rules presiding over the construction of authoritative knowledge and the boundaries between certainty and uncertainty have been shown to vary from one context of use to another, between different scientific traditions, over space and time, and between different regulatory systems. Concurrently, the informal inferences, judgments, and commitments which cement scientific activities and which normally remain implicit have emerged to suggest that scientific knowledge is established, assimilated, and transmitted among scientists by social trust and authority, rather than by the radical scepticism suggested by science's dominant public image (Wynne, 1987: 422-3).

Science, in sum, has been shown to develop within traditions limiting scientific inquiries to a taken-for-granted theoretical and methodological framework whose authority is not normally questioned. In this scheme, existing knowledge provides a normative framework for shaping acceptable problems and for evaluating new evidence and ideas. Scientific uncertainties, in turn, are limited to puzzles and anomalies within a given paradigm of certainty.
2.2 The Constitutive Nature of Scientific Uncertainty

Notwithstanding the very public and thorough deconstruction of scientific knowledge which tends to occur systematically when science is used for policy purposes, conflicting assessments with regards to the adequacy of a piece of knowledge have been shown to exist prior to the consideration of the relationship between knowledge and some practical problem.

"Scientists can be divided by a variety of internal factors, including disciplines, schools of thought within or across disciplines, or the interpretive ingenuity which they exhibit as individuals. Interpretation does not start with policy."

(Campbell, 1985: 439. Emphasis added)

Indeed, epidemiologists by training, tend to give more weight to human data, while the disciplinary paradigm among animal pathologists naturally encourages them to place credence in animal studies. In addition, Campbell has shown that the value or adequacy of a piece of scientific knowledge is never expressed in a vacuum but instead is always stated by reference to what is already known and deemed reliable at a particular point in time or to what needs to be known for practical purposes. Depending on the social environment they address, scientists will give diverging accounts of the knowledge, uncertainty, and scientific consensus
existing in their field and provide different reasons for justifying particular commitments. Consistency in their statements can be found only if one interprets their claims along with the social context which, in each case, is part of the constitution of their knowledge (Campbell, 1985).

So while risk policy decisions are made on the basis of "more" or "less" information regarding scientific knowledge and uncertainty, the problems of knowledge adequacy and uncertainty do not appear to be fundamentally quantitative. Rather, what is considered scientifically adequate or uncertain is a matter of social definition and negotiation.

"There is not an objective amount of uncertainty attached to any given estimate or statement that can be stated for policy. The degree of uncertainty perceived by an expert in a piece of knowledge depends upon its perceived role in a relationship or context of use." (Wynne, 1987: 348-9)

Thus, if uncertainty arises because observation itself is always mediated by other social actors rather than because of the nature of a reality which is physically difficult to observe, scientists can be expected to negotiate, argue, and enrol each other to monopolize the definitions of what problems are important, what methods are legitimate, what counts as evidence, and, correspondingly, what is enough knowledge.
"The issue of uncertainty can be more fruitfully analyzed as a strategic element in expert arguments, than as something which causes scientists as experts to disagree." (Campbell, 1985: 447)

The strategic importance of the issue of uncertainty to expert arguments has been emphasized by many. Funtowicz and Ravetz, for instance, noted the increasing tendency for public debate to focus on the various uncertainties surrounding the numbers rather than on the policy relevant quantities themselves (1990, 20). Arie Rip, for his part, suggested that scientific controversies often crystallize around questions concerning which areas of uncertainty are sufficiently irrelevant to remain uncertain, rather than about the interpretation of a given area of uncertainty (in Wynne, 1987: 309).

However, in contrast to the view that scientific knowledge simply reflects dominant ideological interests, the "interests" present in strategic negotiations over the relative adequacy of a given piece of knowledge have been shown to be broad and to refer to a multi-layered complexity involving institutionalized routines of method and socio-cognitive framing. Ethnographic studies of laboratory practices, in particular, have outlines that "values" and "interests" enter the constitution of agreed-upon scientific knowledge in ways that are far more diffused and complex than the deliberate play of specific external interests and value
commitments. As cultural habits, socially transmitted as the natural ways of doing and thinking, they should not even properly be described as values or value commitments. While it is often assumed that negotiation about extrapolation of data, simulation models, inferences and the like occur solely where policy relevant values are in play, the social negotiation over various accounts of the objective world has been shown to stretch deep into the heart of scientific knowledge, far beyond the realm where any explicit policy implication can reasonably be traced (Callon and Law, 1982; Cambrosio et al., 1991; Collins, 1981; Woolgar, 1981, 1992).

"Since what is to be counted as 'social' rather than 'scientific', 'rational', or most broadly speaking 'non-social', is itself negotiated in scientific practice, the 'social' cannot be unproblematically presupposed as an analyst's resource in describing this practice. Instead of drawing upon the 'social' to account for scientific knowledge, one can see the 'social' itself grow out of the construction of this knowledge."

(Knorr-Cetina, 1982: 322)

Overall, social studies of the constitution of scientific knowledge point out that, the boundary definitions between "scientific knowledge", "scientific uncertainty", and "social interests" are clearly incomplete and negotiated into practical adequacy by social action. Thus, the uncertainties which risk analysis tries to
control or ignore do not merely flow from nature, an objective problem or scientific method. Rather, scientific uncertainties are present in scientific knowledge from the very the outset as part and parcel of a process of ongoing interpretation and negotiation amongst scientists. In short, scientific uncertainty needs to be treated as an extension of science rather than something outside science, that is as a constitutive rather than a residual category.

2.3 Uncertainty, Ignorance and Risk Management

So far this discussion emphasizes how an examination of the nature of scientific knowledge per se is difficult to conduct because one is immediately confronted with its social-bound character. Reference is made to studies in the sociology of science tradition which have shown the social imprint on science to extend from the earliest point of knowledge creation to the closure of questions concerning the realms of science to be considered scientifically certain. In fact, attempts to analyze the scientific enterprise separately from the society in which it develops or to isolate "scientific" from "social" uncertainty may be doomed to failure from the outset.

Rather than viewing scientific uncertainties as uncharted areas not yet processed by scientific knowledge (as in the Mertonian and Popperian traditions) or as "trans-scientific" issues ultimately
unsuitable to scientific treatment because not purely scientific (Weinberg, 1982), Brian Wynne suggested a more realist and useful conception of the nature of uncertainties for risk management which cuts across the purported demarcation between the scientific and the social. According to this author, uncertainties in scientific risk management are better characterized by:

(1) Ignorance (there are factors and combinations of potential alternative frameworks that are not even identified, let alone 'estimable').

(2) A wide scope of legitimate expert analytical choice in defining the relevant risk-generating system structure - structural 'uncertainty'. (Wynne, 1987: 283)

The usefulness of this definition lies in part in that its second proposition distinguishes between "orthodox" technical uncertainty or imprecision in risk analysis, and structural or "institutional" uncertainty brought about by framing differences regarding problem definitions. The main reason why various parties to a controversy often differ as to what they consider important and as to the kind of information they require for decision is that they are actually addressing different problems. Rather than being due to technical uncertainty alone, expert disagreement in risk analysis can usually be traced to different definitions of what the risk problem is.
In the MacKenzie Valley oil pipeline inquiry, for instance, different experts made tacitly different assumptions about social and organizational behaviour. For example, some experts, but not all, assumed that construction-season limitations would be unofficially stretched into the more damaging summer season. They reached different conclusions because they were drawing very different boundaries around the technical risk problem that was the focus of analysis (Wynne, 1988: 159).^4

Rather than resulting merely from observational imprecision, divergence over the meaning of uncertainty - scientific or otherwise - is more often than not the outcome of conflicting framing. Knowledge and uncertainty are created by actively strategizing agents who arrive at diverging definitions of the problem at stake because it is set by them in a different network of connecting problems, experiences and constraints. In sum, uncertainty is created by conflicting views of reality rather than by the incompleteness of a single one.

"The germane uncertainties are often not those 'passive' ones to do with lack of precision in our scientific inability to measure the objective world but instead are those 'actively' created uncertainties which are functions of contending cultural backgrounds, institutional purposes, and needs within the risk system being defined and analyzed." (Wynne, 1987: 271)
The other practical benefit of Wynne's formulation of uncertainty lies with its focus on ignorance - a notion which, again, applies indiscriminately to the scientific and social realms. Can anything useful be said about that of which we are ignorant? Although it would appear that, by the very definition of ignorance we cannot, some useful lessons can nevertheless be drawn from the repertoire of strategic responses risk management institutions have deployed for dealing with the unknown. Genuine uncertainty in risk management arises because of our ignorance about possible alternative frameworks. It is also an increasingly central and important feature of both scientific and social uncertainty.

2.4 Uncertainty and Science's Dual Roles in Risk Management

This discussion started by pointing out that the growing influence of the scientific outlook in our modern societies had led risk management institutions to rely too exclusively on scientific definitions of knowledge and uncertainties for the management of societal risks. Paradoxically, this extensive use of science in risk management, has coincided with the emergence of scientific uncertainty as a dominant issue in risk management and with rising problems of regulatory credibility.

Science has lent itself easily to bureaucratized forms because, like bureaucracy, it progresses by freezing a defined context and assuming an ideal world. Both activities, in particular, embrace
the triple aim of formalization, standardization, and universalization. These are achieved by stripping the background away and by idealizing entities so as to purify the phenomenon of interest and render it analyzable or manageable.

"The bureaucratic aims of formalization (e.g. of procedures), of standardization (in contrast to ad hoc negotiations), and universalization (applicability to all, independent of particular situations) find their counterparts in scientific aims. Formalization enlarges the scope of the analyst; standardization makes exchange and cumulative work possible; while universalization is a general aim of science (...), its importance derives from the fact that it makes knowledge transportable and thus enlarges its domain". (Rip, 1986: 9)

Science therefore actively contributes to the "bureaucratization of uncertainty" which artificially converts genuine ignorance, ambiguity, and indeterminacy into apparently controllable risks or marginal uncertainties (Wynne, 1987: 338).

"Large scale ignorance of the basic structural framing of analytical problems is falsely represented in conventional scientific approaches as a marginal, probabilistic uncertainty in analytical parameters and data." (Wynne, 1987: 400)
In turn, risk management’s use of formal caricatures of science as a context-free, objectively neutral activity has resulted in a serious misfit between the deep and diverse uncertainties of the real world and traditional approaches in risk management. Indeed, the later view uncertainties in the real world as if they were narrowly limited and could be credibly managed within unidimensional, quantitative boundaries. Oblivious of the fact that risk analysis is always a simulation of a postulated risk-generating process, regulatory risk management encourages the conversion of ignorance into apparently manageable certainty. Although it focuses upon known uncertainties only, conventional risk management acts as though it comprehends all uncertainties.

When conflicting policy positions are being advocated and credibility is at stake, formal risk analysis is virtually always demanded as an antidote by regulators who seek rational, seemingly apolitical justifications. Yet, if rituals of scientific precision and certainty are increasingly used to clothe risk decisions in scientific terms and project public reassurance, they have done so without much effectiveness and at escalating costs. While expertise is increasingly used to justify regulation, it is also increasingly challenged.

"The appeal to science is made because of the absence of respect for any adjudicator. When science is used to arbitrate in these conditions, it eventually loses its
independent status, and like other high priests who mix politics with rituals, finally disqualifies itself."
(Mary Douglas, 1990: 12)

In sum, science now plays a dual role in risk management. Upstream, it is responsible for generating a descriptive and empirical account of the risks and for providing a scientific basis for risk management decisions. Downstream, it is used normatively to legitimize risk management decisions and as a symbolic response to public concerns.

Given risk management fundamental goal of public protection, its limited resources, and the overall context of public mistrust in which many regulatory decisions are received, it is perhaps time for risk management practitioners to seek legitimacy on new grounds. Demands for definitive risk-benefit management knowledge should not systematically result in an artificial bounding and concealment of ignorance. In other words, risk management institutions would be well advised to stop pretending their decisions are driven by the scientific assessment of risk and uncertainties and seek instead to address more effectively the conflicts of rationalities which consistently compromise the viability of risk management decisions.

This, however, may be difficult to achieve since many conflicting parties in health and environment controversies have now stepped up
their demands for better access to scientific expertise. In Brian Wynne's terminology, structural or institutional uncertainties are now actively engaged in generating and maintaining orthodox, technical uncertainty.

In any case, the myths of scientific rationality and authority in public decision making need to be dealt with because they falsely imply the existence of an adequate knowledge for regulation and attempt to side-step the issue of public trust.

"The focus for the analysis of uncertainty should not be on how to minimize or respond to uncertainty, as if the amount of knowledge is part of an external decision-making environment. It should rather be directed toward these social processes of definition and negotiation."

(Campbell, 1985: 450)

The arguments put forward throughout this section indicate that such a change in orientation may provide more favourable conditions to roll back the frontiers of ignorance and increase the stabilization of risk management practices.

3.1 Two Understandings of the Public’s Views on Science and Technology

Despite the complexity of the socio-technical systems which make up our present environment, the tendency of technical experts to strip their risk definitions of the institutional and organizational context in which risk is assessed and managed has resulted in overly simplistic and misleading public images of science and technology. The experts’ sanitized and overly formal accounts of science and technology as mechanical, rule-following entities regulated by a unitary rationality misrepresent the scientific enterprise and the functioning of technological system-networks as well defined, intelligible processes under expert control. As a result, the public understanding of these activities lags far behind what constitutes, in effect, the complex nature of scientific and technological processes.

This argument, most persuasively articulated by Brian Wynne (1987, 1988), holds that there is now a yawning gulf between the state of risk-analytic knowledge and the actual working of most of the complex and intertwined technological systems to which this knowledge is applied. Yet, the experts’ external accounts of science and technology make it virtually impossible for the public
to examine the actual internal workings of science and technological system-networks. Purified accounts of the inner workings of socio-technical networks impoverish social learning and insure that public expectations about risk and technological safety will always be set too high. Although a disabling and degenerative myth, this "white boxing" of science and technology is now risk management's strategy of choice for maintaining order in the face of controversy (1988: 160).

The inadequacy of the official rhetoric that serves to account for technological activity and socio-technical interactions is apparent, for instance, in the experts' pronouncements that can often be heard in the wake of a technological mishap. Such statements usually appear in the following sequence:

First movement: "There is no need to worry. The technology, is under control."

Second movement (after the unthinkable has happened): "Human error was to blame but there is no need to worry now because everything has been planned to insure a similar accident will never happen again."

Third movement: "It is unreasonable to expect that technological knowledge does not harbour areas of uncertainties. Only the naive believes in the rhetoric of zero risk." (see for instance Lagadec, 1981: 139)
The end-result of this strategy is a great deal of confusion in the ways the public perceives what science and technology can be expected to deliver and about those in charge of controlling it.

"The point is that with the effective causes and structures of responsibility so obscured, the only possible public responses are total acceptance (...), or total rejection (...). There is no possibility for internal discrimination, measured criticism, or conditional, qualified responses - all possible currencies of moderation are historically obliterated, leaving behind inflexible absolutes." (Wynne, 1987: 368)

In short, popular perceptions of science and technology can be expected to alternate indiscriminately and capriciously between naive trust and embittered criticism. The key challenge for contemporary risk management institutions would thus lie in managing essentially unpredictable and polarized responses to technologically incurred risk. 

An altogether different account of public reaction that stands in stark contrast to this view has been advanced by Peter Sandman.

Toward the end of 1984, agency officials of the New Jersey Department of Environmental Protection launched a campaign of public information to warn residents about radon, a naturally
Occurring radioactive gas entering private homes through basement cracks. The experts agreed, the risk was serious. The USEPA suspected radon emissions to lead to an estimated 5,000 to 30,000 lung cancer deaths annually. Home owners were encouraged to monitor the levels of emissions in their homes and, when necessary, to take remedial actions to reduce radon radiations to levels considered acceptable. Although state officials were initially wary of a panic reaction, they were surprised to see their radon information campaign being met by public apathy (Sandman et al., 1987).

However, when the same agency planned to create a site to dispose of soil contaminated by industrially produced radon, the public reaction it encountered was radically different. Although the site the USEPA selected was removed from populated areas and large enough to reduce radiations to a safe level, angry demonstrations led by citizens vowing to commit civil disobedience resulted in the Project cancellation. Three years later, public opposition to the project showed no sign of abatement and officials were still looking for a site to dispose of their contaminated soil.

While in both cases public reactions were inconsistent with the risk analysis’ estimates, they were congruent with the findings of risk perception research which suggest that the subjective characteristics of a risk (its origin, controllability, catastrophic potential, and so on) are highly significant in the
public' eyes and can contribute to the public perception of a risk as "outrage". Risk, thus, can be conceived as an amalgam of hazard and outrage, with outrage being "everything about a risk that's relevant except how likely it is to hurt you" (Sandman, 1988: 163-4). According to Sandman, then, public and expert attitudes towards risk can be inferred with a relative degree of predictability:

"High-outrage, low-hazard risks will provoke a stronger reaction from the public than from the experts. High-hazard, low-outrage risks will provoke a stronger reaction from the experts than from the public". (Sandman et al., 1987: 107)

"It follows that when the hazard is low, authorities should do everything in their power to get and keep outrage low. (And when the hazard is high, work to make outrage high [...] When risk managers begin attending seriously to outrage, I believe this will free the public to begin attending seriously to hazard."

(Sandman, 1988: 167)

Public and expert views on risk are often at odds because they emerge from two different framings of the problem. Although each constituency exhibits differences in how it articulates the problem, in what factors it deems relevant to the analysis, and in who it considers the experts to be, each understanding of risk
problem has been said to be logical and coherent in its own terms. In short, the outright dismissal of public reactions as irrational or whimsical has been widely acknowledged as one of the main unwarranted assumptions. The lack of adequate consideration given to public perceptions by risk managing institutions is now considered to have been a key impediment to effective health and environmental public policies (Krimsky et Plough, 1988; Leiss, 1989, 1994; NRC, 1989).

3.2 Managing Public Input: Some Practical Problems

The use of administrative mechanisms designed to make use of public input in risk decisions has been promoted as the most effective means to avoid polarized reactions, regain credibility, and enhance governability and public safety in the long run. The ways in which public perceptions can be incorporated in the risk management process are, however, problematic in many ways (Carpenter et al., 1988; Jasanoff, 1987a, 1989; Leiss, 1994; Limoges et al., 1993).

First, there is, of course, no such thing as one homogeneous "public" but countless publics with a broad array of priorities and preferences. Second, public participation mechanisms are frequently plagued by differences in perspectives between the various parties involved. From the stance of the regulators, public participation is often viewed as a "means" to supplement regulatory expertise with the perspectives citizen groups bring to
bear on a situation and as an instrument to reduce conflicts by creating greater acceptance for regulatory decision. Public participants by contrast, tend to approach participatory efforts with an "ends" goal, focusing their contribution so as to influence the broader mechanisms of risk imposition, or aiming at the cancellation of the risk altogether. Such discrepancy between regulatory and public expectations seems to assure that at least one set of participants will be dissatisfied with the process (Kasperson, 1986).  

The problems encountered in bridging the respective concerns of public officials and private citizens via public participation mechanisms are well documented. They include the participant's relative unrepresentativeness, the problems of procedural mechanisms arbitrarily predetermining outcomes, and the consultative or decision-making role public participation is to play in regulatory decisions (Carpenter, 1988; Salter, 1981; Cambrosio and Limoges, 1991; Limoges et al., 1983). The relative strengths and weaknesses of some of the most popular institutional mechanisms used by the USEPA to tap the public views on risk have been summarized as follow:

"Negotiated rule making promotes collective problem solving and sharing of information, but at the national level is unlikely to achieve direct participation by amateurs. A hearing is an open forum, with minimal
preparation, but may force participants into a reactive, oppositional role. The dominance of the hearing process by organized interests can bias policymakers' perceptions of public concerns. A survey is more representative and can measure intensity of views, but takes opinions out of context, with no opportunity for discussion. An initiative delegates authority to citizens and may stimulate discussion and a search for information, but forces a majority decision."

(Fiorino, 1990: (297). Emphasis added)

3.3 Towards Decision-Making: Framing the Risk Problem with MAUT

One mechanism that offers another possible basis upon which a sophisticated understanding of public reaction may be incorporated into the process of regulatory risk management is the multi-attribute utility technique or MAUT. MAUT is a mediation procedure which associates professional expertise and stakeholders' judgment. Its main purpose is to arrive at a comprehensive information base developed and shared by all interested parties to a risk controversy (Edwards and von Winterfeldt, 1987; von Winterfeldt, 1992).

Two broad conceptual guidelines shape the development of the MAUT process. First, access to a sound information base is believed to
be an essential prerequisite of effective risk management decisions. Second, the model assumes equal competency on the part of all parties involved in their ability to construct a meaningful definition of the problem at hand. MAUT is thus grounded in the belief that properly assisted groups of well informed citizens can contribute to quality decision-making on a variety of semi-technical risk management tasks.

By providing organizational and procedural assistance, this process can assist various groups in the form of careful and balanced policy analysis. This is achieved by promoting flexibility and creative participation in designing options and by suggesting alternative ways to structure the problem. By encouraging and comparing alternative framings, MAUT makes it possible to highlight the implications that unfold from various arguments and possible regulatory options. Independent experts can help stakeholders analyze complex technical material and facilitate their control over the information to enhance their grasp of the policy choices.

The use of interactive communication processes to revise proposed options is one of the most creative parts of the analysis. Aimed at stimulating thinking about the possible limitations of each group preferences, it also guarantees, in principle, the legitimacy of the results in the eyes of the different stakeholders as well as between stakeholders and their constituents. Regulatory preferred options are rarely hard-and-fast single position commitments. The
constant revision mechanisms built into the value-tree construction process encourage the consideration of alternatives, help refine positions and can prepare for later conflict resolution.

For the regulators, then, MAUT provides an aid to diagnose the nature and extent of value controversies and can help them structure their final decisions accordingly. It also forces particular intervenors to come to term with the problems of priority-setting. Express consideration given divergent alternatives weakens the more radical attitudes based on "sacred and inviolable principles". At the same time, the process can help various publics to articulate their views for bargaining and negotiation.

A research tool as much as a decision-making instrument, MAUT should not be expected to resolve value questions. As opposed to operational theories of technical advice in problem solving, MAUT is mired in reflexive theories. Its strength lies essentially in helping participants develop a fuller and finer understanding of the problem at stake. By clarifying the implications of alternative decisions for various groups, the interweaving of the psychological, cultural, and political dimensions of the risk problem can be brought to light and linkages between values and action made explicit.

The fact that MAUT does not result in a specific decision outcome
but rather aims at a comprehensive rendering of the alternative framings constitutive of a given risk problem is both a strength and a weakness. While the analysis is pragmatic and decision-oriented - in that it is focused on the policy implications of different framings of the risk (rather than on their cause or origins) - its contribution to risk management is not a substitute for decision-making. MAUT leaves regulators with the responsibility for selecting their preferred set of regulatory options.

By contrast, participatory and consultative approaches aimed at reaching negotiated agreement in lieu of elected or duly appointed officials have been criticized for their lack of procedural fairness and for reaching risk decisions having limited public legitimacy. The Washington Fish and Wildlife Agreement, for instance, has been accused of promoting pluralistic "elite" consensus and negotiation behind closed doors (Bingham, 1986).

In addition, the strength of negotiated rule making which stems, in part, from the flexibility of its procedures is also a weakness. Since no public record is kept, it runs the risk of inviting abuse (idem). The informal and private character of such procedure stands in sharp contrast against MAUT interactive communication processes that are involved in the multiple revisions of the value trees and of the final document publicly endorsed by all stakeholders. Furthermore, while both techniques aim at unblocking
a stalemate situation by supplying parties with new information so that they will come to see both the situation and their interests differently, the massaging of information suggested by the roles of negotiator-mediator and that of the MAUT manager may be quite different.

The role of the former being to reach consensus, chances are that the information privileged for attention will be that which can most readily conduct to consensual agreement. Information that can be useful to all parties involved can be discarded by those it might best serve for it is presented in a context which, from the outset, is oriented towards closure and, as such, privileges a narrow treatment of the information available. Jasanoff also notes that decisions channelled through "consultative" or "cooperative" procedures can be particularly misleading because they perpetuate the semblance of a consensus without the substance (1986: 59). Rather than signifying a real accord, decisions by consensus may conveniently paper over the capitulation of the weakest adversary before more powerful opponents. In the long-run, there is thus a risk that, decisions reached this way may again be perceived as relying on an insufficiently broad base of information and interests.

By contrast, the research orientation of the MAUT approach can shield the process from the immediate pragmatic imperatives of reaching a decision and at the same time encourage a more
systematic and procedurally fair analysis of the options at hand. In the long-term, the overall learning potential it offers for incorporating a sophisticated understanding of risk perception in regulatory risk management is thus arguably greater. Yet, it remains that the MAUT approach is far from being a panacea. Let alone the heroic simplifications required to code the values attached to different decision options, it is important to keep in mind that the MAUT model is just another representation of social reality. As such, it can be criticized for expropriating the laypersons meanings of risk into an alien framework.

"Contrary to the central faith of decision-analysis, freedom may be tantamount to maintaining imprecision in values, which allows flexibility to negotiate them amongst one's own complex social networks." (Wynne, 1987: 383)

"This is only another statement of the truth that there will always be a gap between empirical social practice and the public language describing it." (idem: 433)

This being said, however, the MAUT process remains one possible and reasonable way of structuring discourse about the criteria against which risk decisions can be evaluated.
4. Conclusion

The essential thesis present in this chapter is that institutional conflict among social actors poses a greater and more fundamental threat to risk management stability and its ability to fulfil its public mandate than the technical uncertainty that is the present focus of conventional risk assessment-management activities.

The first section suggests that risk analysis and risk management knowledge are rooted in an inadequate perception of science and scientific development as uncertainty seeking. This misunderstanding of the scientific enterprise, it is argued, stimulates demands for definitive risk-benefit management knowledge that result in an artificial and overelaborate concealment of ignorance. The second section discusses some of the problems and opportunities attached to various institutional mechanisms used for incorporating inputs negotiated from other frames of social experience in the assessment and management of risk.

Implicit in the use of such mechanisms, is the belief that, at the core of a coherent approach to the societal management of risk lies a new and enlarged conception of rationality for regulatory knowledge. While the policy-relevant sciences have spent great amounts of energy and resources in producing rational-objective
knowledge for regulatory consumption, the seemingly untractable problems encountered by regulatory agencies responsible for the management of health and environmental risks have raised questions regarding the validity of this purportedly objective knowledge and encouraged the search for more viable and useful conceptions of rationality. This new kind of policy-relevant knowledge emphasizes "knowing how" as opposed to "knowing that".
CH 3: METHODOLOGICAL APPROACH

THE CASE STUDY AS RESEARCH STRATEGY TO HEALTH & ENVIRONMENT CONTROVERSIES

1. Introduction

Part of the armamentarium of qualitative social science research, the case study method constitutes one of the preferred research strategies for analyzing health and environment controversies. The popularity of this methodological approach may be inferred, in part, from its suitability to research which seeks to investigate empirical topics whose causal links are too complex for being adequately addressed by other strategies such as the survey or the experiment. The complexity of the relationships and entities that are involved in health and environment controversies as well as their dynamic character makes them primary candidates for case study research.

The following definition encapsulates several important characteristics of the case study approach which further contribute to this analytical strategy being well attuned to the examination of the empirical dimensions of health and environment controversies.
According to Robert Yin,

"[a] case study is an empirical inquiry that:
* investigates a contemporary phenomenon within its real-life context; when
* the boundary between real-life and context are not clearly evident; and in which
* multiple sources of evidence are used." (1988: 23)

The complex, evolutionary and controversial nature of health and environmental controversy also makes them impossible to approach, let alone understand, without resorting to some form of theoretical framework to sort through the empirical data of the case. The statement 'empirical information without a theoretical framework to give this information meaning is meaningless' is perhaps nowhere more justified than in the context of these controversies. To be meaningful, then, case studies need to be informed by a set of theoretical propositions which provide a blueprint for research and point to what questions to study, what data are relevant, and how to analyze and interpret the results.

Yet, while the selection and interpretation of empirical data must be guided by a specific set of theoretical propositions, that same empirical material is also used, in the end, to prove or disprove the validity of the theoretical framework which led to the organization and treatment of this same empirical data in the first
place. Thus, not only do case studies provide an adequate analytical strategy for investigating health and environment controversies, they also constitute a particularly interesting medium for observing the continuous interactions between the testing of theoretical propositions developed to account for these contemporary societal phenomena and the empirical data collected to this end.

This chapter reviews several case studies concerned with health and environment controversies in light of their methodological approach and treatment of empirical material. These studies were selected primarily on the basis of the significance of their subject matter and because of their contributions to the understanding of risk communication and risk management activities. Although this chapter was initially conceived to focus solely on questions of methods, the brevity of treatment given this issue in the majority of the studies reviewed has forced a reconsideration of the central theme of the chapter. The emphasis placed by most researchers on the elucidation of their theoretical outlook - as opposed to questions of method per se - points to the critical importance played by their respective theoretical framework in selecting and analyzing empirical data.

Rather than being viewed as a lack of consideration for questions of validity, reliability, or methodological rigor generally speaking, this emphasis may be more appropriately interpreted as
speaking for the inseparable character of theoretical and empirical propositions, with a detailed exposition of the former leading to a better appreciation of the later. In other words, the apparent lack of interest in methodological considerations constitutes, in effect, the expression of an implicit methodological stance. In order to do justice to the approach privileged in these studies, the concern with theoretical propositions had to be reflected in the review presented below. The final section outlines some of the theoretical and methodological considerations that were instrumental in designing and conducting the PCB case study.

2. Sheldon Krimsky and Alonzo Plough; Environmental Hazards: Communicating Risk as a Social Process

In their book Environmental Hazards: Communicating Risk as a Social Process, Sheldon Krimsky and Alonzo Plough, draw on the anthropological works of Mary Douglas and treat risk events as part physical processes, part socially constructed phenomena. The case-study approach is selected for it is considered the best research strategy to illuminate the cultural aspects of risk communication which, in these authors' view, have not been satisfactorily addressed in the existing literature.
"The risk communication literature lacks detailed analytical cases that describe the genesis and development of a risk event and the associated messages, meanings and perceptions that become risk communication." (Krimsky and Plough, 1988: 5)

The authors start by laying out a set of theoretical presuppositions which includes, for instance, asserting that risk events need to be studied in situ with all their cultural expressions. Concurrently, they ascribe a symbolic meaning to the term risk communication in addition to the conventional use of the term. In its new and expanded acceptation, risk communication refers to any public or private communication about risk, either intended or fortuitous. This, it is claimed, simply ought to reflect the fact that risk communication enters our lives in a multitude of forms, "sometimes part of the imagery of advertising, sometimes a local corporation’s formal statement, or its failure to say anything, sometimes a multi-volumed and impenetrable technical risk assessment" (idem).

In order to expand the boundaries of analysis of what they view as a narrow and sometimes mechanistic paradigm, Krimsky and Plough, then, present a series of case studies that analyze risk events within their larger societal context. This approach makes it possible to understand risk communication as both a technical and cultural phenomenon.
The five risk events selected for analysis illustrate different forms of environmental risk as well as diverse dimensions of the risk communication activity. The first case involves the pesticide and soil fumigant ethylene dibromide (EDB) and reflects the general category of risks associated with low-dose and long-term exposure to pesticide residues. The second case pertains to the first environmental release of genetically modified organisms into the biosphere and examines how the hypothetical risks associated with the proposed field test were defined and communicated by different parties to the controversy.

The third case compares various regulatory approaches to communicating the risks of radon, a naturally occurring radioactive gas found in many private homes, and analyzes the public reaction to these risk communication efforts. The fourth case considers an intensive public information and communication strategy developed by the U.S. EPA to involve a community living near a copper smelter in the setting of national standards for airborne arsenic emissions. The fifth case concerns a hazardous waste site in Massachusetts but is representative of the problems associated with scores of potentially hazardous sites scattered throughout the United States.

To construct the cases, the primary data utilized reflect the authors' contention that risk messages can be conveyed by diverse modes of communication and can take literal or symbolic forms. The
archive they developed for each case study consisted of audiotape recording of on-site and telephone interviews with key participants, videotapes (of media coverage, news conferences, public meetings), reports, news articles, and analytical studies.

The five case-studies are designed similarly and start with a presentation of the general context in which the risk event occurred before turning to a specific examination of the risk communication activities. About half of each case-study is thus dedicated to describing in some details the historical, regulatory and legal context as well as the specific risk assessment processes pertaining to the risk at hand. These preliminary sections serve to account for the conditions under which the risk events became fully realized as public problems and provide the background on which risk communication activities per se -- i.e., risk-benefit communications initiated at the local and national level by various stakeholders -- are described and analyzed.

To study risk communication activities, the actions of key actors are examined and placed in their causal and temporal sequence. The main segment of each case is devoted to how the contextual factors described above influence risk communication and lead to different constructions of the risk event. The emphasis is on the evolution of the risk communication events - which may include a long gestation period during which the essential morphology of the crisis develops - and on the factors that shape the overall pattern
of risk communication. By reporting what people and institutions say about the risk and how they are saying it, Krimsky and Plough highlight what substance and symbols are important factors in understanding these events. In short, their approach to the case-studies is guided by two sets of questions:

* How were the risks presented and interpreted by major parties and constituencies to the controversy?
* How, by whom, and in what form were risks communicated?

Each case-study concludes with remarks addressing a series of queries concerning which socio-economic elements were important in understanding the social responses to the risk events, the primary modes and channels of risk communication, and whether the goals of risk communication relative to some group or agency were realized. The final chapter concludes with a re-affirmation of the importance of the situational context for risk communication. It also posits the existence of two kinds of rationality instrumental in structuring and affecting the enfolding of environmental controversies, namely a 'technical rationality' at play among those legally responsible for making risk decisions and a 'cultural rationality' found essentially among those on whose behalf risk decisions are made. This cultural rationality, it is argued, reflects both the content and the context of risk analysis and thereby provides a richer conception of the risks by incorporating technical knowledge into a broader decision framework.
From a methodological standpoint it is interesting to note that a major portion of the risk communication activities described by Krimsky and Plough is consumed by attending to the uncertainties associated with each risk event. This holds true whether they address the risks of consuming or inhaling minute quantities of toxic substances (EDB, radon), some hypothetical risk scenarios (speculating on the release of genetically engineered organisms into the environment), the setting of different levels of mercury concentrations in stack emissions, or the type of remedial actions needed to clean up a hazardous waste site. This is evident in the attention given to the symbols, metaphors, analogies and comparative risk estimates which serve as frames of reference for addressing these uncertainties. Thus, the authors' broad definition of risk communication is actually implicitly extended to the communication of uncertainty.

Given the level of scientific and social uncertainty surrounding each risk-event, the case-studies show few indisputable facts and even fewer unarguably clear policy inferences that can be based on risk assessments. Rather, Krimsky and Plough's analysis unravels how structural factors (historical, political, economic) generate multiple accounts of a crisis, and the varied assumptions that can underlie the patterns and direction of risk communication. Their epistemological position is clear:
"In this analysis, we do not play the role of modern-day Diogenes looking for the truthful account."
(Krimsky and Plough, 1988: 14)

Indeed, their analysis shows that the history of each risk episode can be described through several different axes, each of which has its own internal logic and illuminates a different perspective on the history of the risk event. For these authors, then, the view that environmental controversies arise because the regulatory or expert messages have been misinterpreted would be far too simple. Each case points to an inherent pluralism of communicators and to a plurality of messages with the later not necessarily corresponding to errors in interpretation.

In sum, these five case studies demonstrate that the scientific, technical, legal and sociopolitical definitions of risk compete to characterize the controversy at hand and that different parties will hold alternative conceptions and expectations with regard to risk assessment, risk management and risk communication. Consequently, each party to the controversy will also entertain different ideas as to the relative "success" of these activities. This finding alone makes Krimsky and Plough's detailed analysis of the relationship between the history, process, and outcome of a set of risk communication problems eminently successful in highlighting the complexity of risk communication activities.
In Search of Safety is about the controversies that arise in the regulation of chemicals known or suspected to cause cancer. The book is the final product of the Scientific Conflict Mapping Project (1983-1986), Department of Health and Policy Management, Harvard School of Public Health and, as such, reflects the collaboration of individuals from a range of scientific disciplines. It starts with the following paradox:

"A growing body of experience seems to suggest that, in fact, more research and better technical information actually exacerbate conflict among experts and in the policy process. How can this be true and what does it mean? Why does more and better technical information seem only to raise more questions than it answers and increase both the disagreement among the experts and the polarization of the public policy debate?"

(Harvey Brooks in Graham et al., 1988, vii)

To approach this general issue, John Graham, Laura Green and Marc Roberts look at the attempts to regulate two suspected carcinogens, benzene and formaldehyde. Their analysis provides a detailed examination of the scientific evidence bearing on the risks of
Public exposure to these chemicals. Their account of the unfolding of the controversies is articulated around the carefully described political and judicial responses to technical disagreement, and includes the reactions of numerous people, both scientists and non-scientists, to each new scientific finding. This analysis essentially amounts to laying bare the growing complexity and confusion of the technical and legal-political situation, as knowledge supposedly improves. At last, the authors describe some of the processes that have been tried to resolve disagreement among scientific experts. They conclude with some recommendations about the role that science can play in the resolution of such disputes.

To explain how and why scientists disagree about the answers that are of importance to regulators, Graham et al. organized three meetings aimed at exploring the sources of scientific disagreement and the nature of the science-policy interface. These meetings, attended by some forty prominent working scientists from academia, industry, regulatory agencies and environmental organizations, helped clarify some of the procedural considerations involved in the elicitation of scientific judgments. By spelling out the scientific questions that were central to the regulatory decisions on each chemical, the meetings also contributed to the design of a blueprint for mapping the sources of disputes. Some of the participants to these meetings remained involved in the project through its final completion.
The two case-studies are particularly interesting in that they unearth some deeply buried linkages of the science-policy interface and make the implications of these links explicit. In each case, the scientific evidence and judgments about the chemical's carcinogenic potential is reviewed in light of the history of the legislative, administrative, and judicial decisions at the federal level. As with toxic chemical regulations in general, the methods and findings of risk assessment played a prominent role in the adversarial disputes about benzene and formaldehyde. A great deal of analytical energy is thus spent dissecting this process. This is done, for instance, by showing how regulators have asked questions to scientists about formaldehyde and benzene and by contrasting this first set of questions with the questions scientists ask of themselves. By articulating the scientific and policy questions that are central to regulatory decisions, the researchers draw attention to the political aspects of technical issues and vice versa.

Although federal regulatory agencies increasingly use risk assessment to bridge the gap between science and public policy, this study shows that in the case of the benzene and formaldehyde controversies, there was no consistent positive relationship between either research and knowledge or knowledge and policy agreement.
"... in some cases the results of scientific studies decrease the controversy about regulatory choices, in other cases they increase it, and in yet other cases they have essentially no impact over the controversy."
(Graham et al., 1988: 3)

By evaluating the process of using science and the advice of scientists in regulatory decision making, the authors seek to find ways to improve the science-policy partnership. Because their approach is essentially exploratory, the case-study method is appropriate for their undertaking and yields some interesting hypotheses about the sources of scientific conflict in a regulatory context and about possible remedies.

When in their last chapters, Graham et al. analyze the promises and limitations of science as a vehicle for resolving conflict about chemical regulation, they take a somewhat more normative and evaluative stance. In the descriptive part of the case-studies, however, their aim is to characterize the regulatory controversies as they emerged, in as neutral a fashion as possible. This means for instance, avoiding making judgments about which scientists are "correct" or about which policy options best satisfy their personal conceptions of the public interest.

"Our epistemological position is at root what philosophers call realism. We do believe there is an
external world and that human knowledge of it can be improved, even though we must do so through the mediating process of concepts and theories and by using evaluating criteria that are our own creation." (Graham et al., 1988: 191)

However, these authors also insist that they are not claiming that what constitutes knowledge either can be, or is likely to be, agreed to by all participants in a policy dispute. This holds true for the scientific knowledge about benzene and formaldehyde they examine, as it does for their own case-study.

"... any characterization of what occurred may never be acceptable to all of those who participated. We do not believe that any observer can stand in some neutral or universal position outside the fray. Nevertheless, we believe that the idea of the knowledge conveyed by a study captures something very important about that study. And that something is also an unavoidable feature of any relevant account of the role of science in social conflict." (idem, 192)
4. William Leiss and Christina Chociolko; Risk and Responsibility: Towards Consensus in Environmental Controversies

This book is mainly about the interplay of risks and responsibilities and is driven by a simple and powerful proposition. In a society "hooked on risk", individuals and institutions alike have a vested interest in avoiding assuming full responsibility for the risks they take. Consequently, both systematically attempt to off-load the potential losses for the risks they initiate on other parties. The book elaborates on this theme in the light of some major controversies about health and environmental risks.

The first case-study involves concerns over the possible health effects associated with electromagnetic fields and power line frequencies. The second deals with Alar, a chemical used between 1969 and 1989 as a growth regulator for food crops. The third describes another protracted dispute over pesticides and concerns the chemicals called antisapstains that are used on softwood lumber products. In addition to these three large case-studies selected for their abundant documentation and because they address controversies representative of societal debates about environmental and health risks generally, three shorter studies (on Alachlor, formaldehyde and tobacco use) are presented with a
similar analytical perspective in mind: to show how the experts and the general public each calculate trade-offs between risks and benefits and how their estimates and assumptions result in the attribution of net benefits or losses to the activities considered.

"These types of controversies cannot be understood unless one is willing to delve deeply into the rival processes of reasoning and accumulation of evidence that the various parties submit for the public record and fight over in administrative hearings, courts, the offices of public officials, citizens' forums, and the media."

(Leiss and Chociolko, 1994: 259)

In all the case-studies, then, the analytical approach is similar. William Leiss and Christina Chociolko track the highly technical assessment of risks and benefits made by the experts and present an account of the public perception of these same elements. The case at hand serves to illustrate some of the specific ways in which the interplay between these two perspectives on risk can generate diverging accounts of a situation. The analysis, then, shows how these different accounts also provide as many rationalizations to escape responsibility for the risks chosen or promoted. The "Communications Processes Model of Risk Communication" by Leiss and Krewski gives a schematic representation of how the main stakeholders in these controversies array themselves in the domain of technical risk or of perceived risk, depending on the type of
Yet, representing the nature and articulation of the rationalities and rationalizations at play in these controversies only constitutes a first analytical step. Indeed, the case-study material is presented with a more essential purpose in mind, namely, to pinpoint key zones of disagreement in order to seek the grounds for possible consensus among the contending parties. In the Alar case-study, for instance, the main purpose of identifying the multiple perspectives corresponding to the different parties and their interests is to set the stage for an imaginary consensus exercise aimed at exploring possible avenues of agreement among the stakeholders involved.

"In our view, this methodical avoidance of responsibility by both individuals and institutions for the risks being incurred at their insistence - this dishonesty, to speak bluntly - is one of the chief sources of mistrust among the parties to risk debates, and also one of the chief obstacles to our arriving at a consensus on how to manage health and environmental risks." (Leiss and Chociolko, 1994: 259)

By forcing each of the constituencies with a different outlook on risk to publicly acknowledge their interest and those of others, the authors hope that the disagreements that have led to stalemate
situations in so many environment and health controversies can move towards consensus building. The most promising route to this end, it is argued, is for the major participants in risk debates to broaden their share of responsibility for the consequences of the positions they advocate on risk taking and risk averting. For industry and governments this means paying more attention to the basic needs of other stakeholders, and making available disinterested risk assessments that use the best available scientific methods; for governments proper, this means continuing to explore around the negotiating table ways in which responsible choices can be made in trade-offs between risks and benefits; and for public-interest groups, this means helping citizens move away from unreasonably risk-averse standpoints, where such exist, and trying to find ways of balancing their attitudes.

In sum, the authors' outlook on risk management is premised on risk communication and in agreement with Jasanoff's proposition that ...

"(...) the most promising way to foster communication among the actors [in the risk debate] is to have them acknowledge their stakes explicitly and to negotiate their differences openly."

(Jasanoff in Leiss and Chociolko, 1994: )¹
The works of Camille Limoges et al. investigate the development and characteristics of a number of public controversies involving technologies with potential health and environmental risks. Their analysis starts with the observation that the frequency and scope of public controversies over risks parallels increasing demands for public involvement in decisions over the use of technology. These demands, it is claimed, have translated into two polarized conceptions of public participation in decision making. One views the public role as strictly consultative, i.e., as an adjunct to the neutral and objective input of professional technology assessors whereas the other associates public participation with a redistribution of political power eventually leading to a new social order. For Limoges et al., however, these two alternative positions do not exhaust all possibilities but instead stake the outer limits of a wide manoeuvring space that exists between technocratic and participatory styles of decision-making.

This "controversist space" which extends between consultation and decision has become the main locus of the technology assessment process. When framing decisions over risks, the effectiveness of the expert-driven, formalized procedures of technology assessment is now constrained by the acuteness and significance of the mobilization taking place in the controversist space.
"In the absence of controversy, or in the case of a limited mobilization of actors, the formal methodologies of TA [technology assessment] get free room to inform and frame decisions. On the contrary, when the controversist mobilization is large, the latter tends to marginalize the contribution of expertise, to undermine the contribution of TA methodologies, whatever their rigour and exactness. Decision makers have then to cope, first and foremost, with the conflicting forces in the controversist space and to act in a framework constructed in a more exclusively political fashion. Most of the time, however, what happens is not that TA is out of play, but rather that it has been given its degree of freedom, its relative relevance and its effectiveness by the very dynamics of the controversy."

To develop a framework which accounts for the dynamics of controversies, Limoges et al. analyze a series of conflicts surrounding the development or implementation of controversial technologies. While in the end, the analysis leads to a set of general guidelines aimed at improving the management of public controversies, it must be emphasized that the thrust of their research effort lies in understanding the very process of controversy dynamics rather than on problem-solving.
This analytical stance is privileged because, rather than taking the nature of controversy as self-evident - as when controversies are seen as a product of public misunderstanding or as a failure of expertise - Limoges et al. conceive of controversies as both social practices and analytical endeavours. In other words, not only are the notions of controversy and of controversist space viewed as major components in the assessment of technology, controversies also constitute active practices of social learning which, by virtue of their experimental nature, also perform an important and self-reflective analytical role for the society in which they occur.

The detailed empirical material gathered in their case studies shows that the structure and unfolding of controversies is largely conditioned by the contingent patterns of interactions prevailing among a specific set of actors. While this calls into question the very possibility to design a "general theory of controversies", their analysis nevertheless yields a series of provisional conclusions which can be used to elucidate the complex processes played out in the controversist space. Some of these "middle range generalizations" are briefly introduced in the paragraphs that follow.
1) **Controversies over risks are sui generis social phenomena.**

In contrast to traditional approaches which posit that risks are the source of controversies, Limoges et al. argue that controversies are actually the cause of risks. Risks and/or their perceptions are not naturally given. Rather, the construction of a particular issue qua risks and the actual content of a controversy obtains from the local modalities of interactions between actors -- which is to say that "the content of a public controversy is its context".

2) **To understand public controversies it is necessary to abandon the bi-polar model opposing the experts and the public.**

The validity of this model is undermined by the fact that, on the one hand, there is no singular force which can be labelled "scientific experts". The controversy over genetic engineering, for instance, could not have been sustained without widely divergent viewpoints being expressed by *bona fide* scientists of diverse disciplines and persuasions.5

On the other hand, the term "public" is more a rhetorical resource used by social actors in conflict than an actual actor or group of actors. For example, a textual analysis of the claims made by some 70 groups participating in the 1981-1985 Quebec controversy over the aerial spraying of chemical pesticides to fight the spruce-
budworm, yielded about half a dozen markedly different configurations corresponding to as many ways of defining the nature and scope of the problem, the solutions, and the relevant actors involved in the controversy.

"Each group engaging in a controversy - and by the term 'group' we are not referring to some pre-defined sociological category but, rather, to an empirical unit of varying size such as, for instance, the authors of a brief - has much latitude to construct in its own way both the various entities that will inhabit that controversy, and the relationships that are supposed to exist between these entities. This amounts to defining what that controversy ought to be about. We have chosen to refer to these particular collections of entities and relationships by the term 'worlds of relevance'. Empirical analyses of hearing transcripts, briefs, leaflets and other documents written and circulated during controversies show that there are always more than two worlds of relevance in the course of a single controversy, sometimes many more than two. They evolve over time, and may converge or diverge."

This diversity in the "worlds of relevance" at play characterizes not only the spruce-budworm controversy but also other cases analyzed, such as the controversies over genetic engineering
research and the field testing of genetically modified organisms in the USA and Canada, the irradiation of food, Quebec's approach to waste management, and others.\

Thus, controversies are not first defined, and then opened up for public participation. Rather, the controversist space is viewed as being highly extensible with no statutory barrier to participation. It is the participants themselves who, by engaging in a dispute and generating interchanges, progressively shape the controversy and define its boundaries and content.

Given the heterogeneous and unpredictable nature of the groups and entities mobilized during controversies, the latter cannot be reduced to debates between two conflicting sides. Rather they are "hybrid fora" with their own particular dynamics – and it is this which must be analyzed.

"... what is at issue during a controversy is the negotiation of the associations which should be established between the various worlds of relevance mobilized by different participants. Such associations are not a priori defined; rather, they are the emergent outcome of the participants' activities."

The various worlds of relevance that give a controversy its particular shape cannot be inferred a-priori as so many foreseeable
inputs to a controversist space whose boundaries have been defined before hand.

"... the production and stabilization of actors and entities is inseparable from the unfolding of the controversy, and counts among its stakes." 3

In contrast to the "reductionist view" of public controversies which envisage the latter as conflicts between the public and the scientific experts, Limoges et al. assert that these processes are more fruitfully understood as "polycentric processes".

"We ought to apply here the sociologists of science's 'principle of symmetry', in a new guise: equality of analytical treatment is called for not just in regard to two parties, but in regard to all the worlds of relevance represented in and constitutive of a controversy." 3

3) **Controversies are not primarily battles of ideas, but rather processes aimed at decisions for action.**

Scientific controversies, insofar as they are equated to exchanges among scientists trying to ascertain what ought to be accepted as truth, aim at consensus through the exchange of arguments. Public controversies, on the other hand, are eventually settled by public decision-making processes which aim, not at consensus, but at
socially acceptable decisions.

"... as a general rule, we would argue that public controversies do not meet closure by consensus. The divergent actors with their concomitant viewpoints do not finally reach consensus, unify, and thereby end the controversy. There are, no doubt, many reasons for controversies ending or fading out, and the basis for that is not altogether clear; yet, closure apparently occurs when opponents realize that the odds are against them and that arguing for or maintaining their particular point has become too 'expensive' in terms of resource or credibility." 

Public controversies do not end when the public is "adequately informed" or because decisions reflect some "popular will" or wish of the 'public'. Rather, closure is achieved through robust decision making which is predicated upon the ability to reflect the interactions of actors, and upon the extension and strength of the network created through these interactions. In other words, the main condition for robust decision is strong association.

This is the reason why the text of decisions which provide a robust closure to a controversy often attests to a careful articulation of the entities present in the different worlds of relevance deployed during the controversy. In the case of the spruce-budworm
controversy, for instance, Limoges et al. point to the Quebec government’s decision which ended the controversy. This decree incorporated more than 30 such entities originally absent from the initial framing of the issue to reflect the major associations among worlds of relevance which had emerged during the controversy.¹²

Thus, the most decisive factor in the unfolding and settling of controversies may well be the state of the regulatory apparatus and the relative degree of confidence towards the institutional implementation of regulations. The case-study of the controversies over rDNA, in particular, shows that public decision making bodies played a central role in this controversy. Controversies, then, are seen as largely conditioned by developments on the regulatory scene.

"So, increased analytical attention should be devoted to the development and functioning of regulatory devices. (...) In general, one should be particularly attentive to the establishment of links between the implementation of regulatory tools and the standardizations and codification of the heterogeneous entities which are mobilized during a controversy."¹³
The second part of this thesis presents a case study of the controversy over PCBs in Canada. This case study draws upon several of the methodological precepts that were instrumental in developing the case studies reviewed in this chapter. The PCB case-study is made of four chapters which sequentially review the information pertaining to the risk assessment, risk management and risk perception of PCBs. The fourth chapter analyses this empirical material in terms of the main themes about risk communication and risk management discussed in chapter one and two. This section introduces the methodological approach selected for constructing the PCB case study and justifies the approach and chapter breakdown chosen in light of the case studies reviewed above. Some justifications are also advanced to explain why this particular case-study was selected.

As the case studies reviewed in this chapter exemplify, theoretical stance and the treatment of empirical data are intimately linked. While the PCB case study is similarly informed by a set of theoretical propositions about risk communication and risk management, it also tries, in some important ways, to let the data drive the analysis. In other words, a deliberate and constant effort has been made to hold the descriptive and the normative in constructive balance.
For instance, the decision to view the PCB controversy as both a technical and a cultural phenomenon and to conduct the analysis along lines that suggest an expert-public divide on this issue (as suggested by Krimsky et al. and Leiss et al.) is based on a combination of theoretical and empirical evidence. In the first instance, the volumes of scientific information pertaining to the expert assessment of PCBs as well as the great number of regulations and rules that have been generated to control these compounds warrant that careful consideration be given to elucidating the "expert" approach to the PCB problem. This could only be achieved through a relatively thorough review and exposition of this empirical material.

Secondly, several case studies introduced in this chapter also explicitly argue that it is not possible to get a meaningful grasp of environmental controversies without accounting in some ways for an understanding of risk which is "other" than the one predicated on science and rational thinking. Although it is not being argued here that this other a-rational understanding of risk is exclusive to the public or that, conversely, non experts do not routinely employ rational though processes, the claim that the ways in which scientific and regulatory actors address the PCB problem only provides a partial account of the PCB controversy is viewed as well grounded.
Indeed, over the last twenty years, PCBs have come to represent many different things to many different people. At the very minimum, these chemicals now exhibit a "split personality". On the one hand, PCBs constitute a particular class of chemicals with useful industrial applications but potentially dangerous toxicological properties, an unfortunate specificity which can be partially remedied through various targeted actions. On the other hand, as controversy about the management of these compounds increased, PCBs progressively took on a new identity that is broader and more complex than the expert definition of the PCB risk problem, generally expressed as the sum of their physico-chemical, industrial and regulatory properties.

For example, there is much empirical evidence to suggest that PCBs have received enough publicity to force their way in the collective Canadian consciousness as the archetypal environmental villain. For the Canadian public at large, the acronym "PCB" now personifies a whole gamut of environmental menaces and is often used in public discourse as a reminder of the inability of regulatory bodies to successfully deal with health, safety and environmental issues. For this reason it seemed appropriate to dedicate an entire chapter to the "public perception" of these compounds and to balance the expert rational accounts of the PCB problem with a chapter that would seek to explain how the acronym PCB had come to assume a very special and symbolic meaning in the Canadian consciousness.
Thus, because the bulk of the empirical information on PCBs reviewed for this thesis arrayed itself almost naturally as either technical in nature or as pertaining to public perceptions, the choice is made to ground this account of the controversy on the approach suggested by Krimsky et al. (1988), Leiss (1989), and Leiss et al. (1994). In practice, this methodological choice translates into a chapter breakdown that sequentially addresses the expert (chapters four and five) and public views (chapter six) on PCBs. However, while this approach appears justified to describe the development of the PCB controversy up to this point in time, Limoges' suggestion that health and environmental controversies are best analyzed as "polycentric processes" would need to be given greater consideration in subsequent studies having as a focus the future management of this controversy.

Chapter four, which presents a chronological and thematic account of the scientific findings making up the risk assessment of PCBs, was particularly challenging to write for someone not trained in the natural sciences. Fortunately, the task was facilitated by Graham et al. case studies on benzene and formaldehyde which provided a stimulating model to follow. Because their case studies are extremely successful in communicating the complexity of the scientific knowledge involved in risk assessment science in terms that make the intricacies of this knowledge intelligible and meaningful to the layman, their work was a precious source of inspiration for the writing of chapter four.
Their case-studies, along with those of Krimsky et al. (1988) and of Leiss et al. (1994) were also a useful guide in the attempt that was made to present an accurate, truthful and relatively detailed rendering of the scientific findings on PCBs, while at the same time, trying to keep in perspective the larger significance of this information for policy decisions. Finally, chapter four’s focus on the sources, nature and scope of scientific uncertainties in PCB risk assessment was prompted by Graham et al.’s provocative observation that, because it increases the range of plausible risk estimates, more scientific information may result in more rather than less scientific uncertainty. It is hoped that, overall, chapter four is both meaningful and true to the scientific knowledge base on PCBs and that it contributes to casting some additional light on the sometimes paradoxical relationship between "information" and "uncertainty" in risk assessment.

Chapter five evolved out of a need to account for the complex set of regulations and protective measures which, since the early Seventies, have grown to control public and environmental exposures to PCBs. Although originally the description of this regulatory framework was to be incorporated in chapter four, Limoges' recommendation that the development and functioning of regulatory devices be given more analytical attention resulted in a separate chapter. In addition, numerous references to the PCB regulatory net were found in scientific reports and in the press. This, combined with the fact that in all the case-studies presented
above, substantial attention is dedicated to the description of regulatory tools, further justified having an entire chapter on this subject.

Whereas chapter four and five are concerned with the expert assessment and management of PCB risks, chapter six then illustrates how non-experts can construct and impose competing explanations for the same set of events. It must be emphasized, however, that this chapter was designed to describe the ways in which PCBs entered the public domain and to account for the identity of "PCBs as a public figure" rather than to reify a monolithic public.

Finally, chapter seven concludes with a discussion of the empirical material gathered for the PCB case study in terms of the theoretical propositions about risk communication and risk management that were outlined in the first two chapters of the thesis. Some important shortcomings in the communication and management of PCB risks are outlined and ways to improve these activities are suggested. In the process, some answers are proposed to the following set of questions which was developed by Krimsky et al. to elucidate controversies over other toxicants. How were the risks of PCBs addressed by the major parties to the controversy? What was the nature and role of the scientific evidence? How did conflicts about the appropriate role of government in managing risk affect the process of risk
communication and risk management? What role did the media play? What factors were determinant in the unfolding of the controversy? Could things have happened otherwise?

If overall, this case-study presents a sociological perspective on the risk communication and management of PCBs, it also tries to avoid any sociological reductionism. While the analysis seeks to account for the sociological and technical components of the controversy, it does not force an integration of these two dimensions by reducing one to the other and by claiming, for instance, that "the PCB problem" boils down to its political dimension. Quite the contrary. The description of the complex nature of the PCB inventory presented in chapter five, for example, serves to illustrate how the siting of treatment facilities to dispose of PCB wastes is conditioned by a number of technical parameters and exhibits an irreducible engineering dimension. All that is claimed here is that, to be successful, decisions relative to the management of PCBs have to hold the political and technical dimensions of the PCB problem in something like a proper tension.

Finally, it must be noted that a number of reasons pointed to the controversy over PCBs as the case-study of choice for a thesis on risk communication and risk management in Canada. First, the drawing together of the information pertaining to the expert assessment of PCBs and to the public perceptions of the same had not yet been performed. This is somewhat surprising given the
unusual attention this controversy aroused at the local and national level and among a full cross-section of the Canadian population. Such attention could, by itself, attest to the significance of the case.

Furthermore, since the PCB controversy is well documented, sufficient empirical evidence is available to present a relatively comprehensive account of the case. While there is always a risk when one relies on a single case, that the analysis will be distorted by idiosyncratic features, the examination in the academic literature of the themes that play out in a range of other risk controversies, shows that the PCB case is not an aberration. Rather it exemplifies, albeit in some extreme ways, several of the communication problems that are recurrently associated with health and environmental conflicts. In particular, the PCB controversy is revelatory of the difficulties risk management institutions increasingly encounter in communicating with a public that has become most sensitive to health and environmental issues. Thus, not only does the PCB controversy provide an interesting case-study for the testing of theoretical propositions on risk communication and risk management, it is also a area of research where practical recommendations could be instrumental in providing relief to a relatively problematic and troubled area of Canadian public policy.
PART TWO: POLYCHLORINATED BIPHENYLS

A CASE STUDY IN RISK COMMUNICATION
1.1 The PCB Saga; An Overview

The commercial production of PCBs began in the United States in 1929 in response to growing concern over the risk of fires created by oil-filled transformers and capacitors. Most transformers and capacitors are filled with a dielectric (isolating) fluid which acts as an insulator and a heat exchanging fluid to prevent overheating. However, power surges in electrical equipment can cause arcs, and a sustained high-energy arc can ignite mineral oil. Increasing occurrences of fires led the electrical industry to search for an alternative dielectric fluid. Beginning in the 1930s, a generic fluid called "askarel" containing 40 to 70% PCBs was introduced as a replacement product for mineral oil in electrical equipment where fire reduction was a concern.

By 1940, PCBs were widely used as insulating fluids in electrical and accessory equipment. PCBs are relatively fire-resistant, very

\[1\] Capacitors allow for the more efficient use of electrical power by automatically correcting the power factor.
stable, resist oxidation, do not conduct electricity, and have good heat transfer properties. These and other characteristics made them desirable components of a wide range of industrial and consumer products.

Although their main use was as dielectric fluid, the number of industrial applications in which these compounds found their way is extensive. For instance, PCBs were used as components in carbonless copy paper and in printing-ink and de-inking fluid for newsprint; as surface coating for washable wall coverings and upholstery fabric; as plasticizers in sealants, caulkings, synthetic resins, rubbers, paints, adhesives, waxes and asphalts; as flame retardants in lubricating oils and hydraulic fluids; as volatilization suppressants in pesticide formulations, and as dust suppressant on roads.

For the first 35 years of their use, few concerns were raised about any negative impacts of PCB compounds. But in 1966, a team of Swedish scientists looking for traces of DDT in wildlife samples ascertained the presence of PCBs in the fatty tissue of wild birds. This discovery alerted the scientific community to the possible existence of a new and yet unrecognized environment contaminant. Subsequent investigations revealed the widespread distribution of PCBs in the environment.
In 1968 an undetected leak from a heat exchanger used in a food processing plant in southern Japan led to the contamination of cooking oil with PCBs (Yusho) and the poisoning of 1200 people. A broad spectrum of toxic effects including chloracne and related dermal symptoms was observed among the victims. Developmental problems in infants born from mothers having consumed the contaminated rice oil were also reported. Although it was later established that the severe acute and chronic effects had been caused by polychlorinated dibenzofurans (PCDFs) and polychlorinated quarphenyls (PCQs) rather than by PCBs alone, the Yusho incident focused public and scientific attention on PCBs.

It is often noted with irony that some of the same properties which made PCBs such superior industrial chemicals, i.e., their stability and resistance to chemical and biological breakdown, also made them environmentally hazardous. When discharged in urban or industrial areas they can be carried away by fine airborne particulates and thus spread by airborne transport to the most remote locations. Their low water solubility also causes them to become attached to sediments at the bottom of rivers, lakes and oceans where they can be absorbed by fish and other aquatic organisms. Moreover, PCBs accumulate in the fatty tissues of living creatures, so that they become more concentrated as they travel along the food chain. Minute quantities of the compounds can build up overtime to levels that cause biological injury.
Since the early 1970s, reports have confirmed the presence of trace quantities of PCBs in ambient air, water, and soils. PCBs have been found in the oceans of the world, in fresh-water fish of tundra lakes, in Arctic bears, as well as in human beings throughout the world. Measurable quantities have been observed in the tissues of persons with no known PCB exposure. There is evidence that most people living in industrialized nations have a measurable concentration of these chemicals in their bodies.

The health effects of PCBs on living organisms have been the focus of extensive scientific research which has proceeded largely on the basis of experimental laboratories studies. PCB accumulations in some sensitive animal species have produced birth defects and affected their reproductive processes, enzyme and immunity systems. Cancers of the liver have been observed in rats fed diets containing large amounts of PCBs. In humans, the known toxic effects result primarily from occupational or accidental exposure to PCBs and include chloracne, eye discharges, headaches, vomiting, fever and visual disturbances. No conclusive, direct relationship between cancer and human exposure has ever been established.

The serious health effects observed in wildlife and laboratory animals together with the ability of PCBs to persist and accumulate awakened the interest of the scientific community. By 1972, scientists and environmental experts were expressing serious concern about the health and environmental risks caused by long-
term exposure to these compounds. As the extent of PCB contamination was discovered, their commercial production was curtailed and their uses strictly regulated in Canada and in most industrialized countries of the world.

From the 1930s' to the early 1970s, PCBs used by various industries, resulted in a world-wide production of about one million tonnes. Of this amount, approximately 635,000 tonnes were produced in the U.S. by Monsanto Chemical, the world largest producer and sole North American manufacturer of PCBs. Canada never produced PCBs but its imports in the same period have been estimated at approximately 40,000 tonnes. During this forty-year time period, the wastes generated by the scrapping of PCB-contaminated equipment and products were disposed of without special precautions.

Large amounts of PCBs have thus been released in the environment through disposal in open landfills, incomplete burning of municipal wastes containing discarded PCB products, leakage into sewers and streams, illegal dumping, and accidental spills. In 1985, Environment Canada inventory indicated that a total of 24,300 tonnes was either in use or in storage across the country. The remainder - equivalent to about 40% of the imported amount - can no longer be accounted for and is assumed to have entered the environment.
In 1977, the manufacture, importation and most non-electrical uses of PCBs on the North American continent were banned. Since that time, the electrical applications of PCBs in closed systems (e.g., in generators and capacitors) is being phased out and PCBs are subjected to stringent requirements for handling and disposal. Safer alternatives have been found for PCBs in all of their previous applications.

However, bans and restrictions are not absolute. PCBs are still being used and loading in the environment continues from a variety of known and unknown sources. Several technologies are available to treat discarded PCB material but several factors have combined to slow their application. These include i) public anxiety towards PCBs and hazardous waste destruction facilities; ii) the lack of regulatory requirement to destroy PCB wastes; and iii) the costs associated with treatment and disposal technologies.

This chapter presents a qualitative overview of the scientific knowledge pertaining to the environmental and toxicological effects of PCB compounds. It starts with some general observations concerning PCBs’ chemical composition.

1.2 PCBs? What Are They?

PCBs were first synthesized before the turn of the century and have been used in commercial applications since the 1930s. The
extensive analysis of these chemicals followed their discovery in environmental samples in 1966.

The identification of PCBs' ubiquitous presence in the environment was the result of a serendipitous discovery. In 1964, a team of scientists looking for traces of organochlorine pesticides in the sample tissues of Swedish birds observed a series of unexplained patterns on their gas chromatograph. Gas chromatography analysis is a conventional technique used for isolating individual chemical substances in environmental samples. Each substance is identified by comparing several diagnostic peaks produced by an environmental sample on the chromatograph with those of standard known substances.

It took two years for Jensen and his colleagues to successfully attribute the origin of these unknown peaks to the presence of PCBs in wildlife samples. Their findings led to the publication of a report entitled "PCB -the DDT Problem of Industrial Countries" (National Institute of Environmental and Health Sciences, 1972: 179).

Polychlorinated biphenyls belong to a class of man-made, chemical substances known collectively as chlorinated organic compounds. Their actual chemical composition is worth considering briefly for it is at the core of many of the difficulties that have emerged in analyzing the environmental dispersion and toxicity of these
compounds. The name "polychlorinated biphenyls" pertains to a group of chemicals consisting of chlorine, carbon and hydrogen. The name refers to the process by which PCBs were manufactured. Polychlorinated biphenyls are chemical compounds comprised of a biphenyl molecule with chlorine substituents.

Biphenyl is a substance created from benzene which in turn is obtained from coal tar. A benzene molecule consists of six atoms of hydrogen and six atoms of carbons with the carbon atoms arranged in an hexagon called the benzene ring. The six hydrogen atoms are attached to the outside of this ring, one to each of the carbon atoms. A biphenyl molecule is composed of two benzene rings attached to one another by a bond between a carbon atom on each ring (Egginton, 1980: 90).

The chlorination of biphenyl leads to the substitution of some of the hydrogen atoms by chlorine. In commercial production, this substitution is achieved by adding a catalyst (eg, iron) to chlorine and biphenyl, and by "cooking" them together at very high heat. The prefix "poly" implies a certain latitude as to which and how many of the hydrogen atoms are replaced.

The substitution of up to 10 chlorine atoms at various locations on the biphenyl molecule can, in theory, result in 209 discrete synthetic compounds also called congeners. More than 100 PCB congeners have been identified in environmental samples (Strachan,
It is important to bear in mind that commercial "PCBs" are in fact mixtures of a number of compounds. Monsanto assigned the trade name "Arochlor" to its PCB mixtures. Typically, Arochloirs are mixtures of 50-70 individual PCBs. Between 1957 and 1971, twelve different types of Arochloirs were manufactured by Monsanto. Further, different batches of the same Arochlor can vary in their composition (de Voogt et al., 1989: 26-27).

While the distribution of individual congeners may vary significantly from one PCB mixture to the next, this has little effect on the mixture's technical performance in industrial applications. In fact, commercial PCBs have not been sold on a composition specification but on their physical properties. Only the mean percentage chlorine needs being controlled to give the mixture its required technical properties. This has resulted in a scarcity of data concerning the physico-chemical properties of individual PCB congeners and their precise distribution in various PCB mixtures (World Health Organization, 1976: 19; de Voogt, 1989: 30).

2 The brand name Arochlor is usually followed by a number indicating the average degree of chlorination. For example, Arochlor 1260 represents a biphenyl, i.e. twelve carbons (12), chlorinated to 60% (60). Various series of PCB mixtures have been marketed under different trade names: Chlofen (Germany), Airoloio (Italy), Kanekoil (Japan), Pyralene (France), Pyroclor (Great Britain), or Sovol (USSR).
This is important because the environmental persistence and relative toxicity of PCBs are a function of the structural characteristics of the chemical. In the words of S. Safe,

"The biologic and toxic effects of PCBs are structure-dependent and the adverse environmental and human health impacts of the different mixtures of PCBs are related to the individual components of these mixtures and their interactions." (Safe et al., 1987: 1)

1.2 Implications Relative to PCBs Chemical Composition

Many discrepancies encountered in data reporting on the distribution and effects of PCBs have been attributed to a failure to take into account the chemical complexity of these compounds. In fact, much of the world data pertaining to commercial formulations and environmental extracts has been reported as "total PCBs" (World Health Organization, 1976: 15).

In addition, to PCB mixtures comprising many different congeners, the manufacturing of PCBs can lead to the formation of small amounts of unintentional by-products. Impurities known to be present in some commercial PCBs include chlorinated dibenzofurans (PCDFs), chlorinated quarphenyls (PCQs) and chlorinated naphtalenes (PCNs). Here again, the quantity of impurities may well vary according to the mode of synthesis used in the manufacturing
process and from batch to batch (Kimbrough, 1980; National Research Council of Canada, 1984).

Finally the dielectric and cooling fluids widely used in the electrical industry which go by the name of "askarels" contain organic solvents and thus are not 100% PCBs. The presence of these other chemicals further influences the chemical and physical properties of PCB fluids.

The need to identify individual congeners in commercial formulations and environmental samples has been emphasised soon after PCBs' ubiquitous presence in the environment was acknowledged. Unfortunately, the majority of environmental residues used to estimate world inventory and environmental trends has been reported as PCB undefined. This is partly a result of analytical deficiencies, partly a result of complexities in data reporting and interpretation.

More recently, the increasing use of specific congener analysis has produced a more reliable data base permitting more accurate evaluations of PCB problems and trends. Paradoxically, this has also resulted in an immense amount of information most of which has not been thoroughly evaluated.

Overall, the variable composition of PCBs has had three main consequences:
"Firstly, analytical methodologies and quantitation procedures can be quite complicated; attempts to streamline these techniques led to inconsistent and frequently incomparable results from laboratory to laboratory and from time to time as techniques were modified.

Secondly, different mixtures of congeners tend to mobilize differently, partition into different phases, and have different degrees of persistence/degradability.

Thirdly, the biological activity differs markedly, both qualitatively and quantitatively among isomers as well as congeners with different degrees of chlorination." (Hansen, 1987: 20-21)

This chapter documents the ways in which expert knowledge has been exerted in assessing the environmental and health risks posed by PCBs. Exposure data (environmental dispersion and population burden) and toxicity data (animal studies and effects on humans) are examined sequentially. The presentation outlines the data gaps and methodological problems that have been encountered throughout the development of this knowledge base. It also shows how much was already known about PCBs in the early 1970s.

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1 (my emphasis). The isomeric composition of a PCB congener refers to the specific position of chlorine substituants on the biphenyl molecule rather than to its degree of chlorination.
2. Environmental Dispersion

2.1 Knowledge and Data Gaps in the Early 1970s

2.1.1 PCB Distribution and Environmental Transfer

Early estimates concerning the distribution of PCBs in the North American environment indicate PCB concentrations in three major compartments: buried in landfill dumps; attached to sediments in rivers and the Great Lakes; and attached to the continental shelf (NIESH, 1972: 34).

The modes of transport of PCBs in the environment are known to be complex. In principle, the rates of transport of a contaminant may be calculated on the basis of its physico-chemical properties and of pertinent data on atmospheric conditions. However, scientific reviewers are adamant that PCB data available at this time is too fragmented - and the interactions between the different elements in the environment too complex - to determine anything but a very speculative model of environmental transfer.

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4 The discussion in this sub-section draws on three reports, each of which presents a synthesis of the scientific knowledge on PCBs. They are i) a 1972 Review by the Panel on Hazardous Trace Substances in the U.S. (thereafter referred to as PHTS, 1972); ii) a 1972 publication of the National Institute of Environmental Health Sciences also in the U.S. (thereafter referred to as NIEHS, 1972); and iii) a 1976 report of the World Health Organization (thereafter referred to as WHO, 1976).
Rough estimations of some of the otherwise unknown routes and rates of transport of PCBs have been inferred from the distribution of DDT which, to some extent, resembles PCBs in its physical and chemical properties and about which more was known. Thus, PCBs vaporized during the incomplete (low-temperature) burning of municipal wastes are expected to be partially adsorbed on particulates, transported with the prevailing winds, and deposited on land or water by particle sedimentation or rain-out. When introduced into water streams, PCBs may be adsorbed by waterborne particulates and then diffused at the bottom sediment.

The transfer of PCBs within the environment is thus suspected to take place by the following main routes: i) volatilization, aerial transport of particulates and fallout; ii) leaching from dumps; iii) transport of sediments in river and the shallow sea; and iv) sedimentation in the ocean (PHTS, 1972: 282). It is generally acknowledged, however, that the development of reliable environmental transport models is limited by the sparsity of data on partition coefficients between aqueous solutions, air particulates and water sediment.

2.1.2 Data Gaps

The fact that PCBs are not single compounds has produced obvious difficulties in assessing their environmental dispersion and resulted in less sensitive analyses for PCBs than for the
chemically distinct organochlorine pesticides. While the properties of PCBs associated with their industrial applications are well documented, attempts to deal with the environmental transport and distribution problem have been frustrated by a lack of understanding of the alteration of PCBs by biological systems at all levels (NIEHS, 1972: 182).

Various PCB mixtures are known to react differently in the environment. For example, it was observed that commercial PCBs with fewer chlorine atoms tend to vaporize and dissolve preferentially, and degrade more readily to form new chemical arrangements. They also display a lesser tendency to bioconcentrate than PCBs with a higher degree of chlorination. However, no clear pattern relative to the mobilization of the various PCB congeners in the environment has yet emerged (PHTS, 1972: 270).

The evidence for the atmospheric dissemination of PCBs is derived mainly from their virtually universal distribution in the global environment and from their presence in areas that receive no pollutants save those that are present in the fallout of the atmosphere. First detected in species of Swedish wildlife, PCBs were subsequently discovered in seals from the North Atlantic, in fish and birds from the Netherlands, and in a broad variety of both terrestrial and marine species of wildlife in North America (NIEHS, 1972: 39).
The concentration of PCBs in living organisms - although a minor route of PCB transfer - has been a focus of attention because of its major biological significance. The biological magnification of PCBs results in highest concentrations being found in the predatory species at the top of the food webs. The extent of biomagnification depends upon several factors including the extent of local pollution, the amount of fat in animal tissues, and the trophic stage of the organism in the food chains (WHO, 1976: 12).

The highest concentrations of PCBs were found in marine ecosystems and in fish-eating and scavenging birds (herons, terns and eagles) as well as in predators of marine birds (falcons). High PCB levels among other top predators were reported in seals from Sweden, Finland, Scotland and Nova Scotia, in the fat of grey seal pups in Southwestern England and in the fat of porpoises and from the liver of white shark in the Bay of Fundy, Canada. Yet,

"Although PCB concentrations in living organisms clearly indicate a progressive accumulation in food chains, [data gaps] make it impossible to give any reliable figure for bio-accumulation at each trophic stage." (WHO, 1976: 32)

An improved understanding of their environmental behaviour could be obtained from a better acquaintance with the commercial product themselves, but such attempts have been frustrated by the scarcity
of data provided by manufacturers. Of the many industrialized nations producing PCBs, Japan and the U.S. are the only two countries to have made production figures available. However, data made public by Monsanto for Arochlor PCB produced between 1960 and 1970 were for total PCB production only. Lack of data on global production, international trade, and patterns of use has produced additional difficulties in assessing the environmental dispersion of PCBs (NIEHS, 1972: 40; PHTS, 1972: 271).

In summary, the limited scientific understanding of the solubilities, vapour pressures, and metabolism of individual PCB isomers combined with insufficient information on PCB production and uses has curtailed the generation of useful scientific knowledge concerning the distribution and transfer of PCBs in the environment.

2.1.3 Methodological Issues

In addition to data gaps per se, discrepancies in data sampling and treatment have further complicated the interpretation of research results. This is evidenced by requests for "standardization of methodology" which are a prominent feature on most research agenda drawn during this period. Interlaboratory comparisons are generally recommended to validate the determination of PCB residues, especially when those are below the part per million range (PHTS, 1972: 347).
This concern is echoed by the World Health Organization which notes that while all share common features, "no two laboratories have the same methods for the determination of PCBs in environmental samples." For example, there is disagreement concerning which tissue level should be used in the calculation of PCB concentration in animal populations - that of the whole body, the fat or the liver (WHO, 1976: 19, 32). Finally, it is recommended that rather than emphasizing the statistical accumulation of data, priority be given to the coordination of approaches to sampling and modelling techniques (NIEHS, 1972: 35).

Overall, the 1972 Review Panel on Hazardous Trace Substances was of the opinion that:

"Sampling of the environment for PCBs has so far been unsystematic and has consisted mostly of surveys of levels in fish and birds. Very few measurements are available of PCB levels in air or water, and no measurements have been published of levels in soils."

"As yet little is known of the distribution of PCBs in terrestrial environments. No studies have been reported of the uptake of PCBs from the soil by fauna or by plants, from plants by herbivores, or from herbivores by carnivores."
"However, perhaps the major finding of this study is that research on the environmental effects of PCBs has been piecemeal and insufficiently coordinated. Despite the large number of detailed studies of PCBs conducted in the last four years, it has proved difficult to assemble the results into a coherent picture because important pieces of the puzzle are missing." (PHTS, 1972: 305, 255, 257)

2.2 Knowledge and Data Gaps in the Late 1980s

The bulk of the information presented below originates from a 1988 report published by Environment Canada. It is to date, the latest review on the concentrations of PCBs present in the various constituent parts of the Canadian environment (air, water, soil, biota). Additional considerations pertaining to environmental trends are mostly from Hansen (1987). While offering specifics to the national situation, a great deal of the information contained in the 1988 report builds upon the findings and observations outlined in the previous section.

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5 This report entitled "PCBs - Fate and Effects in the Canadian Environment" (Strachan, 1988) is an update of an original review entitled "Report of the Task Force on PCBs" prepared jointly by Environment Canada and Health and Welfare Canada in 1976. This 1976 report was part of a Canadian response to a 1973 OECD decision regarding PCBs (see chapter 5, section 2.1).
2.2.1 General Considerations

The 1988 report upholds the conclusions of the original 1976 study which found extensive PCB contamination in most parts of the country with the Great Lakes being an area of particular concern. However, current (1988) data also indicate a reduction in the PCB levels in the Great Lakes biota so that the original disparities between this area and the rest of the country are less pronounced (Strachan, 1988: x).

Within the Great Lakes system itself, PCB load is declining in the more contaminated areas (Lake Ontario) but it is increasing in less contaminated areas (e.g., Lake Superior). This may not be specific to Canada but partake of a more general continental trend. Indeed, it has been noted elsewhere that the mean and maximum PCB residue levels in wildlife samples appear to be declining in highly contaminated areas. At the same time however, the frequency of detectable residues in all classes of vertebrate wildlife is increasing (Hansen, 1987: 43).

Various forces of dispersion, particularly atmospheric transport, are assumed to be responsible for this levelling effect. The fact remains, however, that data gaps and differences in interpretation still preclude any definitive conclusion as to the precise fate of PCBs released in the environment (Strachan, 1988: xi).
The general consensus is that PCBs degrade rather slowly and that their "removal" from the open environment largely consists of dispersion or dilution, the alternative being covering up via sedimentation. Transportation out of one system to another simply passes the problem along to the receiving system (Strachan, 1988: 11-12; Hansen, 1987: 44).

The 1988 reports reiterates the fact that various PCB mixtures have different qualitative and quantitative biological activities, and that these differences can be attributed to the relative concentrations of isomers and congeners present in these mixtures. Yet, although "a true understanding of PCB environmental behaviour will require evaluation on a congener-specific basis" almost no comparable data exist for congener-specific environmental residue levels (Strachan, 1988: 10).

The new data also corroborates the earlier finding that lower chlorinated isomers degrade faster, with environmental residues usually producing patterns resembling the higher chlorinated mixtures of congeners. Yet, principles to account for PCB dispersion in the environment were still, as of 1988, not fully understood:

"There is no single parameter or even a suite of chemical-specific parameters currently available that would allow the quantitative prediction of the rate of
degradation of PCBs in any particular environment -- other than measurement in the system itself." (Strachan, 1988: 12)

"As important as water solubility, vapour pressure, and partition coefficients (water/oil and water/air) are to PCB disposition, there does not seem to be good general agreement on these properties. (...) Reported partition coefficients can differ by two orders of magnitude or more." (Hansen 1988: 24-25)

This particular point can be illustrated by the disagreement concerning whether the waters of the Great Lakes are currently serving as sinks for or sources of atmospheric PCBs in the region. Contrary to previous expectations, some research is now indicating that - "currently there is a net diffusion of PCBs in the Great Lakes from the sediment to the water to the air." This means that the net movements of PCB loads has reversed direction due to a decrease in rain and other PCB inputs to the lakes. If indeed this was confirmed, such trend could constitute evidence for the curbing of PCB discharges in the region and subsequently attest for the effectiveness of PCB regulations that have been put in place in the last fifteen years. This trend is difficult to evaluate, however, for the aquatic environment is probably serving both as source and sink for the dynamic PCB load in the atmosphere (Strachan, 1988: 11-12).
2.2.2 Data Gaps and Methodological Issues: 

The Canadian Situation

An aspect of some concern to the evaluation of national PCB exposure estimates is the paucity of data from some Canadian regions. More specifically, few data are available from the pacific and Yukon regions and from the territories part of the western and northern regions. Sediment data is limited to the three eastern region (Atlantic, Quebec, Ontario).

Overall, the data available show a wide disparity in the number of sites examined, the number of samples collected, and the number of those samples in which quantifiable amounts of PCBs are present. For these reasons, the 1988 report recommends monitoring programs for PCBs which are based upon fewer stations with more frequent sampling so as to provide comparability over time as well as between different parts of the country.

Analytical methodologies and quantitation techniques are often cited as critical factors which result in equivocal PCB residue data. For example, some of the more useful data showing PCB trends in the atlantic region are from seals. One study reporting on 1982 grey seals from Sable Island, Nova Scotia, shows little reduction in PCB levels from levels reported in a study conducted six years earlier. Indeed, in the case of pup blubber, the levels were slightly higher (in Strachan, 1988: 15-16) Unfortunately,
comparisons between the two studies could not be made easily because the mean ages of the seals were quite different (6.8 years in 1976; 14.5 in 1982).

Sampling inconsistencies are not limited to animal studies. The monitoring of PCB residues in wet precipitation (rain, sleet, snow, hail) in the Atlantic region between 1977 and 1984 resulted in the compilation of a substantial data set. However, due to inconsistencies in the number and frequency of samples collected at the various monitoring sites, the meaning of the data produced remains unclear (Strachan, 1988: 15).

To provide scientifically sound answers to questions relative to geographic and temporal trends would require the design and establishment of statistically based monitoring programs. For instance, in 1983 Environment Canada undertook a major review of the PCB situation in British Columbia. Extensive data for water, sediment, aquatic invertebrates, fish, birds and various discharges in the Lower Fraser river and estuary area were produced.

Comparisons generally showed an improvement in the system - and this in spite of some 68 spills documented in this province for the period 1979-82. However, the scope of this review was greatly undermined by the fact that its results could not be considered statistically significant due to the wide range of values present in each data set (Strachan, 1988: 32-4).
Also intriguing is the observation that water samples from Western Canada do not appear to contain PCBs at quantifiable levels. This is surprising given the widespread nature of the pollutant in other parts of the country. Whether or not this results from differences in analytical procedures among the various laboratories undertaking these surveys is unknown (Strachan, 1988: 13).

In sum, uncertain data quality still creates substantial difficulties in interpreting environmental information on PCBs. Even in cases where sampling is consistent and accurate, long-term data are difficult to analyse because methodologies and accuracies change over time.

This later point can be illustrated by the studies on the state of PCBs in the atmosphere done by the Ontario Ministry of the Environment. These studies have resulted in a relative abundance of data for atmospheric PCBs in this region. When this ministry altered its analytical procedures in 1980 the levels of PCBs in air dropped by one to two orders of magnitude. Whether the PCB levels in air actually decreased or whether this is a reflection of changes in analytical methods has not yet been clarified (Strachan, 1988: 25).

2.2.3 PCB Load in the Canadian Environment

Even though, as indicated above, there are difficulties in
producing a clear and reliable picture of the precise distribution and modes of transfer of PCBs with respect to the Canadian situation, there appears to be little disagreement that PCB loading in the environment originates mainly from atmospheric deposition.

For instance, data produced for the Great Lakes region indicate that air concentrations could result in an annual dry deposition of 1.8 to 7.8 tonnes of PCBs to each lake. Wetfall alone could account for an input of 0.5 to 2 tonnes of PCBs per lake per year. The atmospheric (air, water, snow) PCB data for Ontario indicate little significant difference between air residue levels in the northern and southern part of the province (Strachan, 1988: 25).

Besides atmospheric deposition, the connecting channels also appear to be an important source of PCB import into the Great Lakes. Annual inputs to Lake Ontario from the Niagara river were calculated to be in excess of 2 tonnes. In this respect, however, it must be noted that the considerable differences in seasonal flow patterns that are typical of Canadian rivers can seriously affect reported PCB concentrations. Since sampling and analyses are seldom done frequently enough, this makes estimates of annual loading particularly difficult.

Urban and industrial runoffs were also considered as potential sources of PCB. A study examining 119 Ontario communities in the basin area estimated this annual loading to all lakes at 121 kg/yr.
This is obviously quite small in comparison with PCB inputs to the Great Lakes via the atmosphere and via the connecting channels."

A study of effluents from a selected number of industrial operations in the Quebec region were investigated during the period 1977-79. Here again, losses reported were small in light of atmospheric deposition and PCBs being exported from the Great Lakes through the St. Lawrence River (Strachan, 1988: 20-21; 27-28).

These results combined with data showing traces of PCBs in the mouth of the major rivers flowing into Hudson Bay and James Bay point to widespread, rather than local, sources of PCB contamination. This, PCB distribution appears to be continental if not global with the atmosphere being a major medium whereby PCBs are transported through the biosphere (Strachan, 1988: x, 28).

This conclusion contradicts earlier beliefs that PCB distribution may be less uniformly global and more representative of local sources than DDT (NIEHS, 1972: 182).

These findings are not inconsistent with a 1973 Swedish study. The study found that PCB emissions from municipal incineration and from the drying of sewage sludge each amounted to about 1 kg/yr per million inhabitants. Such loadings are small when compared to the 2 tonnes deposited yearly from aerial fallout in southern Sweden (WHO, 1976: 28-29).
2.2.4 Environmental Trends

One purpose of the 1988 report was to evaluate the effectiveness of regulations put in place to control PCBs environmental dispersion and to see whether further control measures were needed. Unfortunately, despite some indications that PCB residue levels are diminishing, the absence of suitable data for comparisons has made it difficult to precisely evaluate the effectiveness of regulatory action.

As indicated earlier, most of the PCB data documented in Canada are for the Ontario region. Analysis of aquatic sediments, a good time indicators of the Great Lakes conditions, shows that the environmental dispersion of PCBs began in the mid-1930's, became significant in the 1950's and peaked in the early 1970's (Hansen, 1987: 42).

PCB levels in the Great Lakes system have been reported for almost two decades and several data sets have been used for trend evaluation. The Herring Gull egg monitoring program is the oldest of these and its data indicate that residue levels in the Great Lakes have decreased. Despite some fluctuations in each lakes and some increase in PCB levels reported during the 1981-82 period, by 1983 all lakes levels displayed a general downward trend.
The data from Lake Ontario lake trout show a similar pattern. Lake trouts are the top predators in most of the Great Lakes including Lake Ontario -- the most polluted of all Great Lakes with respect to PCBs. For the other lakes, however, lake trout data are ambiguous with few trends being apparent.

Decreased levels of PCB residues have been reported for rainbow trout, coho salmon, and splake. However, trends for other Great Lakes species such as rainbow smelt or spottail shiner are either ambiguous or uncertain (Strachan, 1988: 21-25).

One good omen comes from qualitative indications that residue levels in precipitation have decreased for Lake Superior. By inference, this could indicate a decrease in PCB residue levels in precipitation to the rest of Canada (Strachan, 1988: 25, 28).

This being said, however, it seems appropriate to emphasize that variations in data consideration may have profound influences on generalizations concerning the fate and effects of PCBs in the environment. While improvements in condition and recovery of some populations seems indicated, trends in ecological effects are contradictory at times.

In the Great Lakes, for instance, the data mentioned above have generated much optimism. The populations of herring gulls and doubled crested cormorants that have been monitored also seem to be
recovering from their exposure to PCBs and other contaminants. However, the beluga whale population in the St. Lawrence estuary which drains the Great Lakes is declining drastically (Hansen, 1987: 40, 42).

It is not surprising, therefore, that not all observers share the same degree of optimism. Summarizing the various presentations made at the 1983 "PCB Seminar" in the Netherland (OECD, 1984), the reviewer made the following comments that illustrate their divergence of opinions:

"It is not possible at this time to make a reliable assessment at the global level of the distribution of PCBs and the degree of contamination of these compounds. Most of the available data have been obtained by analytical methods which only allow for rough estimates of the actual environmental levels of PCBs. (...) This should particularly be kept in mind when statements about trends in residue levels are made, since these trends are probably realistic only in certain cases."

"Contamination has been found to be increasing in some areas, possibly due to diffuse sources or to aerial fallout. If consideration is given to the whole body of monitoring studies which have been carried out, no conclusion of an overall decline can be reached."
"The restriction of PCB-use to close applications has not led to a clear and consistent downward trend of environmental levels of PCBs, except in certain local situations." (Barros, 1983: 3, 4, 10)

The following comments illustrate the same point:

"PCB input into the environment has declined but not ceased." (Hansen, 1987: 44)

"PCB levels only marginally declined in the last decade." (Waterson, 1989: 81)

To conclude, the Canadian situation can be summarized as follow:

"It is apparent that contamination is greatest in the Great Lakes followed by Quebec and the Atlantic Regions and then B.C. and the Prairies; the rank of the territories is unknown. PCBs are ubiquitous throughout Canada and all organisms including man, have been exposed to them. This latter fact suggests a common mechanism for such exposure -- atmospheric transport and deposition is one such possibility." (Strachan 1988: 35-36)
3. PCB Residue in Food and Human Tissue

This section introduces some of the most prominent findings on human exposure to PCBs. As in the preceding section, no attempt is made to evaluate the effects of PCB dispersion in terms of their toxicity. Rather, the focus is on describing the type of exposure information available, the ways in which this information is generated, and the difficulties encountered in the process.

3.1 Human Body Burden (I): The Early 1970s

3.1.1 Early Findings

Reports published in the early 1970s already provided evidence of the ubiquitous presence of PCBs in human population. This evidence came from mainly two sources: biological monitoring and market-basket surveys. Both attested for the presence of measurable amounts of PCBs in human tissues and food.

Biological monitoring in human populations is undertaken with different tissues or excreta depending on availability and convenience. Biological indices of human exposure consist of surveys of human blood, adipose tissue and human milk. Despite unexplained variations and anomalies in reported values, surveys have consistently showed residues of these compounds to be commonly
present in human populations from industrialized countries and occasionally in other parts of the world. (WHO, 1976: 43) In Canada, nationwide surveys of adipose tissue in 1972, and of breast milk in 1975, indicated that 100% and 98%, respectively, of the samples contained detectable levels of PCB residues (Grant, 1983: 387).

Undoubtedly, some of the defining characteristics of PCBs like their stability, lipo-solubility, and tendency to bioaccumulate as well as their widespread use for over 40 years are responsible for their ubiquitous presence in biological systems. Yet, point sources also played a role in human exposure, sometimes in quite unexpected ways.

3.1.2 Exposure Routes

The discovery of PCBs in packaged food in Sweden, the U.S. and Canada, illustrates the insidious way in which human populations have become exposed to these compounds. In the early 1970s, high concentrations of PCBs were reported in packaged food, particularly in breakfast cereals. In the same period, however, no PCB could be detected in cereal grain. Eventually, the PCBs were found to have migrated into the cereal from recycled paper used in the fabrication of cereal boxes and their liners. The major source of PCBs in the recycled paper came from carbonless copy paper. Until 1971, PCBs had been routinely incorporated in
the manufacture of duplicating copy paper as a component of the dye carrier. At about the same time, PCBs were discovered in the packaging of other food products including rice, candy gum drops, spaghetti and raisins (Anderson, 1989: 332; NIEHS, 1972: 64).

Besides PCBs being found in various food commodities as a result of migration from their packaging components, PCBs were frequently reported in fatty foods - especially in fish, poultry, milk and eggs. Contamination occurred in various ways. Sometimes, milk contamination resulted from the use of caulking material and paints containing PCBs in farm silos. On occasion, animal feed became contaminated by PCBs leaking from farming electrical equipment (NIEHS, 1972: 59, 85-86).

In 1979, for instance, PCB leaking from a transformer in storage led to the contamination of animal fat in a slaughter house in Montana. This contaminated fat was then incorporated into poultry feed some of which was imported into British Columbia. A large and costly program had to be undertaken by Agriculture Canada and Health and Welfare Canada to control the problem (Grant, 1987: 30).

These and other findings resulted in the ongoing monitoring of national food supply for PCB content. By 1972, however, it was known that, sporadic instances of contamination set aside, most PCBs in human diets are in fish, particularly in fresh water fish (PHTS, 1972: 305).
3.1.3 Population Variations

These early findings also acknowledged that, superimposed on an ubiquitous and nearly unavoidable background exposure, some segments of the population are exposed to much higher concentrations than the average person. Sports, native and subsistence fishermen, for instance, were suspected of having relatively high PCB intakes. Nursing infants exposed to PCBs via human milk, in particular, became a matter of special concern (PHTS, 1972: 305).

In sum, the major source of exposure for the general population was believed to be through the ingestion of foods. As various reports were suggesting considerable similarity in the general patterns of food contamination, a coherent body of knowledge concerning the presence of PCBs in the food supply started to develop.

In contrast to the relative consistency and predictability of the data concerning PCB residues in food, the results obtained from biological monitoring has showed important variations in PCB levels between different human population. Some gross features of Population distribution have been identified to explain these variations. For example, reported PCB concentrations in adipose tissues, blood, and human milk sampled from occupationally exposed
individuals are understandably higher.  

However, most variations in PCB levels reported in human body tissues and fluids remained largely unaccounted for. For example, biological indices of human exposure indicate some extremely high PCB levels in the U.S. population (PHTS, 1972: 304). Average levels of PCB in milk fat from different OECD countries also showed large unexplained differences by country and year (Jensen, 1983: 83).

The inability to explain differences in PCB levels across various populations has been imputed to two main factors. First, unrepresentative population sampling and methodological differences in monitoring PCB burden may have resulted in inadequate measurements of human exposure. Second, interpretation of available data has been hampered by the lack of understanding of the kinetics, distribution and metabolism of PCBs in humans (NIEHS, 1972: 183-4).

In this respect, analyses conducted by Jensen and Sundstrom in 1974 show that some congeners were present in a much higher content in human adipose tissue than in the commercially available technical mixtures. As environmental PCBs pass up biological food chains, a progressive loss of the lower chlorinated components takes place due to selective biotransformation. The mixtures found in human

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7 Sometimes as much as two orders of magnitude higher than those of the general population (WHO, 1976: 43).
diet are thus being biologically filtered and their original composition altered. These findings indicated that the PCBs to which humans are exposed through their food differ in their composition from the technical mixtures and thus, are largely unknown (WHO, 1976: 13; Barros, 1983: 129, 133).

3.2 Human Body Burden (II): The Late 1980s

The major routes by which most people are exposed to PCBs are through the food they eat and the air they breathe. Absorption through the skin can be a major source of intake but is usually limited to occupational exposure.

In its review of PCBs' human body burden, the 1988 Environment Canada report emphasizes that, compared to dietary intake, human exposure to PCBs via air and water are minimum. In conclusion of its review the report states:

"It appears that the major exposure of adult humans is via the consumption of fish, milk, meats and poultry."  

(Strachan, 1988: 42)

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The estimated average consumption rates for foods which may contain PCBs is based on data provided by Statistics Canada. These data estimate the daily consumption of a variety of foods present in the diet of the average Canadian.
3.2.1 Methodological Caveats in Reporting Dietary Exposure

Several caveats concerning the assessment of PCB exposure via dietary intake need consideration. First, the report warns that estimations of exposure of the general population must be viewed with caution, because various food types are consumed and residue levels in some food types are unknown. For instance, the report's numerical estimates do not include contributions from fruits, vegetables and cereals because few data on PCB residues in plant products are available. This is a concern, the report claims, because these items are found in relatively high volumes in the diet of average Canadians. Even a low concentration of PCBs in these materials could make an appreciable input to human exposure (Strachan, 1988: 41).

Furthermore, because of PCBs liposolubility and their propensity to accumulate in fatty tissues, PCB levels in food products are determined from fat samples rather than edible tissue. However, since fatty tissues are often discarded prior to consumption, the conversion may not be entirely appropriate. Even where edible tissues are analyzed, the consumer may not be exposed to the PCBs due to loss during preparation (Strachan, 1988: 41). Another caveat is that average consumption rates can be misleading and misrepresent real PCB exposure altogether. In particular, average consumption rates do not reflect the fact that fish consumption is not distributed evenly across the population.

160
Native people, for example, are believed to be much greater consumers of freshwater fish than non-native. PCB exposure for this particular group can thus be expected to be at variance with that of the general population. In a 1985 study conducted on Broughton Island, researchers for Health and Welfare Canada concluded that the food chain in the Eastern Arctic was indeed contaminated with PCBs and that the dietary habits of many Inuit increased their chances of consuming high amounts (HWC, 1992: 61).

Subsistence fishermen are another population particularly exposed to PCBs as confirmed by a 1990 study of fishermen living on the Lower North Shore of the St-Lawrence Gulf. The study reports great plasma concentrations of PCBs in these isolated communities and relates this finding to a relatively great intake of seafood and a specific local dietary habit - sea-bird egg consumption. Reported mean concentrations in the blood of this population were 5 to 9 times higher than those generally reported for non occupationally exposed individuals (Dewailly et al., 1992: 1251-5).

Aggregate number describing average dietary exposure then, cannot reflect the markedly different exposure rates that prevail within the Canadian population.

3.2.2 New Findings

Acknowledging and mapping methodological shortcomings is a standard
scientific practice. One of its main benefit lies in providing a context within which results can be interpreted. In other words, it creates meaning by providing perspective. In addition, this practice is useful for refining or correcting procedures in the future. Yet, while the exercise can be beneficial in improving a given line of research, real breakthroughs often occur from outside rather than from within the dominant research paradigm.

New data on the sources of human exposure to PCBs presented in a recent government document entitled "Multi-Media Exposure Analysis for PCBs" illustrate the point. This (unpublished) internal document claims that PCB concentrations in indoor air are relatively high and may, in fact, constitute the major exposure pathway for the average Canadian (Federal-Provincial Multi-Media Guidelines Advisory Committee [thereafter referred to as MMGAC, 1990: 6-8, 14]). This claim stands in sharp contrast with the findings of previous reports on the subject.

As indicated by the table below, the inclusion of indoor air estimates in the total estimated exposure recasts previous apportionments of the sources of PCB exposure in an entirely new light - with dietary exposure now taking second place. This is surprising for, prior to this report, hardly any mention at all of

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This document was written in preparation of negotiations aimed at setting common interprovincial standards for maximum permissible PCB concentration in the environment. As provinces failed to arrive at an agreement, the document was not published.
indoor air as a source of PCB exposure appears in the literature.

Only three studies dating from the mid-eighties (1981, 1984, 1986) are cited in the internal document to support the revised apportionment of PCB sources of exposure. Further, the document acknowledges that, given the lack of consideration attributed to this pathway in other assessments, data on PCB concentrations in indoor air are lacking and "considerable uncertainty" is associated with the data available. No contributing sources of PCBs to indoor air, other than vapours leaking from fluorescent light ballast, are identified (MMGAC, 1990: 6).

It must therefore be assumed that the unexpected weight attributed to these studies results from something akin to a "paradigmatic" shift in the apportionment of various sources of exposure to PCBs. The incremental gathering of data from previous studies certainly provides little evidence to explain the change in research perspective which characterizes this later assessment and the recent prominence given indoor air data.

10 None of the studies reviewed for this chapter give any indication that indoor air may be a potential (let alone significant) source of PCB exposure. In particular, this source of exposure is conspicuously absent from Strachan's report which otherwise reviews most PCB sources in some length, including some (like water and root crops) that are known to be minimal. The exception is Jensen (1989: 353) who refers in passing to a 1981 study reporting relatively high PCB levels in some kitchens.
Estimate Lifetime Intake of PCBs:

<table>
<thead>
<tr>
<th>Exposure Pathway</th>
<th>Estimated Daily Intake for Average Adult (ng/kg b.w.)</th>
<th>Average Intake as a % of Current Exposure</th>
<th>Average Intake as a % of TDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Air</td>
<td>31.2</td>
<td>55.5</td>
<td>3.12</td>
</tr>
<tr>
<td>Food</td>
<td>24.8</td>
<td>44.1</td>
<td>2.48</td>
</tr>
<tr>
<td>Drinking Water</td>
<td>0.2</td>
<td>0.4</td>
<td>0.02</td>
</tr>
<tr>
<td>Soil</td>
<td>&lt;0.1</td>
<td>&lt;0.2</td>
<td>0.01</td>
</tr>
<tr>
<td>Total</td>
<td>56.3</td>
<td>100</td>
<td>5.63</td>
</tr>
</tbody>
</table>

N.B.: These estimates assume that individuals are breast fed during infancy, since at present this is true for the majority of Canadian infants.

11 From "Summary of Multimedia Exposure Analysis for PCB", in Multi-Media Guidelines Advisory Committee Proposed Interim Apportionment of Exposure and Guidelines for Polychlorinated Biphenyls (PCB), Table 1, p. 4.
The exposure data from this table indicate that the combined estimated lifetime exposure is well below the interim Tolerable Daily Intake (TDI) of 1 microgram per kilogram body weight (ug/kg bw) used by the Food Directorate of the Department of National Health and Welfare. This is true for both the "average Canadian" and the high risk subgroups (as can be gathered from the more detailed information presented in Table 1 in appendix C). Some exceptions are noted.

One such exception is the intake of PCB via breast milk which is estimated to exceed the interim TDI during the period when the infant is breast fed. However, people are exposed by this means for only a small fraction of their lifetime, about three months on average and rarely beyond one year. In this regard, the report notes that the equivocal behavioural changes observed in children of highly exposed mothers (discussed in section 2.8) are correlated to prenatal rather than postnatal exposures (MMGAC, 1990: 13).

Overall, these data show that the consumption of contaminated sport fish at average rates typical of Ontario anglers, dominates the exposure of persons from the general population to PCBs and in this respect, they provide a confirmation of previous exposure estimates. However, even though anglers consume by far the greatest amount of PCBs, their overall exposure rarely exceeds the

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12 The intake of PCBs via breast milk is estimated by Strachan (1988: 58) to be 2.6 ug/kg (bw/d).
No matter how detailed or accurate present exposure data may be, their practical significance cannot be appraised in a historical vacuum. Indeed, the literature reviewed for this chapter indicates that, as a rule, the significance of new exposure data results, to a great extent, from their comparison to previous findings. Over the years, several attempts have been made to provide some historical perspective for the interpretation of new data on human exposure to PCBs.

Before presenting these findings some of the difficulties encountered in making trend estimates deserve to be discussed. This is necessary in order to gain a better appreciation of the type of assumptions involved in making these trend assessments.

3.2.3 Selected Problems in Assessing PCB Human Body Burdens

Of the three biological indicators used for the monitoring of PCBs in the general population - human blood, adipose tissue and human milk - human milk has been investigated most. After introducing

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The average lifetime exposure for sport fishermen is estimated to be 208.2 ng/kg b.w. Some salmonids from Lake Ontario contain PCB concentrations several times higher than those used to model intake, but most anglers follow recommended guidelines for sport fish consumption. Thus, it is believed that only a small fraction of anglers consume these fishes (MMGAC, 1990: 8, 9).
some analytical problems associated with the use of biological indicators in general and some brief comments about results obtained from the analysis of blood and adipose tissue, the discussion centres on breast milk monitoring.

3.2.3.1 Biological Monitoring

As mentioned earlier, quantitation for the determination of total PCB content is normally accomplished by comparing selected peaks in chromatograms from samples and standard mixtures. However, the composition of PCB mixtures found in human differs substantially from that of the commercial mixtures. As no standard mixture exists with a peak pattern similar to that found in human tissues, different investigators have selected different PCB mixtures as standard.

Obviously, the results obtained will depend very much on which standard and which peaks are selected for quantitation. The fact that a generally accepted quantitation procedure does not exist has resulted in different analytical techniques and sampling methods being used for the determination of PCBs in blood, adipose tissues and breast-milk. This explains, in part, why "[m]any published data are not valid" (Jensen, 1989: 353).

For instance, international data produced between 1972 and 1986 concerning average PCB levels in bodily tissues and fluids show
important variations by country and year. In particular, no explanation - other than differences in analytical techniques and sampling methods - is offered to account for the much higher PCB blood serum concentrations found in the U.S. population as evidenced by some studies (Jensen, 1989: 353-7).

Comparison of PCB data in adipose tissues is difficult because of variations in sampling methods and because the donor materials differ very much. As most data on adipose tissue levels are from autopsy samples and very seldom from biopsies, donors are usually older than those providing blood and milk samples. Thus, it is claimed that "data from different countries are in fact not comparable." (Jensen, 1989: 358)

3.2.3.2 Breast Milk Monitoring

The benefits and disadvantages of using breast milk for the monitoring of PCB levels have been reviewed by Jensen (1983). Since the bulk of biological monitoring data comes from this source, his review is briefly summarized below.

Several advantages are associated with using breast milk as a biological indicator of PCB exposure. First, during lactation period, daily intakes do not significantly affect PCB levels in breast milk. Thus, the levels of PCB in breast milk fat reflect PCB concentrations better than PCB levels in blood. Second, milk
sampling is more straightforward and allows for easier gathering of a large volume of samples than the collection of blood and adipose tissue. Third, PCB levels in breast-milk being about ten times higher than those in blood, chemical analysis is more exact and reliable.

This technique also has some drawbacks. The availability of data from only one sex is perhaps the most obvious. This is a disadvantage because, as with other organochlorine compounds, females in general seem to have lower PCB levels in fat tissues than males. A second disadvantage is that data pertain to only a limited age group whose health status is considered to be better than average. Finally, on occasion human milk studies use pooled samples obtained from milk banks at children’s hospitals. Sampling excess milk from nonrepresentative mothers can skew the final results (Jensen, 1983: 81).

Other difficulties identified with this procedure pertain to the selection of donors, sampling time and analytical methods.

Since contamination is usually higher in urban and industrialized centres than in rural areas, the mothers’ area of residence needs to be accounted for when comparing and interpreting results. Maternal diet is also an important determinant of PCB levels in human milk and may vary within a region depending on the mothers’ cultural habits, country of origin, and so on.
Other more or less regular fluctuations in PCB levels in individuals have made interpretation of results somewhat difficult. In a given woman’s milk, fluctuations in PCB levels in whole milk and in milk fat can occur during one single nursing session as well as during the day. A decrease of PCB levels in both milk and fat has been observed during the lactation period.

Despite difficulties in interpreting the available data, the analysis of breast milk remains an important tool for the biological monitoring of PCB levels, especially with respect to high-risk groups. The fact that PCB levels in breast milk decrease with increasing numbers of deliveries and lactations indicates that lactation is, in fact, the most important route for maternal detoxification. The average daily intake of PCBs (per kg bw) for breast feeding infants has been estimated to be about fifty times higher than that of adults (Jensen, 1983: 81-82; Strachan, 1988: 58).

In sum, agreement on quantitation procedures is necessary if comparison of data is to be achieved. For example, one observer claims that women occupationally exposed secrete up to twenty times as much PCBs in their milk than nonworking mothers. Yet, for another observer the reported difference is qualified by a factor of three hundred (PCB Seminar, 1983: 5; Silbergeld, 1983: 142).
These observations, combined with reservations mentioned earlier about the use of different analytical standards for the determination of PCBs, explain why in the eyes of some:

"Most claimed time trends in [human milk] levels are not reliable." (Jensen, 1983: 83)

3.2.3.3 Trends in PCB Exposure

It is an assumption of this chapter that the ways in which problems occur in the generation of scientific data are important to comprehend in some details. The above discussion underlines how the validity of reported data can be compromised by the selection of samples submitted to analysis and by the analytical methods applied. The ways in which details in the performance of individual studies can affect their final results was also discussed. The fact that methodological procedures are often not clearly or thoroughly described has rendered comparison between different data sets difficult.

At the minimum, this approach should provide some insights as to why summary statements on trend evaluation need to be viewed with caution.

A recent Health and Welfare Canada publication reports that nationwide surveys of chlorinated hydrocarbons residues in human
fat tissue carried out in 1969, 1972, 1976 and 1985 show a downward trend in residue levels. Surveys done before 1977 (i.e., prior to the implementation of restrictions on the use of PCBs) showed no decrease in residue levels. By 1985, PCB levels in the Canadian population had been halved (HWC, 1992: 59).

PCB levels in whole breast milk also appear to have decreased in recent years and, compared to other Western nations, Canadian levels for PCBs in breast-milk fat are generally below average (HWC, 1992: 60, 63). Finally, with respect to PCB exposure from food products, Strachan presents data indicating that "the exposure of Canadians has improved substantially for some food types since 1970" (1988: 39).

Yet, it must be emphasized that, as with environmental dispersion, trend assessments pertaining to human exposure may vary depending on the particular data base and the time frame considered. The present diminution in human exposure to PCBs observed in the Canadian situation, does not necessarily reflect a global trend. Comparing results of international studies Jensen, for instance, noted that,

\[14\] It is generally acknowledged that, since milk fat concentrations differ, data is best expressed on an fat basis. (Grant, 1987: 30; Jensen, 1989: 346) Two figures summarizing the HWC studies are available in appendix C (Figures 1 and 2).
"In the few instances were the same methods have been used for several years, PCB levels in human milk seem to be relatively stable, contrary to a strong downward trend in DDT levels." (1989: 352)

In these circumstances, it may be wise to accept the assessment of yet another reviewer who prudently advanced that on the basis of "world data" on PCB residues in human milk and adipose tissue reported over a twenty year period - and despite fluctuations in the number of data points ranging from one to nine, ...

"(...) it can be concluded that there has not been an obvious increase in PCB residues over the last 20 years." (Grant, 1987: 31)

4. Animal Toxicology

4.1 The early 1970s

In the few years that followed the identification of PCBs in the environment, a considerable amount of scientific information on their toxicological effects was generated. The number of biological effects investigation that can be done on these compounds is almost limitless and led to an enormous amount of
studies being published. Because PCB physico-chemical properties are similar to that of DDT and because the effects of DDT on fish and birds were better known, both environmental monitoring and toxicological studies were initially focused on these species. Later on, general toxicity studies with technical mixtures were carried out on mice and rats mainly.

The following pages report on some of the earliest findings concerning the toxic effects of PCBs on laboratory animals and animal populations. In the reports reviewed for this purpose, these findings are generally preceded by cautionary statements alluding to the constraints that bore on the conduct of the studies and affected the results produced. As in the preceding sections, the findings reported below are followed by some qualifying comments.

4.1.1 Early Findings

The first generation of toxicological studies indicates that PCBs are of low acute toxicity but that their effects are cumulative with prolonged administration. Studies of acute exposures (i.e., exposures over relatively short periods of time or even a single dose) show effects occurring at levels that are greatly above those actually found in the environment, and often involve death at the observed end-point.
The main symptoms observed in severely poisoned animals include weight loss, ataxia, and diarrhoea. Progressive dehydration and nervous system breakdown are considered to be the cause of death (WHO, 1976: 13, 50).

The most consistent effects observed in long-term tests of low exposure to PCBs include the following: enlargement of the liver and induction of hepatic microsomal enzymes.\textsuperscript{15} \textbf{Immunosuppressive} effects are suggested by a number of studies of chicks, rabbits and guinea pigs. \textbf{Reproductive} effects include reduced mating indices in rats, embryotoxicity in rabbits and birds, as well as estrogenic and antiandrogenic effects in rats and birds.\textsuperscript{16}

There is no evidence of \textbf{teratogenic} effects in mammals at this point in time. Testing for \textbf{carcinogenicity} and \textbf{mutagenicity} is incomplete with early experiments giving conflicting results. Of all effects observed in animal species, reproduction appears to be the most vulnerable function (PHTS, 1972: 256, 323; NIEHS, 1972: 183).

\textsuperscript{15} PCBs induce microsomal enzyme activity by bringing about more rapid metabolism of drugs, insecticides and other foreign compounds (Buxton, 1972: 111).

\textsuperscript{16} The first indication in the literature that PCBs might be embryotoxic or have teratogenic effects dates from 1963, five years prior their recognition as an environmental pollutant (DHEW: 1977: 33).
4.1.2 Perspectives on Early Findings

A number of factors make the toxicological information on PCBs difficult to encapsulate. First, the material with which laboratory studies are carried out comes from different manufacturer, has different degrees of chlorination and possesses unknown contents of toxic impurities. While different chemical components in the crude PCB preparations are known to have distinctive patterns of pathological outcomes, only preliminary experiments have been conducted with individual isomers (NIESH, 1972: 105, 184).

Differences in toxicity are observed between commercial and environmental samples. In some instances PCBs found in the latter appear to be more toxic than "fresh" PCBs while in other cases the PCBs in the environment is similar in toxicity to the commercial product. Marked differences in toxicity are also noticed between commercial preparations with approximately the same degree of chlorination.

For example, some of the effects noted above increase with increasing chlorine content of the mixture; other decrease. Generally, lethality increases with different degrees of chlorination. In mammals, however, reproductive effects decrease with increasing chlorination (PHTS, 1972: 308, 321, 327-8). In short,
"There is no consistent relationship between toxicity and degree of chlorination which is valid for different species and different routes of exposure." (PHTS, 1972: 326)

The toxicological characterization of PCBs is confounded further by the occurrence of toxicologically significant traces of chlorinated dibenzofurans (PCDFs) in at least some commercial preparations. PCDFs are similar structurally and toxicologically to the dibenzodioxins, an extremely potent toxiccan in animals, particularly for the fetus. However, the toxicological implications of traces of PCDFs in commercial PCBs remain to be explored. A refined understanding of the pathogenesis of PCBs is viewed as dependent upon the pursuit of congener specific analysis conducted with purified trace contaminants and isomers (PHTS, 1972: 334; NIEHS, 1972: 184).

The enormous range of sensitivity to PCBs between animal species is another important factor which makes toxicological findings difficult to summarize. For example, aquatic invertebrates show effects at levels of a few ppb, but E.Coli\textsuperscript{17} appears to thrive at thousands of ppm. Fish, birds and mammals fall between these extremes, with mammals showing less sensitivity than fish and birds. However, the extreme sensitivity displayed by some

\textsuperscript{17} E. coli, is a bacterium found in human and animal waste. It is a commonly used indicator organism for the determination of fresh water quality (NHWC, 1992: 27).
mammalian species like the mink has raised concern. One summary report concludes:

"This area of comparative toxicity from species to species seems so large and uncharted that generalities seems out of place." (NIEHS, 1972: 183)

In addition to the different activities of the component PCBs, the presence of impurities, and the influence of inter- and intraspecies variations\textsuperscript{18}, PCBs toxicological assessments have had to account for the synergistic action of these compounds. For instance, PCBs are comparatively nontoxic to terrestrial insects but act synergistically to increase the toxicity of several pesticides to this species (PHTS, 1972: 256).

Finally, very little work on metabolism has been carried out and the movement of PCB into, within, and outward from animals is very poorly defined. Despite the toxicological relevance of this information, the kinetics, distribution, and excretion of PCB in animals are thus only very scantily understood (PHTS, 1972: 315; NIEHS, 1972: 183; WHO, 1976: 32).

\textsuperscript{18} Not to mention other variations regularly observed in toxicological studies with respect to the age and sex of animals.
4.1.3 Preliminary Assessment

The purpose of animal toxicology is essentially three-fold: i) to assess the toxicity of PCBs in animal populations; ii) to provide clues as to PCB mechanisms of action in living organisms; and iii) to evaluate PCB toxicity to humans. The latter being discussed in the next section, only the first two contributions are mentioned here.

On the question of toxic effects to animal populations, the review by the Panel on Hazardous Trace Substances concluded:

"In the case of PCBs, it can be stated with confidence that PCB levels in many ecosystems are higher than those which have shown effects on reproduction and survival of representative species in the laboratory. It is therefore unlikely that they are not having adverse effects on populations and communities, but it is very difficult to show conclusively that they are." (PHTS, 1972: 329)

Animal toxicity studies conducted in the laboratory then, provide theoretical evidence about PCBs deleterious effects on animal populations. Indeed, it would appear reasonable to conclude that a chemical stress (lethal or otherwise) to a laboratory organism would also have an adverse effect on the organism in its natural
environment. Acknowledging this however, it appears that outside
the laboratory, a causal relationship between exposure and adverse
effects can rarely be established empirically.

"Although some wild animal populations are contaminated
with PCBs to levels which cause adverse effects on
comparable animal species in the laboratory, it is
difficult to show conclusively that adverse effects are
taking place in the field. Conversely, where changes in
populations or diversity are observed in the field, it is
difficult to show conclusively whether or not PCBs are a
causative agent." (PHTS, 1972: 258)

The presence in the environment of other pollutants certainly makes
the adverse effects of PCBs difficult to isolate. On the other
hand, however, it is true that since a multitude of chemicals act
upon the animals either additively, synergistically or
antagonistically, the results from laboratory testing may not be a
true reflection of PCB toxicity in the field.

Hence, the gap between the toxicological knowledge produced in the
laboratory and the real effects of PCBs on animal populations
cannot be resolved on empirical grounds. Indeed, it is always
possible to argue that the effects observed in experimental studies
are an artifact of the laboratory procedures employed. To this, it
is possible to respond that, while there is enough evidence to show
that adverse effects are likely affecting animal populations in the environment, this cannot be definitely established with the scientific apparatus currently available. With PCBs as with other toxic chemicals, this dilemma has affected the overall import of animal studies in assessing toxicity.

On the second point concerning the contribution of animal studies to the understanding of PCBs mechanisms of action, one author concluded a review on the subject by noting:

"[...] it can hardly be said at this stage, that we have good suggestions as to the major underlying mechanisms of [PCB] toxicity. Rather than to hastily examine the effects of PCB's on a myriad of in vitro test systems, it would seem wiser that these studies be carefully planned as aids to understanding the observed course of PCB poisoning in the intact animal."
(NIEHS, 1972: 184)

In this respect, then, toxicological research is not that much different from other scientific disciplines where focusing on only the more concise relationships can obscure broader and more significant patterns of interactions.
4.2 Animal Toxicology: The Late 1980s

As mentioned earlier, the fact that clinical signs vary with the species of animal exposed has made the concept of a commonality of toxic responses to PCBs especially difficult to appreciate. While in a given species, the toxic reactions induced by PCBs are qualitatively similar, vast differences exist in the amount of PCBs required to produced an effect. Thus animal species vary considerably in their susceptibility to intoxication of PCBs.

4.2.1 Variations Across Species

"PCB toxicoses are so complex that an entire spectrum of effects is never seen in an individual or in every species." (Hansen, 1987: 44)

A review of adverse effects observed in aquatic species show many of the same types of biological responses occurring in the aquatic and terrestrial worlds. Observed effects include:¹³ behavioural (avoidance) effects (1974); impaired structural development (bone) (1978); liver changes (1977, 1982); thyroid effects (1979); testicular abnormalities (1981) and enzyme induction (1980, 1982, 1983) (Strachan, 1988: 50).

¹³ Numbers in bracket refer to the date of publication of the findings.
Depending on the animal species involved, environmental samples of PCB mixtures have been found to be more (1980) or less (1981) potent microsomal enzyme inducers than the parent mixture (Hansen, 1987: 31). In avian species, the alteration of enzyme levels caused by exposure to PCBs is probably reversible and not necessarily adverse in itself to the well-being of the individual birds. However, since this condition is symptomatic of an animal under stress, the effect can be considered adverse (Strachan, 1988: 46). Conversely, other analysts have mentioned the possibility that low-level exposure to PCBs could be beneficial by enhancing various detoxification enzyme systems (Hayes, 1987: 95).

Across species, the reproductive cycle is the most commonly cited life stage impaired by PCBs. With birds, decreased egg production and hatchability, are the effects most often reported. The direct injection of PCBs into the egg performed in some laboratory studies, however, may be difficult to relate to natural exposure from the parent (Strachan, 1988: 45, 46).

A large number of reports exist on the effects of PCBs on mammalian species. Again, those have shown that, generally, in acute exposures, PCBs are not highly toxic. Symptoms of PCB toxicity in mammals include: wasting syndrome; skin disorders; liver damage; reproductive dysfunction; cleft palate and kidney malformations in offspring of exposed test mammals (MMGAC, 1990: 2).
Yet serious effects including mortality have been observed in monkeys fed doses as low as 0.006 ug/g (bw)/day. Because of the relatively small numbers of monkeys used in any particular experiment, however, studies with primates cannot generate the level of statistical significance and confidence usually obtained with other species. Studies with minks exposed to Great Lakes fish and to contaminated meat at doses of 0.07 ug/g (bw)/day have resulted in reduced reproduction and some deaths among kits (Strachan, 1988: 49).20

Overall, the literature indicates that PCBs have a depressive effect on reproductive capacity. In general, females are more sensitive than males and young animals are more sensitive than adults. Poultry, guinea pigs, mink and non-human primates are among the most susceptible species to the toxic effects of these compounds. Frogs, on the other hand, appear to be quite resistant (McConnell, 1989: 139, 164).

4.2.2 PCB Mixture Composition

Differences in susceptibility across animal species is not the only factor which makes the concept of PCB toxicity difficult to

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20 These latter laboratory results have been used to confirm a suspected correlation between PCB presence in the environment and diminished seal populations in the Baltic Sea due to a decrease in the reproductive abilities of exposed animals (Hansen, 1987: 40). Laboratory studies can thus strengthen observations made in the field when results from both data set concur.
encapsulate. The differences in toxicity between various PCB mixtures must also be considered.

"Various PCB mixtures have different qualitative and quantitative biological activities, and these differences can be attributed to the relative concentrations of isomers and congeners present in these mixtures." (Hansen, 1987: 44)

Metabolism and toxic response to PCBs are thus governed by the number and position of the chlorine atoms that are substituted on the biphenyl ring and the particular ability of a species to biotransform a particular PCB.

The wide range of species susceptibility on one hand, and the confirmed differences observed in the general toxicity of various PCBs on the other, has made it impossible to establish a single no-effect level on the basis of animal studies (NHWC, 1985: 42). With the biological and toxicological effects of PCBs highly dependent upon the chemical composition of specific congeners within each mixture, non-congener specific data cannot be related adequately to toxicity. However, the evaluation of the toxic effects of individual PCB isomers and congeners has been limited by three problems:
"First, individual PCBs are not readily available in large quantity, but must be synthesized and isolated by procedures that preclude co-purification of highly active polychlorinated dibenzofurans and dibenzo-p-dioxins.

Two, the toxicity of PCBs cannot be evaluated adequately with *in vitro* systems, but must be assessed *in vivo* which requires much more material.

Three, PCBs are relatively non-toxic when administered at a single dose, for which reason large dosages must be given acutely or smaller dosages must be given chronically." (Parkinson & Safe, 1987: 56)

Because of the unpracticality of assessing the toxic effects of each and every possible PCB congeners in laboratory animals, most research has focused upon the most toxic congeners.\(^2\)

This, along with the fact that laboratory studies are usually carried out with the most sensitive animal species, and the tendency to emphasize the more sensitive responses in reporting results needs to be kept in mind when assessing the overall

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\(^2\) PCB mixtures like Aroclors have lower toxicities than chlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF). However, in some short-term toxicity tests, some PCB congeners have toxic potencies approaching that of 2,3,7,8 tetrachloro- dibenzo-p-dioxin TCDD. Four congeners, structurally related to TCDD have been classified as "most toxic". Another eight are considered "moderately toxic". The remaining congeners are expected to be relatively non-toxic with respect to their "TCDD-like" activities (Safe et al., 1987: 11).
Significance of animal studies for the toxicity of PCBs (Hansen, 1987: 31; Strachan, 1988: 49; MMGAC, 1990: 3)

4.2.3 Reproductive and Carcinogenic Effects

Reproductive studies carried out in the 1980s tend to confirm previous reports. The depressive effect on reproductive capacity noted earlier has been observed in female animals especially, but very little work has been done on male animals. In most species offspring born from exposed mothers are abnormally small and weak (McConnell, 1980: 139).

With respect to the mutagenic potential of PCBs, no signs of chromosomal abnormalities or other evidence of mutagenic activity was observed either in in vitro experiments or in in vivo studies.\(^{22}\) Thus, "it is generally agreed that these compounds are not mutagenic (...)" (Strachan, 1988: 43).

PCBs are reported to have only low teratogenic potential for causing gross deviation in morphology. There are, however, indications that PCBs are teratogenic to a number of bird species like chickens and ring doves. Studies with mice have also shown malformation of fetuses as well as cleft palates (Strachan, 1988:

\(^{22}\) One study, however, has shown some lower chlorinated mixtures to be mildly mutagenic. As the study has not been replicated in other laboratories, this finding remains unconfirmed. (idem)
Overall however, "PCB is not considered to be teratogenic" (HWC, 1985: 43).

There is also little evidence to show that PCBs are carcinogenic. The ability of PCBs to cause cancer in experimental animals is dependent upon factors which include the sex, strain, and species of the test animals.

Some studies suggest that PCBs induce hepatocellular tumours in mice and rats, and probably lead to the induction of adenocarcinomas of the stomach of rats (Kimbrough, 1974). In contrast, other evidence indicates that in some strains of rats, some PCBs (Kanechlor 500) inhibit the induction of liver tumours induced by known carcinogens (WHO, 1976: 65; Hayes, 1987: 85).  

In monkeys, proliferative lesions of the gastric mucosa are reported two weeks after exposure. Yet, no actual tumours were seen to develop for up to nine years.

"These results suggests that the long-term gastric lesions are more likely a proliferative inflammatory response rather than part of a spectrum leading to...

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In this regard, Hayes (and others) have emphasized that many experimental studies are not designed to measure carcinogenicity but instead to maximize the chances of detecting a potential effect of PCBs on the carcinogenic response (p. 87).
Due to the extremely long half-life of PCBs, however, symptoms of chronic toxicity can develop long after exposure has ceased. Thus, the possibility that tumours may have eventually developed remains since the latency period may not have been of sufficient duration to prove otherwise.

PCBs are thus "generally considered not to be initiators of tumour growth" although the possibility that they induce a carcinogenic effects by acting as promoters has not been ruled out (Strachan, 1988: 44).

Finally, PCB interactions with other toxicants, demonstrated in earlier experiments and implicated as enhancing PCB effects on various populations have received confirmation. Again, the multiple mechanistic pathways through which these effects proceed have not yet been delineated.

In summary, recent findings in animal toxicology appear to have expanded the spectrum of PCB effects while concurrently acknowledging at least a modulatic role for "nontoxic" PCB congeners (Hansen, 1987: 40, 44).
5. Human Health Effects

5.1 The Early 1970s

5.1.1 First Reports

During the 1930s and 1940s, few reports appear in the industrial medical literature regarding the toxic effects of PCBs. During World War II, sporadic cases are reported among electrical workers. When poisoning occurred among men engaged in their manufacture and uses, subsequent safety precautions seem to have prevented further outbreaks of pathological symptoms. Chloracne - a painful and disfiguring skin affliction with acneiform eruptions - is one of the first signs clinically described in PCB workers (PHTS, 1972: 253).

Recorded cases of occupational chloracne describe exposed workers developing small dermal cysts and comedos on the face and ears. Other areas - including the abdomen, back, thighs, forearms, buttocks, and scrotum - are also commonly affected. Dermal contact is generally considered a more important route of exposure than inhalation; the widespread distribution of dermal symptoms is ascribed to direct contact with contaminated clothing. Systemic effects (ie. remote from the specific sites of exposure) such as digestive disturbances, impotence, hematuria (1936), nausea,
lassitude, and anorexia (1941), are also reported in severe cases (PHTS, 1972: 329).

The onset of chloracne is generally quite slow, occurring after about seven months following initial exposure (1941). The course of the disease is protracted with symptoms persisting for several months and up to four years after removal from the source. In some cases the liver is involved, occasionally with fatal consequences (1937) but reports of lethal effects are isolated and data difficult to corroborate. From 1953 onwards, several reports of related disease in Japanese factories manufacturing electrical condensers are mentioned in the literature (NIOSH, 1977: 31-33).

It is likely that, in addition to the exposure taking place in manufacturing plants, a considerable number of workers have been exposed to products containing PCBs, e.g., from paints, vapours from air compressors, refuse, etc... However, almost no data are available to assess the importance of occupational or semi-occupational exposure to PCBs. This is in part because, until the mid-1960s, PCBs were not generally regarded as dangerous chemicals (PHTS, 1972: 303; WHO, 1976: 11).

5.1.2 Yusho Poisoning

Knowledge concerning the toxic effects of PCBs in man has been gained mainly as a result of the 1968 contamination of cooking rice
oil in Japan. The most striking effects observed following this food-poisoning incident have included severe cases of chloracne, hyper-pigmentation, eye discharges, and disturbances of the respiratory system. Babies born to Yusho mothers were of less than normal size and initially showed skin pigmentation. Over a six-year period, the effects on the skin diminished very gradually. Overtime, however, the nonspecific symptoms (headaches, fever, visual disturbances) became somewhat more prominent (WHO, 1976: 14).

The Yusho episode affected over a thousand people and resulted in a quick rallying of medical and scientific talent. Numerous detailed clinical and experimental studies were published to clarify the effects of human PCB poisoning. These investigations showed the contaminated oil to contain levels of PCDFs far exceeding those found on occasion in "normal" industrial PCB mixtures.

Studies conducted in the wake of the incident showed that, because of the important role played by PCDFs in the etiology of the Yusho poisoning, the adverse effects experienced by the victims could not be conclusively attributed to PCBs. For example, one such study showed that occupationally exposed workers with PCB blood levels 10 to 150 times higher than those of Yusho patients were mostly free from the signs and symptoms characteristic of Yusho contamination (WHO, 1976: 67; Idler, 1986: 5-6).
In addition to the large concentrations of PCDFs found in the mixture, the route of exposure to PCBs (ingestion over a short period of time) further compromised the relevance of the Yusho episode to human PCB exposure. Yet, because it is rare for such incidents be so systematically studied, the Yusho data played a major role in the assessment of the human hazards from PCBs. For instance, some of the data collected made it possible to establish that PCBs can be transmitted from mother to fetus, and, in the milk, from mother to child (NIOSH, 1977: 49).

5.1.3 Preliminary Assessment

The toxicological information resulting from the Yusho incident, combined with experimental studies conducted with monkeys, has been interpreted as an indication that man is the species most sensitive to PCBs (WHO, 1976: 70-71). However, as previously mentioned, the validity of both data sets on which this conclusion is based has been questioned.

As a whole, the scientific evidence on the chronic toxicity of PCBs available in the early 1970s points, with some certainty, to two distinct actions these compounds may have on the body, namely, a

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24 Monkeys are the only experimental species showing effects qualitatively approaching those in man. Their greater sensitivity has been attributed to metabolic differences leading to a slower elimination than that observed in other species tested (WHO, 1976: 67). The dog, on the other hand, eliminates PCBs more rapidly than other species.
skin effect and a liver effect. In addition to having a dermal effect, PCBs were known to activate the metabolic enzymes of the liver which results in an increased breakdown of certain reproductive hormones. A consequence of this is a potential modification in the reproductive rate of animals and man (Buxton et al., 1972: 56, 111).

Scientific reports are generally unanimous in reporting that there is no epidemiological evidence to suggest that PCBs cause tumours in man (WHO, 1976: 70-71). At the same time, however, no adequate studies are available to conclusively rule out the potential carcinogenic effects of PCBs in humans. Some animal experiments can thus be interpreted as providing enough evidence that such effects may indeed occur. The reading that the U.S. National Institute for Occupational Safety and Health (NIOSH) made of the available scientific data illustrates the point. Commenting on the human toxicity of PCBs, NIOSH noted that:

"[A]ll PCB mixtures adequately tested in rats and mice have shown carcinogenic activity. (...) These findings indicated to NIOSH that PCBs have potential carcinogenic activity in humans."

The report continued:

"Although PCBs have little mutagenic potential, they may
alter the **mutagenicity** and carcinogenicity of other compounds by stimulating microsomal enzyme activities."

"PCBs have been found in embryonic and fetal tissues of humans and experimental animals after introduction of PCBs in the maternal body, demonstrating that the potential for direct **teratogenic** effects exists." (NIOSH, 1977: 118, 119, 120)

In NIOSH's interpretation, it appears that the lack of sufficient epidemiological evidence to confirm or deny the long-term toxicological effects of PCBs, amplifies the relevance of positive animal studies to human populations. The absence of conclusive findings in one scientific discipline can thus act as a magnifier on the data produced in another.

5.2 The Late 1980s

Since the early 1970s, many laboratory experiments and other studies have tried to determine the full health effects of PCBs in humans. As can be expected, none has been definitive. As a result, many questions remain concerning the human toxicology of PCBs and expert conclusions on the subject vary significantly. Scientists in general agree that short-term, low-level exposure to PCBs is unlikely to have a significant health impact but there is concern and disagreement over the effects of long-term exposure to low concentrations.
The following pages provide a sample of the range of expert opinion on the subject available in the late 1980s along with a rationale upon which this opinion is based. The discussion highlights how epidemiological and toxicological data can provide a basis for diverging interpretations.

5.2.1 Epidemiological Studies: Some General Considerations

Generally speaking, human studies conducted after 1976 did not add significantly to the understanding of the toxicity of PCBs. Silbergeld (1983) has argued that, to a large extent, this is due to a series of methodological constraints which limit the explanatory power of epidemiological studies. Some of these methodological hurdles are structural and intrinsic to the field of occupational and general population epidemiology. Others, however, are of a more conjectural nature and have to do with the characteristics of the particular compounds under investigation. Typically, epidemiological investigations are limited by methodological problems which involve on the one hand, the subjects under study and, on the other hand, the determination of exposure.

In the first instance, the rather small number of subjects involved in occupational studies and the relatively nonspecific nature of PCBs' adverse effects have compromised the ability to detect the impact of PCB exposure. If PCB toxicity resulted in an unusual or rare disease, this problem of statistical representation would be
of a lesser concern. However, since the symptoms of concern already occur with some frequency in the "unexposed" population, an increase in the rate of PCB-incurred effects could likely go undetected unless large numbers are studied.

Secondly, when most exposure occurred, i.e., between 1965 and 1971, little or no data on concentrations in air or other workplace environmental media were available. Measurements of exposure have thus often been inferred on the basis of subjective recalls and qualitative information such as work hours or job classification. When measurements have been done, actual environmental levels have shown great variations. Data attributed to these categorical divisions may have been highly inaccurate (Silbergeld, 1983: 138).

In addition, uncertainty as to the toxicokinetics of PCBs have made it difficult to determine the time point at which internal measurements reflect steady-state; post-exposure physiological events such as weight loss or pregnancy may change the body distribution of PCBs. Further, interindividual variability is large, and plasma/adipose ratios are known to vary with specific PCB congener. These observations indicate that many of the studies which used blood sampling and other internal measurements of exposure have produced results which are open to question.

In both areas then, population sampling and determination of exposure, problems traditionally identified with the general nature
of occupational epidemiology (e.g., small sample-size, imprecise characterization of exposure) have been amplified by the specific attributes of PCBs (e.g., non-specificity of effects produced, uncertainty in time-point measurements). Additional shortcomings of human studies include the relative unrepresentativeness of male workers data and the limited time elapsed between exposure and health evaluation. This time period is usually too short to allow for the detection of increases in cancer mortality (Silbergeld, 1983: 137).

This later point is of some significance since surveillance of occupational populations has been relatively restricted in design to evaluating mortality, particularly that associated with cancer.

5.2.2 The Focus on Cancer

The focus on cancer mortality characteristic of many clinical investigations stands in sharp contrast to the scant attention paid to the range of other effects observed in experimental studies.

For instance, while animal studies indicate that the lung is a target of PCB toxicity, few studies have examined lung function in workers. While the confounding factors of smoking and age make interpretation difficult, enough evidence is available to suggest a possible synergism between PCB exposure and smoking.
The ability of PCBs to affect thyroid-dependent immune functions is another example of an effect that is well documented experimentally and has not been investigated appropriately in humans. Yet, no extensive studies of immune function or of resistance to infection have been conducted in exposed populations.

Other endpoints likely to be more sensitive indicators of toxicity than cancer mortality but not investigated as such also include the effects of PCBs on reproduction. Some studies suggest that, together with other organochlorines and metals, PCBs may be responsible for declining sperm counts and a rising incidence of abnormalities in the human male reproductive tract. Despite the well-defined hormonal effects of this chemical, no assessment to reproductive function has been made of PCB workers. (Silbergeld, 1983: 138-141; International Joint Commission (thereafter referred to as IJC, 1993a: 6).

Over the years, the view that the current emphasis on cancer is inadequate has received support from several scientific quarters. Concurrently, there has been an increasing recognition that human toxicity needs to be defined with consideration to the whole gamut of PCBs health effects, including in utero damage to the unborn (IJC, 1993b: 94, 95).
In sum, Silbergeld's review indicates that an absence of positive epidemiological findings does not necessarily constitute by itself sufficient evidence of no-adverse effect. Her systematic mapping of methodological shortcomings is also helpful in staking limits as to the significance of previous epidemiological investigations. Such critical reviews can also be used for the steering of future studies.

5.2.3 Epidemiological Findings

In 1979, a second mass contamination involving over 1900 people occurred in central Taiwan. The toxic effects observed in the Taiwanese (Yu-Cheng) incident were similar to those of the Yusho poisoning and linked to an identical cause: the ingestion of rice oil contaminated with PCBs containing high levels of PCDFs. Because of the impurities present in the mixture, data gathered in the aftermath of this later incident were of limited use in furthering the understanding of PCB effects in human populations.

The literature on effects associated with occupational exposure to PCBs available today is extensive.25 Observations concerning increased occurrences of some types of cancer have not, generally, been statistically significant. These occurrences usually involved

25 A table summarizing a number of reports qualitatively indicative of these effects is presented in appendix along with a list of the signs and symptoms observed following the Yusho and Yu-Cheng poisoning (Tables 2 and 3).
various sites in the body, an inconsistency which has complicated the identification of any human cancer risk from exposure to PCBs.

For example, in one of the largest studies ever conducted a slight increase in rectal and liver cancer was reported among the 2,567 workers of two capacitor manufacturing plants (Brown and Jones, 1981). However, the overall number of deaths from cancer in this population was lower than expected. Unsurprisingly, these findings have been subjected to differing interpretations (Silbergeld, 1983: 139; Idler, 1986: 3; Strachan, 1988: 54).

The health effects resulting from the consumption of PCB-contaminated sport fish have received much scientific and public attention. Much of this concern originates from a 1982 study of 242 infants born to women consuming Lake Michigan fish. The study reported that the newborn had slightly reduced birth weight and head circumference. The infants also displayed behavioral immaturity and developmental defects relative to the controls. A follow-up study indicated that certain learning deficits were still occurring at age four. However, because of limited sample size, small magnitude of observed effects, and possible confounding factors, these results - and those from general population studies more broadly speaking - need to be interpreted cautiously.

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26 Physical growth and short-term memory deficits appear to be specifically related to in utero exposure (IJC, 1993a: 5).
In this case, for example, a total of 73 potential confounding variables were screened, and the effects of 37 were assessed; confounders like higher alcohol, caffeine, and cold medication use in the group of exposed mothers were controlled or adjusted for in the statistical analysis. However, other contaminants such as DDE and DDT known to be present in Lake Michigan fish were not investigated as possible confounding exposures.

Inconsistencies in reported results have created additional difficulties in interpreting these findings. A 1989 study, for instance, reported that increased consumption of Lake Michigan fish is associated with increased, rather than decreased, birth weights (Anderson, 1989: 328-9; MMGAC, 1990:3; IJC, 1983b: 94).

5.2.4 Methodological Caveats in Perspective

So far, this discussion has concentrated upon several data gaps and limitations in scientific methodologies which have prevented the establishment of a solid scientific consensus on the question of the toxicity of PCB to man. It is also important, however, to keep those alleged shortcomings in perspective for there is indeed substantial evidence that the elusiveness of effects in human populations can be attributed to the PCBs themselves.

For instance, people who have been occupationally exposed to PCBs tend to have higher concentrations of PCBs in their blood and fat
than people without occupational exposure. Reported plasma levels also indicate that the incidence and severity of chloracne appears to be correlated with intensity and duration of exposure. Yet, while there may be a relationship between skin problems and levels of PCBs in blood, no clear relationship between symptoms and concentrations of PCBs in the body has been found.

Since it is not possible, at present, to relate particular PCB concentrations to health effects, the analysis of body tissues and fluids can only indicate whether exposure to PCBs has occurred at levels higher than those present in the general environment. Incidence of chloracne by itself is not even a reliable indicator of PCB exposure. Conversely, many instances of exposure have not resulted in reported chloracne (Silbergeld, 1983: 140; Idler, 1986: 4, 7).

A recent summary of the scientific literature on the subject states that:

"Exposure of humans to high levels of PCB in the work place has been associated in some instances with one or more of chloracne, irritation of the eyes, skin, and respiratory membranes, nausea, dizziness, hepatomegaly, increases in serum levels of lipids and liver enzymes, induction of liver enzymes, and decreases in newborn birth weight and gestational age." (MMGAC, 1990: 2)
Yet, the reviewers are quick to immediately qualify these findings:

"The range of these effects observed in any given study is quite limited, and is often not consistent across studies." (idem)

5.2.5 Experimental Evidence and Human Toxicology

In the absence of a clear and consistent correlation between PCB human body burden and health effects reported, data generated in the laboratory controlled environment have received increased attention. Although epidemiological studies have established that the effects most clearly associated with PCBs in human population are chloracne and altered liver function, cancer has often been considered the expected effect of greatest significance.

Despite a general agreement that increases in cancer mortality have been observed conclusively in animal studies only, some PCB mixtures are suspect human carcinogens. The evidence for this comes from studies in which mice and rats developed liver cancers. However, as Hayes (1987) explains, the value of these findings depends upon the conceptual framework within which the studies have been designed and interpreted. Of course, there are additional problems in extrapolating those findings to human populations.
Some laboratory experiments with mice and rats indicate that prolonged exposure to PCBs can initiate preneoplastic lesions and a low incidence of hepatocellular and gastric carcinomas. While this apparently suggests that initiation can occur under some highly sensitive experimental conditions, many biological processes involved in chemical carcinogenesis are yet unexplained. In particular, the carcinogenic effects observed "could be a mere reflection of the promoting influence of PCBs initiated by other, as yet, unidentified mechanisms" (Hayes, 1987: 84).

In addition, Hayes (and many others) have noted that, because rodents spontaneously develop numerous preneoplastic foci and nodules as they get old, they are particularly susceptible to hepatic tumour promotion. Humans apparently do not generate these lesions to anywhere near the same extent.

Finally, promotion by PCBs is dose-dependent and the threshold for promotion may well be above the levels encountered in animals and humans exposed to environmental PCBs (Hayes, 1987: 89; MMGAC, 1990: 5). 27

27 As discussed earlier, the biologically filtered mixtures of congeners to which man is exposed through his food probably differ in composition and toxicity from the technical mixtures with which the majority of the animal studies has been carried out. This further compromises the applicability of animal results to man (OECD, 1984: 133).
Hence, the demonstration of carcinogenicity or cocarcinogenicity potential of PCBs under contrived experimental conditions is perhaps of equivocal predictive significance:

"Collectively, this [experimental] evidence suggests that PCBs may potentially be carcinogenic under some specific conditions. However, under natural exposure circumstances, PCBs are perhaps more likely to prevent carcinogenesis than enhance it. Accordingly, the risk estimates based on the worst-case analysis of the potentially carcinogenic effects are likely to be substantial overestimates of the real risks."

(Hayes, 1987: 92)

Such interpretation is consistent with the absence of correlation observed between the levels of PCBs in human tissues and the occurrence of specific lesions such as breast cancers. It also supports the lack of clear evidence for carcinogenic toxicity documented for those individuals accidentally exposed to high levels of PCBs (Hayes, 1987: 91, 92).

When in 1987, the International Agency for Research on Cancer reviewed the different types of evidence linking cancer and PCBs, it concluded that the evidence for the carcinogenicity of PCBs to

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28 Although a recent study indicates an elevated risk of breast cancer associated with PCBs, these results are not statistically significant. (IJC, 1993b: 94)
humans was "limited". The evidence for the carcinogenicity of PCBs to animals, however, was judged "sufficient". The combination of limited evidence in humans and sufficient evidence in test mammals resulted in the classification of PCBs as "probable" human Carcinogens (MMGAC, 1990: 2).

In sum, it is clear that the scientific data base on PCBs allows for a relatively broad range of legitimate opinions on the subject of just how severely these compounds affect living organisms in general, and humans more specifically. The potential for human injury from long-term exposure to low levels of PCBs in particular is likely to remain in controversy. Nevertheless, concern over long-term risks has been significant enough to warrant concerted regulatory action to reduce PCB levels in the environment and to keep human exposure to a minimum.
CHAPTER 5: THE EXPERT MANAGEMENT OF PCB RISK

1. Introduction

Most of the PCBs presently accounted for in Canada are either in storage or are used in electrical equipment. As PCB-filled transformers come to the end of their service life they are being replaced with PCB-free equipment and this source of contamination should eventually be eliminated. Under present regulations, however, replacement will not take place until PCB-containing equipment is gradually phased-out, and this type of equipment has a long life time (i.e., 30-35 years). A recent estimate indicates that 50% of all PCBs ever produced are still in use and that loading in the environment continues from a variety of known and unknown sources (IJC, 1993a: 5).

Many experts in the scientific and regulatory communities are of the opinion that natural attrition followed by storage does not promise a sufficient resolution to the environmental PCB problem. From their perspective, destruction of PCBs is the ultimate goal in PCB waste management.
A variety of destruction technologies are available for the treatment and disposal of PCBs. For example, a number of sodium-based chemical dechlorination processes are currently employed to destroy PCBs in low level contaminated mineral oil. High efficiency boilers can sometimes be used and several other techniques are also in the development stage.

For high concentration PCBs, the most effective method of disposal is through high temperature incineration or thermal destruction. At a temperature of 1200 degrees Celsius for over two seconds, more than 99.9999% destruction is achieved. Gas scrubbing systems are used to remove by-products of combustion from the flue gas.

In OECD countries, high temperature incineration is the method most frequently used to destroy PCBs. Like Canada, however, several member countries currently lack adequate facilities and either store PCB wastes pending the establishment of destruction facilities or transport them across international boundaries to established facilities in other countries (an option no longer available in Canada). Landfilling is not generally considered an acceptable alternative for PCB disposal, except in the U.S. and in Germany.

Mobile and transportable incinerators have been developed and are operating in the U.S. and to a limited extent in Canada. But siting, even on a temporary basis, is not done without difficulty.
This chapter has three main components which describe in turn the regulatory, technical, and political dimensions of the PCB management problem in Canada.

2. The Regulatory Framework

2.1 Regulation Development for PCBs

One of the earliest motivations for Canadian governmental action on PCBs was the OECD decision of February 13, 1973. This decision recommended that member nations restrict the use of PCBs to dielectric fluids in transformers and capacitors; heat transfer equipment (other than that used for food processing); hydraulic fluids in mining operations; and small capacitors.

With regard to these applications, it was recommended that PCBs only be used where requirements for noninflammability outweighed the need for environmental protection. OECD nations were also urged to provide a safe means for the disposal of surplus PCBs and PCB wastes, to establish a common labelling system, to develop safe means of transporting these materials, and to limit their exports.

1 Unless otherwise specified, the description of the regulations which follows is taken from Environment Canada information kit on PCBs and from the Extract of the Canada Gazette Part II. A summary of the development of regulations is presented in table form in Appendix D (Table 1).
When in 1982, the OECD reviewed the PCB situation in member countries, it stated that the major remaining problem with PCBs was their disposal and that the most effective means for disposing of liquid PCBs was incineration. It noted that Canada had recognized the destruction problem but had not determined its own particular solution (Strachan, 1988:2-3).

The first step towards controlling PCBs in Canada was a Notice to Disclose published in the Canada Gazette requiring any person using PCBs to report such usage and the quantities involved. This information was required by the Department of the Environment and National Health and Welfare in order to develop an inventory of the quantities of PCBs in use and in storage. As a result of the information obtained, the PCB regulations were developed and implemented (Environment Canada, 1986: 20)

In 1977, Chlorobiphenyl Regulation No.1 was promulgated under the 1976 Environment Contaminant Act. This regulation prohibited PCBs from any "open" uses but continued to permit existing "closed" (largely electrical) applications which were in use in Canada before March 1, 1977. The regulation also allowed the continued use of PCBs in the manufacture of electrical capacitors and transformers.

Amendments to Chlorobiphenyl Regulation No.1 were put into effect in 1980. As a result of these amendments, existing PCB-containing
electrical equipment could continue to be used, but no new PCB-containing equipment could be manufactured (including electrical equipment), and no new PCBs could be used to refill or otherwise service existing equipment. As of 1980, therefore, no new PCBs could be put into service in Canada. Also included in these amendments were restrictions prohibiting the use of PCB-containing equipment in the handling of produce, food or animal feed, or anything intended to be added to food or animal feed.

Two additional Chlorobiphenyl Regulations came into effect in 1985. Chlorobiphenyl Regulations No.2 (Product) stipulates that any product offered for sale in Canada (new or used) cannot be contaminated with or contain PCBs at a concentration greater than 50 ppm by weight. Exceptions to this are for equipment whose purpose is the destruction of PCBs, or for storage awaiting destruction, or when the equipment is an integral part of a building, plant or structure.

Chlorobiphenyl No.3 (Release) was designed to reduce the release of PCBs to the environment. This regulation sets two restrictions on the release of materials containing PCBs:

1) 50 ppm is the maximum concentration of PCBs by weight that can be released to the environment by any commercial, manufacturing

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2 Environment Canada has proposed a new PCB initiative which will move the ban on PCBs in new products from the current 50 ppm level to a 2 ppm level (British Columbia Hydro and Power Authority, 1992: 3).
or processing activity except for use as dust suppressants on unpaved roads where the limit is 5 ppm (0 ppm in Quebec); and ii) 1 gram per day is the total allowable release in the course of operating, servicing, maintaining, decommissioning, transporting or storing PCB-containing equipment.

Also in 1985, Regulations Respecting the Handling, Offering for Transport, and Transportation of Dangerous Goods were promulgated under the Transportation of Dangerous Goods Act (TDGA). These regulations were passed in the wake of a highly-publicized spill of transformer askarel containing 56% PCB near Kenora, Ontario. They cover all hazardous goods and wastes, including PCBs. Requirements for transportation of PCBs stipulates that PCBs or equipment containing PCBs must be enclosed in a rigid leak-proof container during transport and large articles (such as transformers) must be drained of PCBs if they cannot be properly enclosed.

These regulations make the documentation (manifesting) of the movement of PCBs during interprovincial or international transport mandatory. The manifest system includes procedures for the proper marking, identifying, classifying, packaging, handling, and inspecting during transport. The regulations also prescribe specific responses in the case of accidents or spills of hazardous waste during transport (Strachan, 1988: 65-66).

In August 1988, a fire at a PCB storage site forced the evacuation
of more than 3,000 residents at St-Basile-le-Grand, Quebec. To ensure proper storage methods for PCB wastes, and reduce the risk of another similar incident from occurring, Environment Canada issued the *Storage of PCB Wastes Interim Order*. The security measures stated in this order are related to the following: access to sites; storage sites; fire protection and emergency procedures; maintenance and inspections; labelling requirements; maintenance of books and records, and; reporting requirements.

Regulations governing the safe operation of mobile PCB incinerators were published in January 1990. The *Federal Mobile PCB Treatment and Destruction Regulations* prescribe maximum emission standards for PCBs, PCDDs, and PCDFs. These standards apply to air pollutant emissions and the release of liquids and solids from incineration and chemical treatment systems operated by or under contract with federal institutions.

In addition to meeting federal standards, incineration equipment must incorporate fail-safe control systems to ensure that the equipment is always operating normally. Any deviation of the prescribed range is to result in the automatic shutdown of the incinerator. The system must show a minimum PCB destruction and removal efficiency of 99.9999% (a standard identical to that of the U.S. EPA). Ontario (Regulation 148/86) and Newfoundland/Labrador (Regulation 102/89) have also passed regulations dealing with mobile PCB incineration.
In August 1989, ship containers filled with St-Basile's PCBs sent for off-shore disposal were turned away by British ports. This event raised the question of Canada's moral responsibility in sending hazardous wastes outside national boundaries and resulted in the promulgation of PCB Waste Export Regulations prohibiting the overseas export of PCB wastes as of August 1990. These regulations represent a national commitment to the domestic management of all PCB wastes in Canada. Consequently, all persons in possession of PCB waste are required to either store or destroy this waste in compliance with PCB storage and treatment requirements.

In March 1991, the Chlorobiphenyl Regulations No. 1 (PCBs), Chlorobiphenyl Regulations No. 2 (Product) and Chlorobiphenyl No. 3 (Release) were incorporated under the Canadian Environment Protection Act (CEPA) of June 1988 under the title Chlorobiphenyls Regulations. The roll over of these regulations from under ECA to go under CEPA resulted in no substantive change.

Finally, in September 1992, the Storage of PCB Wastes Interim Order setting out procedures for the proper storage of PCBs and protection of storage sites containing PCBs was replaced by the Storage of PCB Material Regulations. These regulations have the same basic requirements than the Interim Order and are intended to ensure the continuation of adequate controls for PCB storage.

2.2 Other Legislation
Besides PCBs being regulated under the CEPA and the TDGA, some dispositions contained in the Fisheries Act, the Ocean Dumping Control Act (ODCA), and the Canadian Coast Guard Regulations also apply to PCBs.

For example, the OCDA regulates the PCB content of materials disposed of at sea and specifies that the concentration of PCBs must not exceed 10% of the concentration shown to be toxic to sensitive marine organisms.

The Canadian Coast Guard Regulations stipulates that, in addition to the requirements specified under the TDGA, PCB marine shipments must be marked "Marine Pollutants" regardless of volume. If the total shipment contains in excess of 10 kg net quantity of PCBs, then it must be individually authorized and inspected by the Board of Steamship Inspection. Several days prior notice of intended shipments are thus necessary.

In sum, the federal government is responsible for setting and enforcing national standards for the use and release of PCBs into the environment, for overseeing the interprovincial and international movement of PCBs, and for safeguarding Canada's boundary waters.

In addition to federal regulations, a second set of legislation regulates the management of PCBs at the provincial level. While
provincial legislation and regulations must meet minimum national environmental quality objectives and standards established by the federal government, provincial government have the options to introduce further obligations for controlling these substances.

In British Columbia, for instance, the provincial legislation which pertains to PCBs includes the Waste Management Act, the Environment Management Act, and the Workers' Compensation Act. As each province implemented legislation controlling the movement of PCBs within its own borders, both federal and provincial legislation apply to the transport of PCB equipment and materials. Release of PCBs to the aquatic environment is another instance where both federal and provincial legislation apply.

Finally, under Canada's constitutional arrangements, provincial governments have responsibility for storage, clean-up of spills, and the disposal of PCB within their own borders. Provincial governments are thus directly concerned with PCBs once those become "waste". In particular, the authorization to operate a PCB destruction facility (thermal means) is a provincial responsibility and the regulatory framework to authorize these operations is province-specific (Idler, 1986: 12).

2.3 Recommendations and Guidelines for the Limitation of PCB Exposure
Complementing the federal and provincial regulative framework, several recommendations and guidelines have been established to control exposure to PCBs. Although these guidelines are developed or endorsed by regulatory agencies, they do not have the force of regulation. Rather they are used as internal "rules of thumb" for management decision-making.

2.3.1 Limiting PCB Residues in Foods

In 1975, the Health Protection Branch (HPB) of the Department of National Health and Welfare (HWC) announced a guideline of 2 mg/kg for PCB residues in the edible portion of fish. This guideline is administered through the cancellation of commercial fishing licenses for those fish that are likely to contain PCB residues greater than 2mg/kg. The great majority of the chemical residue analyses of commercial fish are carried out by the Federal Department of Fisheries and Oceans. The program requires the cooperative participation of the provincial department which has jurisdiction over commercial fishing.

In the Great Lakes, where the potential for PCB residues in fish is the greatest, samples are collected by the Ontario Ministry of Natural Resources and analyzed by Fisheries and Oceans. The

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1 To arrive at this maximum residue limit (MRL) the following factors were taken into consideration: available residue data, PCB exposure from other sources, economic impact on the fishing industry, and potential decrease of food source to the consumer (Grant, 1983: 390-91).
results are used to determine which area will be closed to commercial fishing (Grant, 1983: 387). 4

Sport fishing comes under the jurisdiction of the provinces. Since 1977, the Province of Ontario publishes a "Guide to Eating Ontario Sports Fish" and currently about 300,000 copies are distributed free per year. The Guide refers to about 1600 locations and usually provides information on two or three species from each location. The advice on the consumption of fish given to anglers is based on guidelines from the Department of National Health and Welfare. This advice is not directed to specialty groups such as subsistence fishermen or native groups (Hayton, 1953: 15).

Administrative guidelines have also been established for PCB residues in dairy products (0.2 mg/kg, fat basis), poultry (0.5 mg/kg, fat basis), eggs (0.1 mg/kg, whole weight less shell) and beef (0.2 mg/kg, fat basis). These administrative guidelines, as well as the 2 mg/kg guidelines for commercial fish, would be enforced under Part 1 section 4 (a) of the Food and Drug Regulations which states that "No person shall sell an article of food that has in or upon it any poisonous or harmful substance."

In 1981, in consultation with HWC, Agriculture Canada established

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4 In 1973, the U.S. Food and Drug Administration (FDA) set the allowable PCB limit in the edible portion of fish and shellfish at 5 mg/kg. After several court challenges and evidentiary hearings, the original tolerance was brought down to 2 mg/kg in June, 1979 (OECD, 1984: 404, 409).
an actionable level of 2.0 mg/kg PCBs in fish oil. Agriculture Canada was concerned about the use of fish oils containing PCBs in the manufacture of livestock feeds. Concurrently, a federal interdepartmental inspection program was established for the food and feed industries to decrease the chance of these products becoming contaminated with PCBs from faulty equipment (Grant, 1983: 389; 1987: 30).

In regard to the question of the health significance of PCB residues in human milk, the Minister of Health and Welfare Canada convened a committee to "consider whether there are any problems related to the presence of PCBs in human milk". In part, the committee concluded:

"At the present time there are insufficient toxicological data to define precisely the level of PCBs in human milk that could cause health problems in the suckling infant. However, on the basis of toxicological data in animals, where levels are 50 ug/kg, the physician should pay particular attention to the mother's history, the child's birth weight, general conditions and subsequent growth and development in advising the mother concerning breast feeding." (HWC, 1978, in Grant, 1983: 388)

In a 1975-76 Health Protection Branch survey of one hundred samples
from across Canada, the HPB found that 98% of the breast milk samples tested were below 50 ug/kg (ppb) whole milk. It was thus the Committee's opinion that:

"(...) in view of the benefits of breast feeding in most instances, it would be advisable to continue nursing."

In 1985, HWC provided similar advice to the nursing mothers of Broughton Island, Northwest Territories, and in 1992, to mothers living on the Lower North Shore of the St-Lawrence Gulf. This last point is worth noting since, in both cases, the levels of PCBs found in the bodily fluids of the people living in those communities were higher than average (see chapter 4, section 3.2.1).

2.3.2 Environmental Guidelines

In addition to administrative guidelines recommending maximum residues for food and feed, several recommended standards pertaining to ambient air, water, soil and waste have been recommended. Again, these standards are not regulations and their application and enforcement is voluntary.5

In 1987, the Canadian Council of Resource and Environment Ministers

5 A summary of environmental guidelines for PCBs is available in appendix D (Table 2).
accepted interim environmental quality guidelines for PCBs in ambient air and ambient water. Depending on the province considered, however, environmental guidelines may vary in value and/or in specificity. For example, in establishing its ambient air quality criteria, the Ontario Ministry of the Environment took into account the carcinogenic potential of PCBs thereby producing a relatively conservative standard. On the other hand, Quebec is the only province to have a recommended maximum PCB concentration for recreational water (Environment Canada, 1987: 2, 9).

2.3.3 Occupational Exposure Limits

Most provinces have adopted workplace air concentration limits as recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). The ACGIH’s standard values are based on animal studies performed in the 1930s and information on the effects of PCBs on humans during occupational exposure. The ACGIH believes that these standards "offer reasonable good protection against systemic intoxication, but may not guarantee complete freedom from chloracne" (Environment Canada, 1987: 12, 13).

The ACGIH air concentration limits are expressed as Threshold Limit Values (TLVs) and Short-term Exposure Limits (STELs) for exposure to specific PCB mixtures (ie, askarels). Threshold limit values are limits defined as the maximum time-weighted average exposure level for an 8-hour working day and 40-hour work week. STELs are
limits defined as the maximum exposure level for no longer than a 15-minute duration and no more than four times per day. The ACGIH workplace air concentration limits are as follow:

For PCBs with 42% chlorine: 1 mg PCBs/m³ air over 8 hours (TLV)
    2 mg PCBs/m³ air over 15 min. (STEL)
For PCBs with 54% chlorine: 0.5 mg PCBs/m³ air over 8 hours (TLV)
    1 mg PCBs/m³ air over 15 min. (STEL)

In contrast to other provinces, the Ontario Ministry of Labour has adopted a time-weighted average exposure criteria of 50 ug/m³. This guideline corresponds to a PCB air concentration to which it is believed "most employees may be repeatedly exposed, on a daily basis within a 40-hour work week, over a working life time, without adverse effects." An important provision of the guidelines specifies that workers should be protected from skin contact by the use of impervious materials (Canadian Council of Ministers of the Environment, 1990: 30)

It is also of interest to note that in the U.S., NIOSH arrived at a time-weighted average for all PCBs of 1 ug/m³ for up to a 10-hour day, 40-hour week. This maximum exposure level is equivalent to the minimum detectable level. According to NIOSH, this "should reduce risks of reproductive and carcinogenic effects, and protect the employees from metabolic disfunction, hepatic injury, and dermal effects due to PCB exposures during their working lifetimes"
2.3.4 The interim Tolerable Daily Intake

In the early 1970s, Health and Welfare Canada set a PCBs "tolerable" exposure level at 5 ug/kg bw per day. This TDI was calculated by applying a 100-fold safety factor to the lowest no-observed effect level (NOEL) reported in toxicological studies of rats and dogs. Then, in the late 1970s, a number of laboratory experiments with female rhesus monkey showed this species' reproductive system to be more vulnerable to the toxic effects of PCBs than the rat (Grant, 1983: 389).

These experiments led HWC to lower its original tolerable exposure level and to apply a 100-fold safety factor to the lowest NOEL in monkey reproduction studies. HWC indicated that, in order to protect human health, total daily exposure to PCBs from all pathways should not exceed the interim TDI of 1 ug/kg bw per day.\(^6\)

This (unpublished) TDI is temporary because, along with the regular

\(^6\) In 1985, the U.S. EPA revised its assessment of PCBs and concluded that suitable data to establish a TDI were not available (Environment Canada, 1987: 8).

With respect to cancer risk, the U.S. EPA (1983) suggested that, a PCB intake at a level of 4.01 or 4.34 ug/kg bw per day (depending on the model used) is associated with a \(1 \times 10^{-6}\) level of cancer risk. By contrast the U.S. FDA considers the scientific data base generally inadequate to accurately quantify such risk (Clarke et al., 1987: 13, 14).

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uncertainties in using animal data to estimate an "acceptable" exposure level to humans, there is the additional problem that the PCBs which were tested may be somewhat different from those present in foods (Grant, 1983: 390). Today, the multigenerational effects of PCBs in monkeys are still under study. The interim TDI guideline of 1 ug/kg bw per day is still in effect.

3. The PCB Inventory and Treatment /Destruction Options

Since 1977, PCB wastes have been stored awaiting the installation of suitable disposal facilities. Some wastes are kept on-site by the companies or institutions owning these wastes. Others are stored at utility sites or in provincially approved central storage facilities.

There are over 3,000 PCB waste storage sites in Canada with the federal government having responsibility for 550 of those. In Metropolitan Toronto, for example, there are 15 federal storage sites and 234 sites belonging to other jurisdictions.

Several technologies are commercially available to treat and dispose of PCBs. In practice, however, this "availability" is relative and largely situation-specific. From a technical

7 To be considered commercial, the technology must have operated successfully under sustained, large-scale, routine field conditions, and must have received regulatory approval.
standpoint, the relative effectiveness of each technological option depends on the types and quantities of PCBs considered. Further, the applicability of a given treatment/disposal option may vary with the particular regulatory environment considered. Finally, the costs associated with these technologies is another parameter whose value may affect the selection of one or another option (doing nothing being also one option).8

Public opposition to siting treatment and disposal facilities has become an important focus of attention in risk management. Yet, there is also a substantial and irreducible engineering aspect to the PCB problem. In addition to making available effective treatment technologies, this engineering dimension includes the logistics of dealing with many different combinations of waste types, generator size, locations and regulations.

The first part of this section introduces the Canadian PCB inventory in relation to the capabilities of proven PCB treatment and destruction options. This inventory is made of PCB-contaminated mineral oil, PCB-containing equipment, and askarel. The second part presents a sample of human health and environmental risk assessments conducted for the purpose of siting high

8 The financial variable of the PCB problem is not considered here. Yet, whether they are public or private institutions, small individual companies or large public utilities, local or provincial governments, cost considerations are key for those parties who own and are responsible for these wastes.
temperature PCB destruction facilities.

3.1 PCB Inventory and Related Treatment Technology

3.1.1 Contaminated Mineral Oil

Canada has about 335 000 contaminated mineral oil transformers in service containing approximately 40 million litres of PCB-contaminated mineral oil. An additional 5.4 million litres are in storage. Four companies operate mobile chemical treatment systems and are approved for operation in most provinces. These companies have been operating since 1983 and have treated over 10 million litres of PCB-contaminated mineral oil. Technically, they have the combined capacity to treat all of Canada's contaminated mineral oil within 2 to 3 years.

To be cost effective, these systems require that more than 10 000 litres be treated at one site. For these quantities of contaminated mineral oil to be gathered, the individuals, companies, or agencies owning this material need to be encouraged and able to arrange for cooperative, centralized treatment sites in their immediate geographical area. Some provincial government

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9 The bulk of the information presented below is taken from a 1991 Environment Canada document entitled: Options for the Treatment/Destruction of PCBs and PCB-contaminated Equipment.

10 At present, mineral oil is considered "contaminated" if it contains more than 50 ppm PCBs. Treatment systems must reduce the concentration of PCBs in the oil to less than 2ppm.
allow this practice by permitting storage consolidation and the associated PCB transportation.  

3.1.2 PCB Containing Equipment

PCB containing equipment essentially includes i) in-service mineral oil transformers; ii) in-service askarel transformers; iii) waste transformers; and iv) capacitors.

3.1.2.1 In-service Contaminated Mineral Oil Transformers

Approximately 310 000 pole-mounted transformers and 25 000 larger distribution and power transformers with PCB-contaminated mineral oil are in service. Although no clear pattern exists to explain why one transformer is contaminated more than another, it is suspected that the year of manufacture plays a role in the contamination problem.

All the technologies currently used to decontaminate in-service

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11 For example, the B.C. Ministry of Environment Lands and Parks has an objective to remove all PCBs currently in provincial institutions such as schools, hospitals and rest homes. The PCBs are to be consolidated on an interim basis in secure storage and BC Hydro has made a corporate commitment to store this waste on a cost recovery basis. However, BC Hydro does not take ownership of the wastes and these institutions remain responsible for their eventual disposal (British Columbia Hydro and Power Authority, 1992: 14).
contaminated mineral oil transformers involve methods that replace the transformers' contaminated oil with clean oil, an operation described in the PCB service industry as "retrofilling". Several retrofilling methods are available, the choice of which depends on the initial PCB contamination level and the owner situations. The type of factors affecting particular situation includes: the number and size of transformers owned, the transformers' maintenance and replacement schedules, site access, and specific provincial and municipal regulations.

Standards set or accepted by provincial governments (by regulation in Ontario only) for the decontamination of mineral oil transformers basically rely on what is referred to as the 90-day test. The mineral oil in the transformer is tested 90 days after decontamination to verify that it contains less than 50 ppm PCBs. The transformer is then declassified and considered to be a non-PCB transformer. In the case of transformers with PCB concentrations in excess of 1000 ppm, multiple retrofillings may be necessary. The process can become prohibitively expensive compared to replacing the transformers.

3.1.2.2 In-service Askarel Transformers

The 90-day waiting period is necessary because of "leach-back". After clean mineral oil is added to the transformers, residual PCBs absorbed in the wood and paper materials or trapped in small interior spaces of the transformer leach out into the clean oil. The leaching process is usually (but not always) completed after 90 days.
There are approximately 7000 in-service askarel transformers in Canada. Because askarel contains high levels of PCBs (with concentrations ranging between 400 000 to 700 000 ppm), they are very difficult and costly to decontaminate using traditional retrofilling procedures. Alternative methods involving for example - a distillation unit attached to the transformer to continuously remove PCBs from the leaching fluid - have been developed and are used in the U.S. and to a limited extent, in Canada.

Because of the costs involved with new declassification methods the alternative of replacing and scrapping askarel transformers is an attractive option. The decision often hinges on the remaining life expectancy of the askarel transformers but as units get older the replacement option is likely to increase.

3.1.2.3 Waste Transformers

A waste transformer is any transformer that contained liquids with more than 50 ppm PCBs. Canada has approximately 3000 contaminated mineral oil transformers and 4000 askarel transformers in storage. This inventory is significant and will likely grow as transformers are phased-out of service. There are two regulated methods for disposing of PCB transformers and both involve incineration to some extent.

The best method of disposing of these transformers is to dismantle
the units, clean separated components with solvent and ship PCB liquids and combustible components to PCB incinerators. After testing, the metal components are smelted for metal recovery; the solvent is distilled for reuse. This has been the method of choice in the United States.\textsuperscript{13}

The alternative method is incineration of shredded transformers. However, metal recovery is more difficult when transformers are shredded and transformers are not preferred feed material for incinerators.

For the solvent-flushing method to become widely used in Canada, consistent decontamination criteria allowing for the subsequent disposal of metal parts by smelting would have to be developed. So far, few provinces have decontamination criteria and testing methods for waste transformers. As of 1991, transformer decontamination technology had been used on a commercial basis in Quebec and Manitoba only. Further, since PCB incineration facilities are available only at Swan Hills, final disposal of contaminated material is not available to the Canadian market outside Alberta.

3.1.2.4 Capacitors and Light Ballasts

\textsuperscript{13} The U.S. phase-out effort is directed mainly towards PCB transformers containing in excess of 500 ppm PCBs and to large capacitors. In this country the storage of PCB material is limited by law to a maximum of 1 year.
Since almost every electrical capacitor manufactured between 1930 and 1978 contains PCB liquids, it is assumed that, unless labelled otherwise, all capacitors contain PCBs.

There are 200,000 capacitors in service and 110,000 capacitors in storage in Canada. These units usually range from 14 to 91 kg. In addition, 63 million small capacitors are in service in light ballasts, and 620 drums (205-L) of light ballasts containing capacitors are in storage.\(^{14}\) Although these capacitors are small, there is no ready method of removing them from the bulk and the entire ballast must be stored. High-temperature incineration of shredded capacitors is the only approved destruction method. Until incineration is accessible, secure storage of capacitors and light ballast is the only option.

### 3.1.3 Askarel

Approximately 13,700 t of askarel are still in use and 6,000 t are in storage. These 20,000 tonnes represent the largest amount of PCBs in Canada on a pure PCB basis. High-temperature incineration is the only approved technology for the destruction of PCBs in askarel.

The Alberta Special Waste Treatment Centre at Swan Hills, 200 km

\(^{14}\) Light ballasts are common in fluorescent lamps used in residential, commercial and public lighting.
northwest of Edmonton, has the only stationary incinerator approved for PCB destruction in Canada. It is currently available for Alberta's PCBs only. A joint venture between the Alberta Special Waste Management Corporation and Chem-Security (Alberta), this facility was licensed by the Alberta government for commercial operation in October 1988.

For PCB treatment, the incineration facility consists of two rocking kilns capable of incinerating both low-level and high-level PCB liquids. The technology was selected because of its ability to incinerate whole 205-L drums of waste without any pre-treatment. The pollution control train has proven itself capable of reducing emissions to levels well below those specified by the Alberta Department of Environment. In 1990, a rotary kiln incinerator was added to the facility to treat bulk solids and sludges.

Theoretically, a single large incinerator could destroy the entire Canadian inventory of askarel in approximately 4 years of operation at one site. Being the largest systems, stationary incinerators constitute the lowest cost alternative. Their disadvantage is that wastes must be transported to the incinerator with attendant risks of accidents. In addition, social consideration are critical in siting facilities and from this perspective at least, mobile PCB incineration is the most viable solution for destroying Canada's askarel inventory.
Canada has experience with two transportable PCB incineration systems. In 1990 at Goose Bay, Labrador, a Department of National Defence stockpile of PCB-contaminated soils, metals, and askarels was incinerated. At Smithville, Ontario, similar PCB-contaminated materials have been destroyed for the Ontario Ministry of Environment.

Transportable equipment is appropriate to service many askarel generators in geographical areas with high concentrations of askarel such as Ontario and Quebec. Smaller mobile incinerators can service individual sites with small inventories of askarel, capacitors and light ballasts, PCB-contaminated equipment, soils, sludges, solvents, and other contaminated materials. However, mobile incinerators have not yet been fully tested and approved for the destruction of PCBs in Canada.

Because of the priority of destroying askarel and the difficulties associated with siting incinerators (stationary, transportable or mobile) the federal government is viewed as having a leading role in providing regional sites. For any siting process to be successful, however, the close cooperation of provincial and municipal governments is also required (see section 4.2).
3.2 Risk Assessments for Siting PCB Thermal Destruction Facilities

The following introduces a sample of the numerous health and environmental assessments that have been conducted for siting hazardous wastes disposal sites. All the studies presented here were intensive and evaluated the potential risks associated with transportation, storage, and disposal of hazardous waste with a special emphasis on PCB destruction.

3.2.1 Ontario Waste Management Study

In 1988, the Ontario Waste Management Corporation (OWMC) published a five volume detailed analysis that sought to review every possible impact associated with incineration and secure landfilling. The study concluded that the routine operational risks associated with a proposed OWMC facility were either very low and acceptable or extremely long term and potentially not significant. While the analysis indicated that on and off site accidents and upsets represented potential risks to human health, the likelihood of such incidents was estimated to be very remote.

The net effects of the facility were found to be moderate and consistent with locations in its vicinity of medium industrial uses. Moderate indirect effects associated with siting the facility included resident dissatisfaction, effects on community stability, and conflicts with existing, planned, and proposed land use. Precautionary measures could be implemented to diminish the possibility of an accident sufficient to create a human health risk and indirect impacts (e.g., a decline in property value). The analysis concluded that the risk associated with the facility could be reduced to an acceptable level.

3.2.2 Cantox Inc. Studies

Cantox Inc. conducted thorough health risk assessments for PCB storage and destruction operations at Smithville, Ontario and Goose Bay, Labrador. Potential impacts were evaluated for inside and outside workers, adults and children living in the nearest town, farm and wild animals (aquatic and terrestrial), crops and wild flora. The conclusions were that there would be no adverse effects as a result of burning PCB wastes in the proposed incinerators.

Likewise, no health effects were predicted for accidents scenarios involving venting to the dump stack, a spill of contaminated oil, or an explosion at the incinerator site without a fire. However, for a worst-case scenario of a one half hour fire involving 450 gallons of oil containing 60% PCBs, the risks for receptors at all
sites was deemed unacceptable. In particular, the risk to children near the site was estimated to continue for 112 years after the fire. At Goose Bay, the unacceptable risks for residents within a 20 km radius of the site was predicted over a 30 year time frame.

In sum, this risk assessment indicated that the health risks encountered during routine operations of both incinerators were acceptable even when several abnormal occurrences were considered. However, the analysis emphasized that extreme precautions that must be taken to prevent the uncontrolled combustion of PCBs and the subsequent risk associated with their long-term storage.

3.2.3 Arizona Waste Management Facilities

An extensive evaluation of the risks associated with PCB handling and disposal at a proposed facility in Maricopa County, Arizona has been carried out by First Environment Inc. With the use of the most conservative assumptions, the excess lifetime cancer probability to a maximally exposed individual was calculated to be one in 1.1 million. Overall, the presence of the facility was considered to be of virtual minimal consequence to the health of nearby residents when compared to other life-time risks.

\[ ^{16} \text{When PCBs are subjected to heat, their PCDF content rises. In addition, PCDDs can be formed by heating chlorinated benzenes which are normally present in askarel fluids.} \]
3.2.4 U.S. EPA Region IV Studies

In 1981, the U.S. EPA Region IV evaluated the potential risks to human health of two high temperature incineration operations in Texas and Arkansas. The EPA's risk evaluation assumed extreme exposure conditions for nearby residents. These included exposure for 70 years to the highest concentrations of furans and dioxins found in tests of stack emissions, with all TCDFs and TCDDs having the same carcinogenic potential as 2,3,7,8-T₄CDD.

On the basis of these conservative assumptions, the calculated risks of additional cancer for residents living near the first operation varied from 0.03 to 0.4 chances per million, and from 3 to 8 chances per million for individuals similarly exposed near the second site. The U.S. EPA then evaluated landfilling storage and chemical destruction as alternatives to incineration. The EPA concluded that chemical destruction was limited in its capabilities and that the options to incineration were not acceptable in the long run.
4. The PCB Phase-Out Program

4.1 The Federal PCB Destruction Program and the PCB Action Plan\(^{17}\)

The federal government is working to address the PCB issue through its "Federal PCB Destruction Program". Concurrently, federal, provincial and territorial cooperative efforts have been formalized through the Canadian Council of Ministers of the Environment's "PCB Action Plan" initiated in May 1985.

After the fire at St-Basile-Le-Grand in September 1988, the Canadian Council of Ministers of the Environment (CCME) held a special meeting. At this meeting, and at the Council's Annual Meeting of that year, Ministers agreed "to phase-out all PCBs in Canada by 1993" (PCB Fact Sheet, 1990: 2).

To meet this goal, a broadly-based PCB management plan was announced. The PCB Action Plan proposed to develop both mobile and stationary destruction facilities; to manage Canada's wastes as much as possible within Canada; to accelerate PCB removal from sensitive locations such as schools and hospitals; and to ensure full reporting by PCB users to enable the PCB inventory to be maintained and updated.

\(^{17}\) This discussion draws on the "PCB Fact sheets" published by Environment Canada (1990, 1991).
As part of this national program to rid Canada of PCBs, the Federal PCB Destruction Program was announced in September 1988. Initially this program entailed the leasing and siting of two transportable incinerators (one in Labrador, one in Central Canada) to destroy federal PCBs. These facilities were to be made available to other owners of PCB wastes. The federal government also committed to the phasing-out and decontamination of all federally-owned PCB-contaminated mineral oil by the fall of 1989.

In October 1988, the Cabinet Decision on this program committed funds for the two above-mentioned projects. It also directed Environment Canada to seek the advise of the Canadian Environmental Advisory Council (CEAC) on the decision-making process appropriate to selecting a site for the second transportable facility. In June 1989, CEAC submitted its Report entitled "PCBs: A Burning Issue" to Environment Canada (CEAC, 1989).

The CEAC report stressed the importance of public education and consultation in the siting of any hazardous waste facility. It confirmed Environment Canada's own findings, obtained over the previous year through extensive public opinion surveys, that the public had to be integrally involved in this process.

At its October 1989 annual meeting, the CCME Ministers decided to shift the emphasis of the federal-provincial PCB program from storage to destruction. Concurrently, the federal environment

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minister announced an "enhanced" Federal PCB Destruction Program. Instead of siting one transportable incinerator, the new program is aimed at siting federally-sponsored mobile PCB incinerators to regions across Canada where warranted by the volumes of wastes.

Participation in the program is voluntary. Communities interested in getting rid of their PCBs can benefit from Environment Canada’s technical and administrative assistance and are offered mobile PCB destruction on a cost-recovery basis. The siting process includes a full application of the federal Environmental Assessment and Review Procedures and federal lands may be made available for siting facilities. Inherent to the program is the understanding that any federally sponsored initiative will include the federally owned PCB waste inventory for the region considered. In addition, the initiative must have the endorsement, if not participation, of the provincial governments.

In November 1989, Environment Canada organized a National Stakeholder Workshop as a first step in an on-going consultation process for implementing the Federal PCB Destruction Program.

At this Workshop, the Program’s director made a plea for help in finding the best and most sensible way of getting rid of PCBs in Canada by 1993 and reiterated the Program’s four objectives:

* to introduce mobile and transportable incineration technology into Canada;
* to analyze the PCB inventory and identify communities and situations where this technology is appropriate;
* to assist those communities to consider the incineration options; and
* to provide federal assistance to communities choosing to proceed to lease the appropriate incineration technology.

The federal government phase-out program is predicated on an open endorsement of incineration as a technically and socially acceptable option for PCB destruction. The following comments make this position abundantly clear.

"Although all ministers recognize that, ultimately, the phase-out and elimination of PCB wastes is dependent upon PCB waste destruction facilities for both fixed and transportable technologies being available, in the short-term, we believe that mobile and transportable incinerator technologies provide the answer to destroying Canada's PCB wastes."

"With mobile incinerators, destruction of PCBs can be expedited immediately, without waiting for permanent waste management facilities to be built."

(Program's director in National Stakeholder Workshop, Environment Canada, 1989)
"High-temperature incineration has been shown to be the best overall approach for the destruction of all types of PCB wastes. (...")

We have large fixed facilities that process 10 tonnes/hour, large transportable facilities that process 5-10 tonnes/hour and small mobile incinerators that process 1-2 tonnes/hour. In addition, cement kilns are a proven technology that can process liquid PCB wastes."

(Head, Waste Management Division in National Stakeholder Workshop, Environment Canada, 1989)

So far, no mobile PCB destruction system has been operated in Canada on a commercial basis. A joint federal, Ontario, and Quebec program to test a small VESTA mobile incinerator system at Swan Hills, Alberta was undertaken in 1989. As of November 1992, the test results and final report had yet to be released.

On August 22, 1990, a Memorandum of Understanding was signed by the federal minister of the environment and his four Atlantic counterparts in view of developing a co-operative program to site a mobile PCB incinerator to destroy Atlantic Canada’s PCBs.
4.2 PCB Destruction Initiatives

This subsection summarizes the activities undertaken by the provinces and other Canadian jurisdictions to dispose of their PCB wastes using thermal destruction facilities. Each case provides additional evidence to document the key role played by public information and consultation processes in carrying these projects through completion. However, taken together these initiatives also indicate that, while a successful public involvement is necessary to site PCB destruction facilities, it is not in itself sufficient to guarantee an adequate management of the PCB destruction problem.

Some of the main PCBs initiatives undertaken during the last 5 years are briefly reviewed. The status of PCB management activities at the provincial level is presented in table form in appendix D (Table 3).

4.2.1 Smithville, Ontario

In 1991, the Ontario Ministry of the Environment rented a transportable incinerator from an Arkansas-based company to clean up an abandoned PCB storage facility near Smithville, on the

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18 This information is extracted from a 1992 report by Envirochem Special Projects Inc. titled PCB Waste Destruction Strategy and prepared for the British Columbia Hydro and Power Authority.
Niagara Peninsula. Contamination on the site had leached into the underground aquifer and a separate groundwater treatment system had to be put in place to pipe fresh water to the community to replace contaminated well water.

Prior to undertaking the project, the company had to undergo test burns and site specific hearings as required by Ontario regulations. Throughout the project, a citizen’s advisory committee acted in an oversight capacity to ensure public concerns were addressed. The operation has been strictly monitored by the Ontario Ministry of Environment and did not experience any problem.

The project is now completed with approximately 20,000 tonnes of PCB waste destroyed. However, the Smithville operation was considered a remediation project. The willingness of local residents to tolerate the incinerator was predicated on the fact that the situation was temporary and that they would directly benefit from the cleanup of the site.

4.2.2 LEAP - Londoners for the Safe Elimination of All PCBs

The motivation for LEAP originated in the necessity to find an appropriate storage facility for PCB wastes generated by the Public Utilities Commission, the hydro operator in London, Ontario. The program expanded to include all PCB wastes in the London area. LEAP’s main role was to increase community understanding of PCB
management options.
In 1990, funding for the initiative was provided via the Federal PCB Destruction Program and continued for the period 1991-92. The LEAP project resulted in a major public communication effort to provide Londoners with information on PCBs and PCB management destruction options and was successful in providing a forum to discuss PCB related issues in an attempt to achieve consensus. However, LEAP does not own or manage PCBs, nor does LEAP have any legal authority or mandate to solve the PCB problem.

The Ontario Ministry of Environment has regulatory jurisdiction over any destruction initiative (outside federal crown land). At this time, neither that ministry nor any owner/manager of PCBs has made the necessary corporate and financial commitments to seeing the project through to actual destruction.

4.2.3 BPC Quebec and Hydro Quebec Baie Comeau

The Quebec government has committed to the destruction of PCB versus long-term storage of PCB waste as the only acceptable waste management option. In October 1991, a program to destroy "orphan" PCB wastes at St-Basile, Baie Comeau, and Shawanigan was established under the jurisdiction of the Quebec Ministry of Environment (MENVIQ). The program incorporates active public participation throughout with an oversight committee at each site. Membership on the committee is decided by the communities in
Although intervenor funding has not been included, the government has supported the committee financially in terms of expenses and through provision or sponsorship of all the technical support necessary to help committees reach consensus on issues relating to their particular sites. An overlapping project is the Hydro Quebec sponsored initiative at Baie Comeau to test the Vesta technology.

In March 1992, Hydro Quebec contracted Vesta Technology Inc. of Fort Lauderdale, Florida to perform test burns using the Vesta 200 mobile incinerator at one of its sites, 25 km from Baie Comeau. Hydro Quebec felt that the previous testing efforts of the Vesta incinerator in Swan Hills did not allow for adequate evaluation of the unit. The transportable incinerators used at Smithville and Goose Bay were also considered too large and expensive for its purpose.

An open public consultation program using the same vigilance committee as the BPC initiative facilitated the test burns. Once again, the fact that the situation was temporary lent support to the initiative. The project was completed in June 1992. The oversight committee requested the incinerator remained to undertake the destruction of the orphan PCB waste from the BPC Quebec program. However, previous contract commitments for the technology in the U.S. precluded this possibility.
4.2.4 CFB Goose Bay

In 1986, a process was initiated with the assistance of the Federal PCB Destruction Program to dispose of PCB-contaminated material owned by the Department of National Defence (DND) and stored on abandoned radar sites on the Labrador coast. A formal community relations plan was filed with DND as a condition of the contract. The technology was mobilized in October of 1989 and underwent a series of three test burns to demonstrate compliance with Environment Canada’s criteria for thermal destruction of PCBs.

Over the next few months, a total of 4,500 tons of PCB-contaminated soils, rock, wood, plastic, transformers, capacitors, steel drums, free PCB liquid, and miscellaneous debris were destroyed. An extensive community relations program was carried out throughout the project to keep citizens of Happy Valley-Goose Bay informed. Once again the fact that the project was not permanent and responded to a local problem made it more palatable to the community. The Smithville and Goose Bay programs have been, to date, the only two occasions were temporary PCB destruction facilities have been successfully sited and operated in Canada.
5. Conclusion

To conclude, Canadian governments appear to believe that PCB risk has been adequately assessed, and further, that incineration when operated according to specified requirements and properly monitored, constitutes both an effective and desirable means to destroy PCBs.
1. Introduction

Popular accounts of the widespread dispersion of PCBs into the environment are often accompanied by picturesque reminders of the varied and multiple commercial applications of this chemical. Indeed, so versatile are PCBs that millions of North Americans lived with the substance for years in their television screens and wallcoverings, in the coloured comics in their newspaper and even in some brand of cosmetics and gum. However, while the image of PCBs as a "wonder chemical" of the thirties is arresting, it is also misleading to the extent that it undermines PCBs' most basic and essential contribution to national development. By cooling the hot boxes connecting the wires that lit up the country, PCBs have been a major contributor to rural electrification and a principal factor in giving us a comfortable lifestyle by keeping the power flowing under some of the most extreme climatic conditions in the world.

Yet, for the general public acquainted with some of the chemical's most publicized deleterious effects, PCBs' principal contribution to national unity has been to become the country's most talked-
about industrial pollutant, and in those years where concerns for the environment were most pressing, to attain the dubious honour of becoming Canada's Public Enemy No. 1. As one commentator bluntly put it: "Canadians have developed both an unwarranted fear of and a morbid fascination with PCBs." These strong words were echoed by University of Toronto chemistry Professor and Nobel Prize winner John Polanyi who added: "Hysteria and lack of solid information have built relatively harmless PCBs into a monster in the public's mind."

This chapter examines the public perception of PCBs in conjunction with the press coverage of a series of incidents that have been particularly influential in shaping the public's views of that chemical. Although properly speaking, the public perception of a risk and the media accounts of the same are two distinct entities, previous works in risk communication research have emphasized that the two are interrelated. The media being the main source of risk information for the general public, the representations of a risk which appear in the former clearly influence the later. Thus, the media portrayals of a risk provide one tangible expression of "the public perception" of that risk, an otherwise essentially elusive concept. In this perspective, the chapter seeks to understand and represent the nature of public concern through the media rendering of the PCB risk.
2. The Extent of the PCB Press Coverage

2.1 The 1968 Yusho Poisoning and the Link to Cancer

As a result of an accidental leakage of PCB in a Japanese plant, approximately 1,200 people contracted various serious disorders after eating rice oil contaminated with the chemical. The poisoning which, according to Huddle et al. started in February of 1968, was not made public until October of the same year, after a scoop on the subject appeared in the prestigious Asahi Japanese newspaper. A week after this scoop, the Japanese national media carried a report revealing the role played by the Japanese bureaucracy in silencing early warning signs that "PCBs" were the causative agent of the "oil disease".

In spite of these media revelations, however, public concern over PCBs does not seem to have actually arisen in Japan before February 1971 when a group of scientists and reporters "pierced traditional professional barriers and constituted a horizontal communications network". Their association resulted in a public announcement on PCB contamination in fish, meats, and birds which received widespread media coverage and set off a mini panic among the Japanese public. In response, the Japanese government allocated funds for a full-scale investigation of PCB contamination and MITI began limiting the compound's industrial uses. By June 1972, all PCB production in Japan came to an end.
The relatively limited attention the poisoning incident originally provoked in the Japanese public can perhaps be explained in light of the following quote attributed to a biologist at Tokyo Metropolitan University:

"[t]he victims unknowingly ate contaminated food, and once they became sick, no one would accept responsibility for causing or treating the disease. It is this social abandonment of the victims and the refusal by industry, government and society at large to accept responsibility for the disease that have turned an 'accidental food poisoning' into a full-fledged case of 'kogai byo'--pollution disease."

(Huddle et al., 1985: 133; my emphasis)

In the United States, however, reports of the Yusho incident and of the discovery that trace quantities of PCBs were widely distributed in the environment combined to make PCBs the subject of intense scientific review and a focus of newspaper stories. This, according to Burger (1990), resulted in PCBs becoming in 1969-1970, the most prominent chemical material used to promote the Toxic Substances Control Act then being considered by the U.S. Congress. In 1971, PCBs were highlighted in national papers as "deadly chemicals in American industry", "thought by many scientists to be serious long-term danger to man and animals", and "linked to birth defects".5

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Despite announcements in 1972 of restrictions on the manufacture, distribution and use of the compounds, PCBs continued to be a focus of media attention. In 1975-1976, press reports started to emphasize the spectre of cancer; during the first half of 1976, several stories appeared in the New York Times making an explicit link between PCBs and cancer. One story, for instance, referred to PCBs as "a class of chemicals... linked to cancer and birth defects". When in August 1976, the U.S. Senate approved the Toxic Substances Control Act, special restrictions and regulations pertaining exclusively to PCBs, were added into the act (Burger, 1990, 142-144).

2.2 The 1977-1982 Period

A manual search of Canadian newspaper indexes for the 1977-1982 period showed an average of about 10 articles published on PCBs yearly, with some years (1979, 1981) having a lower than average number of articles, perhaps because during these years, the press environmental coverage was almost entirely focused on the acid rain issue. These particular years set aside, stories on PCBs were a fairly regular and stable fixture of the press coverage on pollution, although coverage intensified on occasion, as when a particular event focused media attention on the subject.
In 1977, for example a great deal of the PCB stories revolved around a fire and spill which occurred in an underground vault housing an askarel-filled transformer on Adelaide Street in downtown Toronto. The event was particularly newsworthy because as the emergency response teams had not been informed of the presence of PCBs in the vault, they did not take any precaution to protect themselves or others from the PCBs and related by-products contained in the fumes and soots. It was only well after the blaze had been put out, when a story raising the health implications associated with the vaporization of the chemical appeared in the Globe and Mail about a week later, that the fire fighters learned that PCBs were involved in the fire.\(^7\)

In the United States, one of the most publicized PCB event occurred in 1981 in Binghampton, New York, when a transformer located in the basement of a 18-story building housing 33 state agencies caught on fire spreading contaminated soot throughout the building. Decontamination efforts took more than three years and government officials later estimated that it would have been cheaper to rebuild the structure. Although at that time the Binghampton fire received minimum press coverage in Canada, the $50 million related cleanup cost it incurred has often been used since as a reminder of the financial risks associated with the ownership of PCB materials.\(^8\)
2.3 The 1982-1992 Period

For the 11-year period extending from January 1982 to December 1992, a computer search of the Canadian News Index (CNI) database for articles published in the popular press with the acronyms "PCB" or "PCBs" in their titles produced a total of 1125 articles. As several observers of the PCB story have remarked, it can hardly be said that the PCB issue was surrounded by a conspiracy of silence.

Although the list of articles produced was not exhaustive, it was comprehensive enough to show that the press coverage on PCBs peaked during the years 1985, 1988 and 1989. In each of those years a PCB related incident received outstanding media attention. By themselves, the 1985 Kenora spill, the 1988 St-Basile-le Grand fire, and the 1989 Baie-Comeau controversy generated so much media activity that over three quarters of the PCB newspaper articles published during this 11-year period were written during these three years.

For this very reason, much of the following discussion will focus on those three incidents and on their purported significance as communicated to the public by the press.
3. A Chronology and Anatomy of Key Events

3.1 The 1985 Kenora Spill

On Saturday April 13, 1985, a flatbed truck carrying a set of undrained Hydro Québec transformers was travelling the Trans-Canada Highway from the Montreal area to an Alberta storage site. While the truck was barrelling down a narrow strip of the highway east of Kenora, a Northwest Ontario community of 9,600 residents near the Manitoba border, one of the transformers sprang a leak and splashed about 400 litres of oil contaminated with 42 per cent PCBs along 70 km of asphalt.

The 1985 Kenora spill received extensive national media coverage and was one of the key events that gave PCBs its special status in the Canadian psyche. The significance of the event can be inferred, in part, from the number and prominence of related media reports which appeared coast-to-coast during and after the incident. More telling perhaps is the endurance of the episode in the Canadian collective memory as witnessed by the fact that today PCBs are hardly ever mentioned in public discourse without some reference being made to "the 1985, Kenora spill".

The media coverage of the spill immediately played up the human angle of the story by stressing the plight of the Eyjolfson family who while en route to a family reunion in Winnipeg, found
themselves caught behind the big flatbed tractor trailer for a
distance of 25 km before being able to pass. When Lloyd Eyjolfson
25, picked up a newspaper at his in-laws' breakfast table the next
morning, he learned that his pregnant wife, his two toddler sons
and himself had been exposed to "mass quantities" of PCBs.

The following comment, printed in the lead article of Macleans'
magazine special issue on the spill, encapsulates the impact of the
event:

"The entire country was riveted by the family's plight
and engulfed by the disturbing realization that chemical
spills can happen anytime, almost anywhere, and that they
can menace every Canadian."

Perhaps because of this readily available human dimension, the
media coverage of the spill capitalized on PCBs' most dramatic
health effects -- cancer and birth defects. Although a
comprehensive examination of all media reports on the event would
show that, in some instances, cautionary lines have accompanied the
association of PCBs with dreadful health effects, most journalistic
accounts of the event made a strategic use of these alleged effects
to give their reports both an objective anchor and a dramatic
quality.
At the same time, the media coverage of the spill has drawn attention to the magnitude of the PCB inventory by reminding Canadians of the thousands of storage sites distributed across the land and of the millions of litres of PCBs still being used. The media dramatization of the health risks and emphasis on PCBs inventory have combined with the obvious difficulties encountered by officials in reacting coherently to the spill (see section 2.2) to give PCBs the image of a chemical outcast out of control.

On the cover of its April 29, 1985 issue, Maclean's, Canada's weekly magazine, showed a picture of the skull-and-crossbones emblem over an oil barrel surrounded by the following headlines:

The Toxic Threat

PCBs: what they are, where they come from - and how they can kill

The Kenora spill that exposed a national menace.

From a broader perspective, the Kenora spill provided a good opportunity for bringing in the open the patchwork of legislations and levels of responsibilities involved in the management of hazardous substances. In the end, the event led to the implementation of binding regulations to govern how shipments of toxic substances should be contained. But for the general public,
it was one of those memorable episodes around which concern about the management of hazardous wastes crystallized. For the experts and the public alike, much of this concern was now encapsulated in the acronym "PCBs".

3.2 A Patchwork of Contradictory Messages

It is often reported that public concern over the management of hazardous waste has been fuelled by confused official responses and bureaucratic stumbling. The official reactions to the disclosure of the PCB spill on the Trans-Canada Highway are a case in point. The confusion went on for an entire week and under intense media scrutiny.  

Although once aware of the spill, local and provincial police were prompt to converge on the service station where the leaking truck had finally stopped after crossing Kenora, the situation was not communicated to senior Ontario government officials until 22 hours later. When those officials decided to close down the highway, thousands of motorists had already driven on or through the PCB splotches. A clerk at a local pharmacy, probably summarizes local sentiments accurately when she declared: "If this were downtown Toronto things would have been acted on a lot quicker."

Provincial officials then advised worried motorists to put on rubber gloves and wipe the PCBs off their vehicles with Varsol.
cleaner and a dry rag. However the advice was dismissed by a University of Western Ontario geneticist who countered that PCBs can cut through clothing and rubber. This, he said of the self-help advice, is "the dumbest, stupidest thing that I have ever heard".

On Sunday April 14th, a day after the spill, an emergency hotline was established at the town hall, and a press release informed Kenorans that although the spill threatened the environment a "brief single exposure to PCBs produces no harmful effects". In the following days, the official message was one of reassurance. Kenora mayor denied that the people of Kenora were seriously concerned about the spill and accused the media of exaggeration. The regional medical health officer, tried to dispel fears that PCBs pose an immediate health hazard by stating that "It would be safer to walk along a highway with PCBs than sitting in a room with a smoker." And the Ontario environment minister tried to downplay the health risk of the spill by saying that the spilled PCBs would only constitute a health hazard "if you are a rat licking the highway." 14

Despite these reassuring statements, 900 people in one 48-hour period alone flooded emergency telephone hotlines with inquiries, and some 20 people, including a second pregnant woman, complained to Kenora health authorities of nausea, rashes, and eye irritation after passing the truck or its route. Meanwhile, officials had
realized that the spill was at least 150 km longer than they had originally anticipated and the national sales manager for the company hauling the transformers had declared at a press conference that he had thought of killing himself when he first heard about the spill.

Then, by mid week, federal transport officials prevented soil and asphalt samples gathered for testing at a Toronto laboratory from being loaded on commercial airlines because they were not labelled and packaged according to regulations governing the transport of hazardous wastes. Air Canada also refused to carry samples of Kenora’s drinking water from Winnipeg to a Toronto laboratory for testing. A waiver had eventually to be issued by Transport Canada to ship the testing samples via a private carrier. Finally, federal transport officials ordered five commercial airlines that carried the samples earlier in the week to be decontaminated.15

On Thursday April 18, the stretch of highway - which had been closed for five days while work crews applied an asphalt sealer over polluted portions - finally reopened. The next day, and for the first time, officials distributed 2,000 leaflets to residents informing them of the nature of the spill.

Although it was later reported that no persistent health effects associated with the spill could be recorded, the mixed messages sent by officials during the handling of the spill and the media
dramatization of the event can go a long way in explaining why questions concerning the health risks and the management of PCBs started to linger in the Canadian mind as determinedly as the enduring chemical now bonds to 220 km of pavement east of Kenora.

3.3 The 1988 St-Basile-le-Grand Fire

About three years later, on Tuesday August 23, 1988 at about 8:40 pm, a privately owned chemical-storage warehouse filled with about 1500 barrels of PCB-laced oil busted into flames near St-Basile-le-Grand, 40 kilometres southeast of Montreal. Because the uncontrolled burning of PCBs can cause their conversion into the more toxic dioxins and furans, local officials immediately decided to evacuate the population living within a 40-km radius of the fire. About 3,000 residents from the municipalities of St-Basile, St-Bruno, and Ste-Julie who were in the path of possibly hazardous smoke and fallout had to leave their homes in the middle of the night.

Although the fire itself was rapidly brought under control, its potential health and environmental effects became the focus of considerable speculation and uncertainty. The next day, nursing mothers were warned to stop breast-feeding and the Quebec government placed an embargo on produce grown on about 600 hectares of rich farmland after smoke from the blaze blew over the region. Farmers were prohibited to harvest crops or graze animals.
Warnings with respect to the fire's potential hazardous effects were issued to residents living as far away as east-end Montreal.

The following week-end, about 3,000 people were examined at Charles Lemoyne Hospital, the regional hospital for the area. While scientists tested blood samples, soil, water and surfaces for PCBs, dioxins and furans and tried to interpret the results, another 500 people were ordered out of their homes because of changing winds which began bringing dust from the site of the fire into a trailer park on the east-end of St-Basile.

By September 1st, results from testing were deemed satisfactory and mothers whose breast milk was tested were told they could resume breast feeding. However, because tests showing very low contamination levels conflicted with the results of preliminary testing, the provincial ministry of environment decided to bring in a team of international scientists to double-check the results before residents were allowed to return home. In the meantime, a general labourer for the town of St-Basile was charged with arson.

On September 7th, the federal government made public a list of more than 2,500 sites across Canada where unused PCB-contaminated materials were stored, and federal and provincial environment ministers announced a $500 million plan to phase-out the use of PCBs by 1993.
On September 10, at a press conference attended by five cabinet ministers, the panel of scientists from Canada, the U.S., and Europe submitted an unanimous report.\(^1\) The panel found that the concentrations of PCBs, dioxins, and furans inside the houses and schools of St-Basile were no higher than the levels usually found in uncontaminated buildings. After 18 days of wrenching uncertainty, the 3,500 evacuees were finally told it was safe for them to return home.\(^2\)

Although it was later estimated that only 8% of the PCB-contaminated material actually burned, the St-Basile fire was probably the largest-ever uncontained PCB fire worldwide and was a seminal event in Canada in terms of environmental-health issues.\(^2\) The disaster was a landmark both in terms of harm inflicted to the surrounding community and with respect to cost to taxpayers for related compensations and cleanup. More specifically, the warehouse fire effectively highlighted the potential risks to human health and the environment associated with the long-term storage of PCB wastes across Canada.

For many, St-Basile has also come to typify government laxness in managing toxic wastes. Because the warehouse owner had broken several provincial laws while accumulating large amounts of PCBs in

\(^1\) The panel included two experts from the New York State Health Department, one from the World Health Organization, one from Health and Welfare Canada as well as three independent experts chosen by the citizen committees of St-Basile and nearby towns St-Bruno and Ste-Julie.
a dilapidated warehouse with the government's full knowledge, a chain of questions emerged concerning the quantities of waste stored, the permits granted, and the role of the Quebec Environment Ministry. The fact that few clear answers to these questions were provided at the beginning of the crisis increased suspicion towards the government ability to deal with these wastes responsibly (see section 3.4).

The issue quickly became politically volatile in Quebec and outside the province. For several days, PCB related accusations and charges dominated Question Period in the House of Commons as all parties and both levels of government sought to control the issue. Opposition MPs and environmentalists criticized the government for failing to press Quebec to safeguard the chemicals, and for having ceded authority to intervene to the provinces when it passed its Environment Protection Act in June of 1988.

The government responded by emphasizing that prior to the promulgation of CEPA it had no legislative authority to regulate the storage of PCB wastes, and on September 16, 1988 the federal government issued an Interim Order for the Storage of PCB Wastes. The order stipulated the minimum security measures needed to provide adequate control over PCBs in storage and made the implementation of those measures mandatory in all provinces.
In a report released a year later, the Quebec fire commissioner sharply criticized the Quebec environment ministry bureaucrats for their handling of the situation. A responsible government, the report said, would not have tolerated the presence of PCBs without an adequate security system in the first place, nor would it have let the situation deteriorate as it did. The report recommended that the Quebec government take over sole responsibility for the storage and disposal of toxic waste because its inadequate monitoring of private enterprise posed a danger to public safety. The commissioner added its recommendations were limited because of a forthcoming royal commission slated to examine toxic waste in the province.26

Four years after the fire, there was no evidence that the fallout had any long-lasting effects on the health of area residents. Exposure to the fire fighters who had fought the blaze (most of them volunteers) was also deemed negligible.27 Overall, about 5,650 people had been interviewed, tested, and medically examined.

By 1989, compensation payments to residents of the St-Basile area had totalled $12.7 million. This figure included compensations for loss of wages and inconvenience to residents, compensations for contaminated crops to some 90 farmers, and for loss revenues to some 200 businesses located in the evacuated zone.28 But the government’s embarrassment and the public uproar over the handling of St-Basile’s PCBs were not over yet. In the end, the financial
costs to clean up the site eventually totalled more than $50 million.\textsuperscript{29} The social cost in lost confidence in the government's abilities to manage PCBs and other toxic wastes is of course more difficult to tally.

3.4 The Press and St-Basile

Myths and legends about PCBs existed in Canadian newspapers before the 1988 fire at St-Basile-le-Grand but the extensive coverage of the fire certainly contributed to their perpetuation. Media stories of the PCB spill near Kenora in 1985 already had privileged the sensationalization of the health effects rather than reporting on the environmental impact of the contaminants. Although - because of the fire and of the potential conversion of PCBs in dioxins and furans - the circumstances at St-Basile where different, many early reports failed to even mention the by-products. Instead, many stories called PCBs toxic, deadly, fetal deforming, or cancer-causing without any further qualifications.

4.4.1 First Reports

In one of its first report on the fire, for instance, the Globe and Mail (the Canadian national newspaper) published a Canadian Press story stating that "PCBs are known to cause brain, nerve, liver and skin disorders in humans, and cancer in laboratory test animals."

Two days later, the same paper simply called PCBs "cancer-
causing";

The press coverage of the fire was extensive. During the 18-day evacuation, the Gazette published more than 100 related stories filed by 23 different reporters, editors, and columnists while the Globe had about one-third as many articles. Yet, neither paper managed to clearly explain the health and environmental implications of the event until 11 days after the fire. On September 3, the Globe printed a backgrounder with scientific information, a feature article covering usage, storage, regulations and destruction, as well as a column by David Suzuki, a prominent Canadian scientist and environmentalist. The same day, the Gazette ran an article quoting several scientists saying that the risks from short-term exposure during the St-Basile fire had been exaggerated.

This delay in providing accurate and balanced information may have been important in increasing perceptions that PCBs are highly toxic if it is true, as one study conducted by the British Chemicals Industries Association after the Bhopal disaster indicates, that "long-term effects and legends depend largely on how the story is handled in the first 48 hours, or in the 10 days following."
3.4.2 The Quebec Press

One of the distinctive characteristics of the media coverage found in some francophone newspapers (La Presse and Le Devoir in particular) is their focus on the frustration and anger expressed by the populations of St-Basile and neighbouring communities. This can be evidenced, for instance, by the many emotionally-loaded terms such as "anxiety, aggressivity, panic, revolt" that were used to depict the public's immediate reactions to the fire.\(^3\)

Also much more prominent in the francophone press is the question of responsibility and of who's to blame for the fire.\(^3^7\) Depending on the stories or editorial considered, answers to this question will point alternatively to the arsonist, the warehouse's owner, the population opposing the siting of adequate facilities, or the government bureaucracy. In the end, however, the bulk of the blame always seems to land on the laps of government officials. In this respect, the role played by the Quebec minister of the environment, is particularly interesting.

Because of his position, the Quebec environment minister, Clifford Lincoln, was quite expectedly the focus of much media attention. Yet, his influence over the events can only be grasped if one takes into account the minister's likeable personality, i.e., if one considers both the minister and the man.
On one level, the environment minister was largely successful in communicating in lay terms the set of circumstances that had made the fire possible. Providing a coherent and credible account of the government’s position was crucial at this point, because it indicated that despite the confusion of the evacuation, government officials understood what was happening and could bring the situation under control. Mr. Lincoln’s reasonable and commonsensical interpretations of the events may well have prevented some desperate and uncontrolled reactions by some particularly disgruntled members of the public which could have easily been fueled by the atmosphere of anger and uncertainty that characterized the aftermath of the fire.

On another level, and perhaps most importantly, the environment minister took it upon himself to publicly voice the frustrations and animosity rampant among the St-Basile residents. By doing so, the minister acted as an effective channel through which people could direct their concern. In the process the minister also became a credible spokesperson for the displaced populations.

Because of his ability at fulfilling the dual role of government and public representative, Mr. Lincoln’s contribution in establishing the basis for a rational response to the St-Basile crisis was significant. It is easy to speculate that without an official capable of articulating at once the regulatory and citizens’ perspectives, public reaction to the evacuation could
have been much more volatile and difficult to manage.

In retrospect, however, the Minister's performance appears as a real "tour de force" and may have been unsuccessful had the media decided not to cooperate. For one thing, the citizens of St-Basile never wanted the PCBs, and in fact had rallied against the facility since 1980 when they first discovered that the chemicals were being stored in their town. Furthermore, on several occasions, provincial government officials had reassured the population of St-Basile that the problems with the PCB storage site were "soon to be solved". In October 1987, the minister himself had declared in parliament that "his government had taken corrective measures in St-Basile and Shawanigan to make the PCB warehouses safe."38

After the fire, the Minister explained that, although he had been aware and worried about the PCB situation for quite some times, his hands were tied for the only possible way his department could ensure the safety of Quebec PCB storage sites would be to assume full ownership of the sites. Because of the great number of sites involved, the Minister explained, his government had chosen the less expensive route of trying to force compliance of provincial regulations on the existing owners. In the case of St-Basile, his ministry was involved in a procedural battle with the owner of the site who was avoiding his responsibilities for the maintenance of the warehouse.
"None of Quebec 50 storage site is really safe" acknowledged Mr. Lincoln the day after the fire. "This could happen anywhere, anytime." Indeed, the only safe and modern storage site available in Quebec remained empty because angry citizens had obtained a court injunction blocking any activity at the site just one month before St-Basile's fire. "I don't blame them" said Lincoln. "The PCB question is very emotional and if tomorrow a storage site was planned for my home town I may react just the same way." 

Mr. Lincoln empathic personality and the press portrayal of the Minister as a honest, hard-working, well-intentioned, knowledgeable about his portfolio, courageous and generally well respected individual may have spared him and his government from the harshest criticisms for their handling of the PCB situation. As one columnist shrewdly commented: honesty turned out to be one of the cleverest PR trick of all.

3.4.3 In Defense of the Media

During the evacuation no columnist - writing in either French or English - appears to have cast a critical eye on the press coverage of the fire. Subsequently, many observers found that the media response had been overblown and misdirected, resulting in the diffusion of partial or inaccurate informations and rumours.
In defense of the media, however, the lack of publicly available information concerning the warehouse permit and later the interpretation of scientific test results may have incited journalists to fill in the gap. In addition, the replacement (August 27th) of the Environment Ministry by a Sécurité du Québec (SQ) representative as the official spokesperson for the government may have raised the media inquisitiveness and suspicion by adding to the impression that a police operation rather than an environmental emergency was under way.

The secrecy that surrounded the interpretation of toxicological data in particular, with the visible role played by the SQ in physically protecting the confidentiality of laboratory data, created an information vacuum which magnified the importance of scientific information. For experts and the public alike, the interpretation of scientific results had become the decisive element for ending the evacuation. Yet, while toxicological information circulated through several complex expert' channels, little of this information was communicated to the people of St-Basile. This situation put the media in the position of being the only information vehicle available to the public. In short, there was a need for scientific information expressed in lay terms and the media filled that need.
This being said, however, there is ample evidence of the reluctance by some media outlets to let a good story die. Many reports continued to play up the most dramatic health effects of PCBs and the uncertainty attached to their long-term effects well after enough scientific evidence calling for a more balanced treatment of the facts was readily available. Either the media did not care to examine this evidence, or their coverage of the issue was first and foremost self-serving.\textsuperscript{44}

3.5 PCBs in a Context of "Environmentalisation"\textsuperscript{45}

It must be emphasized at this point that the St-Basile fire coincided with environmental concerns taking top priority on the national consciousness. For instance a June 1988 Gallup Poll on national issues showed Canadians viewed the environment to be a more pressing issue than the much debated Free-Trade Agreement with the United States, while an Environics poll showed that 9 in every 10 Canadians felt their health had suffered from pollution. Another survey by CROP-Focus showed a majority of Canadians felt the government did not provide enough regulation of toxic pollution.\textsuperscript{46}

The end of 1988 also corresponds to the awakening of the political class to the fact that "the environment" had become a serious preoccupation in the mind of the electorate and to the emergence of the same as a leading public policy issue on the platform of
politicians of all stripes. For example, after the return of the federal conservatives to power in the November 1988 election, the Prime Minister, in his April 1989 throne speech, made a commitment to place a high priority on the environment during his government's second term.

This commitment followed some early initiatives and a shake up in the senior ranks of the environment ministry. A new Federal environment minister had already announced an overhaul of Canadian environmental policy and renewed promises to find a solution to the PCB disposal problem. As one long-time environment official commented: "There is a whole new team in here with a mandate to jump start the bureaucracy and turn things around."47

When in the summer of 1989, Quebec Premier Robert Bourassa called a provincial election for September 25, his appeal focused mainly on Quebec's strong economy and vigilance on the environment. After the disastrous fire at St-Basile, Alberta, the only province with a toxic waste incinerator, had offered to destroy the remaining PCBs. But Alberta's disposal site could only absorb these wastes in staggered amounts over several years. For reasons of political expediency, environment minister Clifford Lincoln had promised a clean up of the warehouse site within one year, and because of the coming provincial election, the Quebec government wanted the PCBs gone immediately.48
3.6 The 1989 Baie-Comeau Controversy

In July 1989, Quebec environment officials signed a $7.9 million contract with a Montreal-based company to ship 206 large metal containers to a PCB incinerator in Pontypool, Wales. This agreement which was similar to others reached between Canadian owners of PCBs and several active disposal facilities in Europe, was to take care of the remaining 3,500 tonnes of waste not consumed by the fire at St-Basile-le-Grand. But, while earlier shipments had arrived and been disposed of without incident, Quebec’s agreement coincided with a mounting campaign by the British wing of Greenpeace against the international trade in hazardous wastes.49

After British Greenpeace activists and Liverpool dock workers forced port authorities to turn the first freighters carrying PCB shipments back to Canada, an embarrassed Quebec government made a hurried and equally controversial arrangement to store the PCB wastes at a hydroelectric power generating station on Quebec’s lower north shore. Although Quebec Environment Minister Lise Bacon managed to convinced the mayor of nearby Baie-Comeau to accept the waste shipment in return for financing of city projects, the soundness of the plan did not appear as clear to local residents as the minister assumed. The proposal immediately touched off protests. Baie-Comeau dock workers vowed they would not touch the cargo, and 700 employees of the Hydro-Quebec Manic 2 plant
threatened to block the shipment.\textsuperscript{50}

With the Baie-Comeau storage site quickly becoming a central fixture of the Quebec election campaign, the provincial Liberals faced a real challenge in convincing voters that the government’s management of the environment portfolio was as healthy as that of their booming economy.\textsuperscript{51} In fact, Quebec’s attempt to dispose of its waste PCBs in Wales had received international media attention and tarnished Canada’s reputation as a model of environmental concern both abroad and at home.\textsuperscript{52} In what appears to be a desperate move to salvage its campaign strategy, the government decided that the PCBs were going to be unloaded in Baie-Comeau no matter what.\textsuperscript{53}

When the first PCB shipment returning from England arrived in the paper mill town of 26,000, more than 2,000 protesters were awaiting the freighter at the dock. This demonstration was followed by the Manicouagan Environment Coalition representing 26 community groups obtaining a 10-day injunction against the unloading of the PCBs. But the injunction was ignored and the shipment was unloaded in the middle of the night while provincial police kept protesters at bay. In response, the Manicouagan Coalition presented the town’s council with a 10,000 name petition seeking a second injunction to have the Manic 2 storage site declared illegal because it did not meet the requirements of the region’s waste management plan. In the meantime the freighter was gone and the PCBs remained stuck on the
town's wharf under the guard of provincial police, angry residents, and television cameras.\textsuperscript{54}

After two weeks of political manoeuvring and court battles bogging down in a legal quagmire, a Quebec Superior Court judge finally ended the stand-off by lifting the temporary injunction banning the removal of the unwelcome PCB cargo from the dock.\textsuperscript{55} Within minutes of the judge's decision, the provincial police ended the coalition attempt to block the road with a show of force which left the demonstrators bruised and humiliated. Television newscasts across the country showed images of the riot squad wielding truncheons rushing into a crowd of protesters to clear the way for trucks to depart with their controversial shipment.\textsuperscript{56}

After the Baie-Comeau incident, the Quebec environment minister vowed that Quebec would no longer export toxic wastes. The federal government had also indicated a preference for seeing all PCBs destroyed within the country but had stopped short of implementing regulations legally preventing the shipment of PCBs to Europe.\textsuperscript{57} The aborted shipment of PCBs to Wales and highly visible and unsuccessful attempt to deal with them when they returned resulted in public outrage and widespread criticism of the export of toxic waste as a socially and morally unacceptable disposal practice. In August 1990, the government put in place regulations effectively outlawing the export of PCBs.
4. Conclusion

Over the last ten years, social circumstances have transformed PCBs into a lightning rod for a host of public dissatisfactions and concerns. As one journalist covering the Baie-Comeau aftermath reported:

"The protesters recognized that the PCBs encased in metal containers posed little danger, but they embraced them as a symbol. (...) The protesters were nothing if not sincere ... people angered not so much by PCBs as by their perceived powerlessness."\(^58\)

It is worth noting, with respect to these later events, that the failure by Quebec Environment Minister Lise Bacon to establish a decent relationship with the people of Baie-Comeau probably fueled whatever frustrations the residents of the area may have felt at the time (a high unemployment rate was certainly among those). When she first arrived in town to explain her proposal she was booed by a crowd of protesters. When she returned to testify in court as to her motives for sending the wastes to Baie-Comeau, she refused to talk to reporters and remained barricaded in a room guarded by provincial police. During the final round of legal proceedings, she awaited the Superior Court judgment in a leased-jet sitting on the runway at a Baie-Comeau airport and returned to Quebec city as soon as the injunction was quashed.\(^59\)
The absence of dialogue between the minister and the residents of the area was probably conspicuous to the people of the entire province in light of the somewhat privileged relationship her predecessor had entertained with the people of St-Basile. This lack of communication between government representatives and the citizens of Baie Comeau was no doubt instrumental in the escalation of the controversy.

However it is still possible that, problems of communication set aside, public uproar about toxic chemicals in general and PCBs in particular is only symptomatic of a more general societal "malaise". Yet, for those who own or are responsible for managing these products, the realisation that public concern about PCBs may not, in fact, be about PCBs per se, is perplexing. Generally it is simply interpreted as additional evidence of the public's misinformation with respect to the risk these compounds actually pose. Not surprisingly, much of the blame for this misinformation is laid at the door of the media.

In many ways, the experts' frustrations at the media's reporting on PCBs are understandable. Indeed, very few attempts were made by the media to set the record straight on the question of the danger that PCBs in general represent. In the CBC's Fifth Estate television documentary that looked back at the three controversies presented in this chapter, the reporter's conclusion expressed to her interview subject, Stephen Safe, was: "Public opinion is
misinformed." To which the toxicologist at Texas A & M University replies: "Public opinion is very misinformed." While the program laments the fact that wherever PCBs are concerned "reason and science take a back seat to fear" and blames the government for bowing to perceptions, it steadfastly averts to mention by whom the public had been misinformed or left uninformed.  

Another indication of the media’s lack of perspective in covering PCBs is offered by a 1991 Globe and Mail editorial which claimed that since the Kenora spill, the paper published a total of 386 stories on PCBs "whose only proven health effect is to cause chloracne, eye discharges and vomiting in people who ingest them." For the same period, however, the paper had run 222 stories on the health risks of smoking, "a habit that killed 38,357 Canadians in 1989." "It is our job," the editorial concluded, "to maintain a sense of proportion when reporting environmental threats. So far, we are failing."  

Numerous statements scattered in the expert literature and in the press attest to the fact that the press coverage of the Yusho incident is generally believed to be at the source of much of the public’s misperceptions of PCB risks. Secondary sources indicate that the link between PCBs and cancer started to become a systematic feature of U.S. press coverage in 1976. The first mention of the carcinogenic potential of PCB was traced, in Canada, to the first articles that were found on the subject and which
pertained to the 1977 fire on Adelaide Street in downtown Toronto. The link to cancer, the association between PCBs and birth defects, and the label "highly-toxic" were subsequently observed (sometimes separately, sometimes together) in an overwhelming majority of articles published thereafter, whenever the health risks of PCBs were mentioned. Furthermore, these qualifications were never revised and remained unchallenged.

Because of the widespread and alarming coverage it generated, the 1985 Kenora spill was likely decisive in permanently associating PCBs with serious degenerative diseases in the mind of the general public. Reports of the events surrounding the St-Basile fire certainly did nothing to dispel this perception. Still today, hardly any mention of PCBs occurs in the media without some references being made to their link with cancer. Despite the absence of any definite proof that they may cause cancer in humans, the repeated assertion that PCBs have been linked to cancer has remained, between 1977 and 1994, a persistent and suggestive feature of PCB media coverage.

This chapter would be misleading if it gave the impression that public concern over PCBs has been limited to the three major controversies described below. In fact, even a cursory look over the totality of the 1982-1992 press coverage reveals that many mini-controversies took place at the local level involving about every segment and organized group in Canadian society. In this
eleven year period, local controversies about PCBs erupted in every part of the country.  

The examination of media reports conducted for this chapter seems to point to a definite and recurring pattern in the ways in which PCB related controversies have developed. Four examples of local controversies are briefly presented below in order to further illustrate this point.

In 1979, a government proposal to burn PCBs at a cement kiln in Mississauga, Ontario, drew scorn from the community. The provincial environment minister refused to leave the proposal's fate to the province's Environmental Assessment Board and sought to impose the licensing of the kiln. The city retaliated by passing a by-law prohibiting the transportation of PCBs on its streets. This was the country's first and last attempt to destroy PCBs by this means.

In 1985, Environment Canada found sludge contaminated with PCBs near the remains of an old wharf in Georgetown, Prince Edward Island. The federal department decided to move and bury the sludge in the harbour, 200 yards offshore but did not inform anyone in the 700 member community about the presence of the compounds nor about the scheme to remove them. When questioned by townspeople about the dredger digging in the bay, provincial and federal officials first refused to answer their questions. Federal officials
eventually agreed to attend a packed town council meeting at which they argued that the burial plan was the safest and cheapest solution to the problem. Town officials were apparently won over by warnings that opposition to the burial scheme could delay construction of a new $8 million wharf, a move that was called "a subtle form of blackmail" by an editorial in the weekly Montague Eastern Graphic. An Environment Canada official later declared in Dartmouth that his department may have learned a useful lesson in the process and that it was now considering a "more open policy toward public disclosure when PCBs are found."66

In the spring of 1989, the Indian band council of Kamloops, B.C. launched a campaign to oppose the continued storage of PCB-laced oil on a reserve located on the bank of the Thompson River in the centre of the city of 60,000. Because of a concern over the possible contamination of the water supply and toxic fall-out that could follow an accidental fire, the band council voted unanimously to order the oil company owning the PCBs to remove its two large storage tanks from the reserve land leased by the band. Spokespersons for the oil company responded by stating that they had nowhere to move the PCBs and that to keep them at their current site was probably the safest option. Environment Canada officials declared that the entire issue of who has jurisdiction over Indian lands was cloudy. The controversy heated up when the band council was joined in its action by the local school board and several other community groups.67

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In the fall of the same year, the federal government’s introduction of stringent guidelines for the storage of PCBs became the source of another controversy in central British Columbia. Because the regulations forced the removal of the hazardous waste from federal buildings, Public Works Canada decided to gather and store in a special container all the burnt-out light fixture ballasts containing PCBs it owned in the province. The container was to be stationed on a parking lot owned by Public Works and situated at the Canada U.S. border crossing, near Osoyoos, a city of 5,000 in the Okanagan Valley. Although Public Works shared this property with three other federal departments (Customs, Employment and Immigration, and Agriculture Canada), no formal consultation process was conducted with federal employees regarding the decision to store the PCB wastes at this site. Because the border crossing drains in Osoyoos Lake, the source of drinking and irrigation water for the surrounding valley, the siting of the PCB container incited a public furore among Osoyoos residents. Press reports of conflicting statements by federal employees as to the soundness of siting PCB contaminated material in such a high traffic location did not contribute to reassure the people of the fruit producing and tourist region.68

These four local controversies, then, like those reviewed at greater length in this chapter, appear to be composed of basically the same ingredients and to share a common scenario involving the following sequence of events: i) a “discovery” publicized by the
media that PCBs have contaminated a public area or that this could possibly happen; ii) a reluctance by officials to be forthcoming with related information accompanied by assurances that the risks are minimal and by a commitment to take additional precautionary measures, just in case; and iii) confusing evidence about the risks at stake or alternatively, evidence of inconsistencies in the ways PCBs are dealt with by managing agencies, either of which immediately becomes the focus of media attention. In the process, the image of "the public" which emerges from these accounts - and which in turn may be most relevant to the ways in which the public "perceives" PCBs - is almost invariably that of a bitter, frustrated, and victimized citizenry.

It is true that in the majority of the examples mentioned above (Mississauga, Kenora, St-Basile, Baie-Comeau, Georgetown, Kamloops, Kelowna) the people whose lives were most affected by the presence of PCBs were always confronted with a "fait accompli" scenario, poorly informed about the potential risks of the compounds, and powerless regarding the decisions of risk managing agencies. On the other hand, there are also good reasons to believe that the often confused responses that PCB-related events seem to systematically provoke within regulatory bodies can be traced to the difficulties these institutions encounter when they deal with the volatile reactions the mere mention of PCBs seems to trigger in the general population. Yet, if overreactions to PCBs are caused by a fear of the health risks associated with these compounds, the
media itself bear an important responsibility for making such fears legitimate.

As mentioned previously, some media have, on occasion, warned of unnecessary public concern over PCBs, but these efforts have been far too few and limited to have any lasting effect. More telling, perhaps, is the fact that media outlets can dramatically change the tone of their coverage on PCB controversies and argue alternatively and with equal ease for one or the other of two opposite conceptions of the public role in managing PCBs. Indeed, as the recent quotations from the Globe and Mail indicate, media coverage can switch quite unpredictably from an alleged concern with the limited power of well-meaning citizens who justifiably demand answers and try to fend-off what they view as the inadequate management of a potential carcinogen, to sudden bursts of righteous outrage at a government whose public policy "simply gives in" to a misinformed, fearful, and ignorant public.

The shipping of Quebec PCB's to Wales in 1989 is, to date, the last episode of the PCB saga to receive salient and sustained national attention. Although the improper storage of PCBs near Smithville, Ontario, resulted in what experts have called "one of Canada's worst industrial waste sites", the Smithville episode received relatively little media coverage in comparison to the Kenora, St-Basile, and Baie-Comeau controversies. This is perhaps because, in spite of several rebounds in the conflicts that pitted local
residents against their municipal and provincial governments, the Smithville saga stretched over a 13-year period, long enough to undermine the newsworthiness of any related story. Yet, because it provides a vivid illustration of the danger of leaving PCBs unattended -- the extensive soil and water contamination of the Smithville’s aquifer resulted in "one of the most expensive toxic-waste cleanups in Canada’s history", the complex set of events that led to the Smithville remediation process comprise a story that would have been worth telling.70

When looking back at the media coverage of the Kenora, St-Basile and Baie-Comeau controversies, it appears that the original focus on PCBs’ health risk has shifted to the background while the government’s unsuccessful attempts at controlling the issue have taken the spotlight.71 Thus, to the extent that the media portrayal of these events provides a reasonably valid insight on the nature and status of the public mood towards the compounds, public concern vis à vis PCBs is now directed towards the management of the risk rather than on the risk per se. The implications of this conclusion are explored further in the next and final chapter.
1. The Main Points So Far

This thesis started with a review of risk communication research and practices. Two points stand out in this review. First, the importance of the societal and cultural context in which concern over health and environmental risks arises is stressed. In this respect, psychometric studies that promote an understanding of risk based on individual responses to questionnaire interviews are criticized on the grounds that they limit the possible outlooks on risk to a combination of predefined reactions to batteries of tests. Not only does this approach force an artificial bracketing of the social context in which responses to risk are actually formulated, it also suggests that the sum of the individual reactions obtained reflects the "public perception" of risk.

Because they focus on the broader environment in which the risk problem is constructed and are attuned to the complex social networks that allow risk to be perceived, cultural approaches to risk perception are viewed as more useful to understand what, in fact, needs to be communicated in the risk communication process. The analytical energy that psychometric approaches expend on the modelling and statistical interpretation of sample test data, on
the other hand, tends to promote the reification of public perception on the basis of a mere simulation exercise.

The second point developed in chapter one is that the construction of a "risk problem" is a complex affair, and that our actual understanding of the processes by which a society considers a given environmental health risk to be worthy of attention is still in its infancy. Consequently, much latitude is necessary in designing future agendas for risk research in general and risk communication in particular. More specifically, the later should encourage research approaches that set out to test widely accepted, yet sometimes mistaken, presuppositions. For instance, some questions could be raised regarding the belief - apparently taken for granted by most risk researchers - that our modern societies are essentially secular. The plea here is for a research orientation for risk communication which, in spite of - or perhaps rather because of - its applied component, should be wary of orthodoxy, encourage a plurality of perspectives, and remain essentially and resolutely open.

Chapter two focuses on risk management and also develops two main themes. Because risk management's systematic resorting to scientific risk assessment increasingly begs the question of the management of scientific uncertainty, the first section probes the implications attached to various understandings of uncertainty in risk management science. The discussion which argues for an
understanding of scientific uncertainty as a constitutive and socially constructed component of scientific knowledge concludes with a focus on ignorance. The focus on ignorance is warranted because risk management approaches often seem in retrospect to have tackled the wrong problems. If this is true, risk management institutions may be well advised to shift their energies towards the management of societal uncertainties rather than expecting - as seems to be presently the case - that the later will vanished if scientific uncertainty can somehow be minimized. The management of societal uncertainty is thus the second theme explored. Various institutional mechanisms designed for this purpose are briefly reviewed. An argument is made in favour of one specific mechanism - the multi-attribute utility technique (MAUT) - whose essential benefit lies in constructing a relatively comprehensive and explicit information base upon which risk management decisions can be predicated.

Chapter three reviews several analysis of health and environmental controversies which used a case study approach as research strategy. Key research results are presented along with the methodological stances that were instrumental in reaching specific conclusions. The discussion stresses the interactions between the selection and treatment of empirical data and the researchers' theoretical presuppositions. The chapter concludes with a rationale justifying the selection of the PCB controversy as the case-study of the empirical data and the methodological approach.
selected for analyzing the PCB controversy is explained in relation to the preceding case-studies reviewed and a set of questions to be used for guiding the research inquiry is outlined.

Chapter four documents the ways in which expert knowledge has been exerted in assessing the risks of PCBs. Based on the expert definition of risk as a function of hazard and exposure, the presentation of experts' findings is arrayed in four main sections. Exposure data (environmental dispersion and population burden) and toxicity data (animal studies and effects on humans) are examined sequentially. The discussion outlines a striking imbalance between the minute measurements and extremely precise character of some assessment data on one hand and, on the other hand, the major data gaps and methodological uncertainties that are conspicuous in each of the four knowledge categories presented.¹

These gaps in scientific knowledge raise questions regarding risk assessment data being used as the main input for decision processes. Indeed, scientific data formulated with a great degree of precision and displaying an aura of certainty can quickly lose much of their significance when they are placed in the context of accompanying uncertainties. The discrepancy between the sophistication of scientific analytical procedures together with the specificity of the information they yield on the one hand and, on the other hand, the ambiguous nature of this information in terms of its practical guidance for risk management was outlined
long ago. By 1972 the Review Panel on Hazardous Trace Substances had already noted that:

"Despite the large number of detailed studies of PCBs (…), it has proved difficult to assemble the results into a coherent picture because important pieces of the puzzle are missing." (PHTS, 1972: 257)

Although many uncertainties remain, progress have been achieved over the last twenty years in developing a more comprehensive scientific data base on PCBs' persistence and toxicity. However, improvements in the reliability of PCBs risk assessment data do not seem to have occurred as a result of new scientific findings per se, but rather from a more sophisticated appraisal of the data gaps and methodological caveats which provide the contextual background upon which discrete scientific findings can be interpreted.

In other words, progress seems to have resulted from a better qualitative appreciation of the multiple sources of uncertainties that are part and parcel of the scientific knowledge on PCBs rather than from a quantitative reduction in the amount of uncertainty surrounding the scientific knowledge base. In this regard, the communication of scientific information (and of accompanying uncertainties) within the risk assessment community played an important if not determinant role in making such progress possible.

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The fact remains, however, that the current data base on PCBs still allows for a range of scientific opinions relative to the severity of the long term effects these compounds may have on living organisms in general and on humans in particular. Different readings of the scientific information (and different interpretations as to its reliability) can support different positions as to how these risks should be managed.

Overall, chapter four assumes that the way in which problems occur in the generation of scientific data is important to comprehend in some details. Indeed, accounting for the type of difficulties encountered in this process is viewed as necessary to gain a full appreciation of the nature of the risk assessment information which, in the end, is made available to decision makers. Focusing on data gaps and uncertainties, it is believed, provides the best means to convey a reliable rendering of the types of assumptions involved in establishing a scientific knowledge base for assessing PCB risk.

This being said, however, the concentration on knowledge gaps brings the risk of implying that our ignorance is greater than it actually is. The many research results produced by reputable scientists and prestigious scientific organizations should serve as an adequate counterbalance against such misunderstanding. As is often the case with the risk assessment of chemicals, the scientific evidence pertaining to PCBs environmental persistence
and toxicity is incomplete in several respects. These data gaps are a source of scientific uncertainties which, depending on whether they are emphasized or downplayed, have lead to diverse expert positions regarding the long-term possible effects of these compounds.²

One important lesson to be drawn from the examination of this body of scientific work then, is that the scientific data base on PCBs does not speak for itself. An effort at synthesizing incomplete and sometimes contradictory evidence the risk assessment of PCBs is made of a series of interpretations concerning the facts of the case. While it is clear that PCBs are not among the most hazardous or toxic chemicals in use today, contradictory and contentious results continue to be produced. Overall, the abundant scientific research on these compounds has yielded results which support the strict regulatory measures now in place to curtail their use and limit their dispersion in the environment in ways that protect public health. Yet, the fact remains that the scientific assessment of PCB risk amounts first and foremost to a cascade of expert judgments.

Chapter five focuses on the regulatory, technical and political dimensions of the PCB risk management problem. It shows the regulatory response to PCBs to have been essentially reactive and piecemeal, resulting in over ten individual pieces of legislation. This parcelling out of the regulatory framework at the federal
level is compounded by the fact that the responsibility for storage and disposal of contaminated material, as well as the setting and enforcement of guidelines for the limitation of PCB exposure, have remained a provincial responsibility.

In spite of its fragmented nature, the Canadian regulatory framework appears to have been successful in preventing the ongoing release of PCBs into the environment and in controlling and limiting public exposure to these compounds. At the same time, however, this complex and cumbersome patchwork of legislation and rules provides little incentives for the expedient and permanent destruction of PCBs and makes it difficult to convince the public that such a highly regulated group of chemicals are not extremely hazardous. The convoluted nature of the regulatory framework, the relatively complex nature of the PCB waste inventory, and public opposition have combined to prevent the implementation of facilities which the government believes could effectively and safely destroy PCBs. Even when extensive information and public consultation processes have succeeded in momentarily suspending public opposition to the siting of incinerating facilities, the lack of political commitment (as in the case of LEAP) or the unavailability of suitable technology (in the Baie Comeau case) have compromised the results of carefully planned siting efforts.
Based on newspaper and magazine accounts of key events, chapter six seeks to understand and represent the nature of public concern with regards to PCBs. As the main channel through which risk is communicated to the public, the mass media have received much of the blame for exacerbating the discrepancies between public and expert’s views on risk. While the exact nature between risk coverage and risk perception is difficult to pinpoint, scholarly research on the effects of media coverage on risk perceptions has generally emphasized that i) both media coverage and public opinion tend to reinforce one another rather than the latter being simply determined by the former; ii) that the influence of media coverage is as much a function of prominence as of content; and iii) that media reporting can be improved. In particular, one major criticism is that the media lead the public to ignore important hazards and worry about minor ones.4

Compared to that of other environmental health risk, the coverage of PCBs by the Canadian media has indeed been extensive. The examination of the press coverage of the Kenora, St-Basile and Baie Comeau events shows the media original focus on PCBs’ health risks to be progressively replaced by an attachment to the government’s unsuccessful attempts at controlling the controversies. To the extent that the nature of public perception can be inferred from the media portrayal of these events, public concern would now appear to be directed at risk management institutions rather than at PCB risks per se. Thus, the evidence gathered in this chapter
concur with Brian Wynne's suggestion that public reactions are reactions not to perceived risks as such, but to the institutional relationships that are part and parcel of technologies.

2. The Controversy Revisited

The essential claim of this thesis is that the public management of health and environmental risks can be improved by paying greater attention to the ways in which risk related information is conceived and communicated. Effective risk communication, it is argued, can contribute to a better fit between regulatory actions devised for making risk-benefit trade-offs on behalf of a society as a whole and that society's support for risk management actions.

As compared to the amount of attention focused upon the scientific assessment and management of risks, very little consideration has been given to processes involving the exchange of risk-related information. Systematic deficiencies in the abilities to communicate over risk have now become a structural weakness of risk management institutions. The PCB saga is particularly symptomatic of this inadequate communication between risk management institutions and their constituencies. Although reactions to PCBs are usually described as a product of media blunders or of wacky
public perceptions, the public concern over these compounds can perhaps be more fruitfully understood and addressed when seen as reactions to regulatory insularity.

The responsibility of regulatory institutions to communicate effectively on matters of risk extends in two directions. Firstly, it is they who bear the main responsibility for communicating to the public in a meaningful way the intricacies and uncertainties inherent to risk assessment. Instead, risk management institutions tend to use the findings of regulatory science as ready-made and unproblematic justifications for policy decisions. Secondly, democratic principles suggest that, when a risk problem is defined differently by different parties, the selection of risk control options should be performed in ways that explicitly take into account this plurality of perspectives. At a minimum, then, risk management decisions need to reflect a balance between public protection objectives and a respect for risk perceptions. To do so, public risk management institutions must ensure that a platform where the risk/benefit trade-offs of various risk control options can be debated does exist. It is easy to see that, in the case of PCBs, regulatory agencies have failed to adequately communicate on both accounts.
2.1 Risk Communication Shortcomings in PCB Risk Assessment and Management

The claim that Canadian regulatory agencies have failed to adequately communicate the results of their PCB risk assessment and the rationale guiding their risk management decisions can easily be substantiated. As chapter six shows, it is the media rather than government agencies that have acted as the main channel for the communication of PCB risk information and that have provided the platform where PCB issues have been publicly discussed. So far as I can determine, Environment Canada and Health and Welfare Canada, the two regulatory bodies responsible for the risk assessment of PCBs, made no concerted attempt to challenge the media's unyielding characterization of PCBs as "cancer-causing" nor to communicate that their risk assessment justified a concern for the compound environmental persistence rather than for its potential health risks.

This lack of effort on the part of regulatory agencies in effectively communicating with the public the results of their risk assessment is surprising given the nature of media coverage. In addition, public opinion surveys conducted in 1988 clearly indicated that a majority of Canadians believed the federal government should take the lead in informing them and in promoting solutions to the PCB problem. Yet, in April 1989, eight months after the St-Basile-le Grand fire, more than 60% of the Quebec
population could still claim to be poorly informed (mal informés) on the subject of PCBs.\textsuperscript{5}

The fact that Health and Welfare Canada and Environment Canada are natural science-based organizations may be invoked to explain that their risk assessment and management activities are technically driven. Yet, one must assume that, at least since the report "PCBs: A Burning Issue" by the Canadian Environmental Advisory Council (CEAC), the federal government was fully aware of public perceptions towards PCBs and PCB destruction facilities. The central thesis of the CEAC report which was released in the spring of 1989 was that the siting of hazardous waste facilities is primarily a social process. In addition, the CEAC council who was acting as the environment minister’s advisor and sounding board suggested in its report that before moving ahead on siting, differences in provincial jurisdictions be harmonized and appropriate regulatory controls be established.\textsuperscript{6}

In spite of this, however, the government’s assurance in the technical soundness of its PCB Destruction Program led it to proceed from policy formulation to implementation without providing any formal or structured opportunity for the due consideration of alternative strategies. Better communication among PCB experts -- natural scientists, engineers, policy analysts and social scientists -- may have resulted in stronger recommendations warning politicians not to place too much confidence in the technological
solution. Instead, politicians kept making repeated promises of a quick fix to the PCB problem. The main effects of these heroic statements of intent seldom delivered upon has been to increase public scepticism and to erode the credibility of Canadian risk management institutions.  

While the federal government's push of incineration as the strategy of choice for PCB disposal was supported by technical analysis and rationale from a technical perspective, this option also happened to constitute a politically convenient solution to dispose of the embarrassing chemicals. Had it been successfully implemented, the 1988 PCB Destruction Program would have provided a fast-track solution to rid the government of its PCB problem. For this strategy to be successful, however, the government should have anticipated and prevented foreseeable criticisms of conflict of interest prompted by the fact that it was acting as both a regulator and a proponent of incineration technology.  

Acting in this dual capacity need not have been so damaging to the regulators' credibility had the selection of the PCB disposal strategy been the result of a carefully designed process of communication and consultation. Instead, the government announced its decision to proceed with the siting of mobile incinerators before any effective stakeholder consultation had been conducted. This compromised the soundness and implementability of its plan of action from the very outset. As could have been expected, the PCB
Destruction Program was abundantly criticized for being motivated by criteria having to do more with political expediency and convenience than with the minimization of environmental and health impacts.\(^3\)

It is possible to speculate that the problems posed by the destruction of PCB wastes could be today closer to resolution if the government had acted on the basis of the CEAC recommendations. This would have meant acknowledging that the regulatory framework was cumbersome and inappropriate, that the timetable for siting PCB incinerators was too hurried, and that the siting of waste disposal facilities needs to be designed around the concerns of the public rather than predicated upon the availability of incineration technology. Indeed, the CEAC recommendations were remarkably attuned with the findings of recent risk communication research. As discussed in chapter three this research indicates that risk controversies should be managed through a process which, on the one hand, promotes the development of adequate regulatory devices and, on the other hand, appreciates the validity of popular attitudes over risk as authentic and legitimate categories of meaning in their own terms. Treating both experts and public perspectives on PCBs as legitimate does not imply automatically assigning the same validity to the substance of their respective viewpoints. But it implies that both experts and public be included as part of a the same communication system.
In summary, while the media's incomplete and exaggerated representation of PCBs as "cancer causing" chemicals cannot be downplayed, the government's reluctance to create circumstances for meaningful communication about PCBs seriously compromised the credibility of its risk assessment and management activities. As a proponent of incineration, the federal government was unsuccessful in communicating the comprehensiveness and thoroughness of its risk assessment as well as the nature of the relative risk and benefits of the incineration option as compared to other alternatives.

As a regulator, the federal government was also unable to provide an effective regulatory framework that would have facilitated the implementation of PCB destruction technologies. Finally, the government did not successfully manage the political requirements that would have inspired the minimum amount of public confidence necessary for making the siting of mobile incinerators publicly tolerable. To gain such confidence, the government needed to provide a forum for the major parties to the controversy to debate the risks and benefits of possible control options before deciding upon and announcing its risk management strategy. Instead, the federal government's self-assurance in the soundness of its own definition of the "risk problem" and in the effectiveness of its incineration "solution" have resulted in an almost complete disregard for the public's alternative framings of the PCB issue. This disregard for public perceptions seem to have been a
2.2 Managing Future PCB Risk Communication Processes

Recent findings in risk communication research suggest that the effective management of the PCB controversy will entail creating conditions for better communication about PCBs rather than providing the public with more "accurate" or "factual" information about these compounds. Correlatively, improved communication about the risks of PCBs and various control options depends upon a better understanding of risk perceptions.

Public opinion surveys which probe the perceptions of PCBs in light of the relative willingness of various communities to accept the siting of a mobile incinerator in their vicinity cannot, by themselves, provide a very meaningful view of public perceptions. Like psychometric studies, public opinion surveys which analyze public perceptions through population breakdowns by age, sex, occupation, place of residence and so on, only present a very truncated and limited understanding of the risk problem. What is more needed to understand and address the public reactions to PCBs and other toxic compounds, is a sophisticated account of risk perceptions articulated through the cultural and institutional factors which inform them.
Such a sophisticated understanding of risk perception could emerge from a mechanism akin in spirit to the MAUT process discussed in chapter two. Such a process would allow for the diversity of views and opinions concerning the disposal of PCB wastes to be freely expressed and confronted and, if managed properly, could provide a more reliable understanding of public perceptions on the basis of which acceptable options for regulatory action could be constructed. For instance, such a forum could help elucidate whether, as has been assumed so far, opposition to PCB destruction facilities is really grounded in a concern for health risks, or whether other factors, such as the lack of perceived benefits to hosting an incinerator facility is at the source of community opposition to these projects. In sum, this forum could generate a new and more reliable information base on the basis of which it should be possible to infer whether and how current positions can be swayed in a publicly acceptable manner so as to go beyond the current deadlock.

Finally, for the exercise to be of any use, sufficient political will is required to insure that once a preferred and feasible route of action is devised, administrative arrangements (federal-provincial-municipal agreements in particular) are in place to facilitate the implementation of a new PCB strategy. It is true that the management of PCB waste is the responsibility of all electricity users, that is of the general public and of the decision-makers who act on their behalf. However, the
responsibility for devising adequate arrangements allowing for effective communication between these two constituencies lies primarily with regulatory bodies.

Since the announcement of the Federal Destruction Program, the Canadian government attempts at finding a permanent solution to the PCB problem have concentrated on finding acceptable sites for hosting mobile PCB destruction facilities. Site selection has been essentially predicated upon technical criteria followed by information procurements (open houses, information sessions, etc.) to selected communities. Given the lack of success this approach generated, the government is now revising its siting strategy and is considering the offering of incentives (such as upgrades of local infrastructure and services) for stimulating community acceptance. A second facet of this strategy would consist of a partial shifting of the government current responsibilities for the siting of mobile incinerating facilities to the private sector.

As alluded to above, the use of incentives can help compensate for a lack of perceived benefits and be viewed as fair compensation for accepting to be the site of a mobile incinerator that will also help neighbouring communities to dispose of their own PCB wastes. However, this approach runs the risk of drawing even more opposition by those who will interpret it as a cynical attempt by regulatory agencies to "buy-off" public consent. The failure of previous siting strategies suggests that to rely on financial
incentives or private sector expertise alone could easily become counter-productive in the absence of a reliable communication mechanism fostering a reasonably adequate exchange of perspectives between various interested parties.

Chapters four, five, and six of this thesis have shown that the experts and the public views of PCBs are each predicated upon a wealth of information which can be used to support different conclusions regarding the relative risks of these compounds and various strategies to deal with them. Furthermore, the material presented in this case-study clearly indicates that each episode making up the PCB controversy in Canada is characterized by a lack of adequate communication between the actors involved. For these reasons, it is recommended that the careful management of risk communication activities be given priority consideration by regulatory institutions in the future. Attention to risk communication is critical to buttress any risk management strategy for PCBs and needs to remain at the core of any such strategy expecting to be successful in the long run.
3. Conclusion

There is a parallel to be drawn between the siting of PCB incinerators in Canada and the problems of finding a permanent repository for high-level radioactive wastes in the United States. Both have received enormous expert and public attention and have resulted in protracted controversies; each provides a kind of microcosm of the overall hazardous waste issue in the two countries. In an article reviewing the state of this later issue, Paul Slovic and colleagues (1991) describe the factors that have led to strong opposition to the siting of the first permanent radioactive waste repository in the Yucca Mountain in Nevada. Two factors stand out to explain opposition to this project: the profound state of distrust towards institutions in charge of managing radioactive wastes and the public perceptions that the risks involved are immense. Such perceptions are in stark contrast to the prevailing view of the technical community which argues that nuclear wastes can be disposed of safely in deep underground isolation. The authors conclude that distrust towards risk managing institutions will not be erased quickly or easily and that in light of the overwhelming political opposition postponing the siting of a permanent radioactive waste repository for the next 100 years may be the only politically viable option available to U.S. regulatory agencies.
In Canada, the continued safe storage of PCBs and contaminated materials could similarly provide an alternative to the currently "socially unacceptable" option of incineration. This alternative, which is justifiable on a variety of technical grounds, could constitute a viable option for the next 30 years or so while the remaining PCBs and PCB-contaminated materials which are still in use are phased-out. In this interim period, technical knowledge will undoubtedly advance and perception of risk and trust in risk management institutions may also evolve provided that risk management institutions make a concerted effort at integrating the findings of risk communication research to their current practices.

This thirty-year time frame does not seem unreasonable given the well entrenched nature of the PCB controversy in this country, the public misconceptions regarding the nature of PCB risk, and current scepticism regarding the government willingness to address the problem of PCB disposal in a fair and open fashion. By that time, consistent and carefully managed communication efforts may have resulted in setting a new and more positive context for dealing with the PCB disposal problem. Since all PCBs will have been taken out of service, it may then be possible to deal with the entire PCB inventory in a comprehensive and definite fashion.

However, the fact that public perception of hazardous wastes in general and PCBs in particular may be changing in ways that would render their disposal less problematic in the future is still
highly hypothetical at this point in time. Several forces may drive or conversely restrain the nature of risk management actions on PCBs in the near future.

On one hand, concerns in the scientific community about the risks posed by existing and future accumulations of PCBs in the environment and the secondary health hazard that these compounds pose in case of uncontrolled burning could stimulate regulatory action and a search for innovative ways to permanently dispose of these compounds. Added to these environmental and health concerns, the potential albeit undefined costs associated with future site clean up and liability could combine with the public perceptions that PCBs are highly toxic and carcinogenic and act as a driving force for risk management action on these issues.

On the other hand, the internal belief within Canadian risk management institutions that the risks of PCBs have been exaggerated and that the regulatory framework now provides adequate and sufficient safeguards against them does not give the federal government a very strong incentive to be proactive. Furthermore, the financial costs, lack of immediate political pay-off, and political risks associated with the establishment of a comprehensive strategy for siting PCB destruction facilities certainly constitute significant restraining forces on future regulatory actions. Overall, there appears to be enough evidence to suggest that the PCB controversy like the chemical waste issue
in general could follow the paralysing and destructive route of the nuclear waste problem.

The "second generation of risk communication" makes the strong assumption that trust in the risk management activities of contemporary societies can be restored by building a record of technically competent and open performance that shows decent respect for the public's sensibilities and common sense.

To make this repair job possible, however, it will also be necessary to address the current disjunction that too often can be observed between risk communication rhetoric in risk management and actual regulatory actions. For instance, statements made by government officials at the 1989 National Stakeholder Workshop on the Federal PCB Destruction Program attest for a remarkable awareness on their part of the political risks involved in focusing on incineration as the only single option for PCB disposal and of the necessity to involve the public in the decision-making process over this issue. In fact, most official statements could have fitted perfectly in a manual for "successful risk communication". Yet, five years later, the independent committee appointed to review progress made by government agencies in siting mobile incinerators in Atlantic Canada could still conclude that "Environment Canada seem to have been too much of a proponent in the process for the siting of the PCB destruction facility", that "Environment Canada gave the impression that this project had to go
forward because it was federal government policy and the deadline was 'cast in stone', and that "[t]o succeed, (...) a siting program would have to be developed that is focused less on the technical aspects of site selection and more on the issue of community acceptance." (Environment Canada, 1994: 10, 11)

This final point should be interpreted as a cautionary note against the use of risk communication research findings as rhetorical ammunition to be used for enhancing the persuasiveness of public relation activities. If this became standard practice, the recent enthusiasm for the ability of risk communication to make a positive and effective contribution to the public management of health and environmental risks could rapidly turn to bitter disappointment. One suggestion to insure that, in practice, risk communication research is not reduced to supplying a new varnish for old practices and that, on the contrary, its full potential is realized, is to insist that "trust" can only develop when the parties involved are willing to take some risk. Rather than an instrument for maintaining the status quo in current risk management practices then, risk communication needs to be promoted and used as a way to improve the resilience and risk-taking abilities of the institutions that are presently in charge of managing health and environmental risks.
A model for risk assessment/risk management

## Qualitative Factors Affecting Risk Perception and Evaluation

<table>
<thead>
<tr>
<th>Factor</th>
<th>Conditions Associated with Increased Public Concern</th>
<th>Conditions Associated with Decreased Public Concern</th>
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</thead>
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<tr>
<td>Catastrophic potential</td>
<td>Fatalities and injuries grouped in time and space</td>
<td>Fatalities and injuries scattered and random</td>
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<td>Familiarity</td>
<td>Unfamiliar</td>
<td>Familiar</td>
</tr>
<tr>
<td>Understanding</td>
<td>Mechanisms or process not understood</td>
<td>Mechanisms or process understood</td>
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<tr>
<td>Controllability (personal)</td>
<td>Uncontrollable</td>
<td>Controllable</td>
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<td>Voluntariness of exposure</td>
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<td>Voluntary</td>
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<td>Effects on children</td>
<td>Children specifically at risk</td>
<td>Children not specifically at risk</td>
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<td>Effects manifestation</td>
<td>Delayed effects</td>
<td>Immediate effects</td>
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<td>Effects on future generations</td>
<td>Risk to future generations</td>
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<td>Trust in institutions</td>
<td>Lack of trust in responsible institutions</td>
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<td>Little media attention</td>
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<td>Unclear benefits</td>
<td>Clear benefits</td>
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<td>Effects reversible</td>
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<td>Caused by human actions or failures</td>
<td>Caused by acts of nature or God</td>
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</tbody>
</table>

*Table 1: From Improving Risk Communication, National Research Council (U.S.), 1989, p. 35.*
APPENDIX B
The communications processes model of risk communication

Figure 1: From "Risk Communication Theory and Practice" in Leiss and Krewski, 1989, p. 100.
Estimates of Canadian Intake of PCB in Air, Water, Food and Soil for Various Age Classes and Exposure Scenarios (ng PCB/kg bw per day)

<table>
<thead>
<tr>
<th>Substrate/Media</th>
<th>Breast Fed Infant</th>
<th>Infant Not Breast Fed</th>
<th>Average Person</th>
<th>Consumer of Contam. Fish</th>
<th>High Ingestion of Contam. Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>33.3</td>
<td>33.3</td>
<td>38.5 42.9 28.6</td>
<td>38.5 42.9 28.6</td>
<td>33.3 38.5 42.9 28.6</td>
</tr>
<tr>
<td>Water</td>
<td>0.2</td>
<td>0.2</td>
<td>0.6 0.3 0.2</td>
<td>0.6 0.3 0.2</td>
<td>0.2 0.6 0.3 0.2</td>
</tr>
<tr>
<td>Food</td>
<td>2209.7</td>
<td>32.5</td>
<td>29.2 12.2 7.1</td>
<td>223.2 190.0 156.7</td>
<td>32.5 29.2 12.2 7.1</td>
</tr>
<tr>
<td>Soil</td>
<td>0.04</td>
<td>0.04</td>
<td>0.08 0.006 0.004</td>
<td>0.08 0.006 0.004</td>
<td>5.9 5.5 0.8 0.2</td>
</tr>
</tbody>
</table>

TOTAL ESTIMATED INTAKE

|                      | 2243.2            | 66.0                  | 68.4 55.4 35.9 | 262.4 233.2 185.5 | 71.9 73.8 56.2 36.1 |

EXPOSURE PERIOD (yr)

|                      | 0.5               | 0.5                   | 3.5 14 50     | 3.5 14 50         | 0.5 3.5 14 50         |

I = Infant
P = Preschooler
C = School Age Child
A = Adult

### Percent distribution of signs and symptoms of Yusho and Yu-Cheng poisoning

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Malcs (Yusho)</th>
<th>Malcs* (Yu Cheng)</th>
<th>Females (Yusho)</th>
<th>Females* (Yu Cheng)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark brown pigmentation of nails</td>
<td>83.1</td>
<td>86.6</td>
<td>75.0</td>
<td>83.3</td>
</tr>
<tr>
<td>Distinctive hair follicles</td>
<td>64.0</td>
<td>40</td>
<td>56.0</td>
<td>41.6</td>
</tr>
<tr>
<td>Increased sweating at palms</td>
<td>50.6</td>
<td>50</td>
<td>55.0</td>
<td></td>
</tr>
<tr>
<td>Acne-like skin eruptions</td>
<td>87.6</td>
<td>86.6</td>
<td>82.0</td>
<td>83.3</td>
</tr>
<tr>
<td>Red plaques on limbs</td>
<td>20.2</td>
<td>16</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>Itching</td>
<td>42.7</td>
<td>52</td>
<td>52.0</td>
<td></td>
</tr>
<tr>
<td>Pigmentation of skin</td>
<td>75.3</td>
<td>72</td>
<td>72.0</td>
<td></td>
</tr>
<tr>
<td>Swelling of limbs</td>
<td>20.2</td>
<td>41</td>
<td>41.0</td>
<td></td>
</tr>
<tr>
<td>Stiffened soles in feet and palm of hands</td>
<td>24.7</td>
<td>46.6</td>
<td>29.0</td>
<td>25</td>
</tr>
<tr>
<td>Pigmented mucous membrane</td>
<td>56.2</td>
<td>47</td>
<td>47.0</td>
<td></td>
</tr>
<tr>
<td>Increased eye discharge</td>
<td>88.8</td>
<td>93.3</td>
<td>83.0</td>
<td>91.6</td>
</tr>
<tr>
<td>Hyperemia of conjunctiva</td>
<td>70.8</td>
<td>66.6</td>
<td>71.0</td>
<td>75</td>
</tr>
<tr>
<td>Transient visual disturbance</td>
<td>56.2</td>
<td>55</td>
<td>55.0</td>
<td></td>
</tr>
<tr>
<td>Jaundice</td>
<td>11.2</td>
<td>11</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td>Swelling of upper eyelids</td>
<td>71.9</td>
<td>86.6</td>
<td>74.0</td>
<td>91.6</td>
</tr>
<tr>
<td>Feeling of weakness</td>
<td>58.4</td>
<td>53</td>
<td>52.0</td>
<td></td>
</tr>
<tr>
<td>Numbness in limbs</td>
<td>32.6</td>
<td>33.3</td>
<td>39.0</td>
<td>56</td>
</tr>
<tr>
<td>Fever</td>
<td>16.9</td>
<td>19</td>
<td>19.0</td>
<td></td>
</tr>
<tr>
<td>Learning difficulties</td>
<td>18.0</td>
<td>19</td>
<td>19.0</td>
<td></td>
</tr>
<tr>
<td>Spasm of limbs</td>
<td>7.9</td>
<td>8</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>Headache</td>
<td>30.3</td>
<td>39</td>
<td>39.0</td>
<td></td>
</tr>
<tr>
<td>Vomiting</td>
<td>23.6</td>
<td>28</td>
<td>28.0</td>
<td></td>
</tr>
<tr>
<td>Diarrhea</td>
<td>19.1</td>
<td>17</td>
<td>17.0</td>
<td></td>
</tr>
</tbody>
</table>

* Pigmentation of lips, black color of nose, pigmentation of conjunctivae, hypesthesia, deformity of nails, pigmentation of gingivae, amblyopia were also observed

---

**Table 2:** From "PCBs: Mammalian and Environmental Toxicology", Safe, 1987, p. 137.
EFFECTS ATTRIBUTED TO OCCUPATIONAL EXPOSURE OF HUMANS TO PCBS

<table>
<thead>
<tr>
<th>Observed Effect</th>
<th>PCB Type (Aroclors)</th>
<th>Blood Levels</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloracne, liver disorder</td>
<td>N/A</td>
<td>N/A</td>
<td>Meigs et al., 1954</td>
</tr>
<tr>
<td>Dermatitis, eye irritation</td>
<td>1242</td>
<td>58 to 282 (µg/L)</td>
<td>Ouwe et al., 1976</td>
</tr>
<tr>
<td>Liver metabolic changes</td>
<td>N/A</td>
<td>N/A</td>
<td>Alvares et al., 1977</td>
</tr>
<tr>
<td>Chloracne, altered liver and blood biochemistry</td>
<td>N/A</td>
<td>33 (µg/L) (5.6 µg/g fat)</td>
<td>Chase et al., 1982</td>
</tr>
<tr>
<td>Dermatitis, neurological symptoms, liver enzyme induction</td>
<td>1254, 1242 (mainly)</td>
<td>33 to 227 (µg/L)</td>
<td>Fischbein et al., 1979</td>
</tr>
<tr>
<td>Chloracne, altered blood biochemistry</td>
<td>N/A</td>
<td>N/A</td>
<td>Hara et al., 1975</td>
</tr>
<tr>
<td>Pigmentation, liver enzyme induction, cholesterol</td>
<td>N/A</td>
<td>370 (µg/L)</td>
<td>Hasegawa et al., 1972</td>
</tr>
<tr>
<td>Chloracne</td>
<td>N/A</td>
<td>130 to 520 (µg/L)</td>
<td>Inoue et al., 1979</td>
</tr>
<tr>
<td>Dermatitis</td>
<td>N/A</td>
<td>820 (µg/g)</td>
<td>Kitamura et al., 1973</td>
</tr>
<tr>
<td>Dermatitis, liver enzyme induction</td>
<td>1242, 1254</td>
<td>342 (µg/g)</td>
<td>Maroni et al., 1981</td>
</tr>
<tr>
<td>Dermatitis, liver and blood biochemistry, neurological symptoms</td>
<td>1242, 1016</td>
<td>89 to 502 (µg/L)</td>
<td>Smith et al., 1982</td>
</tr>
<tr>
<td>Rectal and liver cancer</td>
<td>1254, 1242, 1016</td>
<td>N/A</td>
<td>Brown and Jones, 1981</td>
</tr>
<tr>
<td>Mortality</td>
<td>1254</td>
<td>N/A</td>
<td>Bertazi et al., 1981</td>
</tr>
</tbody>
</table>

* N/A = Not Available

Table 3: From "PCBs - Fate and Effects in the Canadian Environment", Strachan, 1988, p.54.
APPENDIX D
Table 1: Summary of Regulations Development for PCBs

<table>
<thead>
<tr>
<th>Item</th>
<th>Canada Gazette Part I (Proposed)</th>
<th>Canada Gazette Part II (Final)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notice to Disclose</td>
<td>Jan. 8, 1977</td>
<td>Sept. 28, 1977</td>
</tr>
<tr>
<td>PCB-No.1</td>
<td>Feb. 26, 1977</td>
<td></td>
</tr>
<tr>
<td>PCB-No.2 (Product)</td>
<td>Jan. 21, 1984</td>
<td>May 15, 1985</td>
</tr>
<tr>
<td>PCB-No.3 (Release)</td>
<td>Jan 21, 1984</td>
<td>May 15, 1985</td>
</tr>
<tr>
<td>Reg. Respecting the Handling, Offering for Transport and Transportation of Dangerous Goods (TDGA)</td>
<td></td>
<td>July 1, 1985</td>
</tr>
<tr>
<td>Storage of PCB Wastes</td>
<td>Sept. 16, 1988</td>
<td></td>
</tr>
<tr>
<td>Interim Order</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage of PCB Material</td>
<td>June 9, 1992</td>
<td>Sept. 9, 1992</td>
</tr>
</tbody>
</table>

N.B.: A close examination of the above regulations indicates that the following uses for PCBs are still permitted:
i) in heat transfer equipment, hydraulic equipment, vapour diffusion pumps and electromagnets (for uses other than the handling of human or animal food or additives) in use in Canada before March 1, 1977;
ii) in electrical capacitors and transformers and associated electrical equipment manufactured in or imported into Canada before July 1, 1980;
iii) in equipment designed to destroy the chemical structure of PCBs. (Idler, 1986: 11)

### SUMMARY OF STANDARDS, RECOMMENDATIONS, GUIDELINES, AND CRITERIA FOR PCBs IN THE ENVIRONMENT

<table>
<thead>
<tr>
<th>Environmental Medium</th>
<th>Region</th>
<th>Concentration</th>
<th>Reference</th>
<th>Notes/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air - ambient</td>
<td>Ontario</td>
<td>35 ng/m³ (1-yr av.)</td>
<td>1 (1986)</td>
<td>- ambient air quality criteria</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150 ng/m³ (24-h av.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>450 ng/m³ (0.5-h av.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NY State</td>
<td>1.0 µg/m³ (short-term max.)</td>
<td>2a (1986)</td>
<td>- recommended standard</td>
</tr>
<tr>
<td>Water - ambient</td>
<td>Manitoba</td>
<td>0.002 µg/L</td>
<td>13 (1979)</td>
<td>- ambient water quality objective</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.014 µg/L</td>
<td>52 (1983)</td>
<td>- surface water quality objective to protect aquatic life and wildlife</td>
</tr>
<tr>
<td></td>
<td>Ontario</td>
<td>0.001 µg/L</td>
<td>14 (1984)</td>
<td>- ambient water quality objective for unfiltered sample</td>
</tr>
<tr>
<td></td>
<td>Quebec</td>
<td>0.001 µg/L</td>
<td>2a (1984)</td>
<td>- ambient water quality objective</td>
</tr>
<tr>
<td></td>
<td>IJC-Great Lakes</td>
<td>0.001 µg/L</td>
<td>15 (1977)</td>
<td>- water quality objective estimated to meet the recommended level in fish and aquatic life of 6.1 µg/kg wet weight</td>
</tr>
<tr>
<td></td>
<td>Canada - CCREM</td>
<td>0.001 µg/L</td>
<td>33 (1987)</td>
<td>- water quality guideline to protect freshwater aquatic life</td>
</tr>
<tr>
<td></td>
<td>U.S. EPA</td>
<td>0.79 x 10⁻³ µg/L</td>
<td>16 (1980)</td>
<td>- water quality criteria for protection of human health (cancer risk 1:10³);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.079 x 10⁻³ µg/L</td>
<td>16 (1980)</td>
<td>- water quality criteria for protection of human health (cancer risk 1:10³);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0079 x 10⁻³ µg/L</td>
<td>16 (1980)</td>
<td>- water quality criteria for protection of human health (cancer risk 1:10³);</td>
</tr>
<tr>
<td></td>
<td>U.S. EPA</td>
<td>0.014 µg/L</td>
<td>16 (1980)</td>
<td>- water quality criteria for protection of freshwater aquatic life</td>
</tr>
<tr>
<td></td>
<td>Indiana</td>
<td>0.03 µg/L</td>
<td>16 (1980)</td>
<td>- saltwater quality criteria for protection of saltwater aquatic life</td>
</tr>
<tr>
<td></td>
<td>Quebec</td>
<td>0.001 µg/L</td>
<td>16 (1980)</td>
<td>- water quality criteria for protection of aquatic life</td>
</tr>
<tr>
<td></td>
<td>Indiana</td>
<td>0.001 µg/L</td>
<td>30 (1985)</td>
<td>- water quality criteria for protection of aquatic life</td>
</tr>
<tr>
<td></td>
<td>Pennsylvania</td>
<td>0.001 µg/L</td>
<td>30 (1985)</td>
<td>- water quality criteria for protection of aquatic life</td>
</tr>
<tr>
<td>Water - recreational</td>
<td>Quebec</td>
<td>0.1 µg/L</td>
<td>2a (1984)</td>
<td>- recommended standard</td>
</tr>
<tr>
<td></td>
<td>Indiana</td>
<td>0.001 µg/L</td>
<td>50 (1985)</td>
<td>- recommended standard</td>
</tr>
<tr>
<td>Water - drinking</td>
<td>Saskatchewan</td>
<td>undetectable</td>
<td>23</td>
<td>- desirable objective</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 µg/L</td>
<td>23</td>
<td>- recommended maximum concentration</td>
</tr>
<tr>
<td></td>
<td>Ontario</td>
<td>3 µg/L</td>
<td>18 (1983)</td>
<td>- recommended maximum concentration</td>
</tr>
<tr>
<td></td>
<td>Quebec</td>
<td>0.1 µg/L</td>
<td>2a (1984)</td>
<td>- recommended standard</td>
</tr>
<tr>
<td></td>
<td>Nova Scotia</td>
<td>3 µg/L</td>
<td>17a (1985)</td>
<td>- recommended maximum concentration</td>
</tr>
<tr>
<td></td>
<td>U.S. EPA</td>
<td>125 µg/L</td>
<td>19 (1981)</td>
<td>- 1-day EPA Suggested No Adverse Response Level (SNARL) for a child</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.5 µg/L</td>
<td>19 (1981)</td>
<td>- 10-day EPA-SNARL for a child</td>
</tr>
<tr>
<td></td>
<td>U.S. NAS</td>
<td>350 µg/L</td>
<td>19a (1981)</td>
<td>- 1-day NAS-SNARL for an adult</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 µg/L</td>
<td>19b (1981)</td>
<td>- 7-day NAS-SNARL for an adult</td>
</tr>
</tbody>
</table>

327
<table>
<thead>
<tr>
<th>Environmental Medium</th>
<th>Region</th>
<th>Concentration</th>
<th>Reference</th>
<th>Notes/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment - dredge spoil</td>
<td>Ontario Great Lakes</td>
<td>0.03 mg/kg</td>
<td>49a (1976)</td>
<td>- recommended criteria for disposal in open water of the Great Lakes</td>
</tr>
<tr>
<td></td>
<td>Quebec</td>
<td>0.1 mg/kg</td>
<td>20a (1982)</td>
<td>- recommended criteria for disposal in open water</td>
</tr>
<tr>
<td></td>
<td>Canada</td>
<td>1 mg/kg</td>
<td>21</td>
<td>- administrative guideline for disposal in open marine waters</td>
</tr>
<tr>
<td></td>
<td>Holland, Norway, Sweden</td>
<td>1 mg/kg</td>
<td>22 (1984)</td>
<td>- administrative guideline used by &quot;Contracting Parties to Oslo Convention&quot; for disposal in open marine waters</td>
</tr>
<tr>
<td>Sediment - quality objectives</td>
<td>British Columbia</td>
<td>0.03 mg/kg (dry wt. max.)</td>
<td>44 (1985)</td>
<td>- provisional quality objective for the Fraser River sub-basin from Kanaka Creek to mouth</td>
</tr>
<tr>
<td>Soil</td>
<td>Quebec</td>
<td>&gt; 5 mg/kg</td>
<td>37</td>
<td>- level considered to be contaminated</td>
</tr>
<tr>
<td></td>
<td>Quebec</td>
<td>&lt; 1 mg/kg</td>
<td>24 (1984)</td>
<td>- recommended target level for cleanup</td>
</tr>
<tr>
<td></td>
<td>Saskatchewan</td>
<td>&lt; 3 mg/kg</td>
<td>23</td>
<td>- target level for cleanup</td>
</tr>
<tr>
<td></td>
<td>U.S. EPA</td>
<td>&lt; 1 mg/kg</td>
<td>43 (1987)</td>
<td>- TSCA regulation for cleanup of low-concentration spills of &lt; 1 lb PCBs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 23 ppm or or</td>
<td>43 (1987)</td>
<td>- TSCA regulation for cleanup of high-concentration spill or low-concentration spill of 1 lb or more PCBs in outdoor electrical substation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 50 ppm + notice</td>
<td></td>
<td>- TSCA regulation for cleanup of high-concentration spill or low-concentration spill of 1 lb or more PCBs in non-restricted access areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 25 ppm</td>
<td></td>
<td>- TSCA regulation for cleanup of high-concentration spill or spill of 1 lb or more PCBs in non-restricted access areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 10 ppm + excavation of top 10 inches;</td>
<td>43 (1987)</td>
<td>- guideline for further investigation of contamination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 1 ppm for replacement soil</td>
<td></td>
<td>- guideline for urgent remediation target level for cleanup of residential areas</td>
</tr>
<tr>
<td></td>
<td>Holland</td>
<td>1 mg/kg</td>
<td>46 (1983)</td>
<td>- guideline for further investigation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 mg/kg</td>
<td>46 (1983)</td>
<td>- guideline for further investigation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 to 5 mg/kg</td>
<td>47</td>
<td>- guideline for urgent remediation</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td>1 mg/kg</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 mg/kg</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 mg/kg</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Solid surface contamination levels for cleanup</td>
<td>Quebec</td>
<td>2.5 mg/m²</td>
<td>36 (1985)</td>
<td>- to be regulated under the Dangerous Waste Regulations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Askarel 1242)</td>
<td>1.25 mg/m² (Askarel 1234, 1260)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 10 μg/100 cm</td>
<td>43 (1987)</td>
<td>- TSCA regulation after low-concentration spill of &lt; 1 lb PCBs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 100 μg/100 cm</td>
<td>43 (1987)</td>
<td>- TSCA regulation for outdoor electrical substation after high-concentration spill or low-concentration spill of 1 lb or more of PCBs</td>
</tr>
<tr>
<td>Environmental Medium</td>
<td>Region</td>
<td>Concentration</td>
<td>Reference</td>
<td>Notes/Comments</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------</td>
<td>---------------</td>
<td>-----------</td>
<td>----------------</td>
</tr>
<tr>
<td>Solid surface contamination - levels for cleanup</td>
<td>U.S. EPA (cont'd)</td>
<td>(&lt;10 \mu g/100 \text{ cm} )</td>
<td>45 (1987)</td>
<td>- TSCA regulation for high contact surface in restricted access area after high-concentration spill or low-concentration spill of 1 lb or more of PCBs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(\leq 10 \mu g/100 \text{ cm} )</td>
<td>45 (1987)</td>
<td>- TSCA regulation for low contact indoor impervious surface in restricted access area after high-concentration spill or low-concentration spill of 1 lb or more of PCBs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(\leq 10 \mu g/100 \text{ cm} ) or (\leq 100 \mu g/100 \text{ cm} )</td>
<td>45 (1987)</td>
<td>- TSCA regulation for low contact indoor nonimpervious surface in restricted access area after high-concentration spill or low-concentration spill of 1 lb or more of PCBs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(\leq 100 \mu g/100 \text{ cm} )</td>
<td>45 (1987)</td>
<td>- TSCA regulation for low contact outdoor surface in restricted access area after high-concentration spill or low-concentration spill of 1 lb or more of PCBs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(\leq 10 \mu g/100 \text{ cm} )</td>
<td>45 (1987)</td>
<td>- TSCA regulation for indoor or high-access outdoor surface in non-restricted area after high-concentration spill or low-concentration spill of 1 lb or more of PCBs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(\leq 10 \mu g/100 \text{ cm} ) or (\leq 100 \mu g/100 \text{ cm} )</td>
<td>45 (1987)</td>
<td>- TSCA regulation for indoor vault area or outdoor low-contact impervious surface after high-concentration spill or low-concentration spill of 1 lb or more of PCBs</td>
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<tr>
<td>Solid waste - sludge</td>
<td>U.S. FDA</td>
<td>(&gt;10 \text{ mg/kg (dry wt.)} )</td>
<td>25 (1983)</td>
<td>- Resource Conservation and Recovery Act regulated restrictions for application to agricultural land</td>
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<tr>
<td>Solid waste - considered hazardous</td>
<td>Canada</td>
<td>(\geq 30 \text{ mg/kg} )</td>
<td>26 (1982)</td>
<td>- guideline for management of PCB wastes</td>
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<tr>
<td></td>
<td>Quebec</td>
<td>(\geq 30 \text{ mg/kg} ) (or leachate (&gt;10 \mu g/\text{L} ))</td>
<td>36 (1983)</td>
<td>- considered hazardous and must be decontaminated or destroyed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(&lt;15 \text{ mg/kg} ) (or leachate (\leq 5 \mu g/\text{L} ))</td>
<td>36 (1983)</td>
<td>- disposal permitted in sanitary landfill</td>
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<tr>
<td></td>
<td></td>
<td>T5 to 50 mg/kg (or leachate 5 to 10 mg/L)</td>
<td>36 (1983)</td>
<td>- disposal in secure landfill</td>
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<td></td>
<td>Alberta</td>
<td>(\geq 30 \text{ mg/kg} )</td>
<td>43 (1983)</td>
<td>- regulated under the Alberta Hazardous Waste Regulations</td>
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<tr>
<td>Liquid waste - considered hazardous</td>
<td>Canada</td>
<td>(\geq 30 \text{ mg/kg} )</td>
<td>26 (1982)</td>
<td>- guideline for management of PCB wastes</td>
</tr>
<tr>
<td></td>
<td>Quebec</td>
<td>(\geq 20.3 \text{ mg/kg} )</td>
<td>36 (1983)</td>
<td>- considered dangerous waste under Quebec's Dangerous Waste Regulations</td>
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<td></td>
<td>Alberta</td>
<td>(\geq 30 \text{ mg/kg} )</td>
<td>43 (1983)</td>
<td>- regulated under the Alberta Hazardous Waste Regulations</td>
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<tr>
<td>Liquid waste - maximum concentration of PCBs in effluents</td>
<td>Ontario</td>
<td>(5 \mu g/\text{L} )</td>
<td>10 (1985)</td>
<td>- recommended by commission as standard for effluents from mobile destruction facilities</td>
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</table>
### TABLE I  SUMMARY OF STANDARDS, RECOMMENDATIONS, GUIDELINES, AND CRITERIA FOR PCBs IN THE ENVIRONMENT (Cont'd)

<table>
<thead>
<tr>
<th>Environmental Medium</th>
<th>Region</th>
<th>Concentration</th>
<th>Reference</th>
<th>Notes/Comments</th>
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<tr>
<td>Liquid waste -</td>
<td>Canada</td>
<td>5 mg/kg</td>
<td>27 (1983)</td>
<td>- regulated under the ECA</td>
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<tr>
<td>maximum level in oil</td>
<td>Quebec</td>
<td>0 mg/kg</td>
<td>37</td>
<td>- road oiling to be discontinued; to be regulated under Dangerous Waste Regulations</td>
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<td>applied to roads</td>
<td>Ontario</td>
<td>5 mg/kg</td>
<td>42</td>
<td>- adopted federal guidelines</td>
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<td>Liquid waste -</td>
<td>Canada</td>
<td>1 g/d per piece of</td>
<td>27 (1983)</td>
<td>- regulated under the ECA</td>
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<tr>
<td>permitted loss</td>
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<td>equipment</td>
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<tr>
<td>during storage</td>
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<td></td>
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<tr>
<td>Food - (max.)</td>
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</tr>
<tr>
<td>Tolerance levels</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>- Fish</td>
<td>U.S. FDA</td>
<td>2 µg/g (edible portion)</td>
<td>32 (1984)</td>
<td>- tolerance level set under the Federal Food, Drug and Cosmetic Act</td>
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<tr>
<td>- Fish</td>
<td>NY State</td>
<td>3.0 µg/g</td>
<td>38</td>
<td>- average contamination level for a collection of sport fish - used as a guideline to assess the need for a health advisory</td>
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<tr>
<td>- Fish</td>
<td>Japan</td>
<td>1 µg/g, 0.5 µg/g</td>
<td>40</td>
<td>- guideline for inshore fish</td>
</tr>
<tr>
<td>- Fish</td>
<td></td>
<td>3.0 µg/g</td>
<td>40</td>
<td>- guideline for offshore fish</td>
</tr>
<tr>
<td>- Fish, meat, and</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>other animals</td>
<td>Japan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Fish (and fish</td>
<td>Switzerland</td>
<td>1 µg/g (edible portion)</td>
<td>41 (1983)</td>
<td>- provisional as of Jan. 1/81</td>
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<tr>
<td>products)</td>
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<tr>
<td>- Fish, crustaceans</td>
<td>Sweden</td>
<td>2.0 µg/g</td>
<td>41 (1983)</td>
<td>- in force since July, 1980</td>
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<tr>
<td>and parts thereof</td>
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<tr>
<td>(unprocessed)</td>
<td>Sweden</td>
<td>5.0 µg/g</td>
<td>41 (1983)</td>
<td>- in force since July, 1980</td>
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<td>- Fish liver</td>
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<td>- Fish</td>
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<td>- shellfish</td>
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<td>- Fish</td>
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<tr>
<td>- Milk/dairy</td>
<td>U.S. FDA</td>
<td>1.3 mg/kg (fat basis)</td>
<td>30 (1981)</td>
<td>- tolerance level set under the Federal Food, Drug and Cosmetic Act</td>
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<tr>
<td>products</td>
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</tr>
<tr>
<td>- Milk/dairy</td>
<td>Canada</td>
<td>0.2 mg/kg (fat basis)</td>
<td>29a (1983)</td>
<td>- administrative guideline established by Health and Welfare Canada</td>
</tr>
<tr>
<td>products</td>
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<td></td>
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<tr>
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<td>Region</td>
<td>Concentration</td>
<td>Reference</td>
<td>Notes/Comments</td>
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<td>Food - (max.) tolerance levels (cont'd)</td>
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<td>- milk</td>
<td>Japan</td>
<td>0.1 mg/kg</td>
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<tr>
<td>- dairy products</td>
<td>Japan</td>
<td>1.0 mg/kg</td>
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<tr>
<td>- powdered milk for infants</td>
<td>Japan</td>
<td>0.2 mg/kg</td>
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<tr>
<td>- human milk</td>
<td>Japan</td>
<td>0.033 mg/kg (mean)</td>
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<tr>
<td>- eggs</td>
<td>Canada</td>
<td>0.1 mg/kg (whole less shell)</td>
<td>29a (1983)</td>
<td>administrative guideline established by Health and Welfare Canada</td>
</tr>
<tr>
<td>- poultry</td>
<td>Canada</td>
<td>0.5 mg/kg (fat basis)</td>
<td>29a (1983)</td>
<td>administrative guideline established by Health and Welfare Canada</td>
</tr>
<tr>
<td>- eggs</td>
<td>U.S. FDA</td>
<td>0.3 mg/kg</td>
<td>30 (1981)</td>
<td>tolerance level set under the Federal Food, Drug and Cosmetic Act</td>
</tr>
<tr>
<td>- poultry</td>
<td>U.S. FDA</td>
<td>3.0 mg/kg (fat basis)</td>
<td>30 (1981)</td>
<td>tolerance level set under the Federal Food, Drug and Cosmetic Act</td>
</tr>
<tr>
<td>- eggs</td>
<td>Japan</td>
<td>0.2 mg/kg</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>- beef</td>
<td>Canada</td>
<td>0.2 mg/kg (fat basis)</td>
<td>29a (1983)</td>
<td>administrative guideline established by Health and Welfare Canada</td>
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<tr>
<td>- red meat</td>
<td>U.S. FDA</td>
<td>3.0 mg/kg</td>
<td>31 (1981)</td>
<td>action level set under the Federal Food, Drug and Cosmetic Act</td>
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<tr>
<td>- meat</td>
<td>Japan</td>
<td>0.1 mg/kg</td>
<td>40</td>
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</tr>
<tr>
<td>- infant/junior foods</td>
<td>U.S. FDA</td>
<td>0.2 mg/kg</td>
<td>30 (1981)</td>
<td>tolerance level set under the Federal Food, Drug and Cosmetic Act</td>
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<tr>
<td>- animal feed components</td>
<td>Canada</td>
<td>2.0 mg/kg (fish oil)</td>
<td>29a (1983)</td>
<td>administrative guideline established by Agriculture Canada for PCBs in fish oil destined for animal feed</td>
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<tr>
<td>- animal feed components</td>
<td>U.S. FDA</td>
<td>2.0 mg/kg</td>
<td>30 (1981)</td>
<td>tolerance level set under the Federal Food, Drug and Cosmetic Act</td>
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<td>- finished animal feed</td>
<td>U.S. FDA</td>
<td>0.2 mg/kg</td>
<td>30 (1981)</td>
<td>tolerance level set under the Federal Food, Drug and Cosmetic Act</td>
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<tr>
<td>- compound feeds</td>
<td>Japan</td>
<td>0.5 mg/kg</td>
<td>40</td>
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<tr>
<td>- paper food packaging material</td>
<td>U.S. FDA</td>
<td>10 mg/kg</td>
<td>30 (1981)</td>
<td>tolerance level set under the Federal Food, Drug and Cosmetic Act</td>
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<tr>
<td>- containers and wrapping</td>
<td>Japan</td>
<td>5.0 mg/kg</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Environmental Medium</td>
<td>Region</td>
<td>Concentration</td>
<td>Reference</td>
<td>Notes/Comments</td>
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<tr>
<td>----------------------</td>
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<tr>
<td>Tolerable daily intake (TDI)</td>
<td>Canada</td>
<td>1 µg/kg body wt. per day</td>
<td>29a (1983)</td>
<td>- estimated daily &quot;tolerable&quot; exposure based on studies using Rhesus monkeys</td>
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<td>U.S. EPA</td>
<td>3.0 µg/kg body wt. per day</td>
<td>33 (1983)</td>
<td>- estimated TDI - based on rat studies - safety factor of 100</td>
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<td>U.S. FDA</td>
<td>0.3 µg/kg body wt. per day</td>
<td>34 (1983)</td>
<td>- estimated TDI - based on rat studies - safety factor of 1000</td>
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<td>3.0 µg/kg body wt. per day</td>
<td>35 (1983)</td>
<td>- estimated TDI - based on rat studies</td>
<td></td>
</tr>
<tr>
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<td>2.5 µg/kg body wt. per day</td>
<td>35 (1983)</td>
<td>- estimated TDI - based on dog studies</td>
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<td>20 µg/kg body wt. per day</td>
<td>35 (1983)</td>
<td>- estimated 30 day TDI - based on Yusho</td>
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<tr>
<td></td>
<td>1.0 µg/kg body wt. per day</td>
<td>35 (1983)</td>
<td>- estimated 22 month TDI - based on Yusho</td>
<td></td>
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<tr>
<td>Air - occupational</td>
<td>Canada</td>
<td>1 mg/m³ over 3 h - 42% Cl°C</td>
<td>3 (1980)</td>
<td>- regulated under the Canada Labour Code (adoption of ACGIH standard)</td>
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<tr>
<td></td>
<td>2 mg/m³ over 15 min.</td>
<td>2 mg/m³ over 15 min.</td>
<td>3 (1980)</td>
<td>- adoption of ACGIH standard</td>
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<td>0.3 mg/m³ over 8 h</td>
<td>0.3 mg/m³ over 8 h</td>
<td>3 (1980)</td>
<td>- adoption of ACGIH standard</td>
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<td>1 mg/m³ over 15 min.</td>
<td>3 (1980)</td>
<td>- adoption of ACGIH standard</td>
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<tr>
<td>British Columbia</td>
<td>1 mg/m³ over 8 h - 42% Cl°C</td>
<td>4 (1982)</td>
<td>- adoption of ACGIH standard</td>
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<td>2 mg/m³ over 15 min.</td>
<td>2 mg/m³ over 15 min.</td>
<td>4 (1982)</td>
<td>- adoption of ACGIH standard</td>
</tr>
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<td>0.3 mg/m³ over 8 h</td>
<td>0.3 mg/m³ over 8 h</td>
<td>4 (1982)</td>
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<td>1 mg/m³ over 15 min.</td>
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<td>Alberta</td>
<td>1 mg/m³ over 8 h - 42% Cl°C</td>
<td>5 (1983)</td>
<td>- adoption of ACGIH standard</td>
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<td>- adoption of ACGIH standard</td>
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<td>0.3 mg/m³ over 8 h</td>
<td>5 (1983)</td>
<td>- adoption of ACGIH standard</td>
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<td>1 mg/m³ over 15 min.</td>
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<td>- adoption of ACGIH standard</td>
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<tr>
<td>Quebec</td>
<td>1 mg/m³ over 8 h - 42% Cl°C</td>
<td>6 (1982)</td>
<td>- adoption of ACGIH standard</td>
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<td>2 mg/m³ over 15 min.</td>
<td>2 mg/m³ over 15 min.</td>
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<td>0.3 mg/m³ over 8 h</td>
<td>0.3 mg/m³ over 8 h</td>
<td>6 (1982)</td>
<td>- adoption of ACGIH standard</td>
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<td>1 mg/m³ over 15 min.</td>
<td>1 mg/m³ over 15 min.</td>
<td>6 (1982)</td>
<td>- adoption of ACGIH standard</td>
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<tr>
<td>New Brunswick</td>
<td>1 mg/m³ over 8 h - 42% Cl°C</td>
<td>7 (1980)</td>
<td>- adoption of ACGIH standard</td>
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<td>2 mg/m³ over 15 min.</td>
<td>2 mg/m³ over 15 min.</td>
<td>7 (1980)</td>
<td>- adoption of ACGIH standard</td>
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<td>0.3 mg/m³ over 8 h</td>
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<td>1 mg/m³ over 15 min.</td>
<td>1 mg/m³ over 15 min.</td>
<td>7 (1980)</td>
<td>- adoption of ACGIH standard</td>
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332.
<table>
<thead>
<tr>
<th>Environmental Medium</th>
<th>Region</th>
<th>Concentration</th>
<th>Reference</th>
<th>Notes/Comments</th>
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<tr>
<td>Air - occupational</td>
<td>Newfoundland</td>
<td>1 mg/m³ over 8 h - 42% Cl₂</td>
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<td>- adoption of ACGIH standard</td>
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<td>2 mg/m³ over 15 min.</td>
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<td>0.5 mg/m³ over 8 h</td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td>3 h - 42% Cl₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ontario</td>
<td>0.03 mg/m³ (av. for 40-h work wk.)</td>
<td>94 (1986)</td>
<td>- recommended - Ministry of Labour;</td>
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<td></td>
<td></td>
<td>0.5 mg/m³ (0.5 hour max.)</td>
<td>10 (1985)</td>
<td>- max. 1/2-h av. air concentration</td>
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<td></td>
<td>recommended by commission as standard</td>
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<td>for area surrounding mobile destruction</td>
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<td>facility</td>
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<td>U.S. ACGIH</td>
<td>1 mg/m³ over 8 h - 42% Cl₂</td>
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<td>- regulated under the Occupational Safety</td>
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<td>2 mg/m³ over 15 min.</td>
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<td>and Health Act</td>
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<td>U.S. NIOSH</td>
<td>1 µg/m³ (average over 40-h work week)</td>
<td>12 (1977)</td>
<td>- recommended by NIOSH for amendment</td>
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<td>of the Occ. Safety and Health Act</td>
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<td>West Germany</td>
<td>1.0 mg/m³ (3-h av.)</td>
<td>28 (1986)</td>
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<tr>
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<td>0.5 mg/m³ (3-h av.)</td>
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<td>3 h - 42% Cl₂</td>
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<tr>
<td></td>
<td>East Germany</td>
<td>1.0 mg/m³ (3-h av.)</td>
<td>29 (1986)</td>
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</tr>
<tr>
<td></td>
<td>Sweden</td>
<td>0.5 mg/m³ (3-h av.)</td>
<td>28 (1986)</td>
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<td></td>
<td>Australia</td>
<td>1.0 mg/m³ (3-h av.)</td>
<td>29 (1986)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Czechoslovakia</td>
<td>1.0 mg/m³ (3-h av.)</td>
<td>29 (1986)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Romanian</td>
<td>1.0 mg/m³ (3-h av.)</td>
<td>24 (1986)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5 mg/m³ (3-h av.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finland</td>
<td>1.0 mg/m³ (3-h av.)</td>
<td>24 (1986)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5 mg/m³ (8-h av.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>1.0 mg/m³ at 25°C</td>
<td>24 (1986)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>and 1 atm. (8-h av.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a These secondary references are cited because primary references were unavailable or unobtainable;
b The U.S. EPA has recently (1985) revised its assessment of PCls and concluded that suitable data were not available upon which to estimate suggested No Adverse Response Level (SNARL) (1983);
c The U.S. EPA has recently revised its assessment of PCls and concluded that suitable data were not available upon which to estimate a Tolerable Daily Intake (TDI) (U.S. EPA - pers. com.);
d Tolerable Daily Intake (TDI) values based on "Yusho" incident were calculated using an average total exposure level of 2000 mg/adult. This was later reduced to about 1/2 this value due to contamination of the PCB liquid with polychlorinated quaterphenyls and furans. The TDI values listed should be reduced by about 1/2 to reflect the intake of PCls. Since furans and quaterphenyls were also present, estimate of a "no observed effect" level due solely to PCls is impossible from this data.
e Weight percent of chlorine present in the PCB molecule.
f Duration of occupational exposure assumed by author based on similarity to ACGIH guidelines.
g The Ontario Ministry of Environment has designated PCls as substances with a "zero tolerance limit", they are hazardous if released at any concentration (14).
Table 3: Summary of PCB Management Activities by Province (adapted from British Columbia Hydro and Power Authority, 1993)

<table>
<thead>
<tr>
<th>PROVINCE</th>
<th>PCB PROGRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.C.</td>
<td>Commissioning a discussion paper to be ready Oct., 1994&lt;sup&gt;19&lt;/sup&gt;</td>
</tr>
<tr>
<td>Alberta</td>
<td>Destroying PCB inventory in high temperature at Swan Hills. Facility may be made available to other western provinces in the future.</td>
</tr>
<tr>
<td>Saskatchewan</td>
<td>Consolidated 3rd party storage managed by Sask Power</td>
</tr>
<tr>
<td>Manitoba</td>
<td>Consolidated 3rd party storage managed by Manitoba Hydro</td>
</tr>
<tr>
<td>Ontario</td>
<td>Extensive studies but no site and no program</td>
</tr>
<tr>
<td>Quebec</td>
<td>Province committed to PCB destruction. Mobile incinerator tested at Baie Comeau</td>
</tr>
<tr>
<td>Maritimes</td>
<td>Consolidated PCB storage funded and managed by federal government</td>
</tr>
</tbody>
</table>

<sup>19</sup> The B.C. Ministry of Environment provides regulations for the thermal destruction of PCBs, but in contrast to the federal government, has never publicly endorsed incineration as an acceptable PCB destruction option.
Chapter 1: Progress, Problems, and Prospects in Risk Communication Research and Practice

1. Some of the earliest risk assessment and management models have been developed in the United Kingdom by the Royal Society Study Group (1983), in the United States by the National Research Council (1983), in Canada by the Interdepartmental Working Group on Risk-Benefit Analysis (1984), and by the World Health Organization (1985). The brief description of the risk assessment/management process which follows is based on a model developed in 1988 and used within the Environmental Health Directorate of Health and Welfare Canada. A schematic illustration of this model is available in appendix (Appendix A, Figure 1). This section draws mainly from Krewski, 1987; Krewski and Birkwood, 1987; and Leiss and Krewski 1988.

2. Merkhofer (1987) presents a systematic exposition and critic of the decision-aiding approaches used in policy analysis. For their application in the Canadian context see Leiss and Chociolko (1994: 40-45). In Canada, formal cost-benefit analysis is not required by law.

3. A more involved exposition of the psychometric paradigm including a detailed historical account of the contributions made by various researchers is made by Pidgeon et al. (1992: 101-8).

4. More specifically, cognitive heuristics include the 'heuristic of availability' (the mental images or pictures of a risk available to the individual influence the perception of that risk), the 'heuristics of representativeness' (new information is related to known categories), and the 'heuristic of anchoring' (which refers to the tendency of people not to adequately adjust their initial estimates of probabilities in the face of new contradictory information). (Tversky et al., 1974: 1124-28)

5. Cognitive heuristics have been shown to subject the judgments of scientifically trained experts to the following biases: inappropriate reliance on limited data (the tendency to impose order on random events and to fit ambiguous evidence into predispositions) and a tendency to systematically omit certain components of a risk (e.g., by overlooking the ways human errors affect technological systems). More generally, cognitive heuristics have been shown to generally influence experts in the direction of overconfidence about the certainty of whatever currently seems to be known (Fischhoff, 1989: 44-47).
6. In this scheme, the 'group' dimension refers to the strength of insider-outsider boundaries, the 'grid' dimension to the strength of role differentiation within the group. Whereas the group variable represents the degree of social integration of the individual to the social unit (i.e., the extent to which individuals take a group mind-set and find identity in this social group), the degree of grid describes the extent to which the group promotes a formal system of hierarchy and procedural rules.

7. Otwinn Renn has also pointed out that, in practice, people may participate in various organizations or groups having different cultural profiles. A business owner (entrepreneurial prototype) may belong to an environmental or religious group (egalitarian prototype) and serve as treasurer in a volunteer charity organization (bureaucratic prototype). Finally, many social groups have agendas and world views that cannot be captured by any of the five cultural category like religious groups which tend to be hierarchical in structure but are often egalitarian in doctrine (1992a: 75).

8. The message transmission model is as follows:

```
   SOURCE    CHANNEL    RECEIVER
       ^           ^           ^
       |           |           |  
       |           |           |   
       |           |           |    
       |           |           |     
       |           |           |      
       |           |           |       
       |           |           |        
       |           |           |         
       |           |           |          
       |           |           |           
   MESSAGE
```

In the engineering theory of communications, the objective is to reproduce the source message (usually an electronic signal) without distortion at the receiving end (Leiss: 1989: 96). Covello et al. describe the risk communication problems according to this model:

"Message problems include the following:

* deficiencies in scientific understanding, data, models and methods, which result in large uncertainties in risk estimates; and
* highly technical analyses that are often unintelligible to lay persons.

Source problems include the following:

* lack of trust and credibility;
* disagreements among scientific experts;
* limited authority and resources for addressing risk problems;
* lack of data addressing the specific fears and concerns of individuals and communities;
* failure to disclose limitations of risk assessments and resulting uncertainties;
* limited understanding of the interests, concerns, fears, values, priorities, and preferences of individual citizens
and public groups; and
* use of bureaucratic, legalistic, and technical language.

Channel problems include the following:
* selective and bias media reporting that emphasizes drama, wrongdoing, disagreement and conflict;
* premature disclosure of scientific information; and
* oversimplification and distortions of, as well as inaccuracies in, interpreting technical information.

Receiver problems include the following:
* inaccurate perceptions of levels of risk;
* lack of interest in risk problems and technical complexities;
* overconfidence in the ability to avoid harm;
* strong beliefs and opinions that are resistant to change;
* exaggerated expectations about the effectiveness of regulatory actions;
* desire and demand for scientific certainty;
* reluctance to make trade-offs among different types of risk or among risks, costs and benefits; and
* difficulties in understanding probabilistic information related to unfamiliar technology." (Covello et al., 1986: 110-12)

9. This critique is carried most systematically and comprehensively by Otway and Wynne (1989). Stallen and Coppock (1987: 414) also present a table juxtaposing competing and sometimes contradictory recommendations formulated by participants at a risk communication workshop in the U.S. government. These guidelines include:

* Be explicit about the objective of risk communication; convey your assumptions. Or alternatively;
  Prevent confusion resulting from two agencies interpreting the same data differently.

* Present all information where possible with uncertainties associated. Or;
  Address and respond to the public's needs with a clear and simple exposition of the facts.

* Be accountable for your actions. Or;
  Prepare joint press releases.

10. It is also important to remember in this context that, independently of the estimates chosen for comparisons, a slight modification in the framing of that estimate can affect how it will be perceived. For example, a surgical procedure can be made to appear intuitively more successful if it is expressed as a percentage of lives saved rather than lives lost. Physicians
themselves have been observed to modify their judgment depending on how the outcome of treatment is expressed (MacNeil et al., 1982).

11. Some interesting data concerning the health consequences of smoking (and the reasons invoked for not dealing with those) are presented in Leiss (1994, 73-77). "About 400,000 Americans and 40,000 Canadians die prematurely each year as a result of smoking, making it by far the largest single preventable cause of premature death. Yet in the late 1980s over 50 million Americans and almost 7 million Canadians were still smoking." (p. 74-75)

12. Most data exploring the relationship between tobacco use and ethnicity pertains to the U.S. context and is of little use to design public health programs in Canada because of the different ethnic composition of the two countries. In addition, to make a reliable use of this data, one would need to speculate about the effect of the American melting pot orientation versus the Canadian value of multiculturalism.

"Data from Mainland China provide a pertinent example of cultural norms which affect the use of tobacco in that country. Tobacco is both a status symbol and a form of social cement. Exchange of cigarettes figures prominently in business contacts and in the initiation and maintenance of interpersonal relationships." (Edwards, 1990: 34)

China has 300 million smokers. The highest smoking rates are found among party members (idem 34-35).

13. The explanation for this is naturally open to speculation. One rationale that has been advanced is that in Catholic countries there is a greater acceptance of authority. Consequently the relationship between the medical profession and its patients is more paternalistic and accepted as such, leading to more medicines being prescribed. Conversely, the Protestant ethic of rejection of authority would contribute to a reluctance to accept medicines from medical authority and explain the greater reliance on self medication. Scepticism towards medical authority could also account for the higher rate of adverse drug reaction (ADR) reporting recorded in Protestant countries.

This type of inquiry can be extended further. For instance, a greater regard for the sanctity of human life has been invoked to account for the lower abortion rates observed in Catholic countries. Conversely, the reluctance to accept the sanctity of human life as unique has resulted in a great level of respect for animal life in Protestant countries and a more active antivivisection lobby (Griffin, 1989: 240-2).
14. Many factors other than medical information strictly speaking can affect negatively the perception and communication of medical risk information and need to be taken into account when assessing drug use and prescribing patterns. For a review of problems and potential remedial strategies pertaining to medication information see my "Communication of Prescription Drug Information Amongst Canadian Health Care Professionals: Overview of Research Results" (Milly, 1993).
1. In this regard, Funtowitcz and Ravetz pertinently emphasize that uncertainty and quality are two different attributes of scientific information and that confusing these two notions leads to the misconception that there is a straightforward relationship between them, i.e., that high quality is equivalent to low uncertainty. They point out that "whereas uncertainty is an attribute of knowledge, quality is a pragmatic relation" (e.g., the totality of characteristics of a product that bear on its ability to satisfy an established use). Consequently, "information of lesser certainty may yet be of good quality for its intended use" (1992: 264).

2. Jasanoff (1986) has argued that the conventional and context-bound nature of scientific activity has promoted two main formulations of the nature of regulatory science. One view holds that differences in scientific claims are reducible to differences in strategic, presumably conscious political ends with the accompanying opposite conceptualization that "good" and "bad" are absolute, unambiguous categories.

The competitive more complex view claims that regulatory science combines norms that are properly internal to science (e.g., empirical testing and peer-review) and external interests pertaining to the political and scientific communities.

"The relative importance of the internal and external norms can vary overtime and across discipline, and in response to the political context." (Jasanoff, 1986: 70)

The problem with these two perspectives, as I see it, is that they are not as different as might appear at first sight. The second view simply provides a richer combination of "scientific" and "political" components. Once formulated in binary terms the tension between scientific knowledge and political frameworks can only be resolved into one or the other of the two extremes. That is to say, either scientific knowledge will be seen as capable of superseding political interests, or at least controlling them, or it will not, and will thus be manipulated and finally reduced to political interests. Of course, in practice what we have is various shades of grey between "good" and "bad" science but the image of science we are left with in the end is always one which is excessively rationalistic or exclusively value-laden depending on who makes use of it.

In this framework, expert disagreement is always presented as due to data imprecision or to deliberate interests illegitimately concealed in the science and the very existence of scientific knowledge always dependent upon the idea that the factual domain, though uncertain, can be treated as prior to and independent of
values. What needs to be emphasized – as the quote by Knorr-Cetina in the text above suggests – is that values enter the process of scientific knowledge construction and development without necessarily leading to its degeneration or being necessarily attached to recognizable social interests.

The big fear inevitably associated with an understanding of scientific knowledge as first and foremost socially constructed is that it leads to sociological reductionism. Thus, it is common place to find, along with an endorsement of the conventional character of scientific practice, a series of redeeming statements about some inherent value and intrinsic properties of science. Yet, as Brian Wynne suggested, the truth value of scientific propositions is essentially relative and a function of the relationship they are meant to uphold:

"Scientific knowledge does have force, but this in itself says nothing substantial. The scope and direction of that force is socially shaped." (Wynne, 1989: 53)

3. The growing monopolization of scientific energies to cope with "orthodox" uncertainties in risk management is reflected in the increasingly popular activity of classifying uncertainties. Salter, for instance, distinguishes between four types of scientific uncertainty: i) legitimate scientific uncertainty (with further resources, resolution is possible); ii) practical indeterminism (resource constraints make resolution unlikely); iii) methodological uncertainty (inherent limitations in scientific techniques, eg, epidemiology, make resolution impossible); and iv) uncertainty caused by the tendency of scientific work to result in ever more complex and ambiguous conclusions (1988: 199-200). Many other classifications, are available elsewhere, eg, in Funtowicz and Ravetz (1990: 22-23; 1992: 259).

4. The Mackenzie Valley Pipeline inquiry, also called the Berger inquiry after the name of the judge presiding over the proceedings, is regarded as a watershed in the history of public inquiries in Canada. The Berger inquiry brought scientists who had conducted several different research studies on the same topic together in a forum where the claims of one group could be tested against that of another. The inquiry’s most important conclusion was that native people had to be taken as serious advocates of their cause (Salter and Slaco, 1981).

5. A taxonomy of ignorance that includes: i) ignorance of actions (ie, objective alternatives about which we are unaware); ii) ignorance of outcomes; and iii) ignorance of values (the outcomes are known to exist but their nature is a mystery) is mentioned in Wildavsky (1989: 241). This author also distinguishes between "expected" uncertainties (also labelled quantitative surprise: we know what can happen but not how often nor how much), "true" uncertainty (or qualitative surprise: neither the class nor the
probability of consequences are known), and ignorance (the ignorant do not know that they don’t know) (idem: 93).

6. As “system-networks” science and technology do not have ‘impacts’ on an essentially passive physical and social environment but instead create inference effects by active but unforeseen interference with other proliferating socio-technological networks. The degree of ignorance and inevitable unforseeability of such effects is of a different, less controllable quality than the former sort of impacts; yet, it is not reflected in any risk-analytic method where the analysis of uncertainties centres, often elaborately, upon data gaps and modelling assumptions (Wynne, 1987: 269-309; See also Callon and Law, 1989).

7. A similar point is made by Funtowicz and Ravetz:

“In the disputes on environmental and occupational health hazards, which are bound to increase greatly before they abate, popular conceptions of science tend to change drastically from naive trust to embittered cynicism.” (Funtowicz and Ravetz, 1990: 11)

These interpretations are consistent with Wynne’s observation that, during the Windscale experience the general public "appeared either indifferent or disoriented." The Windscale inquiry was held in Britain in 1977 to evaluate plans by the government to construct a massive reprocessing plant for spent nuclear fuels. Although less successful than the Berger inquiry in securing public participation and in illuminating the political aspects of the proposed policy, it is another notable example of a public forum where experts and public representatives have met to explore the uncertainties and technical complexities surrounding a major risk management decision (Wynne, 1982: 169).

8. Since public consultation serves several purposes and since the motives and expectations of the parties engaged in the process usually differ, assessing the relative success or failure of participatory exercises will be no easy task.

"The rhetoric of ‘failed consultation’ is standard fare in politics, and one of the truly scarce political skills is the art of differentiating bogus from legitimate claims in this regard." (Doern and Phidd, 1983: 88)

9. Modelled after industrial-labour negotiations, MAUT has been found effective in a variety of context. In particular, this technique helped reach settlement in the structuring of Germany’s energy objectives, in the sitting of offshore oil drilling in southern California and in controlling water flow in central Arizona. MAUT’s main contribution to risk management lies in providing an explicit mapping of both the publics and the
regulators' concerns. It stimulates a critical appraisal of those concerns by seeking an explicit articulation between values and regulatory options.

Very schematically, the MAUT process can be boiled down to a four-step approach:

1) Interested parties are identified and 5 to 10 representative groups including the project main proponents, opponents and regulators are selected.

2) Each stakeholder group designs scenarios corresponding to possible regulatory alternatives. Participants are encouraged to stretch their imagination and to consider the most extreme options. Each group must advance some suggestions likely to be compatible with the concerns and values of other groups.

3) Value weights are used by each group to rank the various regulatory scenarios along with the values that have been influential in opting for particular alternatives. The selected regulatory options and accompanying values are then compiled in a series of "value trees" that stakeholders representatives present to their constituents for comments and modifications.

4) Redundant values and options are regrouped in a common value tree representing overall stakeholders' preferences. The value tree is then made available to decision-makers and the public.

By treating each situation as a particular research problem, MAUT offers great flexibility in tailoring the approach to the requirements of particular contexts. The invention and packaging of options is developed in situ so that the information is directly relevant to the interested parties involved (Edwards and von Winterfeldt, 1987).
Chapter 3: Methodological Approach: The Case Study as Research Strategy To Health and Environmental Controversies


4. For instance, the case-study over the development and use of recombinant DNA (rDNA) shows that despite similar scientific knowledge pools, controversies over this technology have taken different forms and displayed different degrees of intensity in different countries. The critical role played by situational elements (e.g., the institutional, legal and historical context framing the controversy in various locale) exemplifies the need to develop local rather than universal responses to effectively address the controversy. See C. Limoges et al., "Controversies over Risks in Biotechnologies (1973-89): A Framework for Analysis", Proceedings, Managing Environmental Risks, Air and Waste Management Association, Pittsburg, 1990, p. 155-174.


The entities that comprise various worlds of relevance are not restricted to human collective actors but are made up of both micro and macro actors that include non-human entities such as 'nature', 'society', 'the economy'; physical artifacts such as biological/chemical insecticides; and a whole variety of black boxes such as mathematical models and 'standards'.

"Worlds of relevance (...) differ in the nature and diversity of the entities they mobilize, and in the ways they relate these entities to each other." (idem, p.8)
An illustration of the ways in which these various entities are “packaged” is provided in Limoges et al. "From ecotoxicology to risk assessment in biotechnology: The standardization of microcosms", Paper presented before the Society for the History of Technology, Uppsala, Sweden, August 1992.


14. One researcher for instance, noted that by the end of the eighties, everybody in Quebec was talking about PCBs as if they were their next door neighbours. See Hélène Denis, "La gestion de catastrophe: le cas d’un incendie dans un entrepôt de BPC à Saint-Basile-le-Grand", Rapport commandité par le Bureau de la Protection civile du Québec, 1989, p.50.
Chapter 6: The Public Perception of PCB Risk


3. A search of various news index starting in 1968 and conducted with the assistance of two reference librarians failed to produce any press articles relating to PCBs or the Yusho poisoning incident before the year 1977. The material presented in this sub-section is taken from two secondary sources: from a book by Huddle et al. titled Islands of Dreams: Environmental Crisis in Japan first published in 1975, and from an article by Edward J. Burger, "Health as a Surrogate for the Environment" which appeared in Daedalus, Special Issue on Risk (1990).


7. See "Why weren't we warned by province, workers complain" in The Globe and Mail, December 16, 1977, p. A1; "Caught off guard" (idem) December 17, 1977, p.12; "PCB levels are not hazardous, fire tests indicate" (idem) December 21, 1977, p.5. The later two articles contain statements indicating that "PCBs (...) have been found to cause birth defects, nervous disorders, impairment of liver functions and cancer."

8. See for instance "Clean-ups of past fires were costly and difficult" in The Gazette, August 26, 1988, p. A7.

In Canada, a large fire at a capacitor bank in the Annex of the
Institut de recherche d’Hydro-Quebec (IREQ) in Varennes, Quebec resulted in a $15 million decontamination operation. During the one year clean up, workers wore full protective clothing with face masks and had to shower before leaving the building. Here again, the press interest in the 1984 IREQ fire arose mainly a-posteriori in relation to the 1988 fire at St-Basile-le Grand. See "Hydro-lab contamination ‘worst of its kind’: Official" in The Gazette, December 13, 1984, p. A3.

9. Still, this search was not exhaustive for articles published in the francophone press as well as those which are PCB related but do not include the letters "PCB" or "PCBs" in their titles were not included in the CNI countdown. During the same period, about 235 articles were also published in professional magazines and business newspapers (e.g., Electrical Business, Hazardous Materials Management Magazine, The Financial Post, etc.). In addition, about 40 articles on the subject appeared in popular magazines (Maclean’s, Reader’s Digest, Western Report, etc.).

Overall, about a third of these 1400 articles were closely examined while another third was simply perused. Articles published in newspapers and magazines with the largest circulation were analyzed in priority. Coverage by The Globe and Mail, for example, was studied with greater care than that of the Vancouver Sun. While references from national press coverage (e.g., The Globe and Mail, The Financial Post, Maclean’s, This Magazine) was used to demonstrate the national prominence of the PCB issue, stories published in the regional press (in La Presse, Alberta Report, Halifax Chronicle Herald, etc.) served to illustrate the pervasiveness of public concern over the compounds or to provide contextual information pertaining to locally circumscribed PCB controversies.

10. The Canadian Newspaper Index data base indicates that the number of articles published in 1985, 1988 and 1989 was 292, 236 and 325 respectively. This contrast sharply with the numbers of articles appearing in bordering years 1984 (24 articles), 1986 (43), and 1987 (23), 1990 (45).


13. The quotes and descriptions of events presented in this subsection mostly originate from Maclean’s, April 29, 1985, p. 14-21. The information selected reflects the focus of the news coverage of the many articles that were published in the daily papers of the country during the week following the spill.


16. Residents of the Montreal east-end were told not to eat home-grown fruits and vegetables, drink water from artesian wells or swim in outdoor pools. See, “3,000 kept from home for second night: Effects of PCB fire on South Shore not certain, but water, produce may be unsafe”, in Montreal Gazette, August 25, 1988, p. A1.


20. On this occasion, the Environment Minister declared: “The governments represented here have committed themselves to a PCB-free Canada”. However, the environment ministers were careful not to make any commitments as to when the PCBs in storage or in use would be destroyed or rendered safe. See “Canada sets 1993 deadline to stop use of PCBs” in The Globe and Mail, September 8, 1988, p. A1. The article notes that in 1985 federal and provincial environment ministers had already committed themselves to urgent action on the problem of PCBs.

22. See for instance "Chemical inferno - The fire at St-Basile sparked a concern across the country" in The Globe and Mail, September 3, 1988, Focus section.


Mr. Chapleau, the man who had been charged of setting the fire is also suing police and the province of Quebec for $1.5 million for malicious prosecution. After spending five months in prison, Mr. Chapleau, who said he had been intimidated and pressured by police when he confessed to the crime, was eventually acquitted by a Quebec Superior Court. In his judgment, the court severely criticized the police investigation. "In my opinion, it is crude and poorly conducted police work that directly tramples on all the well-known principles that must be applied while interrogating suspects. The legal status of Mr. Chapleau transformed dramatically from witness to suspect, from suspect to accused, and from accused to prisoner," wrote the judge. See "Acquitted in PCB fire, man sues Quebec" in The Globe and Mail, September 2, 1989.

29. This later estimate is from the Canada Gazette, Part II, Vol. 126, No. 19, September 1992, p. 3582.


of the liver, biliary tract and gall bladder." The report also indicates that victims of the 1968 Yusho poisoning still had high levels of PCBs in their bodies 10 years later and that at least five of them died of liver cancer within five years of the accident. The report concludes by noting that the Ontario Workers Compensation Board has about 30 claims from people who say they contracted cancer after being exposed to PCBs. See "Properties of PCBs like Jekyll and Hyde".

33. This point was first made by Ann Marie Wolicky. See "Forgetting the facts" in Content, Nov-Dec 1989, p. 17-18.

34. For instance, Prof. Stephen Safe indicated that when compared to the risks faced daily by industrial workers, the risk from exposure to PCBs, dioxins and furans during the St-Basile fire were "trivial". See "PCB risk was exaggerated, some scientists say" in The Gazette, September 3, 1988, p. A7.


37. See for instance "BPC: A qui la faute?" in La Presse, August 25, 1988, p. B2; "Quebec a failli a sa responsabilité", idem, September 1, 1988, p. B3; or "Saint-Basile: le PQ refuse d'absoudre", idem, September 2, 1988, p. B3. While the editorialist of La Presse said Quebec government's first task is to compensate the victims, Le Devoir's publisher called for a full public inquiry into the problem of storing and destroying toxic chemicals.

38. See "Saint-Basile: le PQ refuse d'absoudre" in La Presse, September 2, 1988, p. B3. According to the official correspondence on the site obtained by La Presse through CEPA, the maximum amount of PCBs to be stored at the site in August 1979 was 1000 gallons. Two months later that limit was extended to 5000 gallons and by 1981 it reached 20,000 gallons. However, in 1983 a request for a 40,000 gallons limit had been refused by the ministry. (About 26,000 gallons of contaminated materials were in storage the night of the fire.) See "L'entreposage des BPC à Saint-Basile devait être temporaire...il y a 10 ans" in La Presse, August 30, 1988, p. A3.

The Quebec Environment Ministry was also aware that another run-down warehouse containing about 5,000 gallons of PCB material was without a valid operating permit since 1985. After the St-Basile fire, the Ministry effectively decided to take responsibility for insuring the safety of the warehouse which belonged to the same elusive owner; almost 40,000 people lived in its vicinity. See "Shawanigan facility houses 1,000 barrels of PCB-laced oil" in The

40. idem. Ironically, Quebec was the first province in Canada to develop a policy aimed at getting rid of all PCBs within a 10-year time frame. The plan, announced in 1986 and agreed to by all PCB users in Quebec, called for the development by a private-sector company of a specialty designed storage facility coupled with an incinerator. The Senneterre storage site located in the isolated Abitibi region, 600 km northwest of Montreal, was the first component of that plan. It had been selected after two other municipalities (Tracy and Pointe Claire) had turned down the site.

The Superior Court Judge who issued the court injunction for the Senneterre site found that, in his haste to get a private disposal plant running, the Environment Department had cut corners by delaying public hearings and environmental impact studies. The plan, which angered citizens of the Abitibi region, was eventually cancelled by the government at the outset of a by-election campaign in the area. See "Quebec hampered in disposal of toxic PCBs" in The Globe and Mail, July 3, 1989; "Government helicopter flies PCBs to Senneterre to avoid blockade" in The Gazette, September 2, 1989, p. A5.


42. For example, in the first days of the crisis, the media conspicuous presence was resented by emergency personal and officials who felt that, by monopolizing communication channels and circulating unnecessary information journalists were interfering with the efficient conduct of their work.

"Les journalistes ont besoin de tout, ta secrétaire, ton téléphone... Ils se fichent que les gens appellent pour savoir s'il y a des blessés. Ils pensent à l'heure de tombée, c'est tout. Ils sont partout. N'ont aucun respect pour le sommeil des gens, dans les centres d'hébergement... Mettent leurs mégots de cigarette partout, sur les tapis..." See Hélène Denis, La gestion de la catastrophe: le cas d'un incendie dans un entrepot de BPC à Saint-Basile-le-Grand, rapport commandité par le Bureau de la Protection civile du Québec, Université de Montréal, 1989, p. 51.

As the evacuation dragged on, residents also ended up feeling uneasy for being under constant media supervision. As one tired resident told a journalist: "Being known as St-Chernobyl-le-Grand was funny at first, but now the joke is over." See "St-Basile residents return" in The Globe and Mail, September 12, 1988, p. A10.

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43. While the safety of the international experts was insured by the SQ, they were also protected by their own bodyguards. After the panel presented its report, their computer data were destroyed (virus 75). See Hélène Denis, 1989, p. 58. This author presents an in-depth analysis of the question of information confidentiality and communication networks during the evacuation (p.45-54).

44. For instance, in its September 5 issue (p.41), Maclean’s News magazine makes references to a "highly toxic fire" involving "PCBs - substances that can cause several types of cancer, liver disorders, spontaneous abortions and birth defects" in "How a Toxic Firestorm is Terrifying the Residents of a Quebec Town". On September 12, in a piece entitled "Fears for the children" PCBs are still labelled "cancer-causing". In concluding their articles the journalists emphasize that "for residents of St-Basile, the main concern is the uncertainty of PCBs' long term effects." See also "Clouds of doubt hovers as St-Basile goes home" in The Globe and Mail, September 12, 1988, p. A1 and "Return to St-Basile: After 18 days uncertainty lingers" which concludes that "it may be years before life in St-Basile returns to normal" in Maclean’s News magazine September 26, 1988, p. 88.


55. "Can’t you just forget all the rules for a minute and listen to what we have to say?" the exasperated Coalition lawyer exclaimed at one point in the proceedings. The Quebec Superior Court Judge buried his face in his hands and sighed quietly...

For a summary of the procedural wrangling and arguments by legal counsels representing the Manicouagan coalition, the city of Baie-Comeau, Hydro-Québec, the disposal company under contract with the provincial government, the shipping company and the provincial attorney-general respectively, see "Judge to rule on lifting ban of PCB move" in The Globe and Mail, August 29, 1989, p. A1.


60. See the fifth estate, "Public Enemy No.1", October 10, 1989. The columnist who first wrote about this documentary also mentions a conversation he had with the associate vice-president for science research at Dalhousie University in Halifax. In this conversation the later criticized journalists for having done a "lousy job" with
the PCB story referring particularly to the CBC’s Journal, not necessarily because it was the worst example, but because of the position The Journal occupies among the media. He felt that the coverage done by the national news commentary program was less aimed at informing people than at scaring them half to death. See "An industry’s mania for nightmares" in McLean’s, October 23, 1989, p. 60.

61. See "The media’s eco-failure" in The Globe and Mail, December 18, 1991, p. A20. Three years later, a remarkably similar editorial was claiming: "In the past 16 years, The Globe and Mail has published 430 stories about PCBs, a rate of more than one every two weeks, the bulk of them concerning PCB scares of one kind or another." After briefly reviewing the Kenora, St-Basile and Baie-Comeau events and a recent PCB fire at a steel mine in Sydney, Nova Scotia, the editorial goes on to voice its indignation at yet another refusal, this time by Atlantic Canadians, to endorse the siting of a PCB incinerator. The editorial concludes: "If that solution [to destroy PCBs] is "socially unacceptable", it is only because of the ignorance and fear that continue to surround public discussion of PCBs. Recommending that we simply give in to that ignorance is an insult to sound public policy." Fair enough. Except perhaps that it may have been useful if the editorialists had given their readers some suggestions as to where they should look to find unalarming and reasonably balanced and informing accounts of the risks of PCBs and related destruction technologies. See "The PCB bogeyman" in The Globe and Mail, July 21, 1994, p. A16.

62. This remark by the director of public affairs for the Canadian Electrical Association summarizes the point:

"Intense media coverage of the Yusho incident put the first and most persistent label on PCBs, that of being cancer causing agents."


63. See for instance "PCBs vaporized in Sysco mill fire" in The Globe and Mail, May 27, 1994, p. A8, which quotes a series of reassuring and alarming statements made by officials and environmentalists in the wake of the fire, then concludes: "PCB were banned in 1977 after they were linked to cancer in mice and to liver, skin and nerve disorder in humans. Incineration is the only proved method to destroy PCBs, but critics say incomplete combustion could be dangerous." Although factually true, this information is of very little use for making sense of the contradictory statements reported and certainly incomplete enough to perpetuate unwarranted fears about PCBs. See also "Treatment plant in doubt" in The Globe and Mail, July 9, 1994, p. A5 which bluntly states: "They [PCBs] have been linked to cancer in
laboratory animals."


65. See "Ottawa has proposal for destroying PCBs" in The Globe and Mail, January 12, 1979, p. 9; "Bubble, bubble, PCB trouble" in This Magazine, December 1988, p. 27, 28.

66. See "A town that demanded answers" in McLean's, August 5, 1985, p. 16.


68. See "Not in my backyard: Federal employees battle each other over Osoyoos PCBs" in British Columbia Report, October 2, 1989, p. 23.


70. A good overview of the Smithville controversy is available in "Bubble, bubble, PCB trouble: The making of a toxic cauldron" in This Magazine, December 1988, p. 25-30.

71. Some government representatives have accepted full responsibility for the blame. For instance, at the 1988 official opening of a $3 million pipe water line replacing Smithville's PCB contaminated local well with water from Lake Ontario, the provincial Environment Minister declared: "This pipeline is a monument to the failure of government to protect the public from PCBs..." in This Magazine, December 1988, p. 25.
Chapter 7: Lessons Learned

1. For instance Table 1 in appendix C shows estimates of Canadian intakes of PCBs - for different segments of the population and for various environmental media (air, water, food and soil) expressed in nanograms of PCB per kilogram of body weight per day. The appearance of scientific accuracy and objectivity which is conveyed by those numerical estimates and the precise categorization of the population to which they apply (breast fed infants, infants not breast fed, etc.) stands in sharp contrast with the broad assumptions and extensive extrapolations which accompany these and other PCBs' risk estimates more generally.

Chapter five shows that the scientific uncertainties which confound the assessment of PCB risk stem from multiple sources. These include: i) the variations in quantitation procedures and analytical methodologies used for exposure assessment; ii) the qualitative and quantitative differences in the biological activity of various PCB compounds depending on the isomeric composition, degree of chlorination, and type of compound considered (e.g., commercial mixtures versus environmental samples); iii) the great variability observed across animal species in their susceptibility to PCB intoxication; and iv) the great toxicity of the compounds in some species (e.g., mortality effect in monkeys fed doses as low as 0.006 ug/g bw/day) and, on the other hand, an absence of epidemiological evidence showing a clear and consistent correlation between PCB human body burden and health effects reported (although chloracne and altered liver function are observed with some regularity in humans routinely exposed to low levels of PCBs).

Chapter five also outlines other sources of scientific uncertainties that are not specific to PCBs exclusively but are typical of chemical risk assessments in general. These concern, for instance, the relative weight to be conferred to toxicological and epidemiological studies, the biological processes involved in chemical carcinogenesis, and risk assessments' systematic focus on cancer risk which have resulted in a lack of attention directed towards other potentially significant indicators of chemical toxicity (e.g., in utero damage to the unborn in the PCB case).

2. A sample of the range of scientific opinions regarding PCB risk and their management can be found in a series of statements that scientists made to the press during and after a seminar on the subject organized by the Institute of Environmental Studies at the University of Toronto, in September 1989. Many prominent scientists participating in the seminar emphasized that the public fear of PCBs was exaggerated.

However, while most downplayed the risk of developing acute illness from casual contact with PCBs, others emphasized the long term risks posed by the chemical. For example the Chairman of the 1976
task force on the regulation of PCBs in Canada, now a biologist at the International Joint Commission, stressed that PCBs are responsible for high rates of embryo mortality and birth defects in Great Lakes wildlife. PCBs, Michael Gilbertson emphasized, are responsible for reproductive failure in mink and are implicated in embryo deformities and death in snapping turtles and bald eagles. Birth defects in birds include missing eyes, crossed beaks, duplicated feet, and exposed internal organs. Because the substance is dangerous in insidious and unexpected ways, the biologist concluded, it should be scrupulously controlled.

On the other hand, a pathology professor at the University of Guelph joined long-term PCB researcher Stephen Safe in arguing that, because of their antidote action in fighting the toxic effects of dioxins and furans that humans encounter, PCBs may have saved many lives.

The middle ground position is perhaps best exemplified by a statement made by a University of Toronto and Toronto General Hospital toxicologist, another authority on PCBs, who declared: "I don’t think there is any justification for the hysteria going on today... (But) I can’t say PCBs are safe or not safe. I can say that on the basis of long observation they are probably safe." Several others, emphasized that although most PCBs are virtually harmless to human beings, some cancers take up to 30 years to develop so more time and research are necessary to prove or disprove a link between pure PCBs and cancer.

For most scientists in the seminar, however, it is the hysterical reaction of the media and the public to PCBs which drew the largest consensus. "We have abandoned perspective in the assessment of risks," said John Polanyi, who added he felt a bit like someone standing up at the Salem, Mass., witch trials in 1692 shouting, "There are no witches."

Like many of his colleagues, Polanyi said the hazards of PCBs need to be put in perspective so the chemical can be safely eliminated and the hundreds of millions of dollars being spent on their management can be redirected towards what the scientists see as more serious environmental problems.

This view was most directly expressed a researcher from the University of Massachussets School of Public Health who declared: "It’s not uncommon for a chemical a year (to cause an unwarranted uproar). Last year it was Alar (a spray used on fruit trees). If someone wants to address a serious health threat, let them look at automobile exhaust and cigarette smoke."

See "The PCB Threat; Myth or menace?" in The Toronto Star, September 2, 1989, p. D1; "Public consider PCBs to be killers but scientists disagree over danger" in The Globe and Mail, September 12, 1989, p. A12; and Michael Gilbertson "PCB threat is real" in
The medical community is also of the opinion that, compared to other environmental contaminants, PCBs are not very toxic. Medical practitioners emphasize that since the general public cannot rely on media information as a source of objective knowledge, they have a responsibility for providing concerned individuals with objective information as to the relative toxicity of these compounds. See for instance "PCBs and the Family Physician" in Canadian Family Physician, Vol. 32, October 1986, p. 2245-2249, which concludes:

"Perhaps the physician's most important task is to reassure the concerned individual(s)."

3. As chapter five demonstrates, the relatively complex nature of the PCB waste inventory stems from a combination of factors. These include: i) the different materials constitutive of the waste stocks (contaminated liquids and solids, pure PCBs); ii) the different treatment/disposal technologies needed depending on the degree of contamination and the materials considered (retrofilling, chemical treatment, incineration); and iii) the geographical spread and relatively small amount of waste concentration at any one location and the financial expenses attached to the planning-installing-operating and decommissioning of waste treatment/disposal facilities. Difficulties in resolving these "technical" problems are often amplified by conflicts over issues of waste ownership and financial responsibility for the proper disposal of the wastes.


"Judgments of what makes a "high quality" news story about risk indicate that traditional news sources - scientists and representatives from government and industry - are more interested in supporting the status quo than journalists and advocates are in undermining
Still, few media scholars would claim that the media of mass communication reports events without influencing them to some degree. The media appetite for what is unusual, dramatic, visually arresting and entertaining contributes to framing risk in ways that have often contradicted the objective of risk managing institutions. Overall, the relative "objectivity" or "fairness" of media coverage in reporting about technological risks is difficult to assess in broad terms for, depending on the issues or the media considered, either pro or anti technology elements can be found to fuel an argument on opposite sides of a debate about media effects and biases. This being said, there is a consensus amongst media scholars that the existence of a reasonably independent media provides an important check on abuses of power and as such is an intrinsic and indispensable element of independent societies.

5. For instance, a public opinion survey commissioned by Environment Canada in the winter of 1988 about the credibility of various information sources on PCBs showed that three in ten (29%) Canadians considered the federal government as the most trusted agency to find solutions to the PCB problem, followed by private waste management companies (17%), and provincial governments (15%). Local governments (10%) and electrical utilities (7%) were named as the least trusted.

For the siting of PCB facilities however, one in three Canadians (31%) thought that information from independent experts was the most important input into decision-making, well ahead of the views of local residents (18%), government technical studies (18%) and information from environmental groups (13%) (Davies, 1989: 3).

The claim that Canadians are poorly informed about PCBs can be illustrated by the fact that the difference between askarel or pure PCBs and materials that are PCB contaminated is not widely understood. All PCB materials are thus regarded by many to be equally dangerous. Much of the PCB waste at St-Basile, for example, consisted of contaminated oil that exceeded the federal standard of 50 ppb rather than pure PCBs. This important distinction was omitted in most media reports of the fire and has only been mentioned occasionally and in passing in the past 25 years of media coverage of PCBs.

6. The CEAC Report clearly stated:

"The Council believes that the federal government should not proceed to the public consultation stage of the PCB incinerator siting process in the absence of a properly developed regulatory framework for PCBs, including efforts to harmonize federal and provincial regulations and regulatory processes where warranted. Public mistrust of government and outrage over past regulatory
failures make it imperative that regulatory issues not be debated in a public forum until the regulatory framework and harmonization have been fully developed and a clearly stated and strict enforcement policy is in place and will be adhered to. (....) It is important that, in the effort to move quickly on this issue, the federal government not compromise the "due process" of regulation development."
(Canadian Environmental Advisory Council, 1989: 15)

7. In this regard, a 1989 Globe and Mail editorial makes an interesting connection between failed government promises in finding a workable solution for destroying PCB wastes and public outrage over the risk management of these compounds. The piece concludes with the following paradox:

"Since last year's conflagration [St-Basile fire], the federal and provincial governments have told us again and again they are tackling the problem of PCBs, and that they are again on the verge of solving the problem. Until that happens, however, hysteria may still be the most rational reaction." (in "PCBs in Canada: A trail of empty promises followed by panic", November 11, 1989, D4)

8. Evidence of these criticisms and of the need to address a range of issues and alternative strategies before moving ahead with the siting of incineration facilities are readily available in the "Proceedings of the National Stakeholder Workshop on the Federal PCB Destruction Program", Federal PCB Destruction Program, Environment Canada, November 1989.

9. In this respect, the recently released report of the Independent Review Committee (IRC) on the siting of PCB incinerators in Atlantic Canada stated:

"The effort to destroy Atlantic Canada's stored PCBs has focused largely on finding the "best" site from technical and scientific considerations as viewed by technically trained people. (....) Experience in Canada and elsewhere indicates that PCB destruction operations can be conducted without harm to the environment or human health. The IRC believes that there are probably many locations in Atlantic Canada where available or emerging technologies could safely and effectively destroy PCBs. The challenge then is not so much to find the "best" site as it is to find a community that is prepared to host the facility in a safe and efficient manner. To succeed, the IRC believes that a siting program would have to be developed that is focused less on the technical aspects for site selection and more on the issue of community acceptance". (Environment Canada, 1994, p. 10, 11)
10. The following statements made by an Environment Canada official illustrate the point:

"Our expertise extends into technical research and analysis of environmental risks. While these skills may come into play in defining the public choice there is certainly other information and experience that must be brought to the table."

"... given our experience on a range of issues over the last six or seven years, Environment Canada recognizes that we cannot build an effective environmental program alone. We recognize that the most effective - and the most credible - programs rely on early and ongoing stakeholder involvement."

"... we are committed to maintaining an open information flow, respecting environmental assessment review processes, and ongoing consulting with national, regional and local stakeholders and residents. Flexibility; self-selection; community veto; and respect of EARP requirements are the four principles we support." (Davies, 1989: 1, 3)
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