From Science to Policy Practice and Public Discourse: Claimsmaking and Chlorinated Drinking Water

By

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ABSTRACT

Since the rise of the environmental movement in the 1960s, public attention became focused on issues of ecosystem and human health. Since that time, there has been a growing public mistrust of industry, policymakers, and scientists. This research focuses on process-oriented issues in an area of scientific and regulatory 'uncertainty': chlorinated disinfection byproducts (CDBPs) and cancer outcomes. There are four objectives in this research. Scientific evidence regarding CDBPs and cancer is examined to explore how it has been constructed (objective 1). Further, the contesting of this evidence within the scientific community and its transformation to 'scientific fact' as 'authorities' is examined (objective 2). The impact these contested scientific authorities may have on the policymaking process in terms of setting guidelines, regulations, policies, and standards in both Canada and the United States is assessed (objective 3). Lastly, media presentations of scientific evidence as compared to framings by scientists, regulators, the chlorine industry, water utility representatives and environmental non-governmental organizations of the CDBP issue is investigated (objective 4). To address these objectives, this thesis adopts a mixed method approach by combining claimsmaking activities, narrative policy analysis, agenda-setting, and the use of language and metaphors to analyze the textual data.

This thesis concludes that although the hegemony of science is challenged, the interpretation and use of scientific claims are increasingly important to establish authority and credibility on risk issues. Risk controversies are not going to disappear. These science-policy risk issues cannot be analyzed from a strict interpretation of 'science'. A 'social' lens must be brought in to understand the underlying political, social and cultural context of an issue. Risk controversies will not always take the same form in all places, and responses to these controversies must be sensitive to contextual differences.

This thesis makes a number of substantive, methodological and theoretical contributions. Substantively, this research provides a detailed case study of a single uncertain and complex issue that links environment and health: CDBPs and cancer outcomes. The case study outlines how the issue has developed in two different regulatory environments (Health Canada and the US Environmental Protection Agency). Methodologically, this thesis incorporates multiple qualitative methods in its analysis of key informant interviews and written scientific, legal and policy documents. Theoretically, this research provides a conceptual model by which other environmental risk issues can be compared with respect to scientific uncertainty in the environmental health policy process.

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My family has always been an unending source of love and encouragement. My parents, with their quiet strength, have been my grounding and my inspiration. Their unwavering belief in my abilities to accomplish anything I set my mind to has been invaluable. I'm proud to have you both as parents and as my close friends. To my Oma, thank you for all the cooking tips when I needed a thesis break. I love that I can share this moment with you. To Paul and Laurie, thank you for your friendship and love. I'm proud to have you as my older siblings. A special thank you to all those who joined my life's journey later on: Moe, Andrea, Peter, Shaanna, Loree, Amy, the two Leannes, Glenn, Kim, and Lynn. You all kept me laughing when I needed it the most.

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This thesis is dedicated to my parents

Lorraine and Herold Driedger

for teaching me that life and learning go hand and hand,

my husband

Jason Morrison

for making the journey fun,

and in memory of

Earl Morrison

the father-in-law I never had the pleasure of knowing.

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PREFACE

This thesis is made up of a collection of papers which are under review or in preparation for submission. The study problem, objectives, and the relationship among the various papers are described in the Introduction. The research papers are as follows:

Chapter Two:

Driedger, SM, and Eyles, J. Constructing cultural authorities of science: Issue framing of chlorinated disinfection byproducts as a public health benefit and a public health risk. In preparation for *Risk Analysis.*

Chapter Three:

Driedger, SM, and Eyles, J. Charting uncertainty in science-policy discourses: The construction of the chlorinated drinking water issue and cancer. Under review with *Environment and Planning: C.*

Chapter Four:

Driedger, SM, and Eyles, J. Drawing the battle lines: Tracing the 'science-war' in the construction of the chlorinated disinfection byproducts, chloroform and human health risks debate. Under review with *Harvard Environmental Law Review.*

Chapter Five:

Driedger, SM, and Eyles, J. Selling the goods on chlorinated disinfection byproducts and cancer: Different frames, different fears. Under review with *Social Science and Medicine.*

While all the papers are co-authored with the thesis supervisor, the first author (i.e. the doctoral candidate) conducted the actual research involving the problem formulation, literature review, interviews and data collection, data analysis, and writing. Dr. J. Eyles made significant intellectual contributions by providing guidance on the direction of research, critiqued all the papers, and provided editorial advice.

CHAPTER ONE

INTRODUCTION

1.0 Background

Media headlines scream: 'Is the water in your tap safe to drink?' and 'Using chlorine risks cancer, scientists say'. Government officials make assurances about the safety of the water supply, and scientists try to convey the equivocal nature of the evidence, all while indicating that chlorine disinfection does not endanger public health. The translation of this 'noisy discourse' to the public often ends up as 'my drinking water may be giving me cancer'.

Current issues within the environmental health area are often clouded with uncertainty. The public is becoming increasingly alarmed over potential adverse health effects stemming from chemical toxicants and industrial wastes being discharged into the environment at all scales (i.e., local, national, global). There is a strong cultural faith in the authority of 'science' (as defined below) to explain reality (Gieryn, 1999), though the hegemony of this is being challenged in the new 'risk society' (Beck, 1992). The public looks to scientists to evaluate, assess, and identify potential risks. There is also an expectation that policymakers make informed decisions, on the basis of scientific evidence, to implement the appropriate solutions which will 'solve' the environmental problems of the day.

However, mismanagement of past risk issues, particularly in the water quality domain, by both scientists and policymakers has left the public distrustful (e.g. Woburn, Massachusetts; Legler, New Jersey; Walkerton, Ontario).

When risk controversies arise, a power struggle may result between the competing interests, ideologies, values and approaches employed by the actors: industry, scientists, policymakers, the media and the public (Graham and Rhomberg, 1996). Each group's conception of what constitutes 'safe' may differ. The typical response from scientists and industry during risk controversies is that the public is 'irrational', the media 'twists' scientific information and policymakers rarely listen to 'objective' scientific evidence. Freudenberg (1996) argues that while such sentiments may be superficially plausible, they reflect a misunderstanding of the uncertain nature of living in a technological society and the limitations of risk analysis (Beck, 1992).

Prior to the 1960s, analytical chemistry was based largely on the senses of sight and smell. Since then, considerable technological and disciplinary advances within analytical chemistry have enabled scientists to identify the presence of elements and chemical compounds as low as *'n'* parts per billion. In fact, detection limits for some substances have reached as low as parts per quadrillion (Harris, 1992). Such advances in measurement sensitivity have often led to a redefinition of toxicity in terms of trace elements and compounds. However, this dependence on apparently precise numbers, which conveys an impression that science is accurate in its estimates (Hrudey, 1996), has done comparatively little

to objectify the processes for determining when such compounds are toxic in terms of their risk to ecosystems or human health (Eyles et al, 1996). Such decisions are, in part, the consequence of social and political processes taking place among scientists and policymakers (Kunreuther and Slovic, 1996). Thus, what begins as a scientific measurement and analysis problem frequently turns into an arena of interpretation and social construction in and of itself (Harris, 1992).

The chlorinated disinfection byproducts (CDBP) issue first began when trace halogenated organics were measured in drinking water supplies (Rook, 1974; Bellar et al., 1974; Symons et al., 1975). A chlorinated disinfection byproduct is formed by the reaction of chlorine, used in the disinfection of water supplies, with naturally occurring organic and inorganic material present in raw water supplies. Surface water supplies (lakes, rivers) typically carry much higher levels of organics and inorganics and hence form higher levels of disinfection byproducts than do groundwater supplies (wells, springs). While several halogenated and non-halogenated compounds (see Mills et al., 1998: 92) are formed, trihalomethanes have been the most studied. Trihalomethanes (THMs) form a group of four halogenated byproducts: chloroform, bromodichloromethane, dibromochloromethane, and bromoform. The discovery of these byproducts resulted in a 'fateful moment' (Giddens, 1991) when toxicological studies demonstrated that chloroform, the THM found in the greatest quantity, was carcinogenic in rodents (National Cancer Institute, 1976). This finding spurred

greater scientific research into CDBPs, as well as prompted water treatment plants to more frequently test and monitor byproduct levels in municipal water supplies.

1.1 Scope and Objectives

This research examines the social construction and communication of risk using the example of chlorinated disinfection byproducts (CDBPs) and cancer outcomes. Particularly, this thesis explores how scientists construct different 'authorities' (see below) concerning the assessment of risks of CDBP exposure and communicate these risks within the scientific community. It also examines how these risks are then communicated from scientists (industry, academe, public health) to policymakers and the media. This research adopts Gieryn's (1999) definition of scientific 'authorities' as the power to name, define and explain reality, a status which is not easily ascribed in other societal domains, such as business, for example. To assess these constructions, this thesis examines how claims about risks are contested within the science-policy domain. This research also adopts a broad conceptualization of 'science'. Following Gieryn (1999), 'science' is a cultural construct. 'Science', then, draws from both the natural and the social world. While many define 'science' as being based on the direct observation of natural phenomena, it is imperative that social, cultural, and political contexts are not excluded. Nonetheless, 'scientific evidence', as reported in this research, is grounded in analytical chemistry and associated health sciences such as toxicology, epidemiology and microbiology.

Since the discovery of chloroform's carcinogenicity in rodent studies, a series of toxicological and epidemiological studies have been conducted. The primary human health effects associated with CDBPs are bladder, colon and rectal cancers (IARC, 1991; Morris et al., 1992; Mills et al., 1998), though some research has also documented adverse reproductive and developmental risks (Dodds et al., 1999; Reif et al., 1996; Kanitz et al., 1996; Bove et al., 1995; 1992; Savitz et al., 1995; Aschengrau et al., 1993; Kramer et al., 1992). While the focus of this project is exclusively on the cancer science, there is an expectation that it will likely be the reproductive effects that prompt future policy changes.

The objectives of this dissertation are four-fold:

1. To examine the construction of scientific knowledge and evidence concerning the relationship between chlorine as a drinking water disinfectant and possible human health effects, exclusively cancer.
2. To investigate how science is communicated and contested within the scientific community and transformed to a level of accepted 'scientific fact' as 'authorities', by exploring how scientists have publicly framed the issue in published documents as compared with private reflections on the nature of the evidence.
3. To assess what impact these contested scientific authorities may have on the policymaking process in terms of setting guidelines, regulations, policies and standards in both Canada and the United States.

4. To investigate media presentations of scientific evidence as compared to framings by scientists, regulators, the chlorine industry, water utility representatives and environmental non-governmental organizations of the CDBP issue.

The goal of the thesis is to explore the contested nature of how cancer risk from chlorinated disinfection byproduct exposure in drinking water has been framed by different actors. Though many have argued that exposure to chlorinated disinfection byproducts is a 'voluntary' risk (i.e., we choose to disinfect with chlorine to protect public health from microbial pathogens), others have framed the issue as an 'involuntary' one (i.e., public health and water authorities choose chlorine over other disinfection methods with no public input. The key distinction here is that CDBPs carry with them a cancer risk). Chlorine is a chemical which is widely used in our society. We use it in everything from pharmaceuticals to plastics to the water we drink. In fact, it is for its application as a drinking water disinfection treatment that chlorine has been hailed as providing the single largest benefit to public health. Consequently, it is not a chemical that is automatically perceived as being dangerous to human health. However, not all of its applications share such positive attributes (e.g. production of organochlorines like PCBs, DDTs, dioxins). Policymakers have made decisions regarding chlorine disinfection of drinking water supplies, a positive public health benefit. But this disinfection also carries some potentially harmful aspects. Such environmental policy decisions are not easy where there is even greater scientific uncertainty

associated with the use of alternative disinfection treatment options. The concluding chapter presents a conceptual framework that has evolved from the thesis research to assist in a better understanding of science-policy decisions, such as the one explored in this research.

This thesis uses a combination of methods to examine these issues, each of which are discussed individually in the empirical chapters, and briefly outlined below. The two primary data sources were published scientific accounts, legal and policy documents (see Appendix A), and key informant interviews. Key informant interviews was conducted in order to understand some of the broader contextual aspects of the project that could not be obtained from written documents. Interview data were analyzed using NVivo (Richards, 1999), a qualitative software package designed to analyze textual data. Appendix B outlines the timetable of the interview schedule, Appendix C provides the interview checklist of topic areas covered during the interviews, and Appendix D outlines the different categories and codes that stemmed from the interview analysis.

1.2 Theoretical Context

This work is situated in environmental health, among other things, a subarea of medical geography - or more recently the geography of health and health care. Last (1987: 131) defines environmental health as "the aspect of public health concerned with all the factors, circumstances and conditions in the environment or surroundings of humans that can exert an influence on human health and well-

being." Public health is broadly defined as the prevention of disease and the promotion of health. It is 'health' as opposed to 'environment' which drives the 'environmental health' agenda within this public health component to monitor particular environments for adverse human health effects. Recognizing the broader determinants of health (see WHO, 1986; Epp Report, 1986; Evans and Stoddart, 1990), Eyles (1997:6) forwards a working definition of environmental health, adopted by this thesis research, as "the health and well-being of human populations in specific environments (physical, social, and societal)" wherein these relationships are multi-directional. That is, the health of the physical, social or societal environments affect the well-being of the other two. Eyles' definition extends the debate to include the multitude of issues that become involved in the conceptualization of what constitutes 'environment and health'. Here, for example, issues of risk construction, perception, and communication are important.

One of the criticisms directed at medical geography, and by extension environmental health, is that health geographers have insufficiently engaged in the broader social theories that have informed its parent discipline, human and social geography (Kearns, 1993; Mayer and Meade, 1994; Dorn and Laws, 1994; Litva and Eyles, 1995; Eyles, 1997). This thesis is grounded in social interactionism, such that 'reality' is a social construction (Berger and Luckmann, 1966), to understand issues of risk in science-policy. The way in which various actors 'see' risk is strongly guided by their social and cultural contexts (Cutter, 1993; Shrader-

Frechette, 1991). Our 'reality' is objectified by language (Eyles, 1997) such that examination of claims (Best, 1995), stories (Stone, 1997; Roe, 1994), and metaphors (Lakoff and Johnson, 1980) is essential if we are to reveal the underlying values and interests which may be motivating particular actors within a policy arena (Sabatier, 1987).

Moreover, there is insufficient understanding of how environmental health policy decisions are made in the face of scientific uncertainty. Research to date, that looks at the nature of environmental risk and the toxicity of chemicals, has tended to focus only on the quantitative aspects of risk assessment, though there are exceptions (Leiss and Chociolko, 1994; Powell and Leiss, 1997; Wildavsky, 1995). It is felt that only through the development of more precise methodologies, the continuous replication of results, and increasingly rigorous studies, that science will be able to resolve much of the uncertainty (Barnard, 1994), possibly making the task for policy makers easier. Similarly, there is some debate as to whether better science will lead to greater certainty in decision making (Latin, 1988). The tendency in science is to reduce phenomena to examinable components in the search for specific cause and effect relationships. This is not an easy task in environmental health where there are a multitude of exposures, confounders and effects. It becomes much more difficult to determine if certain health effects are the result of a dominant cause, or if they are due to a combination of environmental assaults (Bates, 1994). As such, social considerations of what constitute important exposures and acceptable risk need to

be incorporated into regulatory decisions (Latin, 1988). One way to understand the interrelationships between various actors in the policy subsystem is through an examination of 'epistemic communities' (Haas, 1992).

Conceptually, 'epistemic communities' evolved as a means to explain the translation of knowledge and evidence into policy action within a complex international environmental arena (see Haas, 1989). Defined as a network of experts with an authoritative claim to policy-relevant knowledge (Haas, 1992), an epistemic community provides consensual knowledge regarding issues of uncertainty (Hannigan, 1995), thereby facilitating policy intervention. Jasanoff and Wynne (1998: 51) outline four defining characteristics of an epistemic community:

- shared normative and principled beliefs providing a values-based rationale for the community's proposed social actions;
- shared causal beliefs, including professional judgements linking causal explanations to possible policy actions;
- shared notions of validity including intersubjective, internally defined criteria for establishing valid knowledge; and
- a shared policy endeavour based on a commonly recognized set of problems to be solved.

Common features of these characteristics involve shared core values and beliefs (Sabatier, 1987), shared ways of 'knowing', and shared ideas for preferred policy solutions to identified problems. In other words, 'knowledge' and 'facts' are constructed and accepted in specifically defined ways according to pre-set criteria for inclusion and exclusion (e.g. the scientific method). Epistemic communities

often are able to define and frame problems in a particular light making some solutions more attractive to decision makers (Kingdon, 1995). Typically, the core values are grounded in culturally ascribed norms, such that 'membership' and 'behaviour' are controlled and monitored by peers (Berger and Luckmann, 1966; Latour, 1987), similar to Gieryn's (1999) conceptualization of 'boundaries' (discussed in chapter two).

Critiques of the concept of 'epistemic communities' argue that the role of 'power' in the policy arena is typically ignored (Litfin, 1994). There is an assumption that it will only be 'expert knowledge' that will sway policy decisions. Yet, policy decisions are usually made based on a number of reasons, expert knowledge being only one input. Jamieson (1996) argues that science is culturally viewed as a knowledge producer, and consequently, it often cannot bring public decisions to closure. Too frequently, issues of uncertainty are paramount often pitting experts against experts; hence the need to control the level of 'uncertainty' in both science and policy. The other main critique is that in categorizing a group of scientists as an epistemic community, shared beliefs which may transfer between communities in a policy subsystem may be masked. Further, the assumption is that communities are homogenous, when in reality, there can be a number of differences within a community group, and similarities with members in different epistemic communities (Litfin, 1994). However, by adopting more interpretive and constructivist approaches, some of these differences can be revealed (Stone, 1997), as is the goal of objective two of this research in examining differences in public/private discourses.

Policy analysis to date has largely been dominated by a rational and incrementalist approach. A rational approach to policy analysis assumes that the intended policy goals are clear and agreed upon, the means of evaluation are well defined, and information about the consequences is complete. Rational policy approaches have been criticized within the literature as reflecting an extremely naive view of reality. They make the assumption that decisions are made in a value-free, linear and sequential manner by completely informed individuals (Hogwood and Gunn, 1984). An alternative to such approaches is incrementalism where policy decisions are made in small cumulative steps. Incrementalism does not assume a value-free approach. Rather, it recognizes that values play a role in how options and alternatives are assessed. Moreover, there is an understanding that 'perfect' information does not exist (Lindblom, 1959). This research extends these two approaches to address the meaning of a policy using an interpretive approach which has been gaining increasing attention in the policy literature (Yanow, 1993). Interpretive approaches focus on language and meaning as a way in which to examine the underlying social context of an issue (Iannantuono and Eyles, 1997). Interpretive approaches respond to researchers' needs for understanding how a policy is 'framed' (Roe, 1994; Gamson, 1992) or what it 'means' (Yanow, 1992). They also involve an analysis of the role that members of a policy subsystem may play in the framing of problems (Sabatier, 1987), as well as how science and policy become co-producers of relevant knowledge (Jasanoff and Wynne, 1998).

Claimsmaking activities and agenda-setting approaches complement such an interpretive policy analysis. Claimsmaking activities examine the construction of the dominant claims or arguments, as well as any counterclaims that are generated within a science-policy arena (see Best, 1995). Agenda-setting issues complement claimsmaking activities by extending the analysis to explore how a particular issue moves on or off a policy agenda at any given time (see Kingdon, 1995). The benefits of incorporating these perspectives in the project are two-fold. First, science has been highly regarded as an epistemic authority (Gieryn, 1999). However, the certainty of science as a knowledge producer is being challenged (Gieryn, 1999; Hilgartner, 2000; Jasanoff and Wynne, 1998; Stone, 1997; Beck, 1992; Latour, 1987). Second, understanding how different scientific authorities are challenged can provide clues as to how an issue may be moving within a policy arena. When different scientific 'authorities' are used within a policy arena, they enter the domain of mandated science (Salter, 1988), where objective rationality cannot be maintained.

Thus, this research adopts different epistemological understandings of 'knowledge'. For scientists, 'knowledge' is privileged through an objective, rational and value-free process. The role of knowledge is to add to the existing understanding and knowledge base (Gieryn, 1999). For policymakers, 'knowledge' is contextual in terms of the issue of concern. The use of knowledge becomes political (Therborn, 1980). Policymakers can choose to use scientific uncertainty as a means to justify a decision which flies in the face of evidence, or

equally, uncertainty can be used to justify no decision (Jamieson, 1996). It is the contest which occurs among knowledge 'authorities', that filter up to the policy decision making process that is the concern of this research. In this research, knowledge 'authorities' are primarily constructed by scientists operating in government/public health, academe, and industry environments.

Lastly, exploring the role and use of language and metaphors is critical to reveal the meanings and context of language, argument and persuasion (Stone, 1997; Best, 1987; Black, 1962; Lakoff and Johnson, 1980; D'Andrade, 1995), as a means to uncover underlying values and beliefs of actors in the system (Stone, 1997). Metaphorical constructs are very systematic in their use, and serve to highlight some aspects and hide others (Stone, 1997). They signal how different groups of actors may be defining and forwarding an issue within a science-policy arena. Examining how issues are 'framed' and described is critical to this understanding. Metaphorical claims are invoked in science, policy and the media and provide clues as to the underlying values of the actors in the arena. Recently a call for more careful examination of language and metaphors in geographical analyses has been made, particularly when issues are framed as being 'out-of-place' (Cresswell, 1997). In the CDBP and cancer outcomes issue, chlorine disinfection is framed both as being necessary to protect human health (i.e., a desirable outcome, and hence an 'in place' metaphor) and as being harmful to human health (i.e., toxic chemicals are undesirable, and hence an 'out-of-place' metaphor).

1.3 Organization of Thesis

To address objectives 1 and 2, chapter two, *Constructing cultural authorities of science: issue framing of chlorinated disinfection byproducts as a public health benefit and a public health risk*, explores the social construction of scientific authorities. The chapter provides a 'baseline' of epidemiological and toxicological evidence concerning the cancer risks associated with CDBPs. It explores the public/private discourse emerging from published documents that provide an interpretation and evaluation of the evidence against private reflections of key informants on the nature of the evidence. The argument of the chapter is that there is a shift in the scientific foci surrounding the cancer research program, such that epidemiological scientists can no longer forward the cancer science until significant improvements can be made to assessing exposures in a human population. Yet toxicological scientists want to close the door on the 'chloroform' issue. Consequently, epidemiologists are largely conducting re-analyses of existing data sets and shifting their foci to an increased emphasis on studying reproductive and developmental outcomes more. Toxicologists are trying to advance the research agenda to consider byproducts other than chloroform.

To extend the understanding of objectives 1 and 2, chapters three (*Charting uncertainty in science-policy discourses: the construction of the chlorinated drinking water issue and cancer*) and four (*Drawing the battle lines: tracing the 'science war' in the construction of the chloroform and human health risks debate*) explore how these contests take place in a regulatory framework, and

serve to meet objective 3. The first of these two chapters provides a reconstruction of the chlorinated disinfection byproducts debate in Canada with the publication of the Health Canada expert panel report (Mills et al., 1998). The second of these two chapters turns attention to the judicial battle that has taken place in the United States when the chlorine industry took the Environmental Protection Agency (EPA) to court over a regulation the EPA set for chloroform. By focusing on how the issue has been contested within the regulatory frameworks of these two countries, the research uncovers clues as to how the issue may develop in the future and indicates which groups may be pivotal in the construction of future claims regarding the chlorine and health debate.

To investigate objective 4, chapter five, *Selling the goods on chlorinated disinfection byproducts and cancer: different frames, different fears*, examines media presentations of science and how these may contribute to the construction of lay risk perceptions regarding the chlorinated disinfection byproducts and cancer outcomes debate. Media presentations of science are compared to framings by scientists, regulators, non-governmental organizations, and chlorine and water utility representatives of the CDBP issue. The analysis shows two main framings of the debate, each of which are powerful in constructing risk perceptions. On the one hand, many (i.e., scientists, industry and government) frame the debate as a 'voluntary' risk: we choose chlorine disinfection to protect us from microbial risks, with a possible adverse consequence of that protection. On the other hand, others (i.e., media, environmental NGOs) frame the issue as an 'involuntary risk':

chlorine disinfection was a 'choice' imposed by public health and water utility officials; a choice that carries a potential cancer risk, and alternative disinfection technologies are advocated.

Chapter six provides a summary of the empirical chapters and revisits the research objectives outlined above. It also reveals the conceptual framework evolving from this thesis as a way to better understand how science-policy decisions are made in environment and health. It draws on additional examples to illustrate the argument. The theoretical, methodological and substantive contributions of this research are presented as well as some directions for future research.

CHAPTER TWO

Constructing cultural authorities of science: issue framing of chlorinated disinfection byproducts as a public health benefit and a public health risk

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Abstract

Chlorine disinfection of drinking water supplies has been hailed as providing the single largest benefit for public health. However, some studies have shown a positive association between exposure to chlorinated disinfection byproducts and cancer outcomes, though the evidence is still equivocal. This paper examines the science agenda regarding the chlorinated disinfection byproducts (CDBP) issue in Canada and the United States. The universality of the CDBP issue in North America implies that scientific evidence presented in one country has implications in the regulatory environment of the other. This paper focuses on the social construction of scientific knowledge and evidence. We argue that there has been a shift in the scientific foci surrounding the cancer research program such that epidemiological scientists can no longer move forward the cancer science until significant improvements can be made in assessing exposures of human populations, and yet toxicological scientists want to close the door on the 'chloroform' issue. Through in-depth key informant interviews with epidemiologists and toxicologists and an examination of the summary baseline of scientific evidence on the debate, we demonstrate that there is a distinction between the 'public discourse' or official position as represented in published documents compared to the 'private discourse' or personal positions of experts as expressed during interviews.

Keywords: risk construction, public vs private discourses, science-policy, chlorine, cancer

2.0 Introduction

Public fears regarding health risks to chemical exposures abound. The 1960s and 1970s marked a period when many people first became aware of the adverse effects of some of the modern technological advances facilitated by the use of chemicals, largely due to Rachel Carson's seminal work (1962). There have been documented case studies regarding public concern over risk controversies with respect to chemical applications in foods and industrial production (for e.g. see Wildavsky, 1995; Leiss and Chociolko, 1994; Harrison and Hoberg, 1994; Powell and Leiss, 1997), as well as accidental environmental exposures (Bertazzi, 1989; Gale, 1987; Colborne et al., 1996; Wildavsky, 1995). This paper adds to this literature by examining how different scientific authorities have been constructed concerning the chlorinated disinfection byproducts and cancer outcomes debate. Adopting Gieryn's (1999) framework, 'science' holds a unique position within society as an epistemic authority. Its power to define, describe and explain reality grants science special features not typically ascribed to other domains.

Chlorinated drinking water, and the byproducts formed during the disinfection process, represent a useful case-study for examining the construction of scientific knowledge concerning risk issues. Chlorine disinfection of drinking water supplies has been hailed as providing the single largest leap in public health history (Mills et al., 1998). Chlorine treatment has ensured a safe drinking water supply for many, and when properly maintained, has prevented the return of major waterborne diseases like cholera, dysentery, and typhoid. A 'fateful moment'

(Giddens, 1991) occurred when chlorinated disinfection byproducts (CDBPs), chloroform in particular, were first measured (Rook, 1974; Bellar et al., 1974; Symons et al., 1975), and subsequently toxicological studies demonstrated that chloroform was carcinogenic in rodents (NCI, 1976). Since then, studies and reviews have shown a positive association between exposure to chlorinated disinfection byproducts (CDBPs) and cancer outcomes, though the evidence is still inconclusive (IARC, 1991; Morris et al., 1992; Mills et al., 1998).

A chlorinated disinfection byproduct is formed by the reaction of chlorine, used in the disinfection of water supplies, with naturally occurring organic and inorganic material present in raw water supplies. Surface water supplies (lakes, rivers) typically carry much higher levels of organics and inorganics and hence form higher levels of disinfection byproducts than do groundwater supplies (wells, springs). While several halogenated and non-halogenated compounds (see Mills et al, 1998: 92) are formed, trihalomethanes have been the most studied. Trihalomethanes form a group of four halogenated byproducts: chloroform, bromodichloromethane, dibromochloromethane, and bromoform. While many would argue that exposure to these disinfection byproducts is a 'voluntary' risk (i.e., we choose chlorine as a disinfection treatment to protect against microbial contaminants), others have framed the issue as an 'involuntary' risk (i.e., chlorinated byproducts may cause cancer).

Leiss and Chociolko (1994: 4) argue that one of the fundamental aspects rooted in risk controversies is the "fear of falling victim unfairly to

uncompensated loss". At the heart of the concept of 'risk', lies a key component: with exposure there is always the chance of 'loss' for one individual/group, often to the net benefit of another. Leiss (1995) has framed this issue as pitting 'winners' against 'losers' in risk situations. As social actors, we engage in daily negotiations of risk. Involved in these issues are concerns regarding the 'voluntary' nature of risks (e.g. driving a car) as compared with risks that are perceived as 'involuntary' (e.g. exposure to air pollution).

Risk issues become further muddied when the scientific evidence related to contaminant exposures is equivocal, particularly when many argue that the public health benefits of a policy action outweigh any potential negative health effects, as is the case with chlorinated drinking water. In these cases, scientists and professionals play a key role in shaping public policy debates (Schneider and Ingram, 1997), particularly in constructing the risk assessments upon which policy decisions are made (e.g. see Harrison and Hoberg, 1994; Jasanoff and Wynne, 1998). This paper examines the science agenda regarding the chlorinated disinfection byproducts (CDBPs) issue in Canada and the United States. The universality of the CDBP issue in North America implies that scientific evidence presented in one country has implications in the regulatory environment of the other. While the focus of this paper is not to examine the regulatory environments of these two countries in any depth (see Driedger and Eyles, 2001a; 2001b), it will be necessary to situate the scientific contests in their appropriate public health policy environments: Health Canada and the US Environmental Protection Agency (EPA).

The objectives of this work are twofold. First, to examine the construction of scientific knowledge and evidence concerning the relationship between chlorine as a drinking water disinfectant and possible human health risks, primarily cancer. This summary 'baseline' is intended to outline the key studies and the role they played in shaping the nature of the debate, rather than serving as a review of all the evidence. Second, to investigate how such scientific studies are communicated and contested within the scientific community and transformed to a level of accepted 'scientific fact' as 'authorities', this research presents an exploration of how scientists have framed the issue in published documents as compared with private reflections on the nature of the evidence during interview conversations.

2.1 Theoretical Framework

This work is informed by social constructionism in examining issues of risk, science, and knowledge construction. Social constructionism adopts a view that 'reality', as played out by what we perceive as facts, values, and knowledge, is socially constructed (Berger and Luckmann, 1966). Rein (1983) argues that as social actors, we establish parameters for what is considered 'knowledge', and subsequently construct our reality in relation to that knowledge. It has been generally accepted that the way in which we respond to scientific facts, or even 'see' science, can also be understood as a social construction (Berger and Luckmann, 1966; Martin and Richards, 1995; Stehr, 1994; Aronson, 1984; Latour

and Woolgar, 1979; Latour, 1987). Within a cultural and societal context, science is viewed as a knowledge producer (Jamieson, 1996), where its objective is to investigate and describe 'reality' (Barnard, 1994). This is important as science has played a significant role in shaping society. However, as we increasingly move into what Beck (1992) refers to as the 'risk society', this hegemony of science as a knowledge producer and as an 'authority' (Gieryn, 1999) is being challenged.

As a knowledge producer, science relies on a persuasive rhetoric (Hilgartner, 2000). Gieryn (1999: 4) argues that scientific 'facts' do not move 'naked' from the laboratory or scientific journals into the courtroom, boardrooms, newsrooms or living rooms. Rather they are 'clothed' in elaborate representations of objectivity and neutrality to lend credibility to scientific knowledge claims. In order to remove from view the 'messy' nature of constructing scientific evidence (e.g. laboratory studies, dissection of animals, experiments, testing and retesting), scientific knowledge is presented linearly in a sanitized version of 'truth' (Hilgartner, 2000). Hence in the construction of scientific facts, scientists seek to modalise their arguments by positioning their evidence against the claims of other scientists (Latour, 1987). Scientists persuade others through the presentation of a line of evidence and interpretation such that no other conclusions are possible beyond those which are proffered (Latour and Woolgar, 1979).

The process of scientific discovery is essential in the construction of knowledge claims. These take place in established institutions: laboratories; working groups; disciplines; peer-review committees; journal publications; and

scientific prizes, such as the Nobel prize (Schneider and Ingram, 1997). While these institutions provide avenues for the construction of scientific facts, it is critical that their 'consumption' in a social world be analyzed. In other words, it is important to examine what happens once scientific claims leave the laboratories and enter journals, professional meetings, reports (Gieryn, 1999), regulatory agencies (Salter, 1988), and the media (Hilgartner, 2000). It is through the consumption of claims that scientists seek to establish boundaries around who can legitimately speak as an authority. Authority can only exist when knowledge claims are conferred to some but denied to others (Gieryn, 1999). Latour (1987) uses the analogy of the two-faced Janus to depict stages of science: ready made science (where facts are agreed upon) and science in action (where facts and evidence are not immutable and are subject to contest). It is this latter stage that is key. It is during this stage that credibility contests occur (Gieryn, 1999) where the credibility of both the producer of the knowledge claims and of the challenger are equally 'on the line' (Hilgartner, 2000).

While credibility contests may occur privately, (i.e., in an environment where there is a controlled membership, like a scientific meeting or a peer-reviewed journal), it is when these contests move into the public domain that scientists may present a unified position in order to protect the autonomy of 'science' (Gieryn, 1999). A public disagreement can occur once scientific facts are brought out into the open through the courts or in the media. For example, in the area of climate change, scientists were instrumental in putting the issue on the

policy agenda. While some scientists raised disconfirming evidence, these 'opinions' were shut out (Garvin and Eyles, 1997). With respect to chlorinated disinfection byproducts, there has been a legal battle in the United States, where the chlorine industry has challenged a regulatory decision made by the Environmental Protection Agency regarding a maximum contaminant level goal set for chloroform. During the legal challenge, the majority of the dispute centred around the use of the 'best available science' where disconfirming studies (e.g. Melnick et al., 1998a; 1998b; 1999) were largely ignored (see Driedger and Eyles, 2001a). Private disagreements were revealed in the personal reflections of scientists.

The public/private disagreements found in this research is an important finding. It extends the sociological literature of public/private narratives of individuals in the context of social interaction. Goffman (1959) argues that people forward a 'public' (i.e., shared) and 'private' (i.e., personal) face in everyday life. On a daily basis, people 'manage appearances' and 'control information' during their interactions with others. Private accounts stem from personal experiences and are only shared selectively with others. Public accounts are partial, seeking to put the 'best face forward' (Douglas, 1971). The self-censorship of public accounts creates a social distance between individual actors (Cornwell, 1984). While rarely visible, this research argues that such 'public-private' accounts are present among scientists. There are different emphases placed on the epidemiological and toxicological interpretation of the evidence from published

documents (i.e., public) compared to personal reflections of the evidence from a public health perspective (i.e., 'private').

This is reflected in some of the credibility contests that the authority of a particular science claim is challenged. In credibility contests, issues of power are pivotal as careers are at stake (Aronson, 1984). Trained in the 'art of persuasion', scientists seek to convince others of the importance of their work as an 'authority' in order to secure funding, have their claims conferred as 'fact', and attempt to control the research agenda (Schneider and Ingram, 1997). Issues of uncertainty are key to this process. In a science-policy domain, there needs to be a balance in the level of uncertainty: too much and the problem seems daunting; too little and there is no motivational push for research funds dedicated to study the issue. Consequently, 'uncertainty' becomes a social and cultural process (Jamieson, 1996) used as a forum for competing ideologies and interests (Aronson, 1984). Consequently, from a risk construction perspective, risks need to be 'born scientifically' before they can gain social recognition (Beck, 1992: 34). Hence, risks are 'invisible' (i.e., not objective constructions of knowledge) until they are measured (Hannigan, 1995). Initially, this measurement only exists in scientific knowledge, and is therefore open to social definition and construction because such knowledge can be 'magnified', 'minimized' or 'dramatized' (Beck, 1992). These knowledge claims then have to be translated within a policy domain, where only that knowledge which is made 'meaningful' or 'salient' gains political attention (Stone, 1997). Salter (1988) refers to these processes as 'mandated

science'; in other words, the use of scientific evidence in policy making. In these situations, Hannigan (1995) argues that there is no 'objectively verifiable truth', only 'serviceable truth' such that 'truth' is made useful to decisionmakers. In this contest, there is a negotiated balance between what constitutes 'fact' in a scientific domain as compared to a policy domain. If science is overly uncertain and unable to resolve a risk controversy with facts and evidence, the issue then falls to the domain of politics and the media, where each holds its own set of ground rules.

A useful conceptual framework for understanding the construction and contest of scientific knowledge claims is 'agenda-setting'; that is, how issues move on or off an agenda at any given time. Largely informed by the policy literature, agenda-setting analyses can assist in the examination of scientific discourses surrounding the chlorinated disinfection byproducts issue and the related health effects. Kingdon (1995) outlines three factors which influence the agenda-setting process. We have modified these for a scientific discourse. The first is problem recognition. Given that many problems and ideas may be pressing at any one time, the ones that gain recognition and move higher up the agenda will provide a focal point for the scientific actors. Sometimes, problems are recognized by 'focusing events' which will draw attention to the issue through a key study and its uptake by a regulatory body.

Second, many scientific proposals are typically generated to address policy problems. However, not all proposals are given the same level of attention, nor do they adequately address the problem as it is being defined. Therefore, the

'goodness of fit' of the proposal with the identified problem will help determine for how long that science remains relevant. Another science or set of scientific 'facts' may then take over, 'tipping' the issue into the public/political consciousness (Stone, 1997). We argue the possibility of the reproductive effects becoming more salient than the cancer in the chlorination debate. This process is by no means simple. Yet scientific proposals reflect a gradual accumulation of knowledge among specialists in a given policy area: the epistemic community. Over time it is necessary for the science to resonate with the values and assumptions of the decision makers. That will determine the level of prominence the science problem will continue to receive (Sabatier, 1987).

The third factor which may influence the science-agenda is the political process itself. Consequently, the 'national mood', public opinion, election results or changes in the administration will influence the nature and level of attention an issue may receive on the agenda (Kingdon, 1995) as well as the funding that may be attached to some research agendas (Irwin and Wynne, 1996). In much of the Western world, 'health' research, and research in general, has become framed around industrial competitiveness and productivity issues, whereas environmental issues are often framed as 'health' ones (Burger, 1990; Iannantuno and Eyles, 2000).

Currently, the disinfection byproducts debate has largely been kept within the scientific domain, though some political responses have been necessary. In Canada, a Health Canada expert panel report (Mills et al., 1998) provided a

scientific evaluation of the issue which necessitated the establishment of a CDBP Task Group to make some policy recommendations (see Driedger and Eyles, 2001b). The activities of this Task Group has been delayed by an e-coli outbreak in the municipal drinking water supplies of Walkerton, Ontario, which resulted in seven deaths. In the United States, an International Life Sciences Institute (ILSI) expert panel report (ILSI, 1997) served as the basis for constructing the scientific claims in a legal challenge between the chlorine industry and the US EPA (see Driedger and Eyles, 2001a). Understanding the nature of these credibility contests in the scientific community, and the concomitant shifts in the science-agenda, is almost as important, if not more important, as knowing why the chlorinated disinfection byproducts issue has captured the attention of policymakers. It is the examination of these knowledge uncertainties and shifts in scientific foci that we concentrate on in this paper. The take-up of scientific evidence for chlorinated byproducts in the public and policy domains is still underway.

2.2 Methodology

Jasanoff and Wynne (1998) argue that in examining science-policy issues, it is important to combine interpretive, reflexive and constructivist accounts to understand how scientific knowledge assumes authority within a public domain. Interpretive approaches emphasize an examination of meaning through language, text, social context and local frames (Geertz, 1973; 1983). Reflexive approaches examine underlying societal and individual assumptions in the construction of

knowledge claims (Beck, 1992). Lastly, constructivist approaches examine how accounts of the natural world are constructed and accepted as part of social reality (Latour and Woolgar, 1979). In this research, we have incorporated these perspectives in the analysis of expert panel documents and key informant interviews.

To explore how scientific knowledge and evidence has been constructed and contested regarding the chlorinated disinfection byproducts and cancer issue, a document analysis was undertaken. We collected and examined studies identified in review articles (e.g. IARC, 1991; Morris et al, 1992; Cantor, 1997; Boorman et al., 1999), and expert panel reports (e.g. Mills et al., 1998; ILSI, 1997). We also conducted a MEDLINE (a health database) search using a combination of relevant subject key words (e.g. trihalomethanes, drinking water, cancer, chlorine, disinfection byproducts) as well as searching by authors known to be actively studying the issue (e.g. Cantor, Bull, King) in order to monitor if these review articles or expert panel reports omitted any relevant studies, given their publication dates. Given that we are not experts in toxicology or epidemiology, we relied on the assessment of the evidence as contained in review articles and expert panel reports.

In order to ascertain differences in expert 'authority' regarding the issue, we solicited the opinions of research scientists active in the chlorinated disinfection byproducts and cancer domain, through key informant interviews (n=18) from August 1999 to January 2001. Interviews lasted approximately an

hour and a half. These interviews were pivotal in identifying and exploring the public/private discourse among these scientific authorities as represented in the published literature and reflected upon during informal conversations. Key informants were identified and selected in two ways. First, those scientists who were actively publishing research in peer-reviewed journals, as identified in the document analysis (i.e., usually first author), were contacted (n=9). Second, a snowball sampling process was employed by asking key informants at the end of the interview who they would identify as an active toxicologist or epidemiologist in this research area (n=9). The use of a snowball sampling approach was beneficial as it identified some public health scientists in both Canada (Health Canada) and the United States (the Environmental Protection Agency) who were active in the issue from a science-policy perspective, but who may not be conducting original research. Health Canada and the EPA both have public health mandates and each monitors scientific evidence for the purposes of drinking water standards setting. Moreover, snowball sampling served as a 'check' to ensure that key individuals were being interviewed. Interviews continued until a saturation of information was reached (see Patton, 1990); that is, key informants were identifying individuals already interviewed as experts in the field, and no 'new' information or opinions were being shared. Suggestions for individuals who may disagree with the scientific evaluation of a key informant were solicited to ensure that a multiplicity of perspectives were explored.

Interview data were taped, transcribed verbatim and later analyzed using NVivo, a qualitative software package designed to analyze text (Richards, 1999). The key informant interviews were semi-structured and followed a checklist of key topic areas (e.g. assessment of the evidence, issue importance, science-policy concerns, risk communication strategies, agenda-setting issues, public perceptions of risk). Data were categorized both deductively (i.e., following natural categories from topic areas) and inductively (i.e., categories emerging from the data; e.g. contested knowledge claims). The broad categories to be reported on in this paper include: how scientists assessed the evidence with respect to chlorinated disinfection byproducts; study and data measurement problems; ongoing toxicological or epidemiological studies; issue importance; and agenda-setting issues.

Because interviews were with key-informants, different individuals provided certain parts of the 'story'. To ensure that all aspects are consistent with the context in which statements were made during the interviews, a process of member-checking was implemented (see Baxter and Eyles, 1997; Gilchrist, 1992). Different sections of the paper that related to comments made by specific individuals were checked with them to ensure that their statements were not being misunderstood or taken out of context. Informants were first contacted by telephone or e-mail to ensure that they were available to make comments (i.e., not out of town), and then given a time frame of two weeks from receipt of the textual passages in which to register any concerns. The textual passages for which

respondents were responsible for reviewing were short enough not to be daunting (i.e., not the whole paper), but long enough that the context of how their statements were being used was present. A two week time frame was deemed adequate for the task. As part of a pre-arranged agreement with informants, the absence of comments at the end of that two week period was interpreted as consent/acceptance.

2.3 Tracing the Science-Agenda: Chemical Risks vs Microbiological Risks

Chlorine disinfection and filtration of drinking water supplies has played a key role in the public health agenda of preventing infectious diseases. Viral, bacterial, protozoan, and parasitic diseases can be transmitted in contaminated drinking water. Health effects can range from asymptomatic to mild discomfort, debilitation and even death. Susceptible populations, such as the very young, the elderly, or those whose immune systems are compromised, can be particularly affected by these infectious agents (Bull et al., 1995). While chlorine disinfection is not 100% effective against many of these parasites and viruses, it is still argued to be the most effective disinfection treatment (Craun et al., 1994a). Nonetheless, in spite of widespread drinking water disinfection programs in the developed world, major public health emergencies, due to exposure to infectious agents such as *Vibrio cholera, Cryptosporidium, Shigella, Escherichia coli*, and enteric viruses, have been declared in past years: for example, the cholera epidemic in Peru (1991); the cryptosporidium outbreak in Milwaukee, Wisconsin (1993); and more recently the e-coli outbreak in Walkerton, Ontario (1999).

Globally, diarrheal diseases due to infectious exposures, are the leading cause of death per year, greater even than the total number of deaths due to AIDS and cancer (Craun et al 1994a). While the goal is to use chlorine disinfection and other treatment alternatives as an 'insurance policy' against contamination by drawing from the least contaminated water source available, there has been an increased reliance on chlorine disinfection to remove and inactivate disease causing microorganisms from surface and groundwater supplies (Craun et al., 1994b). In other words, there has been a greater reliance on science and technology (Beck, 1992) to ensure water quality safety as opposed to protection of source waters from contamination due to improper waste disposal practices, accidents, and industrial, agricultural and wastewater runoff into drinking water supplies.

While bacterial diarrheal diseases outnumber other causes of death, one of the primary research foci concerning chlorinated drinking water has been the potential negative cancer health effects of exposure to disinfection byproducts as opposed to microbial risks and pathogens. For example, Dr. Gunther Craun (pers.com.), formerly of the US Environmental Protection Agency (EPA), indicated that he was involved in committees which established research priorities within the EPA for drinking water contaminants, particularly in the 1980s. Based on a multi-disciplinary committee process, involving experts knowledgeable about chemistry, microbiology, toxicology and epidemiology, these committees would assess research priorities for funding in drinking water research and present

these to senior management officials at the EPA. These informal workshop activities involved experts both inside and outside of the EPA. Dr. Craun argued that while he was involved in the setting of these research priorities, many of the funding priorities were directed from the top down. This might occur when the EPA was directed by Congress to regulate particular contaminants and the EPA Office of Ground Water and Drinking Water, whose primary responsibility is dealing with drinking water regulations, needed to have research done to make a proper risk management decision (Craun, pers.com.).

Toward the late 1980s, one of these workshops identified a research priority in the area of microbial risks, particularly for giardia lamblia and cryptosporidium which are difficult pathogens to disinfect. Giardia and cryptosporidium are both single celled protozoas which infect the intestinal tract. These concerns grew over outbreaks of giardiosis due to infected water in the United States and Puerto Rico where approximately 50 outbreaks of the illness affected almost 26,000 people (Craun, 1990). Similarly, in Milwaukee, Wisconsin, over 400,000 people were affected by cryptosporidium in 1993 when the water supply was contaminated by increased oocyst concentrations from Lake Michigan. However, since the mid 1970s when disinfection byproducts were first identified, these chemical risks captured the attention of regulators at the EPA more noticeably than microbial risks. Dr. Craun said:

> My general impression was once the disinfection byproduct issue was identified in the mid seventies it was pretty much recognized by most people in EPA as a high priority and sometimes at the expense of funding

> research on some of the microbial issues. So I think the Agency got a late start in conducting research on *Cryptosporidium* which had been identified as the cause of several waterborne outbreaks in the late eighties. It took Agency managers awhile to recognize that *Cryptosporidium* was an important waterborne pathogen that would have to be dealt with. So in general, I think their focus was more on the chemical contaminants (Craun, pers.com.).

Hence, the majority of the scientific research has focused on exposures to trihalomethanes (THMs), with chloroform being used as the surrogate or proxy measure for all four THMs. Other byproducts, such as the chlorinated acetates (i.e., dichloroacetic acid and trichloroacetic acid) have also been a focus of research, but these have not been studied as extensively as THMs.

2.4 Constructing Scientific Knowledge Claims and Challenging Authorities

Table 2.1 outlines key scientific 'moments' in the construction of scientific authorities on the nature of the evidence over time. These moments either represented a review of the evidence at a particular time, or represented a consensus report or expert panel, which shaped the disinfection byproducts debate. These reviews represent both toxicological and epidemiological assessments of the cancer risks associated with exposure to disinfection byproducts.

As shown in Table 2.1, the International Agency for Research on Cancer, part of the World Health Organization, conducted one of the earliest and most comprehensive evaluations of the toxicologic and epidemiologic literatures on

Table 2.1: Defining Moments in the Chlorinated Byproducts and Cancer Debate

Author (Year)	Study Type	Study Focus	References Used
IARC (1991)	Review monograph	Epidemiology and Toxicology	206, combined toxicology and epidemiology
Morris et al (1992)	Meta-Analysis	Epidemiology	12 studies reviewed (10 case/control, 2 cohort)
Cantor (1997)	Review article	Epidemiology	36 studies (13 ecologic, 18 case-control, 1 cohort, 4 fluid intake)
ILSI (1997)	Expert Panel Assessment of chloroform's carcinogenicity	Toxicology	184 chloroform references
Mills et al (1998)	Expert Panel Assessment of DBPs	Epidemiology and Toxicology	52 references (22 toxicology, 16 epidemiology, 7 reproductive effects, 7 risk assessment)

chlorinated disinfection byproducts prior to 1990 (IARC, 1991). The overall conclusion of IARC's working group was that there was inadequate evidence for the carcinogenicity of chlorinated drinking water in humans and experimental animals. Therefore, IARC was unable to classify chlorinated disinfection byproducts in drinking water as to their carcinogenicity to humans.

Cantor (1997) provides a useful summary of the epidemiologic research that has carried out from the late 1970s to the mid 1990s by categorizing the research into three stages. The first stage of research consisted largely of ecological studies which were adjusted for age, gender and race. Typically cancer mortality rate comparisons were made at the regional level (city, county) against a series of factors: ground versus surface water; chlorinated versus non chlorinated water supplies; and levels of trihalomethanes in the water supply (Salg, 1977; Kuzma et al., 1977; Page et al., 1976; Cantor et al., 1978; Hogan et al., 1979; Wigle et al., 1986; and Morin et al., 1985). Bladder, colon and rectal cancer incidence rates were also associated with water supply variables in Iowa (Bean et al., 1982; Isacson et al., 1983), Norway (Flatten, 1992), Spain (Morales Suarez-Varela et al., 1994), and Finland (Koivusalo et al., 1994; 1995).

The second stage of epidemiological research was characterized by early case-control approaches, largely based on analysis of death certificate data to identify cases and controls (Alavanja et al., 1978; Young et al., 1981; Brenniman et al., 1980; Crump and Guess, 1982). There were a series of data limitations to these studies as they depended largely on death certificates to identify the

residence source of drinking water. Residence identification listed on death certificates does not adequately reflect length of residence or mobility characteristics. For example, an individual could have lived in the same community for two months or forty years at the time of their death. Additional limitations included an inability to control for known confounders (e.g. smoking, diet, lifetime occupational exposures). Some earlier case-control studies attempted to remove some of these data limitations by incorporating information about a person's previous residence and their water supply inferred from the place of birth listed on the death certificate (Gottlieb and Carr, 1982). Lawrence and colleagues (1984) obtained some residential history information from retirement records, and Zierler and colleagues (1988) conducted next-of-kin interviews in order to better reconstruct exposure history. The findings from these case-control studies were generally supportive of the positive associations found in the earlier ecologic studies, and served to strengthen the hypothesis of a link between chlorinated disinfection byproducts and bladder, colon and rectal cancers, though further research was required.

The third stage of epidemiologic research has been improved interview case-control study designs based on incidence cases in North Carolina (Cragle et al., 1985), Wisconsin (Young et al., 1987), Iowa (Cantor et al., 1998; Hildesheim et al., 1998; Cantor et al., 1999; Cantor et al., 1996), Colorado (McGeehin et al., 1993), Ontario, Canada (Marrett and King, 1995; King and Marrett, 1996; King et al., 2000), Maryland (Ijsselmuiden et al., 1992; Freedman et al., 1997), and ten

other locations in the US (Cantor et al., 1987). For all of these studies, individual residential and water source histories were collected from residence information in questionnaires and historical data from water utilities. In each of these studies, consumption of chlorinated water, using total trihalomethane levels as the surrogate marker of disinfection byproduct exposure over time was used. The overall conclusion from these interview studies is that there is a positive association between exposure to chlorinated disinfection byproducts and cancer outcomes, particularly for bladder cancer, though not all associations are statistically significant, and there are variations among males and females. Many of these results are summarized in Cantor (1997) and Mills et al. (1998).

2.4.1 Challenging 'Authorities': The Morris Meta-analysis

Morris and colleagues (1992) conducted a meta-analysis examining the chlorinated disinfection byproducts and epidemiological cancer studies (see Table 2.1). To be included studies had to have estimated a person's cumulative exposure to an environmental contaminant or risk factor using historical data or records. Thus, in the drinking water context, the exposure factors were: source of tap water; concentration of chlorinated byproducts in that water supply; and amount of tap water consumed. A study which measured these three exposure factors *and* also collected historical records for these three factors was included in the meta-analysis. Ten case-control studies (Alvanja et al., 1978; Brenniman et al., 1980; Young et al., 1981; Gottlieb et al., 1982; Sullivan, 1982; Lawrence et al., 1984;

Cragle et al., 1985; Zierler et al., 1986; Cantor et al., 1987; Young et al., 1987) and two cohort studies (Wilkins and Comstock, 1981; Schulte et al., 1986) met this exposure assessment criteria. The conclusion of the Morris meta-analysis was that for all cancer sites, there was a relative risk estimate for exposure to disinfection byproducts of 1.15 (95% CI: 1.09-1.20). When examining specific organ sites, there was a pooled relative risk estimate of 1.21 (95% CI: 1.09-1.34) for bladder cancer and 1.38 (95% CI: 1.01-1.87) for rectal cancer. A pooled significant relative risk estimate for colon cancer was not possible based on the studies available. Morris and colleagues estimated that these relative risk estimates would result in approximately 4200 bladder cancer cases per year and 6500 cases of rectal cancer per year in the United States.

The first major challenge to the 'authority' of science stemmed from the reception of the Morris meta-analysis in the scientific community. The Morris meta-analysis served as a 'focusing event' (Kingdon, 1995) in promoting the scientific cancer research agenda, particularly in how the issue played out in the media and in the EPA. The media stories in the US emphasized the number of bladder cancer cases that could be expected due to disinfection byproducts (Craun, pers.com.). At the same time, in 1991, several areas of Peru experienced a breakdown in their treatment of drinking water. Water supplies were not being sufficiently chlorinated and thousands of people died. Aron and Zimmerman (2000) suggest that there were a multiplicity of events which led to the Peru cholera outbreak, and that the cancer 'fear' played a very minor role. Morris (pers.com.) has commented:

> The backlash against that meta-analysis is still playing out. It's astounded me. I've been vilified in a lot of quarters for doing that, and for a wide range of reasons. I think those who did not like the meta-analysis or the message of the meta-analysis, fan the flames of the "Peru cholera due to cancer fear" urban legend a little bit. I think there were people who saw this as an opportunity to say we're going to have cholera all around the world again if we even think about this issue (i.e., CDBPs).

The meta-analysis was challenged in a second, and arguably more legitimate way. While favourably received in the EPA early on, the methodology used by the Morris meta-analysis was later challenged by the EPA. Part of the drinking water standards setting in the United States relies on a negotiated process among various stakeholders. There was a disagreement among members of the Negotiating Committee regarding the science-policy conclusions that could be drawn from epidemiologic studies, and in particular the use of single point estimates from aggregated data (a fundamental feature of the Morris meta-analysis) (US EPA 1994a). As a response, the EPA decided to convene a panel committee to review the state of cancer epidemiology research (US EPA 1994b). A recommendation from that panel was for the EPA to complete an assessment of the Morris meta-analysis (Poole, 1997).

Poole argued that the data contained in the meta-analysis were produced by different designs. In order to conduct a proper meta-analysis, a test for heterogeneity should be done to assess whether the aggregation of the study data results into a single measure is appropriate. This test examines whether the results of different studies or subgroups that will be used in the meta-analysis are more

different than you would expect from chance alone (Snedecor and Cochran, 1989). Poole argued that the Morris meta-analysis did not conduct such a test. Moreover, Poole also charged that "there was evidence of a publication bias within the body of literature" (US EPA, 1998a: 15678). Publication bias refers to a situation where "the literature search and inclusion criteria for studies used for the meta-analysis indicated that the sample of studies used is not representative of all the research (published and unpublished) that has been done on a topic" (Ibid.). Lastly, Poole found that the aggregate estimates reported by Morris were sensitive to small changes (i.e., adding or deleting a single study). The peer-review process of the Poole report concurred with Poole's assessment (US EPA 1998b). Yet the EPA also conducted an analysis of population attributable risk to bladder cancer and arrived at levels similar to the same range as that of Morris (see US EPA 1998a). In calculating the estimate, epidemiologists quantified "the fraction of the disease burden in a population (e.g. cancer) that could be eliminated if the exposure was absent (e.g. DBPs in chlorinated water)" (US EPA, 1998a: 15679). The key difference between the two methods, used by Morris and the EPA, is that the EPA did not rely on aggregate data as a single point measure, although the results were within the same range.

However, at a policy level, prior to the Poole review, the Morris meta-analysis did favourably capture the attention of the EPA. So much so, that Dr. Patricia Murphy, from the EPA, felt that it needed to be examined and critiqued before being used for regulatory purposes, in spite of the fact that the Morris

meta-analysis was peer-reviewed. Dr. Murphy commented during our interview that: "true peer review begins after publication, when all scientists can read and evaluate a study and see if it stands up over time" (Murphy, pers.com.). In Dr. Murphy's opinion, it seemed, at least in the beginning, that "there was a vested interest in having that meta-analysis because it appeared as if it were an open and shut case which is very attractive to a policymaker" (Murphy, pers.com). In fact, at the International Life Sciences Institute first international conference on drinking water and disinfection byproducts in the early 1990s, the Morris meta-analysis had been very well received. Dr. Murphy felt that:

> There was a lot of excitement about the relationship between chlorinated drinking water and cancer the meta-analysis seemed to show. But, after my presentation, after I talked about the study in terms of some of the things that should be looked at methodologically before one uses a study for risk assessment or for regulatory purposes, I wasn't treated very nicely. It was as if it had been inappropriate on my part to raise any scientific criticisms of the work, which to me, as a scientist, was really odd (Murphy, pers.com.).

2.4.2 Challenging 'Authorities': ILSI Expert Panel and the Competing Chloroform Hypothesis

A second, and perhaps more significant challenge to emerging scientific 'authorities' regarding disinfection byproducts occurred in the area of toxicology. One of the primary directions of toxicology research has been to focus on chloroform and its mode of action. This has particularly been the focus of research in the United States, partially motivated by regulatory decisions that the EPA has made with respect to setting non-legally enforceable level goals for chloroform in

drinking water. Some studies (e.g. Larson et al., 1994a; 1994b; 1995a; 1995b; NCI, 1976; Templin et al., 1996) have demonstrated that liver tumours are a secondary occurrence to cell proliferation and death. This would imply that chloroform is safe at low doses. The International Life Sciences Institute, representing scientists from government (including a representative from Health Canada), academia, and industry, conducted an expert panel assessment of chloroform and dichloroacetic acid and concluded that chloroform is safe at low doses (ILSI, 1997). The same conclusion was reached in the EPA's evaluation of chloroform's toxicity in its risk characterization document (US EPA, 1998c).

The findings of the ILSI (1997) expert panel report and the EPA (1998c) evaluation of chloroform's toxicity were controversial in some toxicological circles. Melnick and colleagues (1998a, 1998b) disagreed with these conclusions. Dr. Melnick, of the National Institute of Environmental Health Sciences, conducted a three-week rodent study examining a hypothesis supported by the ILSI report that "liver carcinogenicity in mice to chloroform exposure is suggested to occur secondary to cytotoxicity as a consequence of regenerative hyperplasia" (Melnick et al, 1998a: 413). In other words, when exposed to very high levels of chloroform, liver cells die, promoting rapid growth of new cells which can become cancerous. But at low doses, or below a certain threshold, such rapid growth does not occur.

Given that chloroform is usually part of a complex mixture (i.e., a family of compounds) in chlorinated disinfection byproducts, Melnick and colleagues

wanted to explore how the different trihalomethanes interact to help understand the dose-response relationship seen in the chloroform-only studies. They were concerned that complements of this mixture might be carcinogenic in animals at lower doses and/or at other organ sites in the absence of regenerative hyperplasia. They found that bromodichloromethane, which is metabolized in a similar fashion to chloroform, and chlorodibromomethane, which is metabolized by a different pathway, both showed liver tumours without cytotoxicity. Regenerative hyperplasia acted as a precursor at much lower doses than that used in chloroform-only studies. The overall concern is that if these other disinfection byproducts which co-occur with chloroform cause liver tumours at lower doses and by different pathways than chloroform, then chloroform's carcinogenicity and mode of action as argued by the ILSI report may not adequately interpret all the relevant data. Consequently, there could be "contributions from other metabolic pathways" (Melnick et al., 1998a: 413).

The controversy between the Melnick interpretation of the evidence as compared with the ILSI expert panel is an interesting challenge of science's authority as a knowledge producer. The ILSI panel wrote a comment following one of Melnick's papers. The panel charged that to effectively study the issue "two-year study(ies) where interim groups of rodents were euthanized to check for liver necrosis and cell proliferation" would be required (Anderson et al., 1998: 133). The panel points out that Melnick's three-week study with single point measurements is insufficient because it can miss the effects of long term exposure on target organs (Anderson et al., 1998: 134).

Melnick's reply, published following the ILSI Panel members, argues that the ILSI criticism is "ironic" given how extensively ILSI relied on Larson et al's (1994a, 1994b, 1995a) three week study to support the ILSI conclusion about "the obligatory presence of cytotoxicity as a precursor in chloroform's carcinogenicity" (Melnick and Kohn, 1998: 135). Moreover, Melnick argues that his studies "were designed as an extension of the Larson studies on chloroform, [and] used the same dosing protocols in our evaluations of other trihalomethanes" (Ibid.). Furthermore, Melnick and Kohn argue that "one issue lost in this debate is how well the mechanistic interpretations of the animal data reflect human risk" (Ibid.). A key point for Melnick, in challenging the 'accepted' chloroform conclusions, is that the human evidence related to THM exposure has been virtually ignored because epidemiological human-based studies are unable to test exclusively for chloroform exposures. The relevance of this to our argument is not to assess the validity of Melnick's counter hypothesis, but rather to comment on the refusal of the expert panel to explicitly engage with the issue signals that there may be more to the story. If all of Melnick's claims can be scientifically disproven, as the ILSI panel members contend in their reply, why are they ignored? The only answer that can be speculated here is that Melnick's argument 'unnecessarily' complicates the neatness of the chloroform threshold finding at a policy level; a finding which may allow toxicologists to shift their research agenda away from chloroform to other byproducts of concern.

2.4.3 Challenging 'Authorities': Toxicology and Epidemiology Tensions

A second expert panel, the Health Canada expert panel (Mills et al., 1998) represents one of the most recent working groups to study both the toxicological and epidemiological evidence for bladder, colon and rectal cancers, as well as for reproductive and developmental effects. The expert panel was divided into working groups by area of expertise (i.e., toxicology, epidemiology, reproductive and developmental effects, and risk assessment) and charged with the responsibility of presenting some consensus conclusions. Experts were drawn from both Canada and the United States. Bi-national membership on expert panels has the potential to make consensus statements from these reports much more 'authoritative' in both countries. (However, it is interesting to note that the expert panel report is only widely known by panel participants and Canadian scientists working in the area. Many American scientists interviewed were aware of the report only peripherally, if at all.) Any data included in the report were discussed and debated by all participants in the expert panel to ensure that the interpretations of the data being presented were consistent with the data available at the time (Mills, pers.com.).

The toxicological studies, as represented in the Health Canada expert panel report, identify that the National Cancer Institute (NCI) and the National Toxicology Program (NTP) in the United States have been the two main research institutions to have conducted studies on the four THMs: chloroform (NCI, 1976); bromodichloromethane (NTP, 1987); chlorodibromomethane (NTP, 1984); and

bromoform (NTP, 1989). The only study to be included in the Health Canada expert panel report regarding THMs that was not conducted by the NCI or the NTP was Jorgenson and colleagues (1985). The Jorgenson study is critical because it measured exposure to chloroform by administering different levels to rodents (male Osborne-Mendel rats and female B6C3F1 mice) in drinking water as opposed to corn oil gavage. The Jorgenson study administered comparable daily doses of chloroform as the NCI (1976) study to female mice. The critical difference between these two studies is that the National Cancer Institute study showed high incidences of liver tumours in female mice when chloroform was administered in a corn oil gavage, but Jorgenson was not able to repeat these results using drinking water. This led Jorgenson to hypothesize that perhaps the differences these studies were showing may be related to some interaction with the mode of administration (i.e., corn oil gavage over drinking water).

Among the human epidemiological studies, there were some key studies which helped guide the consensus conclusions. For both colon and rectal cancers, out of a total of nine and eight studies respectively, the key studies were: Marrett and King (1995) and Hildesheim and colleagues (1998). For bladder cancer, out of a total of eleven studies, the key studies were: King and Marrett (1996), Cantor and colleagues (1987; 1998), McGeehin and colleagues (1993), and Freedman and colleagues (1997). The evaluation of these data are summarized in the expert panel report (Mills et al., 1998).

In order to establish its 'authority' in providing a comprehensive interpretation of the panel-identified relevant evidence concerning disinfection byproducts and adverse health effects, the expert panel was asked to arrive at some consensus conclusions. The question put to the panel was: "Given currently available evidence, how likely is it that chlorination byproducts cause cancer and/or reproductive effects in humans? If likely (possible or probable), how important a public health problem is it?" (Mills et al., 1998: 99). The most significant conclusion (i.e., 'official position') to stem from the report was that: "it was possible (60% of the group) to probable (40%) that chlorination byproducts pose a significant risk to the development of cancer, particularly bladder cancer". In assessing importance for public health, the risk of bladder cancer presented a "moderately important public health problem" (Mills et al, 1998: 99).

The third challenging 'authority' lay in the overall assessment of the evidence. The possible/probable dichotomy found in the expert panel report represented an almost equal split among toxicologists (i.e., possible) and epidemiologists (i.e., probable) (Mills, pers.com.), with the exception being Dr. Thomas, a toxicologist and a then Senior Scientific Advisor at Health Canada, who sided with epidemiologists (Thomas, pers.com.). Reflecting on the expert panel report, Dr. Wigle indicated: "the epidemiologists felt that it is probably a cause and effect relationship that still needed to be proven, and the toxicologists said it's possible, which means almost nothing. Almost anything is possible. Pigs might nest in trees, I suppose is possible, but not likely" (Wigle, pers.com.).

Overall, the 'official' published views of scientific experts in toxicology is that CDBPs, particularly chloroform, may not be the 'bad actor' that is contributing to cancer (ILSI, 1997). In fact, the Society of Toxicology symposium overview of water chlorination (Bull et al., 1995) argues that at a science-policy level, there is a need to fully assess whether the nature of the equivocal scientific evidence warrants regulatory changes in disinfection treatment plans, particularly when there will be both positive and negative impacts on the public.

Among the toxicologists, there are concerns that the brominated species of THMs, haloacetic acids (HAAs) and MX (3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone) might be more of a public health problem, although the primary research focus has been on chloroform and THMs in general. Nonetheless, some work has examined the occurrence of disinfection byproducts in drinking water (Krasner et al., 1989). There are several critical studies identified by the Health Canada expert panel report which focused on HAAs (Herren-Freund, 1987; Bull et al., 1985; 1990; DeAngelo et al., 1991; 1996; Daniel et al., 1992; Pereira et al., 1996; So and Bull, 1995). The majority of studies on MX have been conducted primarily in Finland (Steffensen et al., 1999; Koivusalo et al., 1994; 1995; 1998; Komulainen et al., 1992; 1997; Jansson et al., 1993). Overall, the carcinogenicity of HAAs has still yet to be demonstrated (IARC, 1990; Boorman et al., 1999). While MX has recently been identified as a carcinogen in rats (Komulainen et al., 1997), it is not easily measured in water supplies (Giddings, pers.com.).

Trihalomethanes, particularly chloroform, have been found to be carcinogens (NCI, 1976). Consequently, it is very difficult for a focused scientific research agenda to examine other possible contributing factors such as brominated species, HAAs, and MX on cancer rates in a more concerted way. Dr. Bull (pers.com.) argues this 'inability' to refocus such a scientific agenda is in large part due to special interests who never allow an issue to "move off the table once a contaminant has been identified as a carcinogen", even when scientific evidence suggests that the contaminant is safe at low doses. In other words, research funding and regulatory directions within a science domain have largely been directed at examining chloroform and THMs over other byproducts. Dr. Bull (pers.com.) suggested that roughly 99% of all disinfection byproducts have not yet been studied. However, the impact of the International Life Sciences Institute expert panel report on chloroform (ILSI, 1997), and its uptake in the EPA and the Courts, might signal a change in the research direction.

In the meantime, the EPA, the National Institute of Environmental Health Sciences, and the US Army have launched a five-year research initiative to develop a comprehensive biologic and mechanistic database for disinfection byproducts (see Boorman et al., 1999). The goal is to create a toxicity database to represent the range of DBPs that stem from different disinfection practices. The research will be examining two year toxicity and carcinogenicity studies in standard rodent models, transgenic mouse models and small fish models. In vitro mechanistic and toxicokinetic studies as well as reproductive, immunotoxicity and developmental studies will also be carried out.

In summary, these sections have outlined the key challenges to the construction of scientific 'authorities' in epidemiology and toxicology concerning the chlorinated disinfection byproducts and cancer debate, and has suggested some shifts in the research direction for toxicology. Shifts in the research focus of epidemiologists will be discussed in the next section. Overall, the evidence is equivocal. Epidemiological studies are only able to establish a statistically significant relative risk for bladder cancer rates, and discrepancies exist among the studies where differences among these rates for smokers (see Cantor et al., 1998; Freedman et al., 1997; McGeehin et al., 1993) and non-smokers (see King and Marrett, 1996; Cantor et al., 1987) were found. Toxicological studies seem to have concluded that chloroform is not the bad actor in drinking water, and perhaps the research focus should be turned elsewhere. We have demonstrated situations where the construction of different scientific authorities on the issue has been contested by competing scientific viewpoints. These contests have been found in the public discourse of the published literature and in the private reflections of this literature by key informants. These public-private discourse challenges will be examined further in the next section, with a greater focus on the private discourse.

2.5 Private Reflections on Published Discourses: Toxicology vs Epidemiology

The published literature, and hence, the 'public discourse' suggests that overall, epidemiologists are more convinced of a relationship between chlorinated disinfection byproducts and cancer, particularly bladder cancer, than the

toxicologists. The underlying 'disagreement' in the strength of the interpretation and construction of the evidence revolve around the differences in study design, study population (animal vs human), study power, exposure misclassification, and other data limitations. Table 2.2 provides an overview ranking of chlorinated disinfection byproducts in terms of its 'issue importance'.

Table 2.2 shows a range of opinions which highlight differences between the 'public' face, as evidenced in the published literature discussed in the previous section, versus a 'private' face as communicated during interviews. Of those who specifically ranked the disinfection byproducts issue, there seems to be an agreement by both the toxicologists and the epidemiologists. That is, it is important to study the CDBP issue given the widespread exposure, but the issue is ranked in the low to medium range of concerns. The public face of these scientists emphasize the concerns of microbial contamination; a concern raised by all interview respondents. However, public health scientists, in both Canada and the United States, appear to place greater emphasis on the microbial risks over the chemical risks. What is interesting is that public health scientists do not require unequivocal evidence to justify an action if they feel there is a legitimate public health risk. Hence, while more research tends to focus on the chemical risk, which is to the benefit of toxicologists and epidemiologists, public health scientists want to shift the research focus to microbial issues.

Public health scientists have been unsuccessful at redirecting the research agenda to microbial concerns. Hence, while toxicologists and epidemiologists

Table 2.2: Ranking of CDBPs as an Important Issue by Disciplinary Background

Background	Key Informant	Comments
Toxicologist	Bull*	Reasonably convinced, but would not trade in chlorination as a disinfection
Toxicologist	Melnick	Important issue for study, and advocates examination of disinfection alternatives to chlorine
Epidemiologist	Cantor*	CDBPs are not negligible but they are not major
Epidemiologist	King	Important issue for study as many people exposed. Important in that exposure to CDBPs is not an individual choice
Epidemiologist	Morris	Important issue for study, certainly in the realm of the precautionary principle of erring on the side of caution, but would not want to compromise microbial protection
Epidemiologist	Poole	People are afraid of cancer and are exposed to chlorinated drinking water — these two factors combined make CDBPs worthy of concern, research, and consideration
Risk Assessment	Hrudey*	The evidence is not as compelling as often presented
Public Health (US)	Calderon	CDBPs low importance because benefits far outweigh the risks
Public Health (US)	DeAngelo	Issue worthy of study, but not overly concerned.
Public Health (Canada)	Giddings and Green	Drinking water is one of the highest priorities of the Safe Environments Program (formally the Environmental Health Directorate) at Health Canada, and CDBPs are a priority. However, must keep disinfection byproducts as low as possible without compromising microbial protection
Public Health (Province of Ontario, Canada)	Jenkins	Need to make sure we are protecting public health by keeping byproducts low, but cannot compromise microbial protection as that would be a much more significant public health problem
Public Health (US)	Murphy	CDBPs rank somewhere in the middle
Public Health (Canada)	Thomas*	CDBPs rank in the medium to low range for overall health, whereas air quality would rank medium-high in terms of environmental risks.
Public Health (Canada)	Wigle	CDBPs are a pretty significant public health issue, but not on the top 10 list of priorities (not when including smoking, poverty, and extreme social injustices, for example, in such a list)

* Participants of Health Canada expert panel

rank CDBP exposure as a low to medium public health concern, it is their 'public' face through expert panel reports which has promoted the policy commitment to more research. This has overridden the 'private' preference of public health scientists operating in that regulatory arena. We are not arguing that public health scientists are not concerned about lowering the chemical risks, but we do argue that public health scientists feel that the emphasis on the chemical risks is unbalanced.

Another public-private tension stems from how epidemiologists and toxicologists frame conclusions in published documents compared to their personal opinion of the issue. For epidemiologists, the 'official' published position is that CDBPs may be a probable risk to human cancers. Epidemiologists are willing to attach a greater strength to the equivocal evidence base than are toxicologists. This highlights a 'tension' between toxicology and epidemiology that several respondents touched on. These 'tensions' lie in the interpretation of some of the internal inconsistencies in the scientific data. In epidemiology, there has not been a consistent relationship between bladder cancer and smoking. Toxicology cannot reproduce the disinfection and bladder cancer relationship found in epidemiology studies in rodent studies. Dr. Mills, for example, in her reflection of the situation indicated: "the fact that you see an effect in human populations without being able to pin down a single chemical culprit is not reassuring. But you don't conclude that your observation of that elevated risk in a human population is erroneous because the toxicology doesn't find the exact

culprit or outcome" (Mills, pers.com.). Several epidemiologists pointed to similar examples where there are situations where toxicology is unable to reproduce effects found in human populations. Dr. Morris (pers.com.) noted that arsenic is a known human carcinogen, but its carcinogenic effects are not generally reproducible in animals. Similarly, Dr. Cantor points to the effects of beta-naphthylamine, a powerful industrial carcinogen. Toxicology studies could not show an effect in rodents, but later found that dogs showed the same susceptibility to bladder cancer as humans (Cantor, pers.com).

There are a series of inherent strengths and weaknesses in the epidemiological and toxicological approaches. One of the key strengths of toxicology is that studies can be conducted in very controlled environments where specific effects of an individual byproduct (e.g. chloroform) can be examined by administering it through different routes of exposure. While toxicology can deal with complex mixtures, these studies are very difficult to perform. In order to properly work through the many compounds in a toxicology study, controlling for the one-to-one relationship that is necessary to conduct mechanistic studies, is very expensive (Bull, pers.com.). There are three main limitations to toxicological studies: 1) extrapolation of data of very high dose effects in animals to the doses to which humans are exposed; 2) toxicology target sites do not concur with epidemiologic studies; and 3) there is a difficulty in showing the same results across species of rats and mice. Dr. Hrudey agrees and carries this one step further by noting that: "the problem is that your toxicology is based with genetically

refined strains of rodents. This toxicological evidence provides very little replication of human individual variability and you're testing a single substance at a time at fixed concentration levels versus human exposure to mixtures of substances at variable concentration, so who knows whether that's giving you the true story" (Hrudey, pers.com.). Thus, even though toxicological studies may try to incorporate some known risk factors (e.g. diets high in fat; smoking) into their animal studies, there is a difficulty demonstrating this in the lab with the 'right' species, let alone in a non-laboratory setting.

Dr. Melnick argues:

> The main point is, as far as I see, related to animal data for human risk assessment versus human data for human risk assessment. Once you make use of animal data for evaluating human risk, I like to see a higher level of demonstration that animal-based hypothesis is correct, and that relevant human data has been incorporated into that assessment, because I don't know what the health impact might be if the hypothesis is incorrect (Melnick, pers.com.)

Moreover, given that drinking water is a complex mixture, some have questioned the validity of the data when extrapolated to a human population. The strengths of epidemiology are that it is dealing with the species under concern (i.e., humans), and can examine drinking water as a complex mixture. Dr. King (pers.com.) argues: "humans are not just getting chloroform, they are getting chloroform mixed in with 50 other chemical byproducts so that the health outcomes might be related to a synergistic effect among a few of those chemicals, or perhaps to a single chemical byproduct that we haven't been able to specifically examine." The

limitation of epidemiology is that many of its studies, including the improved interview based case-control study designs, are subject to a recall bias among study participants. In reconstructing exposure histories, epidemiologists must rely on a person's recollection of places they have lived, match these with water sources, frequency of exposure (e.g. how much water was consumed in a day; how long did study participants shower; etc.), and water utility data. Dr. Poole (pers.com.) adds to the list of epidemiological data limitations to include: missing data bias; participation bias; and control selection bias. In spite of these limitations, Dr. Morris argues:

> Given that you're dealing with a complex mixture, there are difficulties when dealing with toxicological inferences about the magnitude of human risk based on animal data. The complexity of the human environment and the human genome and the interaction of all those factors is something that the reductionist approach of the toxicologists is never going to fully deal with. So, am I saying that there is absolute proof in the epidemiologic data of risk? No. But I certainly don't think that there's anything close to proof in the toxicological data that there is an absence of risk or even proof that the risk is dramatically smaller than the epidemiologic data suggest (Morris, pers.com).

The underlying message out of these personal evaluations of the evidence is the need to improve epidemiological exposure assessments. This represents one of the shifts in the epidemiology research agenda. There are two main data re-analysis studies that are ongoing. One is headed by Gary Amy, using bladder case-control data from King's Ontario study, Cantor's Iowa studies, and Cragle's North Carolina data. The goal of these re-analysis studies is to apply the same exposure criteria and classification to all three data sets to see what impact this has on the different relative risk associations found in each of these studies. The other

initiative is being led by Dr. Manolis Kogevinas, which is a meta-analysis using the data from these and other previous studies. Moreover, Drs. King and Cantor are working with the American Waterworks Association Research Foundation (AWARF) to look at specific byproducts. In this project, they are working in conjunction with environmental chemists to improve historical estimates of exposures in anticipation of re-analyses of the case-control data. Specifically, they are hoping to be able to re-analyze existing data to examine for a specific level of a byproduct (e.g. bromodichloromethane) in historical water supply data bases rather than having to rely solely on the study of THMs.

Thus, while there are no new large scale epidemiologic studies planned, improving the exposure assessment of past studies may lead to new initiatives. However, there are two additional shifts in the epidemiological cancer science agenda. One, some researchers are examining different cancer sites, such as brain cancer (Cantor et al., 1999; and an ongoing study by Cantor, pers.com), as opposed to the traditional bladder, colon and rectal cancers. Two, there seems to be a movement away from the cancer epidemiology towards a focus on reproductive and developmental effects. For example, while Dr. King is still working on cancer studies related to disinfection byproducts, he has recently published a Nova Scotia, Canada study examining trihalomethanes in drinking water supplies and adverse birth outcomes (Dodds et al., 1999). One reason for this shift in focus is that the epidemiologic evidence for reproductive and developmental effects is still very much in its early stages, these studies are of

much shorter duration, and exposures can be measured prospectively as well as retrospectively. Nonetheless, the need to improve exposure assessment is key for both the cancer and reproductive epidemiologic studies. In fact, to that end, an international workshop, co-sponsored by Health Canada and the EPA, was held in May 2000 in Ottawa, Canada to examine how to make improvements to exposure assessments in epidemiologic studies (Health Canada and US EPA, 2000). While no clear answers were present, participants agreed that there was a need to await the results from the re-analysis studies, and work towards establishing better biomarkers of exposure.

In summary, there seems to be a difference between the public discourse of scientists in published documents as compared to some of the private discourses that come out of interview conversations. While these public-private discourses are often present at meetings of both toxicologists and epidemiologists, they are rarely, if ever, articulated in published documents.

2.6 Discussion

The translation of scientific knowledge and evidence within a policy domain is an area of considerable contest through what is studied and the ways things are measured and presented. Scientists hold within their 'power' the ability to influence the scope of knowledge. Scientists when conducting their research can identify the criteria for examination, inclusion and exclusion (Beck, 1992). These criteria can set the parameters of knowledge boundaries of what 'exists', what is

'good', and what is 'possible' (Therborn, 1980). If scientists choose not to focus their attention on certain aspects of an issue, or focus exclusively on one aspect over another, this can significantly affect the contestation of knowledge within both scientific and policy communities. Hence, the power to 'name' (Foucault, 1980) or 'define' (Beck, 1992) risks is critical within a scientific arena before those risks can be legitimized and gain social recognition. Similarly, within a political arena, the public can influence what issues are pushed on a policy agenda.

There was a series of events which raised awareness of the disinfection byproducts debate. The Morris meta-analysis served to direct attention to the issue within the United States. However, the Morris meta-analysis created its own controversy. Some refer to the media uptake of the Morris meta-analysis as being responsible for the cholera outbreak in Peru. The controversy surrounding the Morris meta-analysis highlights the differences between the public 'published' positions vs the private 'personal reflections' of key informants. The implication of this challenge for our argument is not as simple as the guiding principle of science: falsification by future research. It highlights the rise and fall of a scientific study in a policy domain when other, and equally equivocal, scientific estimates are forwarded for policy consideration. The numeric values arrived at by Morris' calculation did not significantly vary from that of the EPA. However, it is the EPA calculation that was considered at a policy level. The challenge to Morris changed from a personal attack via the Peru myth to a professional challenge

based on 'sound science'. While a legitimate shift, personal reflections of the issue return back to the 'urban legend'; highlighting that the challenge may indeed be more personal than professional.

Similarly, expert panels, as advisory bodies to regulatory agencies, offer a powerful arena for the legitimation of some knowledge claims over others. In these two expert panels, membership was intentionally mixed (i.e., including Canadian and/or American experts), and in the case of the ILSI expert panel, the assessment of the issue from industry scientists was also included. Having a mixed membership of scientists is key to add credibility to the conclusions reached by the reports. It helps remove the 'aura' of impropriety, such that one group is not able to advance an agenda which would override the larger agenda of advancing scientific 'truth'. In order to maintain credibility (Stone, 1997; Gieryn, 1999; Beck, 1992) scientists, especially when participating on expert panels, must be above reproach. However, operating within a 'mandated' sphere (Salter, 1988), that is, when scientific evidence is interpreted for policy recommendations, competing sciences can be marshaled to any value position in the polity (Jasanoff and Wynne, 1998). Thus, strategies, such as the reliance on consensus conclusions (as was the case in these two expert panels), become important to create 'credibility' within the science-policy domain.

Nonetheless, some public health scientists have been reluctant to arrive at definitive conclusions regarding the CDBP relationship. Dr. Murphy believes that if she were to offer a firm conclusion in regard to the evidence at this early stage

that she would be compromising her objectivity. She would then have a 'stake' in ensuring that her assessment was continuously proven over time. Many scientists do not want to find out that their original hypotheses and conclusions were later disproved by others. Even though scientists maintain their objectivity as much as possible, they usually have a vested interest in having their personal work stand the test of time (Murphy, pers.com.). It is 'human nature' or at least one nature of scientists as constructed by the need to ensure authority to their claims.

However, until exposure assessments are improved, it seems as though there will not be any new cancer science being undertaken to further examine the chlorinated disinfection byproducts debate for bladder, colon, and rectal cancers. Thus, some are switching their focus to reproductive and developmental effects. From a regulatory perspective, the reproductive evidence could serve to drive policy decisions much more quickly than the cancer science. Table 2.3 outlines how Ms Giddings and Mr. Jenkins, both public health scientists involved on the Federal Provincial Subcommittee on Drinking Water, and the CDBP Task Group, as well as those from Dr. Murphy of the EPA, and Dr. King, a research scientist, characterized the potential impact of evidence with respect to reproductive effects on policy.

For regulators, reproductive risks could prove to be a much more significant problem because they would be classified as acute as opposed to chronic effects. Acute risks are always weighed more heavily than chronic risks because the latency period is much shorter. It is a recognized fact that the

Table 2.3: Assessment of Reproductive Evidence in Regulatory Settings

Background	Key Informant	Comments
Health Canada, Microbiologist	Giddings	"If this one (i.e., reproductive effects) does prove out to be more of a risk, which we're looking at all that data, it will change the way guidelines for THMs are interpreted. It is the reproductive studies that are coming out now that are more of a concern because if it is a reproductive problem, that's actually an acute effect versus a chronic. We have to definitely deal with that in a different situation. It would not be an average level of THMs that we have now, it would most likely be a maximum value to account for the acute effect (reproductive risk vs cancer risk). That data is fairly new but it's coming on stronger and is easier to get at than a cancer study is (i.e., it takes less time to do a reproductive epidemiological study than it does to do an epidemiological cancer study - a lot of work is going on in this area."
Ontario Ministry of Environment, Microbiologist	Jenkins	"We don't believe it is the chlorinated compounds that are the primary concern with the short term reproductive and developmental outcomes. We feel that the brominated compounds may be the primary concern with respect to these adverse outcomes. While historically our concern and focus regarding CDBPs has been on long term exposure in terms of cancer, in the coming decade, the more immediate effects for reproductive outcomes is creating a much larger concern for us as regulators in protecting public health."
Queen's University, Epidemiologist	King	"I think that in the reproductive area there are about 5-6 studies on the go, and there will be a large body of evidence there to make more definitive decisions. I think those studies might help to drive the decisions about setting guidelines."
US EPA, Epidemiologist	Murphy	"More than ten years ago we tried pushing things in the reproductive area at EPA. We convened a group to focus on reproductive and developmental issues because we felt that, compared to a cancer study, there would be fewer methodological issues related to assessing exposure, given the shorter exposure window of intent. We believed that there would be a better chance of finding a relationship, if it existed, and that there would be fewer uncertainties when it came to interpreting the study results. We recognized the need for the information in the future, but we weren't able to generate the necessary support to implement any work in this area."

protection chlorine disinfection has afforded with respect to microbial risks far outweighs the small increase in the relative risk of certain cancer types over an exposure period of 35 years or more to a particular water supply. However, in the uptake of these policy decisions in a public domain, such distinctions are not meaningful. Cancer is viewed as such a 'dread disease' that the public may fear that their relative risk for cancer may increase with consumption of chlorinated drinking water. Water is a necessity of life. From a public perspective, these risks are not viewed as voluntary, even if the risk is extremely small (and to date, not even conclusively proven). From a public health perspective, the small cancer risk is viewed as a voluntary risk. Yet public concerns regarding the future and survival of the species — i.e., the reproductive effects — may also be important in emerging public and policy attention (see Eyles et al., 1993; Baxter et al., 1999).

2.7 Conclusion

Duncan Ellison of the Canadian Water and Wastewater Association commented that:

> those who are promoting health programs and environmental programs have their life made, to some extent, easier (and occasionally more difficult) with appropriate headlines. But nevertheless, supports for program initiatives, policies, are all coloured by the political perception and social environments in which they occur. If you can manipulate those in favour of your particular initiative or thrust, then it's more likely that your initiative or thrust will be accepted (Ellison, pers.com.).

In the drinking water debate, many scientists, in the EPA and in Health Canada, have been trying to get regulators to pay more attention to microbial risks and

pathogens. These scientists do not want policymakers to ignore disinfection byproducts, but they do want to ensure that there is not an overly skewed emphasis placed on contaminants which carry a low relative risk of harm, as compared to microbial pathogens which carry a very high relative risk of harm. The apparent shift in the scientific research foci into examining the epidemiological effects of reproductive and developmental effects could be providing an avenue to deal with these byproduct concerns. Dr. King (pers.com.) argued that should regulations be adopted which addressed the contaminant exposure of disinfection byproducts to minimize reproductive and developmental effects, that at the same time, it might also take care of the cancer risk. Epidemiological reproductive studies can be done in a much shorter time frame, can be designed retrospectively and prospectively, and are not as limited to bias and misclassification error due to reconstructing residential histories and historical levels of byproducts at treatment plants. Hence a much stronger data base could be established.

In both Canada and the United States, the focus of the scientific agenda surrounding disinfection byproducts is changing. The judicial battle in the United States regarding chloroform's toxicity suggests that, at least toxicologists, will be able to shift their attention to a much greater degree away from chloroform studies to the brominated species, haloacetic acids, and other byproducts. In Canada, there is not as clear a signal as to how the scientific agenda will be changing. However, the emphasis is primarily on how to improve exposure assessments, with a

marked increase of reproductive outcome studies being carried out. In this issue science is driving much of the agenda. As Jamieson (1996) argues, issues of scientific uncertainty are critical to any debate. There needs to be a balance of uncertainty in science and policy. The right amount of uncertainty can support calls for further research; too much uncertainty can make the problem seem insurmountable, particularly in a policy domain. Prior to the more recent improved case-control interview studies, there was an overall call for more scientific research to examine cancer outcomes, particularly bladder cancer outcomes. At a policy level, the continued uncertainty of science was insufficient to significantly change regulations, but could potentially be sufficient enough to redirect funds away from the entire disinfection byproducts agenda. Hence, the switch in focus to reproductive effects has served to redirect the nature of uncertainty to a domain of 'more research is necessary' and the construction of 'new' scientific authority.

Similarly, the debate that ensued between the chlorine industry and the EPA regarding chloroform, was framed in terms of 'chloroform is not the bad actor' vs 'water is a complex mixture'. In this particular issue, the chlorine industry 'won' that battle. Toxicologists are not likely going to continue to study the chloroform effects, with the possible exception of Melnick who is not convinced that chloroform is safe at low doses. Moreover, several scientists interviewed for this research also suggested that the focus on the chloroform aspect of disinfection byproducts may not be where the real concern lies. In effect,

this shift, too, has moved the 'uncertainty' level to a different domain. If regulators cannot see any closure on the issue, they may be less inclined to keep the disinfection byproducts issue on the agenda. Toxicologists have 'proven' that chloroform is not the 'bad actor' therefore, scientific uncertainty has moved back into the domain of 'more research is required in the search of the bad actor'. Epidemiologists must examine disinfection byproducts as a complex mixture because it is impossible to isolate out individual effects. Consequently, it will be difficult for epidemiology to provide this 'closure'. However, if a proper re-analyses of the Ontario, Iowa and North Carolina epidemiological data can be done, this could make a significant contribution towards improving exposure assessments. That could then pave the way for better designed cancer studies, and better designed reproductive and developmental outcome studies. Perhaps new findings could give the epidemiological authorities the leverage they require to gain the 'upper hand' in regulatory decision making currently enjoyed by toxicology, at least within the American regulatory context. By contrast, in Canada, for example, the microbial events of an e-coli outbreak in Walkerton, Ontario in 2000 (briefly referred to in section 2.3), have clouded the policy domain and hence made dormant the issue on the authority of chlorinated disinfection byproducts science.

CHAPTER THREE

Charting uncertainty in science-policy discourses: The construction of the chlorinated drinking water issue and cancer

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Abstract

Environment and health issues are becoming increasingly important in policy research. However, by their very nature, these issues are clouded by uncertainty, both in terms of the data collected as well as the interpretation of the evidence in the policy arena. Cancer science suspects that chlorinated disinfectant by-products, particularly trihalomethanes, contribute to elevated risks of bladder, colon, and rectal cancers, although no conclusive proof exists. Yet, cancer is not the only primary health concern stemming from disinfection byproducts. While there have been some studies examining the reproductive effects (e.g. miscarriages) of such by-products, the evidence is even more equivocal than it is for cancer, which further complicates policy decisions regarding drinking water guidelines. This research explores the scientific discourse around drinking water and cancer, using Health Canada's Laboratory Centre for Disease Control's workshop report, *Health Risks of Drinking Water Chlorination By-Products: Report of an Expert Working Group* (1998), as a base document. We (de)construct this science agenda and go on to explore the trajectory of the scientific discourse into the public policy arena. While this paper examines cancer science as the driver of policy with respect to chlorinated drinking water, we assert that reproductive effects are likely to be central to the debate for controlling chlorine use for disinfection purposes in the future.

Keywords: science-policy, chlorine, drinking water, cancer, Canada

3.0 Introduction

Like Janus, science presents two faces: one where facts and knowledge are already accepted as true, and one where facts and knowledge are both developing and contested. Latour (1987: 4) refers to these respectively as 'ready made science' and 'science in the making'. This paper explores the development of the latter and its uptake within the policy domain with respect to a growing health concern surrounding disinfection byproducts found in drinking water. Drinking water guidelines remain an ongoing issue within Canada. Spurred on by a methodologically strong case-control epidemiological study conducted in the Great Lakes region (Marrett and King, 1995; King and Marrett, 1996), some branches within Health Canada have been undertaking an extensive review of the evidence on the issue. The key research objective for this paper is to examine what impact contested scientific authorities may have on the policymaking process in the setting of Canadian drinking water guidelines. In other words, how does scientific evidence affect the nature of the policy process? Adopting Gieryn's framework (1999) 'science' is granted special features by society as an 'authority' in defining, describing and explaining reality; a status not ascribed to other domains. This paper will examine the construction of a scientific discourse surrounding the contested nature of chlorinated disinfection byproducts in drinking water and potential associated health risks to humans, utilizing Health Canada as a focal point. It will then examine the uptake of this discourse in the policy domain. First, some background is necessary.

Chlorination of drinking water is seen as one of the greatest public health initiatives in the 20th century in its prevention of waterborne diseases (Mills et al., 1998). It has been routinely used to disinfect municipal water supplies since the early 1900s. However, there is growing concern that chlorinated disinfection byproducts, especially trihalomethanes, may lead to elevated rates of bladder, colon and rectal cancers in humans (Morris et al, 1992), although this evidence remains inconclusive (Mills et al, 1998). Chlorinated disinfection byproducts are produced during the chlorination process when chlorine reacts with the organic matter present in the raw water supply. While byproduct levels vary depending on the water source (i.e., surface or ground water, presence of high or low levels of organic matter), trihalomethanes (THMs) form the group of byproducts found in greatest quantity (IARC, 1991). Yet, cancer is not the only health concern potentially linked to disinfection byproducts. There have been some studies examining the reproductive health effects (e.g. spontaneous abortions, developmental effects) of disinfection byproducts (see Dodds et al., 1999; Reif et al., 1996; Kanitz et al., 1996; Bove et al., 1995; 1992; Savitz et al., 1995; Aschengrau, et al., 1993; Kramer et al., 1992), although the evidence appears to be even more equivocal than for bladder, colon, and rectal cancers. In order to address these human health risks, Health Canada, through the Laboratory Centre for Disease Control (LCDC), convened a scientific expert panel to review the current evidence on chlorinated disinfection byproducts and human health. Their report, *Health Risks of Drinking Water Chlorination Byproducts: Report of an*

Expert Working Group (Mills et al., 1998), served as a 'focusing event' (Kingdon, 1995) from which to study the development of this issue.

In this paper we examine cancer as the driver of science-policy with respect to chlorinated drinking water. We hypothesize, however, that reproductive effects are likely to be central to the debate for controlling chlorine use in the future. Adopting an agenda-setting approach, this paper explores the construction of a scientific discourse on how the disinfection byproducts, particularly trihalomethanes and cancer outcomes issue has taken shape. Its translation into policy is only just currently underway. We will also map the current trajectory of that discourse into the public arena and suggest some future scenarios for what may shape any potential policy outcomes. We first outline the theoretical and methodological principles behind agenda-setting as an issue reconstruction technique. We then provide some of the background and context for this issue, before discussing the production of the cancer science through the LCDC report.

3.1 Theoretical Framework: Agenda-Setting and Issue Reconstruction

Wildavsky (1979) argues that policy analysis involves a study of the transformation of preferences within a policy subsystem. As an art and a craft (Majone, 1989) the role of policy arguments is to persuade (Yanow, 1996). There are three primary audiences in science-policy: scientists, policymakers and the public (Throgmorton, 1991; Harrison and Hoberg, 1994). This is particularly the case when scientific evidence is being used in policy decisions; what Salter (1988)

refers to as 'mandated science'. However, science is not omniscient and policymakers' agendas seem partial (Beck, 1992; Stone, 1997).

Agenda-setting provides a useful framework to understand policy issues, and can be extended to an examination of the scientific discourse surrounding the chlorinated byproducts issue and the related human health effects. Currently, the byproducts and cancer issue is not being driven by policymakers (see Driedger and Eyles, 2001a). Rather, it remains a debate over the strength of the scientific evidence that is capturing the attention of the public through the translation of this evidence in the media, by regulatory and public health scientists (e.g. in Health Canada), and research scientists (e.g. leading researchers in the field).

Understanding this process is almost as important, if not more important, as knowing what happens to the policy idea once it gets on the agenda (Kingdon, 1995). As with policy, so we argue with science, much depends on who presents the idea or argument, how the idea itself is being presented, how it fits with prevailing paradigms, and what is the timing of its presentation. The credibility of the presenter also influences the reception of an idea. These agenda setting issues are very similar to the social problems research approach of 'claimsmaking activities' (see Best, 1987; Hannigan, 1995; Spector and Kitsuse, 1977).

Baumgartner and Jones (1993) identify two intertwined factors for understanding policy issues or ideas: 'problem definition' and 'policy images'. Stone (1989: 282) writes: "problem definition is a process of image building, where the images have to do fundamentally with attributing cause, blame and

responsibility." In this fashion, problem definition is often strategic, in that it is designed to gather support for one perspective over another, by manipulating the conflict (Stone, 1997). Given that problem definition is values based (Kingdon, 1995) it represents a central element in policy statements and ideas; for if there is no perceived problem, there is no need to posit a solution (Pal, 1997). For example, bad conditions must be attributed to humans and not to fate or nature (Stone, 1989). To illustrate, an earthquake cannot be viewed as a public policy problem. By contrast, designing stricter building codes which minimize the structural impact of an earthquake fall within the public policy domain. In order to avoid any opposition to what may amount to more costly building practices, the solutions proffered will be framed in language promoting the protection of human lives during natural disasters.

Thus, problem definition will be couched in images and symbols in order to enlist support and minimize opposition (Baumgartner and Jones, 1993). Nonetheless, the key element in problem definition is that in framing the problem, issues are couched in terms of a public problem as opposed to private misfortune (Baumgartner and Jones, 1993; Stone, 1997). Hence in the chlorinated disinfection byproducts issue, cancer outcomes must be framed as a public health concern (i.e., public problem) as opposed to an outcome which will affect only a few individuals (i.e., private misfortune) in order to support any kind of policy changes.

Stone (1989) argues that there are three methodological strands which underlie the agenda literature. The first has its focus on identifying who is involved in the issue (i.e., the actors themselves) by examining their resources and values as a way to understand how policy problems take shape and appear or disappear off the agenda. The second looks to how the problem is being presented. These messages tend to be dichotomous. For example: Is the problem new or recurring?; Is it serious or trivial?; Does it focus on health or economic effects?; Is it presented in a way that pits social costs against concerns for economic growth? The third strand has its focus on the use of language and symbols to manipulate issues on or off the agenda to ensure that the issue resonates with significant and appropriate policymakers and publics.

Yet, as with policy, so a scientific agenda can be understood. Thus key questions in science are with: 'Who brings the issue forward?'; and 'How is the problem being defined?'. Irwin and Wynne (1996:7) carry this one step further and ask: 'What is the nature of both the scientific institutions (i.e., those bodies which provide the funding, management and implementation of science and technology) as well as the larger institutions which draw upon science for "defense, legitimation, or profit" (i.e., government, industry, etc.)?' Thus there exists strong parallels of science and policy with agenda-setting ideas resonating with Kuhn s paradigm shift (1962) and Barnes' (1970) 'reception of scientific beliefs' in terms of how scientific ideas are accepted or rejected, with underlying factors being the tensions over language, beliefs, and agendas.

Kingdon (1995) further argues that there are three factors that influence the agenda-setting process. We have modified these for scientific discourse. The first is problem recognition. Given that many problems and ideas may be pressing at any time, the ones that gain recognition and move higher up the agenda will provide a focal point for scientific actors. Sometimes, problems are recognized by 'focusing events' which will draw attention to the issue through a key study and its uptake by a regulatory body. Second, many scientific proposals are typically generated to address policy problems. However, not all proposals are given the same level of attention, nor do they adequately address the problem as it is being defined. Therefore, the 'goodness of fit' of the proposal with the identified problem will help determine how long that science remains relevant. Another science or set of scientific 'facts' may take over which may 'tip' the issue (Stone, 1997) — we argue there is the possibility of reproductive effects becoming more salient than cancer in the chlorination debate. This process is by no means simple. Yet scientific proposals reflect a gradual accumulation of knowledge among specialists in a given policy area: the epistemic community (Haas, 1992). Over time it is necessary for the science to resonate with the values and assumptions of the decision-makers. That will determine the level of prominence the science problem will continue to receive (Sabatier, 1987). The third factor which may influence the science-agenda process is the political process itself. Consequently, the 'national mood', public opinion, election results or changes in the administration will influence the nature and level of attention an issue may receive

on the agenda (Kingdon, 1995) and the funding that may be attached to some research agendas (Irwin and Wynne, 1996). In much of the Western world, 'health' research, and research in general, has become framed around industrial competitiveness and productivity issues, whereas environmental issues are often framed in a 'health' context (Burger, 1990).

The agenda-setting framework is therefore useful to understand the role and uptake of science in policy. In applying an agenda-setting framework it is therefore necessary to understand: how the problem is being defined; who are the actors involved in problem definition, and what are their interests in seeing the problem defined as such; what are the proposals that are being proffered (and by whom) to deal with the problem; and how has the issue developed. These elements of the framework involve a careful analysis of text (usually interview transcripts and written documents) to understand how a particular discourse emerges and is represented.

3.2 Methodology: Document and Interview Text Analysis

To analyze texts, we utilize a variety of techniques. By its very nature, the focus of text analysis is on language and symbols. Text analysis has been used as an interpretive tool by those working in semiotics and policy analysis. Text analysis has a focus on language and meaning as a way in which to examine the underlying social context of an issue (Iannantuono and Eyles, 1997). Language helps us create a social reality which gives us the power to include and exclude features

(Yanow, 1992; 2000). While there is often considerable power in what is explicitly stated, there is a great deal more involved in the hidden assumptions, values and beliefs (Iannantuono and Eyles, 1997). These hidden assumptions, or 'silences' (Yanow, 1992) are common features exposed in text analysis. Text analysis then enables researchers to reveal the rhetoric, stories, claims and hidden assumptions.

In the analysis of texts for this research, we adopted the approach of Yanow (2000), Lakoff and Johnson (1980) and Stone (1997) for understanding the use of metaphors. Metaphors are frequently used in everyday language, and typically provide clues as to aspects which may be taken for granted. For example, one respondent, referring to risk assessments, indicated that numbers 'put values on human life'. In this sense, human life can be measured, counted and balanced against risks in the interests of rendering appropriate policy decisions for protecting human life.

We also adopt Stone's (1997) and Roe's (1994) analysis of stories to understand the framing of the problem. Stone (1997) outlines several variations on two primary story types: decline (i.e., things were good, then got worse, and are now intolerable); and helplessness and control (i.e., things are bad and beyond our control, but we have now learned that we may be able to control things). The chlorinated disinfection and cancer issue follows more a variation on the helplessness and control story line: 'Due to cholera epidemics, public health was seriously endangered, but with chlorine as a water disinfectant, lives were saved.

But now the byproducts formed by chlorine could be contributing to elevated cancer rates. The dilemma is if we stop disinfecting, the number of people who will die will increase astronomically'. Roe's (1994) analysis of stories extends this framing to examine what type of counter-stories (i.e., stories which run opposite to the main story) and non-stories (i.e., those hidden assumptions that underlie the story) are present to form an overall narrative. Counter-stories could include arguments which point to the equivocal nature of the evidence, and non-stories could allude to the level of risks we should be willing to take on as a trade-off against certain death if we were to stop disinfecting our drinking water supplies.

Similarly, we adopted Kingdon's examination of agendas, as well as examining the claimsmaking activities (Best, 1995) of the actors involved in the process. As is the case with the agenda-setting framework, claimsmaking involves an analysis of who is making the claim, the claim itself, and who may be launching a counterclaim (i.e., a statement which argues against a dominant claim). Claimsmaking techniques are also paralleled with Roe's analysis of stories in terms of the story/claim and counter-story/counterclaim. For example, a toxicologist may attach different strengths to animal-based data than an epidemiologist, and vice versa, this being reflected in their claims. This could result, as it does in this exploration, in a difference in the type of language used when assessing the overall evidence on the byproducts and cancer issue. Therefore, we broadly have looked at the meanings of particular statements, as well as the context for particular events.

These analytical techniques were combined in an examination of texts in order to build the overall 'story' highlighting this issue. First, we use Health Canada's Laboratory Centre for Disease Control workshop report, *Health Risks of Drinking Water Chlorination Byproducts: Report of an Expert Working Group* (Mills et al, 1998), as the key document to understand how the disinfection byproducts issue took shape within a Canadian context. This document was specifically chosen because it provided an up-to-date comprehensive, bi-national (i.e., included experts both from Canada and the United States) scientific evaluation of the available evidence for Health Canada. A political response has already occurred since the expert panel report's release, through the establishment of a Chlorinated Disinfection Byproducts Task Group. The mandate of the Task Group is to continue studying the issue with the specific purpose of providing some recommendations regarding Canadian drinking water guidelines.

Second, we conducted key informant interviews with some of the expert panel report authors (n=4) to reconstruct how the disinfection byproducts and cancer issue was defined as a 'problem' and emerged as a science-policy issue. Not all report authors were interviewed. One author was an expert in the reproductive and developmental health effects associated with chlorinated byproducts, and our focus was on the cancer science; the other was a consultant hired to help in the writing of the report. However, in order to reconstruct the context for why such an expert panel was convened at that time (i.e., why was it such a pressing agenda issue) and to evaluate the process of the panel and the

Task Group that was later created, additional key informant interviews were required. In addition to report authors, interviews were carried out with: a) public health scientists in Health Canada who were able to provide background context (n=4 - two of whom were also part of the Federal-Provincial Drinking Water Subcommittee, that body responsible for drinking water guideline setting in Canada); b) the co-chairs of the Task Group (n=2); c) other scientific experts actively researching the issue who would be in a position to evaluate the strength of the toxicological and epidemiological evidence, as well as the assessment contained in the expert panel report (n=8); d) Pollution Probe, an environmental Non-Governmental Organization who has identified the issue as an agenda concern (n=1); and e) representatives from the Canadian chlorine (i.e., Canadian Chlorine Coordinating Committee) and water utility industry (Canadian Water and Wastewater Association) who would have a vested interest in any policy changes regarding chlorine disinfection of drinking water (n=4). In total, 23 key informant interviews were conducted from August 1999 to January 2001.

These individuals were identified and selected by a combination of techniques. Scientific experts who were actively publishing research in peer-reviewed journals, as identified in the expert panel report (i.e., usually first author), were contacted. Some informants were identified by their activities, such as Pollution Probe which held a conference in November 1998 regarding water, chlorinated disinfection byproducts and health outcomes. Lastly, some informants were identified via snowball sampling. Key informants, at the end of the

interview, were asked who they would identify as an active toxicologist or epidemiologist in this research area. The use of a snowball sampling approach was beneficial as it identified some public health scientists in Health Canada (whose primary mandate is protection of public health), who were active in the issue from a science-policy perspective, but who may not be conducting original research. Moreover, snowball sampling served as a 'check' to ensure that key individuals were being interviewed. Interviews continued until a saturation of information was reached (see Patton, 1990); that is, key informants were identifying individuals already interviewed as experts in the field, and no 'new' information or opinions were being shared.

Interview data were taped, transcribed verbatim and later analyzed using NVivo, a qualitative software package designed to analyze text (Richards, 1999). The key informant interviews were semi-structured and followed a checklist of key topic areas (e.g. assessment of the evidence, issue importance, science-policy concerns, risk communication strategies, agenda-setting issues, public perceptions of risk). Data were categorized both deductively (i.e., following natural categories from topic areas) and inductively (i.e., categories emerging from the data; e.g. contested knowledge claims). The broad categories to be reported on in this paper include how scientists assessed the evidence with respect to chlorinated disinfection byproducts; background and contextual issues; issue importance; and agenda-setting issues.

Because interviews were with key-informants, different individuals provided certain parts of the 'story'. To ensure that all aspects are consistent with the context in which statements were made during the interviews, a process of member-checking was implemented (see Baxter and Eyles, 1997; Gilchrist, 1992). Different sections of the paper that related to comments made by specific individuals were checked with them to ensure that their statements were not being misunderstood or taken out of context. Informants were first contacted by telephone or e-mail to ensure that they were available to make comments (i.e., not out of town), and then given a time frame of two weeks from receipt of the textual passages in which to register any concerns. The textual passages for which respondents were responsible for reviewing were short enough not to be daunting (i.e., not the whole paper), but long enough that the context for how their statements were being used was present. A two week time frame was deemed adequate for the task. As part of a pre-arranged agreement with informants, the absence of comments at the end of that two week period was interpreted as consent/acceptance.

By analyzing the expert panel report and conducting key informant interviews, we have reconstructed how the problem was defined and emerged as a science-policy issue. Given that scientific opinion is split with respect to this issue, it is demonstrating Latour's (1987) contested 'science in the making'. As noted earlier, we concentrate on the science discourse but briefly trace this into the policy arena.

3.3 The Scientific Discourse: Setting the Science-Policy Agenda

3.3.1 Background and Context

The development of the 'chlorine' issue, as a general environmental concern, has been ongoing for some time. Classified as an element, chlorine plays a role, either directly or indirectly, in the manufacture of some fifteen thousand chemicals (Baarschers, 1996: 197). Given its pervasive use, it is rarely given much thought in our everyday lives. As a water disinfectant, chlorination helped save millions of lives from typhoid, malaria, and cholera in the early part of the 20th century. It is used in the production of plastics, found in everything from hospital IV drip bags to beverage containers. However, it is not always perceived as 'harmless'. Back in the 1960s, with the start of the modern environmental movement through such treatises as Carson's (1962) *Silent Spring*, which looked at the impact of DDT (a chlorinated hydrocarbon) on birds and animals, we see some of the first connections between anthropogenic activity and adverse ecological outcomes. Similar problems were found for other applications of chlorine such as PCBs, which for a time was seen as one of the most dangerous substances potentially affecting human kind (Colburn et al., 1996). (PCBs have since been replaced by dioxins in the 'rogue's gallery'.)

It was not until 1974 that the first group of disinfection byproducts, trihalomethanes (THMs), was measured (Rook, 1974; Bellar et al., 1974). A chlorinated disinfection byproduct is formed by the reaction of chlorine, used in the disinfection of water supplies, with naturally occurring organic and inorganic

material present in raw water supplies. Surface water supplies (lakes, rivers) typically carry much higher levels of organics and inorganics and hence form higher levels of disinfection byproducts than do groundwater supplies (wells, springs). While several halogenated and non-halogenated compounds (see Mills et al, 1998: 92) are formed, trihalomethanes have been the most studied. Trihalomethanes form a group of four halogenated byproducts: chloroform, bromodichloromethane, dibromochloromethane, and bromoform. Chloroform is the THM found in the greatest quantity. In 1975, a toxicological study showed that chloroform was carcinogenic in laboratory rats (National Cancer Institute, 1976). Over the years since then, water treatment plants have more frequently monitored water levels of THMs, with total-THMs used as a surrogate marker for all disinfection byproducts.

One of the most important events in the development of this issue was the initial involvement of Health Canada's now defunct Great Lakes Health Effects Program. Concern for water quality in the Great Lakes region has been ongoing for approximately 90 years. In 1909, the United States and Great Britain (on behalf of Canada) signed the *Boundary Waters Treaty*. Under Article IV, the parties agreed not to pollute boundary waters in an effort to protect against injury or property damage on either side. Under this treaty, the International Joint Commission (IJC) was established to adjudicate matters of concern regarding the boundary waters. It was not until the 1960s that concerns grew over the pollution of the waters. By 1972, the IJC signed the first *Great Lakes Water Quality*

Agreement, primarily concerned with addressing eutrophication. This agreement was renegotiated in 1978 with an expanded mandate to more broadly address priority pollutants such as organochlorines (Gilbertson, 2000; Iannantuono and Eyles, 2000). By 1989, the IJC echoed concerns raised among other international bodies regarding chlorine-use and its concomitant byproduct pollutants, by calling for the elimination of chlorine use in industrial practices (Baarschers, 1996). The IJC was concerned about the health and reproductive effects associated with eating contaminated Great Lakes fish, the bioaccumulation of organochlorines in humans, an elevated cancer rates in the basin communities (Health Canada, 1997), and the quality of community drinking water. Lake Ontario serves as the primary drinking water source for the majority of Southern Ontario. Other non-drinking water concerns regarding chlorine were also present (see Driedger and Eyles, 2001b; Thornton, 1992). While they form part of the underlying context surrounding the issue, they will not be expanded in this paper.

Many of these concerns were transmitted to the public domain through the media (e.g. the release of scientific reports, the publication of IJC meeting recommendations, etc.), and hence registered with concerned citizens. Stemming from public and scientific concerns regarding drinking water quality and associated health concerns, the Great Lakes Health Effects Program contacted Dr. Lorraine Marrett at the Ontario Cancer Treatment and Research Foundation (now Cancer Care Ontario) and the University of Toronto to study the issue. Following a feasibility study, it was determined that there was sufficient data to perform an

extensive case-control study. The work was carried out by Marrett, and her then graduate student, Will King (now a prominent researcher in the field). Initially, Marrett and King conducted a literature review on the broader water quality and cancer issue and determined that "perhaps the biggest issue in terms of cancer risk was that of chlorination byproducts" (King, pers. com.). The rationale for this was grounded in the fact that the province of Ontario relies heavily on chlorinated surface water for its drinking water supply, and that much of this comes from Lake Ontario. Consequently, drinking water quality and chlorine use represented a particularly relevant issue for the Great Lakes population. The Marrett and King (1995) study was a strong case-control epidemiologic study which used all bladder cancer cases in Ontario (excluding Northern Ontario) against a set of matched population controls. The authors collected residential and water source history of drinking water, and data from municipal water supplies to estimate individual exposure to disinfection byproducts (represented through THM measurements, primarily chloroform as an exposure indicator) according to water source and chlorination status.

While this study received very little attention when it was first released as a Health Canada publication in 1995, it was more widely picked up by the media when it was released in the journal *Cancer Causes Control* the following year (see King and Marrett, 1996). While neither author argued that chlorine should be eliminated as a disinfectant, media articles focused on the 500 new cancer cases and 140 cancer deaths that could be attributed to chlorine per year in Ontario (McAndrew, 1996; Derfel, 1996).

On the basis of the strength of the Health Canada Marrett and King (1995) study, Don Wigle, a Director at the Bureau of Chronic Diseases (later the Director of the Cancer Bureau in 1995) asked Christina Mills (then Chief, Disease Control Division, Bureau of Chronic Diseases) to convene an expert panel of scientists to critically assess the evidence on the issue of chlorination byproducts. Wigle was motivated to have the issue studied more closely because while as a scientist he knew that the evidence was not sufficiently strong to prove a cause and effect relationship, from a public health perspective he was concerned that there was a potential danger with byproducts and cancer outcomes (Wigle, pers. com., August 18, 1999). The Laboratory Centre for Disease Control (LCDC) Expert Panel Workshop meeting was held in May 1997, with a consensus report published in *Chronic Diseases in Canada* (peer-reviewed) in November of 1998 (see Mills et al., 1998). Accompanying the publication of the Expert Panel consensus report in the same journal issue was a Position Paper written by Wigle (1998).

3.3.2 Report Construction and Development

The panel for the workshop consisted of several top scientists in toxicology (headed by Richard Bull), epidemiology (headed by Ken Cantor), risk assessment (headed by Steve Hrudey), and reproductive and developmental effects (headed by John Reif). From the perspective of toxicology and epidemiology, the evidence for bladder, colon and rectal cancers, along with reproductive health effects, was examined and critically assessed. In terms of the risk assessments, discussions

ensued as to how risk assessments are conducted based on both human and animal studies, and how numeric values that stem from such studies can be interpreted. To ensure rigour, the other workshop participants similarly assessed the evidence from the different areas to confirm if the findings were consistent with the manner in which they were presented. If there were any disputes, they were discussed and debated (Mills, pers. com.). Though no single debate resonates in the memories of the report authors, some 'differences' in opinions regarding the strength of the evidence were present, and will be discussed later. In the drafting of the report, each individual responsible for a particular area of expertise, wrote up a summary of the current assessment of the evidence for each health effect. These drafts were vetted through the workshop participants to ensure that the views presented were consistent with that of the group (Mills, pers. com.).

3.3.3 Primary Conclusions of the Panel

After reviewing all the evidence, the Expert Panel participants deliberated two questions to arrive at some consensus conclusions. These two questions were:

> 1. Given currently available evidence, how likely is it that chlorination byproducts cause cancer/reproductive effects in humans? If likely (possible or probable), how important a public health problem is it?
> 2. Given the state of the current evidence, are there enough quantitative data to be useful in an in-depth quantitative risk/benefit/cost evaluation? (Mills et al, 1998: 99).

In developing the response to question one, the panelists made an assessment about the current evidence for each health outcome individually (e.g. bladder, colon and rectal cancers, and reproductive and developmental effects). The overall

conclusion was that there was insufficient evidence to establish causation between disinfection byproducts and reproductive effects. With respect to cancer, the Expert Panel was only able to conclude that "it was possible (60% of the group) to probable (40%) that chlorination byproducts pose a significant risk to the development of cancer, particularly bladder cancer" (Mills et al, 1998: 99). In assessing importance for public health, the risk of bladder cancer posed a "moderately important public health problem". However, for reproductive and developmental effects, "if the suggested findings of the limited data are confirmed, chlorinated byproducts in current surface water supplies could pose an important heath problem" (Mills et al, 1998: 99). Last, the Expert Panel determined that there were insufficient quantitative data at this time to conduct a quantitative risk/benefit/cost analysis.

3.4 Tracing the Scientific Discourse into the Public Arena

3.4.1 Media Reaction to Workshop Report and Position Paper

To accompany the publication of the expert panel report (Mills et al., 1998), Don Wigle was asked to produce a written editorial to update the issue given that almost a year and a half had passed since the workshop was convened and the publication of the consensus report. Wigle had indicated that it was important to put the expert panel report into perspective. The panel report was very cautious in its presentation of the evidence. The editorial was only to represent Wigle's personal opinion on the issue, and not reflect official Health Canada policy.

However, because his paper was too long to be considered an 'editorial', it was labeled a 'position paper' (Wigle, pers. com.).

In the abstract of Wigle's position paper, he argues that on the assessment of the evidence for cancer that:

> there is an urgent need to resolve this and to consider actions based on the body of evidence, which at a minimum, suggests that lowering of CBP [chlorinated byproducts] levels would prevent a significant fraction of bladder cancers. In fact, given the widespread and prolonged exposure to CBPs and the epidemiologic evidence of associations with several cancer sites, *future research may establish CBPs as the most important environmental carcinogens in terms of the number of attributable cancers per year* (Wigle, 1998: 103, emphasis added).

However, while in the body of the position paper Wigle does not echo these statements exactly, he argues for the adoption of a 'weight of evidence' approach. He points to the US Environmental Protection Agency (EPA) which recognizes that while a relationship between epidemiologic evidence on byproducts and bladder cancer cannot be demonstrated conclusively, there is an "*assumption* of a potential causal relationship...supported by the weight of evidence from toxicology and epidemiology" (Wigle, 1998: 105, emphasis in original, paraphrased from EPA 1998). He further points to the conclusions reached by the Krever inquiry on tainted blood products in Canada that "action to reduce risk should not await scientific certainty" (Krever, 1997 as cited in Wigle, 1998: 106). By contrast, the expert panel report, representing a consensus viewpoint, does not call for a 'weight of evidence' approach. As a supplement to their conclusions noted in the previous section, the report more broadly argues for further research

into the issue. In order to reflect some of the individual concerns of workshop participants, the panel report also published a list of recommendations (non-consensual) to address research concerns regarding hazard identification, exposure assessment and risk characterization.

The media reaction to the release of the expert panel report and the position paper focused more on the latter because it appeared to make more definitive (rather than cautious) statements. The statements in the newspaper articles were largely based on quotes from Wigle. Moreover, the media typically credited Wigle as the author of the expert panel report. The release from the Canadian Press, picked up by the *Toronto Star* (Canadian Press, 1998) the *Montreal Gazette* (Bueckert, 1998) and the *Vancouver Sun* (Ward, 1998) writes:

> Despite the undisputed benefit of chlorination in controlling infectious diseases, "the epidemiological evidence now available clearly suggests that CBPs pose a cancer risk to humans" says the study..."Given the wide and prolonged exposure of Canadians to this risk, public health authorities must decide if the available evidence warrants actions to at least reduce exposure of Canadians to this risk."... In addition, epidemiological studies — based on data about large numbers of people — indicate an elevated incidence of bladder cancer among those who have been exposed to chlorinated drinking water for long periods. "If you put these two lines of evidence together, I would say it comes out as a probable link (between chlorinated water and cancer)," says Health Department expert Donald Wigle, who wrote the review (November 21, 1998).

Given the media interpretation of the issue, Health Canada was faced with a problem. First, the Wigle position paper, while intended to reflect his personal opinion, was nonetheless written by a Health Canada official and published in a Health Canada peer-reviewed publication. Hence, the *appearance* was that

Wigle's position reflected official policy, although this was not the case. Second, the media reaction prompted Health Canada to respond to this issue by establishing a Chlorinated Disinfection Byproducts Task Group. The task group was officially struck by Health Canada in July 1998 (months before panel report and position paper release along with the media reaction); the Federal-Provincial Subcommittee on Drinking Water (DWS), was already aware of the evidence from the expert panel report and the Wigle position paper (Giddings, pers. com.). In fact, drinking water guidelines are always open for re-evaluation. The DWS had been following the published literature since the publication of the 1993 guideline and based on the evidence, the DWS concluded that there was probably enough new data to warrant revisiting the guideline in April 1998 — three months prior to the establishment of the Task Group.

The Federal-Provincial Subcommittee on Drinking Water is responsible for providing timely advice on all matters that can affect the provision of safe drinking water to federal and provincial agencies responsible for drinking water quality (e.g. health, environment, municipal affairs). Emphasis is on: collecting and evaluating information on constituents of drinking water and their potential health effects; developing guidelines for potable water quality based on health assessment, treatment costs and economic analysis; reviewing and evaluating the adequacy of treatment technology; promoting the exchange of information on drinking water issues; and identifying research needs in Canada. This group, which consists of representatives from each of the provinces and territories,

Health Canada, and Environment Canada, establishes the Guidelines for Canadian Drinking Water Quality. These guidelines are then used by the provinces as a basis to establish their own enforceable drinking water regulations, objectives or guidelines (Giddings, pers. com.). In the case of Ontario, most federal and some additional provincial guidelines have been adopted as standards (Ontario, 2000). Given this joint relationship between the federal and provincial governments, Health Canada conducts risk assessments from scientific literature and exposure data, including exposure data provided by the provinces. However, the ultimate responsibility for deciding if action is necessary on the basis of the evidence rests with the provinces (the risk managers).

With respect to the drinking water byproducts issue, it is primarily the Drinking Water section of the Environmental Health Directorate which has been studying the issue the longest. It is through this section of Health Canada that the risk assessments for THMs are conducted. Moreover, this section acts as the technical Secretariate to the DWS. The mandate of the DWS is to conduct risk assessments for drinking water. In 1992, the DWS went through the process of revising its guideline for THMs which had been set at a level of 350 μg/L[1]. Through their consultation process with various national organizations[2] regarding

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A μg/L represents 1 millionth of a gram, or 10^{-6}.

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In addition to consultations with Provincial and Territorial members of the Federal Provincial Subcommittee on Drinking Water, the federal government through Health Canada, sought comments from 11 national organizations,

the THM guideline the DWS originally proposed a reduction in THMs to 50 μg/L. But, based on a risk management decision, the guideline eventually agreed upon in 1993 was 100 μg/L. The reason for adopting a higher guideline than originally proposed was threefold. First, the health risk evaluation showed that the risk was in the same order of magnitude for both the 50 and 100 μg/L values. Second the risk assessment was underway for other disinfection byproducts, or DBPs, (e.g. haloacetic acids) and these other DBPs might drive the ultimate guideline for total DBPs instead of the THMs. Third, there was a significant cost implication to lower the guideline to 50 μg/L when THMs might not be the ultimate DBP of concern (Giddings pers. com.).

Moreover, it was believed that most municipalities could meet a 100 μg/L guideline with relative ease, but the costs of reaching the lower 50 μg/L might be too expensive for some without achieving a commensurate health benefit when compared to other water treatment quality improvements that might be made (Ellison, CWWA, pers. com.); a similar argument was made concerning tritium guidelines in Ontario (McMullan and Eyles, 1999). While the guideline was set at 100 μg/L, municipalities are encouraged to keep their "levels of THMs as low as

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including: Assembly of First Nations; Canadian Environmental Law Association; Canadian Institute of Public Health Inspectors*; Canadian Public Health Association; Canadian Water and Wastewater Association*; Consumers Association of Canada; Federation of Canadian Municipalities; Friends of the Earth; Rawson Academy of Aquatic Science; and Society of Toxicology of Canada. Those organizations listed with a * indicates those that actually provided input to the process (Green, pers. com.).

possible without compromising disinfection" (Giddings, pers.com.). Nonetheless, given that the drinking water guidelines are not requirements, municipalities would not have to make any changes in their treatment practices unless the provincial government deemed it necessary.[3]

While the Chlorinated Disinfection Byproducts Task Group was established as a 'political' response to the media reaction to the position paper, the scientific evidence on the issue, from studies published since the acceptance of the 1993 guideline for THMs, including the Marrett and King study and the Expert Panel report, was itself sufficient to motivate the DWS to re-open the guideline a year following the Expert Panel workshop meeting.

The DWS members constantly monitors any and all evidence regarding drinking water issues, as does the Drinking Water section of the Environmental Health Directorate that reports to the DWS. Based on the King and Marrett (1996) study, and subsequent statistically significant studies in both epidemiology (Cantor et al., 1998; Freedman et al., 1997; Hildesheim et al., 1998) and toxicology (DeAngelo et al, 1996; Pereira, 1996; So and Bull, 1995), the Drinking Water section would have raised the issue of revisiting the guidelines for trihalomethanes, even without the Expert Panel workshop. In addition, the Drinking Water section is currently preparing an evaluation of the evidence for haloacetic acids (HAAs) which form the other most significant group of

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Currently only Alberta, and very recently Ontario and Quebec, have adopted drinking water standards, which require legal compliance.

disinfection byproducts found in drinking water. While the United States and the World Health Organization have developed standards/guidelines (respectively) for some of the HAAs, there is currently no Canadian guideline. Hence, given that the Task Group is going to be having to assess and evaluate the evidence assembled for THMs, the Drinking Water section is hoping that since the HAA document is also in preparation (though there have been some delays), that it will be included in the overall assessment if it is ready at the same time as the THM document. The Task Group is expecting to complete its task sometime in 2001-2002 to send its recommendation to the DWS (Giddings, pers. com.).

3.5 Discussion

3.5.1 The Problems in Science

There are several issues arising out of this scientific discourse which influenced how the problem was recognized and defined. Broadly speaking, there appeared to be a 'tension' between toxicology and epidemiology with regard to the strength of the evidence for health risks associated with drinking water byproducts. Toxicologists are often able to make very definitive statements regarding negative health effects in animals because their tests are conducted in a controlled fashion. The difficulty lies in extrapolating results to humans. Although complex mixtures (as opposed to single-chemical mixtures) are sometimes considered in these studies, toxicologists are unable to control for all possible confounders within the human environment (e.g. poor diet/exercise habits, smoking, etc.). Moreover,

toxicology studies are very expensive, and as such the number of animals used in studies is often low. A benefit of toxicological studies is that they can be conducted within a very short time frame, often over generations of animals.

Epidemiology, by contrast, deals with human data. Hence, epidemiologists are able to assess the effects of very complex mixtures while trying to account for (but unable to completely control for) a variety of confounders. But, the predictive power of epidemiologic studies is often very low, particularly in exposure situations. Very rarely is the evidence sufficient to demonstrate causation. Moreover, human-based studies are very expensive and often take years to finish (e.g. cohort studies). In general, randomized control trials, the gold standard of medical science, are rarely possible in environmental epidemiology. Consequently, in the case of assessing health effects due to chemical exposure, epidemiologists often have to rely on retrospective case-control or ecological studies. Ecological studies were common in the early history of examining byproducts and cancer outcomes, but have largely been replaced by the stronger case-control design. For drinking water, statistically significant associations with cancer have only been found after long periods of exposure (approximately 35 years or more) to byproducts (King and Marrett, 1996). While not a longitudinal study, the King and Marrett study did try to include some data on residential history. However, the most significant problem with epidemiologic studies for byproducts is that the majority of studies conducted thus far, have focused almost exclusively on THMs because it represents the longest-standing byproduct

measured. Consequently, other types of byproducts, which could potentially not co-vary directly with THMs but create higher risks, like haloacetic acids (HAAs), have been largely ignored.

These differences in the interpretive strength of epidemiological and toxicological evidence have influenced both problem recognition and definition. Toxicologists largely do not feel that public health is at risk due to chlorinated disinfection by-product exposure. The animal data have not been able to demonstrate any definitive association between byproducts and bladder, colon and rectal cancers. The cancer sites most frequently measured in toxicology studies are the liver and kidney. Only three of the toxicological studies listed in the Expert Panel workshop report (Mills et al., 1998) measured colon tumours, and the byproducts measured were bromodichloromethane (National Toxicology Program, 1987), bromoform (National Toxicology Program, 1989), and bromoacetic acid (So and Bull, 1995). The first two of these studies are byproducts found in the THM family, whereas the third study is part of the HAA family. The reason for so few studies is the difficulty in assessing "the many byproducts involved and the different modes of action that may result in carcinogenesis" (Mills et al, 1998: 92).

Moreover, there are often discrepancies within the epidemiological data. For example, in a National Bladder Cancer Study by Cantor et al. (1987), a statistically significant relative risk of bladder cancer (1.8) was found for those who had consumed chlorinated water with high THM levels over a long period of

time. The association was found to be stronger in non-smokers than in smokers, for both men and women. By contrast, Cantor et al. (1998) found a statistically significant relative risk ratio of 1.5 in an Iowa based study, where the risk for bladder cancer was higher for smokers than non-smokers, and among men but not women. A study by Freedman (1997) and by McGeehin et al. (1993) found similar results with respect to smokers, but while McGeehin's Colorado based study found the relationship to be consistent for both men and women, Freedman's Maryland study only confirmed an association for men. Cantor et al. (1998) speculate that possible reasons for these internal inconsistencies may be found in the differences in water quality and treatment in the respective areas. This could result in different variations in the byproducts mixtures. Nonetheless, Cantor et al. (1998) further speculate that these differences should not vary by sex if this were the case. There is still no satisfactory explanation for these inconsistencies.

Hence, toxicologists have defined the chlorinated disinfection byproducts and cancer issue as one in which the evidence does not support a definitive association; thus byproducts do not as yet pose a significant health risk. Epidemiologists recognize that the evidence can only demonstrate a statistically significant association between THMs and bladder cancer but that such evidence remains equivocal. However, the reason government scientists and regulators have been prompted to pursue the issue through the Workshop report, the Chlorinated Disinfection Byproducts Task Group and the revisiting of the drinking water guidelines, has been due to the strength of some of these epidemiological studies

and new studies relating to the possible reproductive risks. Nevertheless, the government scientists in the Drinking Water section largely define the issue as one in which 'we want to keep the disinfection byproduct guideline levels as low as possible without compromising public health due to increased microbial risk'. For these scientists, the evidence does not have to be unequivocal before justifying regulatory action, but the primary concern is protecting the water supply such that the public is not exposed to microbial risk while at the same time minimizing the risks from the disinfection byproducts. Hence, any guideline recommendations must keep that primary concern at the forefront.

3.5.2 The Interface with the Public

The way in which the scientific discourse of the expert panel report was translated into the public domain was through the use of the terms 'possible' vs 'probable'. Sixty percent of the workshop participants, comprised primarily of toxicologists, argued that it was only "possible" that disinfection byproducts 'pose a significant risk' to bladder cancer. For them, the evidence was not sufficiently strong to argue that there was a "probable" risk, as did the remaining participants, largely epidemiologists. These distinctions, possible/probable, stem from definitions used by the International Agency for Research on Cancer (IARC).

Within a scientific audience, 'probable' means that there is 'inadequate' to 'limited' evidence about an association in human-based studies, but that there is 'sufficient' evidence in animal studies. Inadequate evidence of carcinogenicity in

humans means that "the available studies are of insufficient quality, consistency or statistical power to permit a conclusion regarding the presence or absence of a causal association" between exposure and cancer (IARC, 1991:30). By contrast, limited evidence means that a positive association has been found, but for which "chance, bias or confounding could not be ruled out with reasonable confidence" (Ibid.). Sufficient evidence in animals means that a "causal relationship has been established between the agent or mixture and an increased incidence of malignant neoplasms [or combined malignant and benign neoplasms in two or more animal species or independent studies]" (Ibid.). Nonetheless, when there is limited or inadequate evidence in humans but sufficient evidence in experimental animals, it is believed that there is strong evidence some mechanism which mediates carcinogenesis in animals also operates in humans. Similarly, the evidence of 'possible' holds the same range for humans, from 'inadequate' to 'limited', but where the range of evidence of carcinogenicity in animal based studies varies from 'inadequate' to 'less than sufficient' to 'sufficient' depending on the supporting evidence from other relevant data (IARC, 1991).

Yet, probable and possible are used heuristically in very different manners within the public domain. Probable means near certainty, and possible means very likely to lay audiences (Eyles and Elliott, 2000; National Institute of Environmental Health Sciences, 1998). Though the probable/possible distinction is never dealt with explicitly, both Margolis (1996) and Shrader-Frechette (1991) argue that the lay-public frequently associates different interpretations to issues of risk than do experts.

3.5.3 Role of Science

Another issue revolves around the distinction between pure and applied science. While neither toxicologists nor epidemiologists would argue that there is a cause and effect relationship with byproducts and cancer outcomes, epidemiologists have attached a stronger assessment to the evidence by arguing that there is a "probable" risk. Moreover, Wigle argues that "science is the search for truth", but that in situations of public health, risk managers (bureaucrats and politicians) do not have the luxury of waiting around for evidentiary certainty before acting (Wigle, pers. com.). Consequently, while an epidemiologist may not be able to prove causation, a public health scientist could conclude that on the basis of the evidence available that some proactive or preventative measure be taken. Consequently, the role of science in policy decisions, or more broadly speaking, the roles of the risk assessors and the risk managers, becomes a struggle over ideas (Stone, 1997), especially those pertaining to actions based on proof or prudence. The DWS sets the drinking water guidelines based on the risk assessments that are conducted, and it is up to the provinces to determine which of those guidelines will be adopted and to what level. Further, there are issues around the application and organization of science and scientific activity.

Yet the Drinking Water section of Health Canada has not been included in some of the activities of the Laboratory Centre for Disease Control (LCDC). In theory, other sections of Health Canada wanting to look at drinking water would include the Drinking Water section in their activities. While the Environmental

Health Directorate (of which the Drinking Water section sits) was involved in the expert panel report, it had no involvement with the Marrett and King (1995) study until it was almost complete. The Marrett and King study was funded by Health Canada, through the Great Lakes Health Effects Program, and supported by LCDC. The Drinking Water section was not involved in the design of the study. Had they been, they would have requested the inclusion of additional information (e.g. some questions in the survey portion of the study to measure different aspects of water consumption habits, such as boiled water products). Nonetheless, the Drinking Water section was involved in the final draft of the Marrett and King study in order to prepare the communication of the results to the Federal-Provincial Subcommittee on Drinking Water (Giddings, pers. com.). The Drinking Water program also had to respond to numerous media requests (print, TV, radio) for information/clarification (Giddings, pers. com.). Given the pivotal nature of the Marrett and King study in 'tipping' this issue, it is important to note that the Drinking Water section was only involved in these ways, especially given the need to make recommendations to the Federal-Provincial Subcommittee on Drinking Water, and the section's mandate to monitor the scientific evidence on water quality issues.

3.6 Conclusion

Given that the issue of disinfection byproducts and cancer is currently unfolding, it is difficult to speculate what may 'tip' the issue in terms of future policy

directions. Nonetheless, some general conclusions can be made with respect to this paper's research objective concerning the role of scientific evidence in the policy process, at least within the context of the disinfection byproducts and cancer issue in Canada. In one respect, it is government science, not policy, that is presently driving the issue. It was a government-funded scientific study which prompted some individuals at LCDC to convene a panel of leading experts in toxicology, epidemiology, risk assessment, and reproductive effects to study the issue of byproducts, primarily THMs, and human health risks. It was also the concern over the scientific evidence that came out of that workshop that prompted Dr. Wigle to express his opinion on the issue, even though it was interpreted as an official position by the media. However, it was because of that position paper that Health Canada responded to the issue politically by establishing the Chlorinated Disinfection Byproducts Task Group with a mandate to make recommendations to the Federal-Provincial Subcommittee on Drinking Water. Even so, the Drinking Water section would have eventually brought this issue to the DWS, where the timing may have been the same as it currently stands, but where there would not be the same push. The Task Group was expected to complete its assessment and make recommendations to the DWS in 2000 (www.hc-sc.gc.ca/ehp/ehd/bch/water-quality/chlorinated_water.htm), though in reality this may not happen until 2001-2002.

Moreover, no one outside of the Drinking Water section (largely because it is their primary responsibility) would rank disinfection byproducts among the top

three public health concerns. Within Health Canada, smoking is one of the most important public health issues. Air quality issues also typically outrank drinking water concerns. And yet, an entire Task Group has been established to deal with the byproducts issue, although there is no guarantee that once the process is over that THM guidelines will be changed. Though several working groups have been established in Health Canada, none have been as complicated or as extensive of the CDBP Task Group (Giddings, pers.com.). Despite this, it has afforded the Drinking Water section a 'policy window' (Stone, 1997; Kingdon, 1995) with respect to setting a guideline for HAAs; a 'window' which likely would not have been opened without the THM debate.

The factor which may have the greatest influence in shaping or 'tipping' this issue may be the evidence for reproductive and developmental effects. Currently, the evidence is still very limited, though many studies have been initiated. It may not be long before there is stronger evidence which can demonstrate a relationship between disinfection byproducts and reproductive and developmental effects because the latency period between exposure and outcome is much shorter than that required for cancer studies. If there were sufficient evidence regarding reproductive and developmental risks, this could 'tip' the issue far more effectively than would the cancer risks. Reproductive and developmental health risks would be classified as an acute problem by Health Canada. By contrast, cancer is viewed as a chronic disease by Health Canada. Acute risks are always weighed more heavily than chronic risks because the latency period is

typically much shorter. It is a recognized fact that the protection chlorine disinfection has afforded with respect to microbial risks far outweighs the small increase in the relative risk of certain cancer types over an exposure period of 35 years or more to a particular water supply. For the public, such distinctions are not meaningful. Cancer is viewed as such a 'dread disease' that the public may fear that their relative risk for cancer may increase with consumption of chlorinated drinking water. Water is a necessity of life. These risks are not viewed as voluntary, even if the risk is extremely small (and to date, not even conclusively proven). Yet public concerns regarding future questions may also be important in emerging public and policy attention (see Eyles et al., 1993; Baxter et al., 1999).

In this issue, it is the scientific evidence which has been shaping the agenda. Thus, the story still remains one of control. The over-arching concern is that we need disinfection to protect against 'certain' death. The small relative risk of bladder, colon and rectal cancers still remain largely defined in terms of a 'private misfortune' as opposed to a major 'public health concern'. These distinctions are keeping the playing field within the hands of the scientific experts. In the meantime, the issue remains for policymakers to determine if the guidelines need revisiting. This is complicated by the fact that some scientists doubt whether THMs are really the bad actor that they seem to have been cast. Right now, only time, more scientific studies and political discourse will tell.

CHAPTER FOUR

Drawing the battle lines: Tracing the 'science war' in the construction of the chloroform and human health risks debate

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Abstract

Within the United States, the Environmental Protection Agency (EPA) and the Chlorine Chemistry Council, the Chemical Manufacturers Association, and others have been embroiled in a legal battle over the EPA's 'reversal' regarding the scientific assessment of chloroform's carcinogenicity. This arose during the EPA's November 1998 promulgation of a Maximum Contaminant Level Goal for chloroform in the Stage 1 Final Rules for Disinfectants and Disinfection Byproducts. In this paper we adopt a claimsmaking approach to trace the development and current outcomes of the judicial battle, or what we refer to as a 'science-war', over chloroform in the US. This 'science-war' (Chlorine Chemistry Council et al., v. EPA et al.,) took place in the US Court of Appeals for the District of Columbia Circuit. The scientific 'authority' in the construction of scientific claims in this dispute is based on the International Life Sciences Institute expert panel report on chloroform. Examining these 'science-wars' is important because they signal critical shifts in science-policy agendas. The regulatory outcome of the chloroform 'science-war' in the US has the potential to influence the construction and acceptance of scientific claims in Canada, and hence the Canadian regulatory framework. In this challenge, we argue that the various actors involved constructed 'boundaries' around accepted and credible scientific claims.

Keywords: scientific claimsmaking, chloroform, US EPA, chlorine

4.0 Introduction

Uncertainty is a fact of life. Most things that surround us — nature, technology, knowledge and risks — are characterized by uncertain and unpredictable outcomes. Chaos theory argues that there is little to no order in many relationships, making forecasting extremely difficult (Gleick, 1988). Science is one of the means employed to bring a semblance of order to chaos, an attempt to understand what seems unknown. For decades, science has been highly regarded as an epistemic authority (Gieryn, 1999). Advances in science and technology have made it possible for society to enjoy a much higher quality of life. Specifically, advances in medical science have found cures for some diseases (Le Fanu, 1999), enabled scientists (toxicologists and epidemiologists) to conduct risk assessments to measure potential health outcomes associated with particular exposures (Harris, 1992), and overall, have led to greater improvements in health. This has not come without a price.

Beck (1992) argues that we live in a 'risk society'. Risk society is a social theory that builds on historical processes to explain both current and potential future conditions. It serves as a critique against a strong faith in the rationality of science and experts to solve potential technological or environmental crises. Scientists have often been the experts that policymakers, the media and the public have turned to in determining the nature of environmental risk exposures and health outcomes. In fact, it has been science's underlying principles of objectivity and the search for truth that have secured the role of science as a knowledge

producer (Latour, 1987). However, the hegemony of science is being challenged by a distrustful public (see Brown and Mikkelson 1990; Edelstein, 1988).

Within the United States, the Environmental Protection Agency (EPA) and the Chlorine Chemistry Council, the Chemical Manufacturers Association, and others have been embroiled in a legal battle over the EPA's 'reversal' regarding the scientific assessment of chloroform's carcinogenicity. This arose during the EPA's November 1998 promulgation of Disinfectant/Disinfection Byproducts Rules (US EPA 1998a) mandated under the 1996 amendments to the *Safe Drinking Water Act*. A chlorinated disinfection byproduct is formed by the reaction of chlorine, used in the disinfection of water supplies, with naturally occurring organic material present in raw water supplies. While several halogenated and non-halogenated compounds (see Mills et al., 1998: 92) are formed, the ones most studied for potential human health risks are trihalomethanes. Trihalomethanes form a group of four halogenated byproducts: chloroform, bromodichloromethane, dibromochloromethane, and bromoform. The issue of dispute concerns the level the EPA set for a non-enforceable Maximum Contaminant Level Goal for chloroform. Given that chloroform is classified as a probable human carcinogen, regulatory changes regarding this chemical byproduct are likely to attract the attention of environmental groups, and hence the public.

In this paper, we trace the development and current outcome of the legislative and judicial battle, or what we refer to as a 'science-war', over chloroform in the United States. Examining these 'science-wars' is important

because they signal critical shifts in science-policy agendas. Chlorine is hailed as providing the single largest public health benefit in the disinfection of drinking water supplies (Mills et al., 1998). However, there has been some evidence demonstrating a statistically significant association between chlorinated disinfection byproducts and bladder cancer (IARC, 1991; Morris et al., 1992; Mills et al., 1998). For other health effects associated with disinfection byproducts, including colon and rectal cancers and adverse reproductive developmental outcomes, the evidence is even more equivocal than that for bladder cancer. Government agencies are evaluating this evidence in both the United States and Canada to determine if changes need to be made with respect to drinking water regulations in order to protect public health. The regulatory outcome of the chloroform 'science-war' in the United States has the potential to influence the construction and acceptance of scientific claims in Canada, and hence the Canadian regulatory framework. Consequently, this issue warrants considerable attention. After outlining our theoretical and methodological framework, we will present the chloroform science-war and its current status.

4.1 Theoretical Framework

Beck (1992) argues that the risk society is merely one potential outcome, from any number of possibilities, to emerge from a 'reflexive modernization'. This reflexive modernity is characterized by the globalization of risks and technological hazards, where no one is 'safe'. In this modernity, science and

technology play pivotal roles in assessing and diagnosing these hazards. Here the power of science is considerable, as science is in a position to construct and define the nature of risks. However, due to the nature of scientific uncertainty owing to data limitations, difficulties in demonstrating cause and effect relationships and in measuring exposures and human health outcomes, the public has become less deferential to expert opinion on the nature of risks. In fact, the monopoly of science has been fractured in that many 'outsiders' adopt scientific tools to advance their claims (e.g. popular epidemiology, hiring of own experts, etc.).

It is because of this rise in competing 'sciences' that boundary-work becomes critical within the scientific domain. Gieryn (1999) adopts a cartographic metaphor to outline his concept of boundary-work, where researchers need to look beyond the construction of 'facts' or 'evidence' from laboratory studies to their 'consumption' in a social world. Here, 'science' becomes "a space on maps of culture" where these maps 'locate' science vis-a-vis non-science. In establishing itself as an 'epistemic authority' (Haas, 1992), a power granted by those who accept science as an objective purveyor of truth, science is afforded with "the legitimate power to define, describe and explain bounded domains of reality" (Gieryn, 1999: 1). In boundary-work, it is the credibility of scientific arguments that are defined, where each 'side' seeks to demonstrate that its claims are valid while the others are not. In credibility contests, scientific facts do not move "naked from the laboratory or scientific journals into courtrooms, boardrooms, newsrooms or living rooms...they are clothed in elaborate *representations* of

science" (Gieryn, 1999: 4, emphasis in original). It is these representations that provide the grounds for why science is the best 'provider' of knowledge.

However, as Golinski (1998: 6) contends, scientific knowledge is a "human creation made with available material and cultural resources, rather than the revelation of a natural order that is pre-given and independent of human action." Thus while the explicit goal of science is the "pursuit of knowledge for its own sake" (Howard, 1988: 92), it is also inherently political (Cozzens and Woodhouse, 1995). The contest of identifying a 'risk' is the result of definitional struggles between various specialties/interests based on their own standards of rationality (Beck, 1992). Hence, science cannot be treated unproblematically; that is, science is not merely a representation of facts or method, but rather should be treated as a heterogenous collection of institutions, knowledge and interpretation which is open to negotiation with other social institutions and forms of knowledge (Irwin and Wynne, 1996).

As Latour (1987) argues, the best approach to examine these credibility claims is not to examine 'ready made science' once all contests have been largely resolved, but rather to examine 'science in the making' as various claims are constructed and debated. It is during these constructions of 'facts' that competing hypotheses or approaches may abound. Hence the fate of claims lies in their reception and later use by others, or what Latour refers to as the 'modalities' of claims. These modalities serve to transform earlier literature, or evidence statements from previous studies to support a particular scientific argument. The

way to deconstruct scientific arguments is to examine how texts have been written. Scientists/writers seek to anticipate all the arguments that could be raised against their claims and they seek to position their claims against these arguments to show where they do not hold.

While the underlying conceptual framework in this research emphasizes the social construction of scientific knowledge and knowledge assessment, there is an equally important need to understand how assessments are made about the nature of risk. Kaplan and Garrick (1981) view risk as a set of hazardous scenarios, where the likelihood of an outcome coupled with a set of consequences is considered. Within such a definition, a series of judgements are required: what is the time frame over which risks will be considered; what scenarios will be included; and what measures can be implemented to mitigate the risks. Consequently, risks cannot be well represented by a single number nor ranked strictly on objective grounds. Moreover, Hrudey (1996) argues that risks cannot be viewed as 'real' because they are based on inferences and subjective interpretation. In other words, the way in which we view *risk* is dependent on how the issue is constructed or framed, what kind of evidence is used to support the claim, and the level of acceptance or credibility we attach to the issue, or the social context. Hence this paper is informed by a social construction of risk framework.

4.2 Methodology

4.2.1 Claimsmaking and Narrative Analysis: Conceptual Approach

Primarily we present a study of scientific claimsmaking. In issue framing (Gamson, 1992) and claimsmaking (Hannigan, 1995; Best, 1995) the way in which an issue is presented provides a critical feature of how it is defined and played out (Stone, 1997; Kingdon, 1995). Given that science is typically granted special features as an epistemic authority, with the power to define, describe and explain reality, science stands "metonymically for credibility, for legitimate knowledge, for reliable and useful predictions, for a trustable reality: it commands assent in public debate" (Gieryn, 1999: 1). When particular knowledge claims are made in science and brought into the public and policy domains through science, they have tended to be accepted without contest. Yet, this is a problematic process. In ambivalent, equivocal or controversial situations, claims may be contested, in that more than one claim likely exists in a particular policy, or as we also argue, in the science domain (Stone, 1997). In this domain, power exists through the knowledge claims of some but denied to others (Gieryn, 1999), where attempts are made to criticize the scientific basis of the claims of others (Sabatier, 1987).

Thus, just as the construction of claims is an important feature in claimsmaking activities, so too is the role of counter-claims. Counter-claims are those statements or messages which run contrary to the dominant claims (Best, 1995). They provide a different frame on the issue and can be instrumental in the

(re)construction of the issue. Similarly, analyzing the role of the claimsmaker can help assess issues of credibility. The source of the message or claim can play a pivotal role in gaining an audience's acceptance (Hannigan, 1995). Identifying which groups are structuring the claims, what their affiliations are, and with whom they have connections, helps pinpoint the rhetoric used. The source also lends authority to the claim (Ibarra and Kitsuse, 1993; Best, 1995).

Toulmin (1958) examines the pattern of an argument through the construction of claims. The claim or *conclusion* is established on the foundation of the facts or *data* that are presented. An example drawn from Toulmin is: Harry was born in Bermuda (data), therefore Harry is a British subject (conclusion). Such an argument can be challenged, but simply offering additional facts may not persuade the challenger. Hence, *warrants* are utilized to provide justification or supporting statements which allow individuals to accept the data both as starting points and as a legitimate step towards the claim or conclusion. To extend Toulmin's original example, a warrant to justify the claim that 'Harry is a British subject' would be that 'A person born in Bermuda will be a British subject'. The distinction Toulmin draws between data and warrants is that data are explicit statements, whereas warrants are made implicitly. Warrants cannot provide justification to the acceptance of claims if the facts themselves are not defendable. Our intention here is not to examine all aspects of Toulmin's argument construction (see Toulmin, 1958), but rather to provide the basis of the analytic framework that has been adopted and modified by others to analyze knowledge claims.

Building on Toulmin's argument, Best (1995: 350) outlines three central questions for analyzing the nature of claims: 'What is being said about the problem?'; 'How is the problem being typified?'; and 'What rhetoric is being used in terms of persuading the audience to accept the situation as it is being defined?'. It is this last question which is often not given sufficient attention. It is primarily through rhetoric or language that we can understand the construction of knowledge claims. There are three aspects to analyzing the rhetoric of claims (Best, 1987). The first, *grounds*, provide the data, the facts, or the examples which frame the issue in a particular light. The second, *warrants*, provide the justification for demanding certain actions be taken. The last, *conclusions*, spell out the action that is required to solve a particular problem. These terms or labels are related to the three original questions identified by Best (1995) in analyzing claims. 'What is being said about the problem' identifies the problem according to an existing set of grounds or facts. 'How is the problem being typified' serves to reveal the warrants. In this context, the justification (or warrants) provides additional support for the interpretation of the 'facts' (or grounds) by the claimsmaker. Thus, we use 'warrants' to identify explicitly the values that underlie the use of particular grounds or facts in particular ways. Last, 'What rhetoric is being used to persuade the audience to accept the situation as it is being defined' identifies which actions (or conclusions) flow from the justification or warrants provided to solve the problem.

It is primarily in the warrants where the greatest challenge lies to any claim. Further, it is here that the values and assumptions of the claimsmaker can be revealed (Stone, 1997; Sabatier, 1987). These values will also shape the type of conclusion or actions recommended to solve a particular problem. Within the context of the case study on chloroform, chlorinated disinfection byproducts and cancer outcomes presented here, the interpretation of the facts in defining the problem and the actions suggested differ according to the values of the claimsmakers. The way in which the warrants are presented is dependent upon the values and assumptions attached to the interpretation of the scientific knowledge claims. Thus, the interpretation of the scientific claims forwarded by the chlorine industry, at least within the chloroform debate - the scientific authority they possess - are judged against the claims of other interested parties.

Extending Best's application of claimsmaking into a scientific discourse, Gieryn (1999) argues that during credibility contests, tacit assumptions of scientific claims can be revealed, especially when scientific boundaries are unclear. Gieryn adopts a cartographic metaphor, to outline the different type of boundary-work that may be present in any given debate. 'Boundary work' refers to the construction of boundaries around what constitutes science vs non-science, or where boundaries are erected to identify where legitimacy is conferred over claims within science itself. In both these instances, what results is a contest between rivals where each side seeks to legitimize their claims through scientific 'facts' or 'evidence' which serve to put boundaries around their claims while

excluding or marginalizing conflicting/contrary claims. Here 'boundaries' are policed, within which all those acting within the boundaries know which norms have to be followed, and what limits exist before certain behaviour/actions/claims are considered transgressions. These practices clearly delineate the 'side' on which one sits, that is, science or non-science, by privileging the membership of who may legitimately 'speak' for that side. For as Hilgartner (2000) argues, credibility is not automatically conferred to a group, rather it is asserted, cultivated and heavily guarded even in the face of opposition. When scientific experts are challenged, the credibility of the challenger is also 'on the line'.

Hence when the epistemic authority of science is challenged, either from non-science or 'popular science', or from within what is considered 'legitimate' science, Gieryn (1999) argues that it is possible to understand how boundary-work or cultural maps are constructed by examining how epistemic authority in 'texts' is discussed and debated. These debates are shaped by their local context and circumstances. Thus, there is a need to examine the players in the debates, their audience, their goals and interests, and finally the arena in which debates take place (i.e., journals, professional meetings, the courts, the legislature, etc.). Last, these interpretive boundaries that are constructed in debates are connected to outcomes, both for attributing or denying the authority of science and for reproducing "the link between "science" and knowledge that is authoritative, credible, reliable and trustworthy" (Gieryn, 1999: 30). While this outlines Gieryn's analytic framework for examining credibility contests, his focus is

largely on examining non-contemporary contests, as opposed to examining current boundary disputes or what he calls 'science-wars'. His rationale was largely to provide the groundwork for examining the application of his framework. Hence its application in the chlorinated disinfection byproducts research may represent one of the few attempts thus far to apply the concept of boundary-work to a current 'science-war'.

4.2.2 Document Selection and Textual Analysis

To derive these elements of claims, we undertook a careful textual analysis of the legal briefs presented to the United States Court of Appeals for the District of Columbia County by both the Petitioners (the Chlorine Chemistry Council, the Chemical Manufacturers Association and others), and the Respondents (the Environmental Protection Agency and others) (D.C. Cir. 2000, Nos. 98-1627, 99-1053 and 99-1056). These legal documents included any and all Amici (i.e., public health scientists; Congressman Tom Bliley) or Intervener (i.e., NRDC) briefs, motions for Voluntary Remand and Vacatur (by the EPA), any pertinent legislative documents through the US *Federal Register* or reports (i.e., Science Advisory Board, 2000; the EPA) relevant to the chloroform issue. We sought to isolate: 1) those elements deriving from science and the claims of scientists (i.e., the facts or grounds); 2) those used to justify problem definition, and, provide the basis of actions (i.e., the warrants) in order to help reveal values and assumptions; and 3) the actions suggested (i.e., conclusions).

Text analysis is utilized in the reconstruction of narratives (Roe, 1994) and in unraveling the construction of claims (Best, 1995). Manning (1987) provides a framework for deriving these elements from language (i.e., texts and its meaning in specific contexts). Indeed, the focus on language and meaning is utilized to reveal and examine the underlying social context of an issue (Yanow, 1996). Implicit within these approaches is a recognition that the construction of claims does not occur in a vacuum. Claims are shaped and defined by the actors involved (Stone, 1997) and often take the form of written texts (e.g. policy documents, reports, regulations, legislation). These written texts or claims assert their authority on issues through language (Iannantuono and Eyles, 1997), particularly scientific argument (Driedger and Eyles, 2001a); not so much in what they say, but in what they represent (Yanow, 1993). The use of language serves to make visible 'symbolic representations' (Stone, 1997) or 'signs' (Manning, 1987). However, the meaning attached to symbols or signs are not intrinsic properties. They gain meaning through their construction and reconstruction (Berger and Luckmann, 1966) in terms of their interpretation and use (Stone, 1997). Yet, there are often multiple meanings involved. Yanow (1993: 47) writes: "meaning is not universal or determinate; it depends on the context and on the perception and interpretation of the participants." This becomes critical within environmental health policy debates because the key elements are issues of interpretation, not facts (Dunn, 1981), that is, the grounds seen in relation to the warrants. Hence, revealing the claims through their construction, (scientific) narratives or arguments, is the fundamental characteristic of our approach.

4.3 The Chloroform Science-War

4.3.1 Background Issues

To understand the issues that are to be presented, it is first necessary to be aware of some background issues, including a timeline of events. The issue of this 'science-war' concerns a dispute over what constitutes a 'safe' exposure to chloroform. The *Safe Drinking Water Act* (SDWA) requires the Environmental Protection Agency (EPA) to regulate drinking water contaminants which may have adverse public health outcomes. The EPA adopts a two-step process in promulgating drinking water standards. The first is to establish a Maximum Contaminant Level Goal (MCLG). Contaminant MCLGs are to be "set at the level at which no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety" (SDWA, 1996, 42 U.S.C. § 300g-1(b)(4)(A)). These MCLGs are science-based risk assessments of contaminants. Following this, enforceable Maximum Contaminant Levels (MCLs) are promulgated as close to the MCLG as is feasible. These MCLs are viewed as a risk management decision. The MCLG serves as the 'objective' benchmark against which non-scientific considerations such as costs and available technology are incorporated in standards setting.

The events surrounding this legislative and judicial battle between the chlorine industry, in general, and the EPA are outlined in Table 4.1. The key moments in this timeline stem from the 1994 proposed MCLG for chloroform that the EPA originally set at zero (US EPA, 1994). Involved in this process was the

Table 4.1: Timeline of events surrounding chloroform science-war

Year	Activity Event
1974	Public Health Service Act amended to include Safe Drinking Water Act (SDWA)
1986	Cancer Guidelines for Carcinogen Risk Assessment - adopts default assumption of zero for all MCLGs of known or probable carcinogens
1994	Proposed MCLG Rule for Chloroform - set at zero by EPA
1996	Proposed Guidelines for Carcinogen Risk Assessment released to replace 1986 Guidelines - still awaiting final approval
1996	SDWA amended to include a requirement that the Agency use the "best available, peer-reviewed science and supporting studies conducted in accordance with sound and objective scientific practices" (42 U.S.C. § 300g-1(b)(3)(A))
1997	Notice of Data Availability (NODA) recognizing new data on chloroform and invites public comment on the regulatory implications stemming from this data (62 Fed. Reg. at 59,387)
1997	International Life Sciences Institute (ILSI) Expert Panel Report on carcinogenic risk assessment of chloroform and dichloroacetate released
1998	
March	New NODA which is much more comprehensive than the 1997 NODA is released which evaluates and summarizes the new health effects of chloroform and proposes a MCLG of 300 $\mu g/L$ for chloroform
Nov.	EPA promulgates Final Rule of a zero level MCLG for chloroform as part of the Stage 1 Disinfectants and Disinfection Byproducts Rule (EPA 815-F-98-009) mandated by SDWA 1996 Amendments
	Health Risk Assessment/Characterization of the Drinking Water Disinfect Byproduct Chloroform, EPA document released
1999	
July	Chlorine Chemistry Council, the Chemical Manufacturers Association and others (Petitioners) file a petition with the US Court of Appeals for the District of Columbia Circuit against the EPA for not using "best available science" in promulgating a final rule
	Amici briefs prepared respectively by Tom Bliley, Congressman and 13 Public Health Scientists in favor of Petitioners
Sept.	EPA submits its 'Response' to Petitioners Review
Oct.	Science Advisory Board (SAB) meets to review Draft Chloroform Risk Assessment report prepared in 1998
Dec.	EPA files with Court motion for 'Voluntary Remand' of the MCLG for chloroform for further consideration and explanation (i.e., to better explain their position for setting zero MCLG for chloroform)
2000	
Feb. 11	Oral arguments heard by Petitioners and Respondents in Court
Feb. 24	EPA motion for Vacatur following oral arguments in Court
Mar. 8	Petitioners opposition to EPA motion for Vacatur
Mar. 31	Court decision on original position rendered with EPA request for Vacatur denied
April	SAB Review of Chloroform Risk Assessment submitted to Administration of EPA

need to assess chloroform's carcinogenicity. On the basis of animal studies, it was determined that there was sufficient evidence to classify chloroform as a 'probable human carcinogen'. As per the 1986 *Cancer Guidelines for Carcinogen Risk Assessment* (US EPA, 1986) a default assumption is adopted which legislatively sets MCLGs at zero for known or probable carcinogens. This is commonly referred to as a linear model which assumes there is no safe threshold or no safe level of exposure. Key features of this default assumption are that carcinogens are assumed to be genotoxic, which means that exposure to the contaminant can act directly on the DNA of cells. Hence, when there is insufficient scientific understanding to the contrary about a contaminant's mode of action (i.e., promoter or initiator), it is assumed that there is no safe dose. The risk assessment characterization of chloroform has been firmly based on the linear model, until recently.

With the 1996 SDWA amendments, a requirement was included that the EPA must use "the best available, peer-reviewed science and supporting studies conducted in accordance with sound and objective scientific practices" (SDWA, 1996, 42 U.S.C. § 300g-1(b)(3)(A)). Also in 1996, the EPA published a set of *Proposed Guidelines for Carcinogen Risk Assessment* (US EPA, 1996) which were to replace the 1986 Guidelines. The 1996 Proposed Guidelines are still awaiting final approval (as of June 2001). One of the key differences between the 1986 and 1996 Guidelines is the default assumption. The 1996 Proposed Guidelines are intended to allow for a deviation from the 1986 default assumption

that all MCLGs should be set at zero for contaminants classified as known or probable carcinogens. The 1996 Proposed Guidelines forwards a default assumption allowing for the consideration of both a linear model (i.e., no safe dose) and a non-linear model (i.e., below a certain exposure level there are no human health risks) of cancer risk to be used when sufficient scientific evidence supports a non-zero level to be calculated. This non-linear model is also frequently referred to as a threshold model.

From 1994 to 1997, over 30 animal-based scientific studies had been conducted examining the carcinogenicity and mode of action of chloroform. These studies were compiled and evaluated by the International Life Sciences Institute (ILSI) as part of a multi-sponsored expert panel, including sponsorship from the EPA, the Health and Environmental Sciences Institute (a branch of ILSI), the Chlorine Chemistry Council, the Chlorine Institute and others. The expert panel report produced by ILSI (1997), was hailed by many scientists and the chlorine industry in general, as a 'blue ribbon' report (Petitioners Brief, 1999). This Expert Panel report was further subjected to peer-review, although not all three peer-reviewers were satisfied with the conclusions reached in the report. (We will return to this issue later.) The purpose of this ILSI report was to evaluate the EPA's 1996 *Proposed Guidelines for Carcinogen Risk Assessment* using chloroform and dichloroacetate as case studies. The report's overall conclusion with respect to chloroform was that its risk assessment characterization should be based on a threshold model (i.e., a non-zero MCLG level), a feature afforded by the 1996 proposed Guidelines.

As part of the 1996 SDWA Amendments, the EPA is also required to provide the public with a Notice of Data Availability (NODA) document on its website which evaluates scientific evidence concerning particular outcomes or exposures for comment when substantial new data are present. Any member of the public is invited to provide written comments regarding the content of the NODA, and the EPA is responsible for addressing those comments and concerns when promulgating rules. These NODA serve as an intermediate step between risk assessment and risk management decisions in that the public, including members of the scientific community, are aware of how issues are considered and at what proposed levels contaminants may be set at some future date. In both 1997 and 1998 (March), the EPA put out NODAs for chloroform. The 1997 NODA identified the recognition of new data on chloroform and invited public comment on the regulatory implications that may stem from this data (US EPA, 1997). The 1998 NODA was much more comprehensive than the 1997 NODA, and incorporated the evidence from the 1997 ILSI report. The 1998 NODA evaluated and summarized the new health effects and cancer risk characterization of chloroform and proposed a MCLG for chloroform at 300 μg/L. However, in the EPA's Final Rule released in November 1998, the MCLG for chloroform was set at zero, representing a return to the 1986 Guideline default assumption of a no-safe level. In July of 1999, the Chlorine Chemistry Council, the Chemical Manufacturers, and others (hereafter referred to as the Petitioners) filed suit in the US Court of Appeals for the District of Columbia Circuit.

4.3.2 The Claims: The Chlorine Industry

As the Petitioners sought judicial redress against the actions of the EPA in setting a zero MCLG for chloroform, it is their arguments that will be first constructed followed by the competing claims raised by the EPA and others. Table 4.2 outlines the dominant claims of the Petitioners. The way in which the 'grounds' of the Petitioners is constructed is very important. The default assumption that will be used in assessing chloroform's cancer risk to humans hinges on whether or not chloroform's mode of action is characterized as genotoxic or cytotoxic. As indicated earlier, genotoxicity identifies a situation in which the DNA of a cell is mutated leading to tumour growth and cancer from exposure to a contaminant. By contrast, some carcinogens are not genotoxic, rather they are cytotoxic. Cytotoxicity indicates that there is a level below which exposure to a contaminant is safe; that is, a threshold exists. However, when exposed to a contaminant above a certain level, that contaminant becomes toxic to cells, which can themselves mutate into cancer. Hence, if it is scientifically accepted that chloroform's mode of action is cytotoxic, then a threshold level of risk characterization is permitted.

The evidence used to support the hypothesis that chloroform is cytotoxic stems from the ILSI 1997 panel report. The membership of the ILSI panel on this issue comprised ten scientists from academia, the government, and the private sector. While the membership consisted of primarily American representatives, a representative from Health Canada was also included in the panel. The participation of Health Canada was to help ensure that the conclusions reached by

Table 4.2: Summary of the Petitioners Claims and Supporting Evidence

The Claims	The Evidence
Grounds	
Chloroform's mode of action is cytotoxic not genotoxic where cytotoxicity does not affect DNA below a certain dose	ILSI 1997 Expert Panel report
Warrants	
The EPA is mandated to use "best available" science	1996 SDWA Amendments
EPA ignored its own science conclusions	63 Fed. Reg. at 15,685 (US EPA, 1998b)
	EPA 1998 Health Risk Assessment/Characterization of the Drinking Water Disinfectant Byproduct Chloroform
Default assumption adopted by EPA inappropriate in this case	1986 and proposed 1996 default assumption is only to apply to situations where there is insufficient scientific understanding of the mode of action - SDWA 1996 Amendments
Conclusions	
Chloroform shows a threshold for cancer risk assessment	The scientific evidence from the ILSI 1997 report, EPA's own scientists in its 1998 Health Risk Assessment/Characterization report, and the legal mandate of the 1996 SDWA
Chloroform should have a MCLG level set at a non-zero threshold	

the ILSI expert panel would be accepted as relevant within a Canadian regulatory framing.

Bringing in a mixed membership of scientists was key in order to add credibility to the conclusions reached in the report. Having scientists from academia, the government and the private sector participate in evaluating the scientific evidence, at least removes the 'aura' of impropriety where one group's agenda of facilitating a particular outcome would be less likely to override the larger agenda of advancing scientific 'truth'. This is not to imply 'nefarious' motives on the part of scientists. However, perception is often reality (Berger and Luckmann, 1962). In order to maintain credibility as purveyors of an 'objective' truth (Stone, 1997; Gieryn, 1999; Beck, 1992), scientists, especially when participating on expert panels, must be above reproach. For example, while some may rightly or wrongly question the agenda of an individual scientist who is on an industry payroll, there may be fewer concerns if the opinions of that same industry scientist is subject to review by a group of scientists who may not care if their overall evaluation negatively or positively affects industry. Their overall goal is to cultivate and maintain the cultural authority of science through the search for 'truth'. In fact, demonstrating their own understanding of ensuring credibility to the process, the ILSI report states: "consideration was given to representing government, industrial and academic sectors and a range of scientific viewpoints among the membership of the Expert Panel *to ensure a balanced and objective work product*" (ILSI, 1997: BG-2, emphasis added).

Moreover, given that the ILSI report was financially supported by both the chlorine industry in general, and the EPA in particular, demonstrates a shared partnership in the outcome. Here, while both have an interest in the outcome, presumably their interests differ and it will be 'scientific truth' that will prevail. This is particularly relevant when scientists from various backgrounds are brought together. Because of a growing public distrust of science, it is necessary for expert panels to be broadly based. Government and industry representatives (including scientists) are not always viewed as 'credible' spokespersons when a great deal of uncertainty governs an issue, especially in the area of environmental exposures and potentially adverse health outcomes. While the 'authority' and abilities of an academic scientist may be no better or worse than a government or industry scientist, academic scientists tend to be viewed more favourably as 'neutral' experts in that they do not appear to be serving any outside interest (i.e., political or profit motives); at least not explicitly. We will return to these issues in our discussion.

The Charge to the ILSI Panel was to review the available database for chloroform's and dichloroacetate's carcinogenicity using the guidance from the 1996 Proposed Guidelines for Carcinogen Risk Assessment to "make recommendations regarding appropriate approaches for assessing the potential carcinogenic risk of these two compounds" (ILSI, 1997: BG-5). Chloroform and dichloroacetate were chosen as important case studies to serve as test cases for evaluating EPA's 1996 Proposed Guidelines because they would be tested against

both the linear (i.e., non-threshold) and non-linear (i.e., threshold) models of risk characterization. As of 1996, there was no quantitative risk assessment for dichloroacetate, and chloroform's risk assessment relied on the linear extrapolation of rodent tumour data. The relevance of these two compounds lie in their representation as surrogate markers for the occurrence of the primary groups of disinfection byproducts from water chlorination: trihalomethanes (chloroform) and haloacetic acids (dichloroacetate). However, for our purposes, we will only be examining the ILSI panel report conclusions with respect to chloroform.

The conclusions reached by the ILSI panel were that chloroform acts through a cytotoxic mode of action, and not a genotoxic mechanism. In other words, chloroform shows a non-linear dose-response relationship where it can be extrapolated that below a certain level, there are no adverse human health effects. The ILSI panel state: "the Panel was *unanimous* in asserting that the preponderance of evidence with chloroform strongly supported a nonlinear mode of action and a margin of exposure assessment" (ILSI, 1997: ES-9, emphasis added). This unanimity among Panel members is key to ensure that its scientific conclusions are credibly received by the broader scientific, and presumably regulatory, community. The agreement of this mixed scientific membership of academic, government and industry scientists, serves to champion the role of science as a legitimate purveyor of truth and objectivity. The underlying message is that the strategies, when employed, can help to ensure that careful attention to the scientific principles of objectivity can override the potentially 'self-motivated' individual agenda-interests of a few.

These efforts to preserve the reputation of science as an epistemic authority, especially among those who participate in expert panels, ties in with the 'warrants' used in the argument. The warrant of the Petitioners was that the EPA is mandated by law to use the "best available" science. The Petitioners further argued that by ignoring its own scientific conclusions contained in their 1997 and 1998 NODAs and by returning to a default assumption of a 'no safe dose', the EPA was not following the "best available" science. The "best available" science is contained within the ILSI (1997) report. The *expert* opinion reached by the panel scientists was that chloroform acts through a cytotoxic mode of action, and thus demonstrates a threshold. Therefore, EPA's return to a zero MCLG defies these scientific truths. The underlying values of these warrants are grounded in the rationality and objectivity of science as the purveyor of truth. Embedded within this value perspective is that 'good science is enough' to influence policy decisions.

Hence, the only 'rational' conclusion to stem from the Petitioners' arguments is grounded within the science itself. The scientific evidence, whose evaluation was agreed upon by the Expert Panel members, demonstrates that chloroform shows a threshold for cancer risk assessment. Consequently, the Court should "direct" the EPA to withdraw its Final Rule MCLG of zero and be made to comply with the legal mandate of the *Safe Drinking Water Act* by applying a non-zero level as supported by the science (Petitioners Brief, 1999: 18).

In support of the Petitioners, two Amici (i.e., 'friends' of one side) also presented briefs to the Court. The first was from Tom Bliley, a Congressman, and the second was from a group of public health scientists. The claims that were constructed in each amicus brief echoed many of the claims argued by Petitioners. In Mr. Bliley's case, he was arguing that the EPA has not always explored 'reputable' contrasting scientific views throughout the regulatory process. He points to a 1992 Expert Panel report on examining the credibility of risk assessment (science) and risk management (policy decisions) in the EPA which states: "EPA Science is perceived by many people, both inside and outside the Agency, to be adjusted to fit policy...where such adjustments could be made consciously or unconsciously by the scientist or decision-makers" (Brief Amicus Curiae, Bliley, 1999: 2). In the chloroform dispute, Mr. Bliley contends that the EPA has ignored the specified criteria of Congress mandated in the 1996 SDWA to use the "best available" science in its decision making. He states that there is an analytic gap between the "relevant and reliable evidence and the Agency's decision" (Brief Amicus Curiae, Bliley, 1999: 7).

The group of thirteen public health scientists supporting the Petitioners also ground their arguments in the EPA's 'failure' to use the best available science. The public health scientists argue that the EPA's use of non-scientific considerations "may have a chilling effect on the use, development and funding of sound science...[as] there will be little incentive to conduct and fund necessary scientific research if researchers and funding entities believe that such work will

be ignored by federal regulatory agencies in their standard setting decisions" (Brief, Amicus Curiae, Public Health Scientists, 1999: 2-3). This 'failure' to incorporate the best available science frustrates the ability to properly balance the risks between microbial pathogens and disease on the one hand if proper disinfection is not followed, and cancer risk to chloroform and other disinfection byproducts via chlorination on the other. Moreover, the way in which the public health scientists characterize the EPA argument is that it overestimated the cancer risk from chloroform, in its promulgation of a zero-level MCLG. They clouded the debate by arguing that the EPA's "incorrect decision about chloroform in drinking water can cause death and disease" (Brief, Amicus Curiae, Public Health Scientists, 1999:3). These scientists are raising concerns about a potential re-creation of the 'Peru incident'. The 'urban legend' of how the cholera outbreak in Peru occurred was that officials decreased the amount of chlorination of their public drinking water supplies, allegedly because of the cancer fear due to disinfection byproducts exposure which resulted in a massive outbreak of cholera. There are disputes over the realities of this 'urban legend'. In order to lay their boundary-work of establishing the threshold-hypothesis as the only logical scientific position, these public health scientists conclude that "EPA's action can lead the public to conclude that science can be accepted or ignored, as the agency pleases. This *fosters distrust* of EPA and *cynicism about* the Agency, *scientists and science*" (Brief, Amicus Curiae, Public Health Scientists, 1999: 6, emphasis added).

4.3.3 The Counterclaims: The position of the EPA and others

The counterclaims of the EPA were not grounded so much in disputing the scientific evidence surrounding chloroform as it was based on due process. The 1996 SDWA set statutory deadlines to be met in promulgating rules for disinfectants and disinfection byproducts. These were divided into two stages, commonly referred to as Stage 1 and Stage 2 Disinfectant/Disinfection Byproduct Rules. The deadline for Stage 1 was to be met in November 1998, and May 2002 for Stage 2 rules. In setting these deadlines there was an implicit understanding that whatever rules were not promulgated in Stage 1 would be promulgated by the Stage 2 deadline. The Act is clear in that the EPA is not allowed to delay the promulgation of final rules by their mandated deadline dates, not even to consult with its Science Advisory Board, which is also a requirement in setting MCLGs. Under the 1996 Act:

> the Administrator shall request comments from the Science Advisory Board...prior to the proposal of a maximum contaminant level goal and national primary drinking water regulation. The Board shall respond, as it deems appropriate, within the time period applicable for promulgation of the national primary drinking water regulation concerned. This subsection shall, under no circumstances, be used to delay final promulgation of any national primary drinking water regulation (SDWA §1412(e), 42 U.S.C. §300g-1(e)).

The term "shall" in legal texts attaches an enforceable requirement within the statute. All of the counterclaims generated by the EPA in its Response to Petitioners hinge on its need to obtain an evaluation of chloroform's carcinogenicity and mode of action as contained in the ILSI report, and its 1998

NODA from its Science Advisory Board, before it felt that it could promulgate a non-zero MCLG on the basis of the "best available" science requirement. However, before the EPA could confer with the Science Advisory Board, it had to first complete a risk assessment characterization of chloroform that would propose a non-zero MCLG level (which was not completed until November 1998) in order to give the Board something on which to comment (US EPA 1998c). Thus, in delaying their risk management decision over what analytic model upon which to base its MCLG, the EPA reasoned that they needed to adopt a MCLG of zero in its 1998 Final Rule as proposed in 1994 as an "interim" measure. This proposed level had been reviewed by the Science Advisory Board.

Hence the construction of their counterclaims are outlined as follows. First, the EPA adopted an MCLG of zero for its 1998 Final Rule as an "interim" action. Second, the EPA was concerned that if it were to adopt a non-zero MCLG, this would represent a deviation from its 25 year legislative history of promulgating zero level MCLGs for known or probable carcinogens. The concern centered around the potential "precedential" effect of such a policy shift and it wanted to be able to consult with its Science Advisory Board in addition to obtaining further public comment. Third, the EPA argued that there was insufficient time to meet with the Science Advisory Board to obtain an evaluation of its scientific conclusions regarding chloroform before the statutory deadline of November 1998. Last, the zero MCLG would not have an impact on compliance obligations of public water systems or the allowable chloroform level in public

water systems as the MCLG is *not* legally enforceable. Only the MCL is an enforceable standard.

It is through the EPA's third argument that the thrust of the counterclaims are found. The EPA published its 1998 NODA in March. The public comments were not completed until June 1998, (and as will become apparent in the discussion of the counterclaims raised by other parties in this dispute, not everyone within the EPA disagreed with the threshold hypothesis). This only left the EPA with roughly five months under which to meet with its Science Advisory Board, allow that Board the opportunity to review and comment on the evidence, as well as carry out its own review of the many other contaminants that were to be considered in time for the 1998 Final Rule in addition to chloroform. Among other things identified in its 1998 NODA, the EPA had to establish MCLGs for dichloroacetic acid, chlorite, and bromate, as well as a Maximum Residual Disinfectant Level Goal for chlorine dioxide (Respondents Brief, 1999a).

Moreover, during the public comment period of the 1998 NODA, the issue was raised that EPA's calculation of a non-zero MCLG did not adequately consider the 'relative source contribution' of chloroform contaminant exposure in drinking water. In addition to ingestion, the public is exposed to other routes of chloroform exposure such as inhalation and dermal exposure. Chloroform is present in treated drinking water, detectable in food, it is ubiquitous in the air (particularly indoor air), and is absorbed through the skin when swimming in a pool or hot tub, or showering (US EPA, 1998c). Within the 1996 SDWA, proper

consideration of the relative source contribution is to ensure an adequate margin of safety as provided by the MCLG (Respondents Brief, 1999a). Public commenters had argued that EPA underestimated the relative source contribution because the EPA based its calculations on the assumption that the majority of public exposure to chloroform would come from drinking water ingestion. Similarly, the EPA had not adequately considered exposure in other subpopulations that may be much more highly exposed than the average person "through the use of humidifiers, hot-tubs, and outdoor misters" (Respondents Brief, 1999a: 31). Hence the EPA had not adequately considered these additional uncertainties in exposure.

Furthermore, the EPA Response (Respondents Brief, 1999a: 35) in their brief to the Court argued that the claims of Petitioners hinged on "a mischaracterization of EPA's actions." The only way the Petitioners could justifiably argue that the EPA was not considering the "best available" science was if the "EPA's statements in the 1998 Notice of Data Availability and the final rule represent EPA's *ultimate* conclusions and findings with respect to chloroform and that EPA has made a "regulatory determination" regarding the best available science relating to chloroform's carcinogenicity" (Respondents Brief, 1999a: 35, emphasis in original). The Petitioners completely disagreed. Before expanding on these issues further, it is necessary to view how the counterclaims of other interested parties were generated.

The Intervener on behalf of the EPA was the Natural Resource Defense Council (NRDC). In the brief presented by the NRDC, the counterclaims were framed both by a concern with due process, but also with respect to evaluating the scientific claims that were under dispute. The legal arguments echo much of what was contained in the EPA counterclaims: the 1996 SDWA mandates that MCLGs be set at zero for known or probable carcinogens, and that the EPA is required to solicit the advice of the Science Advisory Board on any proposed MCLG. A 'new' legal argument raised by the NRDC, but not echoed in the EPA brief, was that the EPA was required to use the 1986 Guidelines for Cancer Risk Assessment in promulgating its Final Rule because the 1996 Proposed Guidelines are not yet approved (as of June 2001).

However, the scientific counterclaims are much more interesting in that they are constructed in a manner that more closely challenges the claims of the Petitioners. The NRDC argued that there is *no scientific consensus* that chloroform exhibits a threshold for cancer risk assessment. The disagreement with the threshold hypothesis was largely two-fold. First, chloroform co-occurs with other disinfection byproducts in chlorinated water supplies. Recall that chloroform is the surrogate marker to measure the presence of a group of disinfection byproducts: trihalomethanes. In drinking water, chloroform is never found in isolation from its other three 'family' compounds. Second, the ILSI 1997 Expert Panel Report failed to include evidence from human epidemiology studies and relevant toxicity evidence of trihalomethanes in general regarding both potential

reproductive and developmental effects in addition to cancer risks. Moreover, the NRDC argue that there are "lingering questions as to whether the mechanisms of carcinogenesis derived from rodent studies is truly understood for humans (especially fetuses and young children)" (Intervener Brief, 1999: 2).

These counterclaims are echoed in public comments on the 1998 NODA which evaluated much of the new evidence on chloroform's carcinogenicity submitted to the EPA. In addition to those raised by the NRDC, these public commenters, including scientists, further argued why they disagreed with the threshold hypothesis. These counterclaims were much more based on the actual scientific conclusions reached. First, there were disputes that the linkage between cytotoxicity (i.e., cell death) followed by regenerative proliferation (i.e., new cell growth) — conclusions reached by the ILSI 1997 report which were incorporated into the 1998 NODA — was not supported by the data. Second, the evidence for genotoxicity (i.e., damage to the DNA of cells) was mixed, and consequently it was impossible to conclude that chloroform had no effect on DNA.

4.3.4 Contested Scientific Claims

One of the strongest opponents[1] to the threshold hypothesis is Dr. Ronald

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[1] Other opponents include Dr. David Rall (former head of the National Institute of Environmental Health Services), Dr. Lorenzo Tomatis (former Director of the World Health Organization International Agency for Cancer Research), Dr. David Ozonoff (Chair of Environmental Health Department at Boston University, and a member of the National Academy of Sciences' Drinking Water Committee), the State of New Jersey's Department of Health and Senior Services, and their

Melnick at the National Institute of Environmental Health Sciences (a branch of the National Institute of Health) who is characterized by the NRDC brief as 'one of the world's leading chloroform researchers'. Dr. Melnick was one of the peer reviewers of the ILSI expert panel report, and also provided public comments to the EPA regarding its 1998 NODA. Dr. Melnick does not feel that the threshold hypothesis has been scientifically proven. He conducted a three-week rodent study examining a hypothesis supported by the ILSI report that "liver carcinogenicity in mice to chloroform exposure is suggested to occur secondary to cytotoxicity as a consequence of regenerative hyperplasia" (Melnick et al., 1998a: 413). In other words, when exposed to very high levels of chloroform, liver cells die, promoting rapid growth of new cells which can become cancerous. However, at low doses, or below a certain threshold, this does not occur.

Given that chloroform is part of a complex mixture (i.e., a family of compounds) in chlorinated disinfection byproducts, Melnick and colleagues wanted to explore how the different trihalomethanes might also help understand the dose-response relationship seen in these chloroform-only studies. They were concerned that complements of this mixture might be carcinogenic in animals at lower doses and/or at other organ sites in the absence regenerative hyperplasia. They found that bromodichloromethane, which is metabolized in a similar fashion to chloroform, and chlorodibromomethane, which is metabolized by a different

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Department of the Environment (Intervener Brief, 1999).

pathway, both showed liver tumours without cytotoxicity. Regenerative hyperplasia acted as a precursor at much lower doses than that used in chloroform-only studies. The overall concern is that if these other disinfection byproducts which co-occur with chloroform cause liver tumours at lower doses and by different pathways than chloroform, then chloroform's carcinogenicity and mode of action as argued by the ILSI report may not adequately interpret all the relevant data. Consequently, there could be "contributions from other metabolic pathways" (Melnick et al., 1998a: 413).

The controversy between the Melnick interpretation of the evidence as compared with the ILSI expert panel is an interesting challenge of science's authority as a knowledge producer. Both the EPA, when addressing public comments related to its 1998 NODA, and the members of the ILSI expert panel disagreed with Melnick's interpretation of the science. In a comment following one of Melnick's papers (Melnick et al., 1998b) written by the ILSI panel members (save one who was unable to sign the letter due to a potential (unnamed) conflict of interest), they argue that to effectively study the issue "two-year study(ies) where interim groups of rodents were euthanized to check for liver necrosis and cell proliferation" would be required (Anderson et al., 1998: 133). The panel points out that Melnick's three-week study with single point measurements is insufficient because it can miss the effects of long term exposure on target organs. Thus, "the data in the Melnick article are inadequate to support the broad conclusions for the entire family of THMs as suggested by its title

[Regenerative hyperplasia is not required for liver tumour induction in female B6C3F1 mice exposed to trihalomethanes]" (Anderson et al., 1998: 134).

Melnick's reply, published following the ILSI Panel members, argues that the ILSI criticism is "ironic" given how extensively ILSI relied on Larson et al's (1994a, 1994b, 1995a) three week study to support the ILSI conclusion about "the obligatory presence of cytotoxicity as a precursor in chloroform's carcinogenicity" (Melnick and Kohn, 1998: 135). Moreover, Melnick argues that his studies "were designed as an extension of the Larson studies on chloroform, [and] used the same dosing protocols in our evaluations of other trihalomethanes" (Ibid.). Furthermore, Melnick and Kohn argue that "one issue lost in this debate is how well the mechanistic interpretations of the animal data reflect human risk" (Ibid.). A key point for Melnick, in challenging the 'accepted' chloroform conclusions, is that the human evidence related to THM exposure has been virtually ignored because epidemiological human-based studies are unable to test exclusively for chloroform exposures.

This leads the NRDC to make an overall conclusion that "there is a deep and fundamental disagreement within the scientific community over what level of chloroform is "safe" and whether it can be said to exhibit a threshold in humans, particularly as part of a complex mixture" (Intervener Brief, 1999:22). All of the opponents to the threshold hypothesis argue that a non-zero MCLG for chloroform in drinking water is inappropriate for several reasons. It contradicts the human epidemiologic evidence regarding trihalomethanes in general and

bladder, colon and rectal cancer sites. It has failed to consider the fact that chloroform is never found alone in drinking water; it always co-occurs with its family of disinfection byproducts. Last, there is a great deal of uncertainty about the validity of extrapolating cancer risk to humans, especially fetuses and young children, from mechanistic data on chloroform's carcinogenicity based solely on rodent data. The overall science-policy counterclaims to be generated as a result of the evidence contained in the ILSI Report and the 1998 NODA are summarized in Table 4.3.

4.4 Discussion and Conclusions

Returning to Gieryn (1999) briefly, to examine 'boundary-work' and the credibility contests that ensue, one must examine how science plays out in local and episodic contests. The key is to examine how science is represented in texts (verbal or written) to see how it privileges or denies epistemic authority. This context is defined by 1) the players and the stakeholders, 2) their goals and interests, and 3) the arena in which they operate. In examining the claims and counterclaims raised by the various parties, several areas of boundary-work become present. Focusing on the boundary-work surrounding the scientific claims exclusively, Table 4.4 outlines a summary of the competing scientific claims of the chlorine industry and the NRDC. In brief, the chlorine industry argued that on the basis of rodent studies on chloroform exposure only, the best available scientific evidence demonstrates a threshold. Implicit within this argument is that

Table 4.3: Summarizing the Science-Policy Counterclaims in the ILSI Report and the 1998 EPA NODA

The Science Counterclaims

- there is insufficient scientific evidence of a threshold for chloroform
- the EPA's threshold assumption is invalid because chloroform co-occurs with mutagenic carcinogens
- the EPA has ignored the human data in establishing an MCLG for chloroform
- the linkage between cytotoxicity and regenerative proliferation is not supported by the data
- the evidence for genotoxicity is mixed and therefore it is not possible to conclude that the evidence demonstrates that chloroform does not have an effect on DNA

The Policy Counterclaims

- a zero MCLG is required to comply with the provisions of the SDWA for known or probable carcinogens, of which chloroform is one
- the EPA was required to use the 1986 Cancer Guidelines and not the 1996 Proposed Guidelines as they are still awaiting approval
- under the 1986 Cancer Guidelines, the MCLG had to be set at zero in the 1998 Final Rule

Table 4.4: The competing scientific claims of the chlorine industry and the NRDC

COMPETING CLAIMS	
The Chlorine Industry	The NRDC
• Rodent studies	• Adult rats are not human kids
• Chloroform exposure only	• Chloroform is never alone in drinking water
• Demonstrates a threshold	• Cannot prove a threshold
• Not likely the 'bad actor'	• Drinking water is a complex mixture, so there may be multiple 'bad actors' when combined

chloroform is not likely viewed as the 'bad actor' that may be contributing to human health risks associated with chlorinated disinfection byproducts. By contrast, the NRDC argue that data from rodent studies are insufficient to extrapolate to humans, that chloroform co-occurs with other disinfection byproducts, and hence the evidence cannot really prove a threshold. Implicit within this argument is that because drinking water is a complex mixture, there may be multiple 'bad actors' involved.

These implicit arguments, or additional warrants, that are made by each side provide clues about how the scientific claims are being interpreted and layered to support their respective conclusions. The claim that 'chloroform is not likely the bad actor' is reductionist. One of the goals of science is to be able to eliminate potentially competing explanations when examining phenomena. Hence, if chloroform could be ruled out as a 'bad actor' or 'not likely the bad actor' efforts could then be directed at other chemical contaminants that may be the 'cause' of adverse health outcomes. The ILSI Expert Panel members, the thirteen public health scientists who supported Petitioners, the scientists within the chlorine industry, the EPA scientists who drafted the 1997 and 1998 NODAs, the 1998 *Health Risk Assessment/Characterization of the Drinking Water Disinfection Byproduct Chloroform* (prepared by the Toxicology Excellence for Risk Assessment under the direction of EPA's Office of Water), and the EPA Science Advisory Board (2000) who evaluated the evidence, all concluded that chloroform is cytotoxic and demonstrates a threshold. In the expert opinion of

these scientists, chloroform does not appear to be the bad actor causing adverse health effects below a certain level. None of these scientific experts believe that the arguments raised by the NRDC, Melnick and others are valid.

The opponents of the threshold hypothesis frame their argument in a much broader scope. For them, the reductionist approach is simply inappropriate when dealing with a complex mixture like disinfection byproducts. Chloroform is never found alone in drinking water. It always co-occurs with the other three trihalomethanes. Moreover, for these opponents, they argue human epidemiologic data should not be excluded. Melnick writes in his public comments to the EPA regarding its 1998 NODA: "epidemiologic data, which suggest a positive association between consumption of chlorination byproducts and elevated risk of bladder and colorectal cancers, should have been included in the [ILSI] Panel's evaluation since EPA's 1996 Proposed Guidelines for Carcinogen Risk Assessment specify that *good quality human data* are generally preferable over animal data and *should be given greater weight in hazard characterization and dose response assessment*" (US EPA 1998b: 1, emphasis in original). Melnick raised the same concern when he served as a peer reviewer of the ILSI Expert Panel report. The most thorough review of the stronger case-control epidemiologic studies conducted thus far is found in Health Canada's bi-national Expert Panel report (Mills et al., 1998). The conclusion reached by this report was that: "participants concluded that it was possible (60% of group) to probable (40%) that chlorination by-products pose a significant risk to the development of

cancer, particularly bladder cancer...and poses a moderately important public health concern" (Mills et al., 1998: 99).

ILSI's response to Melnick's peer review comments was to add the following phrase to its report: "a thorough review of the epidemiology literature was outside the scope of the Charge to this Panel" (1997: BG-5). Nonetheless, the ILSI panel does conclude that: "available epidemiological data are *not informative* with respect to the potential carcinogenicity of chloroform in humans" (ILSI, 1997: C-1, emphasis added). Similarly, the EPA Science Advisory Board write: "the extensive epidemiologic evidence on drinking water disinfection by-products, [is] largely irrelevant, given the goal of the draft risk assessment to isolate the health effects of chloroform in drinking water" (SAB, 2000: 2). To be fair, the Science Advisory Board argues that while the epidemiologic literature is not definitive, it is "pertinent to the broader question, i.e.,, the effect of disinfection by-products in the aggregate" (2000:2). The Science Advisory Board rightly points out, "the reason for a lack of epidemiologic research on chloroform in drinking water and cancer is that humans are not exposed to chloroform alone in chlorinated drinking water so it cannot possibly be studied" (Ibid.). Another reason is that few water utilities collect individual trihalomethane data (i.e., for the four family compounds). Those that do collect such data have only been doing it for a relatively short period of time, and therefore are not useful to epidemiologic studies trying to retrospectively study the effects of one compound over time.

However, it is the contestation that 'humans are not exposed to chloroform alone in chlorinated drinking water' that is the basis of the argument behind the non-threshold hypothesis. To these scientists, it does not make sense to arrive at a non-zero MCLG based exclusively on chloroform exposure in rodents. The basis of their argument is two-fold. First, given that drinking water is a complex mixture, it is possible that none of the disinfection byproducts alone may be a 'bad actor', but when combined, the synergistic effect could override an individual's resistance level. The second reason lies in the claim that 'adult rats are not human kids' generated by the NRDC. They argue that the adult-rodent chloroform mechanism studies do not definitively demonstrate a threshold for in utero or infant/child exposures in humans. For one, 'true risk' cannot be properly calculated for children if solely based on incidence rates of renal or liver cancer in children because this assumes that exposed children will remain at the same level of risk to non-exposed children over the course of their lifetime. In other words, while incidence rates may not be manifest during the child-years, it does not address potential exposure latency when the child becomes an adult (SAB, 2000). Additionally, to ensure an adequate margin of safety for children, one needs to be cognizant that a "child drinks more water on a per kg of body weight basis than does an adult, and inhales more air on a body weight basis than does the adult" (SAB, 2000: 18). The Science Advisory Board, while overall in agreement with the cytotoxic threshold hypothesis feels that subpopulations at risk should be more fully explored. Nonetheless, they conclude that "children's risks [are addressed]

quite adequately, based on the scientific information that is currently available" (SAB, 2000: 19).

Thus, the boundary-work demonstrated by these claims attributes numerous allies to the side of the threshold-proponents. Threshold-proponents can point to several animal-based chloroform mechanistic data, they have several government, academic, and industry institutional-based scientific supports, and they have the decision of the Court on their side. (The Court ruled that the EPA did not follow the "best available" science when promulgating its MCLG chloroform rule; we will discuss this more later). The threshold-opponents have Dr. Melnick and other scientists (though much fewer in number) to count as allies.

In credibility contests, numbers and reputations count. Latour (1987) argues that modalizing claims, that is, tying one's argument to others and modifying them as they suit the case at hand, is key to any scientific dispute. Adopting Latour's scientific framework, several reputable scientists have taken up the case of the Petitioners that, based on the current scientific evidence, chloroform should be treated as a threshold carcinogen. Since Melnick's work was published in 1998, no one seems to be giving it any voice. Latour argues that the challenge to any claim lies in its later use by others. Melnick's hypothesis is not included either in the Science Advisory Board's review of the EPA 1998 Health Risk Assessment/Characterization of chloroform document, or in that document itself. The ILSI panel itself in its comments (see Andersen et al., 1998) on the Melnick hypothesis argued that it was not based exclusively on chloroform

and hence was not considered. One cannot argue that ILSI was unaware of the Melnick paper, even if it was published a year after the ILSI report because the ILSI panel included non-published data as well as peer-reviewed published literature in making its assessment of the evidence. Given that Melnick was one of the external reviewers of the ILSI panel, it could be reasonable to argue that Melnick had at least made mention of his hypothesis in his review.

A potential conflict of interest is notably absent from these credibility contests (i.e., whose credibility should be privileged as the epistemic authority). Most institutions are concerned about conflict of interest situations that are financial in nature, or otherwise improper. As Aronson (1984) argues there is also a conflict of interest over the nature of scientific reputations. A scientist who has spent time studying an issue and arriving at a conclusion will be reluctant to completely abandon what s/he once thought was correct unless the evidence is irrefutable. In this situation, none of the evidence is irrefutable, so there is a vested interest by the scientists involved to ensure that their side is supported, even if their explicit value is the search for 'truth'.

Of the thirteen public health scientists that filed an amicus brief with the Court in favour of Petitioners, three of these scientists were either members of the ILSI Expert Panel or members of the ILSI Steering Committee. Hence, they potentially had a vested interest. Two of the three external peer-reviewers of the Health Risk Assessment/Characterization chloroform document (US EPA, 1998c) were supporters of the threshold hypothesis. This begs the question of how critical

a reviewer would be of a position that they support. These two reviewers were current or former employees of the Chemical Industry Institute of Toxicology that is funded by the Chlorine Chemistry Council and the Chemical Manufacturers Association (now the American Chemistry Council).

These issues tie back to earlier discussions about the necessity for scientific panels to be both actually, and perceived to be, completely 'above board'. In order to accomplish this, mixed membership from a variety of institutions is often incorporated. It was argued earlier in this paper that academic scientists often have the greatest credibility because they are viewed as 'neutral' in the debate. However, even this is changing. Academics are typically in need of obtaining external grants to fund research. They obtain this money through arms-length government institutions, but they also obtain research funds from industry agencies. While groups like the Chlorine Chemistry Council fund a great deal of academic research, they try to do so at an arms-length basis. They await the results and evidence when they are published in peer-reviewed journals. There is no expectation that they are notified of results before hand. The motives of the Chlorine Chemistry Council are not purely altruistic, but they are also not purely based on self-interest. The Chlorine Chemistry Council needs to stay on top of scientific research regarding the applications of chlorine in order to monitor how chlorine may be regulated in the future, and also to be able to dispel some 'myths' or 'inaccuracies' that may be raised by environmental groups opposed to particular chlorine applications. At the same time, the Chlorine Chemistry Council

is able to show how it is a responsible corporate citizen. From the scientific research that is generated and published in peer-reviewed journals, the Chlorine Chemistry Council is able to make modifications to harmful practices.

One resultant boundary-mapping of this debate is visible in the public health scientists' brief to the Court. These scientists argued that when regulatory agencies ignore "sound science" in standard setting decisions this serves as a disincentive to support or fund scientific work. The chlorine industry, which funds a great deal of scientific work as part of their changing image towards responsible corporate citizenship, may doubt the continued merits of such funding if decisions are not based on the best available science. Arms-length funding agencies might also arrive at similar conclusions. Consequently, according to the public health scientists, this endangers good science. The boundary-work here is that only science is the purveyor of truth, and that policy is not objective given that non-scientific considerations are included in decision making. The public health scientists make the issue of 'trust' in science a key feature of their argument.

The EPA constructed its boundary-work by not focusing on the content of the science, but by focusing on the process mandated by law. The EPA is a massive organization comprised of several departments and branches. Some scientists within the EPA agreed with the threshold hypothesis. Others did not. Hence, the EPA likely made its focus the process of evaluating science in promulgating rules rather than the actual content of science, because it would have been pitting scientists against scientists within its own organization. The

Petitioners note in their legal brief to the Court that the EPA scientists who were part of the 1998 NODA largely disagreed with several of the counterclaims listed in Table 4.3 that were generated through the public comment process.

The Court, in the end, decided that the EPA did not follow the best available science. The Court writes:

> however desirable it may be for EPA to consult a [Science Advisory Board] and even to revise its conclusions in the future, that is no reason for acting against its own science findings in the meantime...EPA cannot reject the "best available" evidence simply because of the possibility of contradiction in the future by evidence unavailable at the time of action — a possibility that will always be present (DC. Cir., 2000: 6).

For the Court, they were not moved by the due process arguments of the EPA, and by association, the scientific counterclaims of the NRDC as Interveners in this case (though these were never mentioned in the Court decision). Based on the science contained in the ILSI report, the 1998 NODA, and the 1998 EPA health risk assessment of chloroform which argued that chloroform's carcinogenicity should be based on a threshold level, the Court found "EPA's action was unlawful" (DC Cir, 2000: 7). This represents an interesting interpretation, and boundary-work, on the part of the Court. What constitutes the "best available" science does not seem to include the participation of the Science Advisory Board, which would not have been possible until after the mandated deadline. As previously stated, consultation with the Science Advisory Board is a necessary step prior to promulgating any new rules; rules which represent a significant step away from the EPA's legislative history. One might think that the participation of

the Science Advisory Board would be necessary to assess if the "best available" evidence was indeed sufficient.

Regardless, the Science Advisory Board was able to review the evidence prior to the Court judgement. It was the opinion of the Science Advisory Board that chloroform did demonstrate a cytotoxic mode of action (SAB, 2000). It was due to the anticipated Science Advisory Board's evaluation that the EPA filed a motion for Voluntary Remand in December 1999 (Schiffer et al., 1999b). This motion, if granted, would have allowed the EPA to consider the Science Advisory Report, and would have left the Petitioners without a judicial ruling on the actions of the EPA. When the Court denied that motion, the EPA filed for Vacatur (see Table 4.1) following the hearing of oral arguments in Court. This motion asks the Court to defer from making a judgement because the EPA "no longer believes that it should continue to defend its original decision" (Motion for Vacatur, 2000:2). In other words, the EPA, on the basis of the then draft Science Advisory Report concluded that it should withdraw its MCLG of zero for chloroform. The new level that the MCLG would be set at remains unstated. The motion for Vacatur was also denied.

The Court continues in its 'boundary-work' interpretations of the science in completely rejecting the EPA's claims that its scientific conclusions contained in the 1998 NODA, did not represent the EPA's ultimate conclusions on the issue. The Court found these "semantic somersaults pointless...All scientific conclusions are subject to some doubt; future hypothetical findings always have the potential

to resolve the doubt" (DC Cir, 2000: 7). For the Court, the key deciding factor on whether or not EPA ignored the "best available" science lay in "Congress's requirement that the action be taken on the basis of the best available evidence at the time of the rulemaking" (Ibid.). However, we return to the same assertion that the Court's boundary-work in interpreting the competing claims seem to indicate that it did not view the participation of the Science Advisory Board prior to rulemaking as being a necessary step in assessing if the "best available" evidence was both indeed the "best" and sufficient.

The Court decision means that the EPA must come up with a non-zero MCLG, though its actual level is still to be determined. The EPA is required to adopt this non-zero level in time for the Stage 2 Final Rules for Disinfectants/Disinfection Byproducts in May 2002 (Phibbs, 2001). As Gieryn (1999) argues, the courts are likely to be one of the key arenas for making determinations regarding scientific claims in standards setting, at least within the American context. In Canada, only Federal guidelines get set. Provinces then determine if they will accept the risk assessment decisions that are recommended and if they will be adopted at the provincial level. There is no requirement that Federal guidelines are automatically imposed on the provinces. Hence the courts are less likely to play as important a role, if any, within the Canadian context.

Throughout this debate, no single participant questioned the Maximum Contaminant Level (MCL) set for total trihalomethanes, which is based on the MCLGs for each contaminant. The EPA in its 1998 Final Rule promulgated a

MCL of 80 μg/L for total trihalomethanes. In a special session examining "Chloroform: Different Viewpoints on the Cancer Risk Assessment" at the 1999 Winter Meeting of the Society for Toxicology, Dr. Jay Goodman, a member of the ILSI panel was representing the threshold-hypothesis, while Dr. Melnick was representing the non-threshold hypothesis. Goodman characterized the debate that the linear or non-linear analytic approach for chloroform is not really the issue. Rather, support for the EPA scientists who favoured the non-linear cancer extrapolation approach for chloroform was what was required from the Society. His reasons boil down to the key issue throughout this science-war: the protection of science as the only rational purveyor of truth must be paramount, and the non-scientific considerations of policy decisions should never be allowed to override science. Hence, the MCLG debate for chloroform represents only a small battle within the bigger science-war: the preservation of science against 'politics' in standards setting; or what some might characterize as scientific proof vs unsupported public health prudence.

CHAPTER FIVE

Selling the goods on chlorinated disinfection byproducts and cancer: different frames, different fears

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Abstract

Risk issues become complicated when scientific evidence concerning a potential environmental exposure is equivocal; particularly when many argue the public health benefits of a policy action outweigh any potential negative health effects. Chlorinated drinking water and chlorinated disinfection byproducts (CDBPs) that are formed during the disinfection process, represent a useful case-study for examining these complications. We conduct a media analysis of chlorinated drinking water stories in the Canadian print media from 1977 to 2000. We examine media presentations of science compared to framings by scientists, regulators, the chlorine industry, water utility representatives, and non-governmental organizations of the CDBP issue based on key informant interviews. We argue that there are two main framings of the debate, each of which are powerful in constructing risk perceptions. On the one hand, many frame the debate as a 'voluntary' risk: we choose chlorine disinfection to protect against microbial risks with a possible adverse consequence of that protection. On the other hand, others frame the issue as an 'involuntary' risk: chlorine disinfection was a 'choice' imposed by public health and water utility officials; a choice that carries a potential cancer risk, and alternative disinfection technologies are advocated. We demonstrate these different frames by examining metaphorical constructs of water, chlorine and cancer contained within them.

Keywords: risk communication, media frames, metaphors, chlorinated drinking water, cancer

5.0 Introduction

Kingdon (1995: 16) poses the question: 'do the mass media focus attention on some issues to the neglect of others or do they report attention rather than create it?'. It brings to mind the adage 'no news is good news', but in the case of the media, 'no news' might simply be they have nothing they can sell (Stocking and Pease-Leonard, 1990). The media prides itself on the fundamental principle of 'the public right to know'. Yet the media can be very particular in the selection and distribution of that knowledge.

Wilkins and Patterson (1987) argue the media has a social responsibility to warn the public of impending dangers. However, while Saarien (1982) argues the media should educate the public about the ramifications of risks, dangers and events, Dunwoody does not feel that the media should play such a significant role in risk communication (unpublished, in Wilkins and Patterson). To explain this negative attitude towards the role of the media in risk communication, Keeney and Winterfeldt (1986: 417) argue that the media is "highly selective, often sensational, and sometimes inaccurate in its reporting of risks and regulatory actions to control them". Mazur (1981) presents a more rooted critique in that the media is unable to explain the underlying complexities involved in science and politics concerning risk issues. To communicate about risks, it is important to create a dialogue between the public and experts, for a shared exchange of knowledge, rather than through the usual one-way form of communication from the mass media (Cronholm and Sandell, 1981).

Leiss and Chociolko (1994: 4) argue that one of the fundamental aspects rooted in risk controversies is the "fear of falling victim unfairly to uncompensated loss." At the heart of the concept of 'risk', lies a key component: with exposure there is always the chance of 'loss' for one individual/group, often to the net benefit of another. The critical issues involve how scientific communications of risk contribute to a public understanding about the nature of risk (Kunreuther and Slovic, 1996). However, typically in risk situations, scientific experts blame the media for the irrational reception of risks by the lay public (Freudenberg, 1996). Risk issues are further complicated when scientific evidence concerning a potential environmental exposure is equivocal; particularly when many argue the public health benefits of a policy action outweigh any potential negative health effects. Chlorinated drinking water, and disinfection byproducts that are formed during the disinfection process, represent a useful case-study for examining the construction of risk.

A chlorinated disinfection byproduct is formed by the reaction of chlorine, used in the disinfection of water supplies, with naturally occurring organic and inorganic material present in raw water supplies. Surface water supplies (lakes, rivers) typically carry much higher levels of organics and inorganics, and hence form higher levels of disinfection byproducts than do groundwater supplies (wells, springs). While several halogenated and non-halogenated compounds are formed, the ones most studied for potential human health risks are trihalomethanes. Trihalomethanes form a group of four halogenated byproducts: chloroform,

bromodichloromethane, dibromochloromethane, and bromoform. Trihalomethanes also serve as the surrogate byproduct in drinking water for the setting of Canadian guidelines.

Nonetheless, chlorine disinfection of drinking water supplies has been hailed as providing the single largest benefit for public health (Mills et al., 1998). Chlorine treatment has ensured a safe drinking water supply for many, and when properly maintained, has prevented the return of major waterborne diseases like cholera and typhoid. However, there have been some studies which have shown a positive association between exposure to chlorinated disinfection byproducts and cancer outcomes, though that evidence remains inconclusive (IARC, 1991; Morris et al., 1992; Mills et al., 1998).

In this paper we examine media presentations of science and how these may contribute to the construction of lay risk perceptions regarding the chlorinated disinfection byproducts and cancer outcomes debate. These media presentations of science are compared to how scientists and non-governmental organizations (NGOs) frame the issue to determine if any 'definitional struggles' (see Miller, 1999) arise. There are two objectives to this research. First, we investigate how scientists, regulators, industry representatives and NGOs have framed the disinfection byproducts debate, based on the merits of the scientific evidence. Second, we explore how these scientific understandings are relayed to a lay audience through media presentations of the issue. We argue that there are two main framings of the debate, each of which is powerful in constructing risk

perceptions. On the one hand, many (i.e., scientists, industry, government) frame the debate as a 'voluntary' risk: we choose chlorine disinfection to protect against microbial risks with a possible adverse consequence of that protection. On the other hand, others (i.e., media and environmental NGOs) frame the issue as an 'involuntary' risk: chlorine disinfection was a 'choice' imposed by public health and water utility officials; a choice that carries a potential cancer risk and alternative disinfection technologies are advocated. We argue that while the chlorinated disinfection byproducts and cancer issue has not been extensively covered over the past two decades, compared to other drinking water issues, such as an e-coli outbreak which resulted in seven deaths (currently subject to a judicial inquiry) in a Canadian community (Walkerton, Ontario), the media presentation of the issue has reflected these two dominant story frames. After outlining our theoretical and methodological approach to this analysis, we will present how scientific evidence has been framed and communicated, and how these may have shaped public perception regarding the construction of risk.

5.1 Theoretical Framework

This work is informed by social constructionism in examining issues of risk, science, and knowledge through the presentation of 'facts' and 'evidence'. Social constructionism adopts a view that 'reality', as played out by what we perceive as facts, values, and knowledge are all socially constructed (Berger and Luckmann, 1966). Rein (1983) argues that as social actors, we establish parameters for what

is considered 'knowledge', and subsequently construct our reality in relation to that knowledge. It has been generally accepted that the way in which we respond to scientific facts, or even 'see' science, can also be understood as a social construction (Martin and Richards, 1995; Stehr, 1994; Aronson, 1984; Latour and Woolgar, 1979; Latour, 1987). Within a cultural and societal context, science is viewed as a knowledge producer (Jamieson, 1996), where its objective is to investigate and describe 'reality' (Barnard, 1994). In this way science has played a significant role in shaping society.

However, there is a recognition among researchers who conduct sociology of science and technology studies that the cultural authority of science is diminishing (see Jasanoff and Wynne, 1998; Irwin and Wynne, 1996; Gieryn, 1999; Nelkin, 1992; Beck, 1992; Hilgartner, 2000). This largely developed in the 1960s when environmentalists, activist groups, and the public were challenging institutional authorities, demanding greater participation over decisions that involve a high level of uncertainty. These 'lay experts' have undercut scientific expert authority through its calls for greater participation in decisions that affect the public, challenging scientific claims, and questioning the objectivity of 'technical expert' analysis. This has been seen through an increase in public groups hiring their own experts to advise them on issues (e.g. Brown and Mikkelsen, 1990; Brown, 1992; Irwin and Wynne, 1996; Leiss and Chociolko, 1994).

To counteract the roles and significance of 'lay experts', scientists may establish boundaries around what constitutes 'science' versus 'non-science' (Gieryn, 1999). 'Science' and scientific evidence are used to legitimate risk assessments through the process of quantification, or as Stone (1997) argues, the 'power of numbers'. This 'legitimacy' is gained through persuasive rhetoric (Hilgartner, 2000; Gieryn, 1999; Aronson, 1984; Ibarra and Kitsuse, 1993; Stone, 1997). To elaborate, Hilgartner (2000) adopts Goffman's metaphor of performance to examine the credibility of scientific knowledge and expertise within science-policy debates, by analyzing 'science on stage'. Scientists, when making public presentations of evidence (i.e., in the media, at conferences, as part of expert advisory committees, or in peer reviewed publications) adopt a series of 'performative dimensions' to position their arguments and claims against those of others. The intent is to lead a reader down a specific intellectual path while blocking others (Latour, 1987). A way in which scientists fulfil this 'performative dimension' is through risk assessments, which convey the impression that science is definitive (Hrudey, 1996). Consequently, the role of science in policy is perceived as lending some objectivity to the issue by separating the 'science' from the 'politics'; though in reality, there is a co-production of relevant knowledge between the two that often goes unrecognized (Jasanoff and Wynne, 1998).

However, assessments of risk involve more than a quantification process. There is a great deal of uncertainty inherent in (cancer) risk assessments, particularly when human subjects are involved. The uncertainty in science can

reduce risk controversies to a different set of competing interests (Aronson, 1984). Policymakers can choose to use scientific uncertainty as a justification for non-decision making as easily as they can use that same uncertainty to rationalize decisions made on other grounds (Jamieson, 1996). Thus, while risk communication has been hailed as one of the 'keys' to reduce tensions between science, policy and the public (see Powell and Leiss, 1997; Leiss, 1995; 1996), Hrudey (1996) argues that when risk assessors (scientists) and risk managers (regulators) are unable to effectively communicate with each other, they create an internal confusion, which then makes effective communication with the public unattainable. This is complicated when the public's primary source of risk communication via presentations of scientific evidence comes from the mass media.

The effective communication of risks, from a media standpoint, rests on a series of 'dread' risks: involuntary, unfamiliar, uncontrollable, unfair, acute, focused in time and space, sometimes delayed, undetectable, and impervious to human mitigation (Fishhoff et al., 1981). In the chlorinated disinfection byproducts and cancer outcomes debate, we hypothesize that the risks are portrayed as involuntary, but controllable, unfair, chronic and acute, focused in time and space, delayed, difficult to detect, but still within the realm of human mitigation. Further, alternative technologies can be used, but whose health effects are equally uncertain. Consequently, successful 'frame alignment' (Snow et al., 1986) must be cast in terms that will resonate with existing cultural concepts and

values (Gamson et al., 1992). Hence, at a media level, risks must be framed at both a macro scale (i.e., statistical risk) as well as at a micro level (i.e., fate of individual victims) (Sharlin, 1987), and must generate a genuine sense of 'outrage' in order to achieve the greatest level of resonance (Sandman, 1988). For example, the beginnings of 'disaster' stories often present death and injury tolls at the start to convey the magnitude of the event and the human cost. Hence, the 'vividness' of the event (Norman, 1994) and the credibility of the source (Best, 1995; Kingdon, 1995; Kasperson et al., 1988) or claims (Best, 1987) are important. Consequently, scientific experts are called upon to provide a credible summary of the evidence and the issue (Nelkin, 1987; Barker and Peters, 1993). In fact, the power of official sources (Gans, 1979) and scientific experts (Klaidman, 1990) often structures how news organizations determine what constitutes 'newsworthy' items.

Given that news stories convey information to the public through words and images (Wilkins and Patterson, 1987), there is a need to examine the use of story frames and metaphors in order to reveal the meanings and context of language, argument and persuasion (Stone, 1997; Best, 1995; Black, 1962; Lakoff and Johnson, 1980; D'Andrade, 1995); what Andrén (1981) refers to as semantical content analysis. Story frames and metaphorical concepts are used very systematically, and serve to highlight some aspects and hide others (Lakoff and Johnson, 1980; Stone, 1997). To illustrate, events or issues are often framed as stories (Stone, 1997) or rhetorical motifs (see Hilgartner and Bosk, 1988; Ibarra

and Kitsuse, 1993) in order to capture the public attention in the news media (Gamson et al., 1992). Similarly, metaphors are used frequently within our daily lives as a mechanism to structure, define, and attach meaning to our cognitive thought processes (Axelrod, 1973; Fiske and Kinder, 1981; Taylor and Cocker, 1981). As linguistic expressions, metaphors exist because they allow us to verbalize our conceptual system (Lakoff and Johnson, 1980). Metaphorical claims are similarly invoked in science, policy, and the media in a descriptive, persuasive, and creative fashion (McReynolds, 1990; Hannigan, 1995). Descriptive metaphors (e.g. 'dread disease') are usually directed at a specific audience to emphasize an argument, while persuasive metaphors are intended to convince an audience of a particular perspective. For example, television advertisements persuade through images and language to convey credibility and authority. Recently, a brand of disposable contact lenses were selling their new products by arguing that they 'advance the science of sight' through their new technology. By attaching 'science' to their product, they are trying to persuade an audience that their product is based on proven and reliable evidence. Creative metaphors are frequently used within policy and the media as a means of agenda-setting (Kingdon, 1995) and problem definition (Stone, 1997). For example, in the early 1990s, to justify the lowering of Canadian federal taxes on cartons of cigarettes, the tobacco issue was redefined from a health issue to one of justice and smuggling (Pross and Steward, 1994).

Hence, metaphorical concepts are used to create strong symbolic representations designed to generate a connection with the audience. Given that cancer is classified as a 'dread disease', any mention of cancer-causing chemicals is guaranteed to grab public attention and concern (Slovic, 1987). Framed as the new 'scare of the week' (Cutter, 1993), issues related to drinking water carry a high degree of salience: for while the human body can survive days without food, it cannot survive without water.

Consequently, the two dominant framings in this analysis ('chlorine disinfection saves lives' and 'chlorinated byproducts are causing cancer'), provide a medium through which we can explore these 'definitional struggles'. Miller (1999: 1239) argues that definitional struggles serve to "illuminate the processes by which scientific judgements are made, promoted, communicated, assessed and judged." These occur in the mass media, peer-review journals, academic conferences, expert advisory panels, legal and regulatory fora, and among policymakers and broader actors involved in the policy arena (e.g. NGOs, interest groups). Hence, by examining these definitional issues in the media, one can investigate how these definitions may be produced in other arenas. The relevance of this for our research is to explore how the dominant framings of the chlorinated disinfection byproducts and cancer issue by key informants (e.g. scientists, government, industry and NGO representatives) compare with the dominant framings constructed in the print media.

5.2 Methods: Interviews and Media Analysis

5.2.1 Key Informant Interviews

In order to investigate how scientists, regulators, and industry representatives have framed the disinfection byproducts debates, key informant interviews, lasting approximately an hour and a half, were conducted from August 1999 to January 2001 (n=36). Key informants were selected on the basis of their level of expertise and involvement with the chlorinated disinfection byproducts and cancer debate. Those informants contacted included: epidemiologists and toxicologists actively researching in the field as identified by publications in peer-reviewed journals (e.g. King and Marrett, 1996; Morris et al., 1992) and their participation on scientific expert panels (e.g. Mills et al., 1998; ILSI, 1997) (n=9); public health scientists operating within regulatory environments (i.e., Health Canada, United States Environmental Protection Agency - EPA) whose primary mandate is public health (n=15), and regulators at the provincial level (Ontario Ministry of Environment) (n=7); representatives from environmental non-governmental organizations such as Pollution Probe (in Canada) and the Natural Resources Defense Council (in the United States) as having identified chlorinated byproducts as a key environmental issue for their organization (n=2); and representatives from the chlorine (i.e., the Canadian Chlorine Coordinating Committee, the US Chlorine Chemistry Council) (n=4) and water utility industries (i.e., the Canadian Water and Wastewater Association) (n=1) who would appear to have a vested interest in any issues related to chlorine and drinking water.

While the majority of informants were identified on the basis of their active participation in the issue, some participants were selected following a snowball sampling process. Snowball sampling to identify other active, but perhaps less visible participants, was largely undertaken to ensure that scientists conducting research studies not yet published in the peer reviewed journals, or other public health scientists or regulators within large organizations such as Health Canada and the United States EPA were not missed. Interviews continued until a saturation of information was reached (see Patton, 1990); that is, key informants were identifying individuals already interviewed as experts in the field, and no 'new' information or opinions were being shared.

Interview data were taped, transcribed verbatim and later analyzed using NVivo, a qualitative software package designed to analyze text (Richards, 1999). The key informant interviews were semi-structured and followed a checklist of key topic areas (e.g. risk communication strategies, public perceptions of risk, assessment of evidence, issue importance, policy concerns, etc.), as opposed to a standardized questionnaire. Data were categorized both deductively (i.e., following natural categories from topic areas) and inductively (i.e., categories emerging from the data; e.g. metaphorical constructs). The broad categories to be reported on in this paper include how respondents framed the issue, assessed the public perception of risk, and what metaphors they employed in constructing the issue.

Because interviews were with key-informants, different individuals provided certain parts of the 'story'. To ensure that all aspects are consistent with the context in which statements were made during the interviews, a process of member-checking was implemented (see Baxter and Eyles, 1997; Gilchrist, 1992). Different sections of the paper that related to comments made by specific individuals were checked with them to ensure that their statements were not being misunderstood or taken out of context. Informants were first contacted by telephone or e-mail to ensure that they were available to make comments (i.e., not out of town), and then given a time frame of two weeks from receipt of the textual passages in which to register any concerns. The textual passages for which respondents were responsible for reviewing were short enough not to be daunting (i.e., not the whole paper), but long enough that the context for how their statements were being used was present. A two week time frame was deemed adequate for the task. As part of a pre-arranged agreement with informants, the absence of comments at the end of that two week period was interpreted as consent/acceptance.

5.2.2 Media Analysis

Similarly, an analysis of story frames and metaphorical concepts was also conducted from media stories. In order to explore how the print media was presenting scientific evidence concerning the potential cancer risks due to chlorinated disinfection byproducts to the public, a media analysis of major

Canadian newspapers was conducted from 1977 to 2000. Disinfection byproducts were first measured in 1974, and then later found to be carcinogenic in rats (see NCI, 1976). In order to access early media presentations of the issue, we relied on both paper indices of the Canadian News Index, and the Canadian Periodical Index, as well as a CD ROM searchable database through the Canadian Business and Current Affairs (CBCA) index (the CBCA merged the Canadian News Index and Canadian Periodical Index).

The CBCA index, as well as the Canadian News Index, provided coverage both nationally and provincially. The following major newspapers were covered by the index: the *Globe and Mail* (which provided national coverage); the *Vancouver Sun* (British Columbia); the *Calgary Herald* (Alberta); the *Winnipeg Free Press* (Manitoba); the *Toronto Star* (Ontario); *Montreal Gazette* (Quebec); and the *Halifax Chronicle Herald* (Nova Scotia). In the late 1990s, a new national newspaper, the *National Post*, was created, and incorporated into the analysis. The CBCA index and the Canadian Periodical Index also captured stories which were written in Canadian periodicals, such as *Time, Maclean's, Horizons, Alternatives, Equinox, Canadian Architect, Environmental Science and Engineering, Medical Post, Health News, Canadian Medical Association Journal, Western Producer,* etc. These indices were searched using the following keyword terms: 'drinking water'; 'chlorine-and chlorine-containing-compounds'; 'chloroform'; 'trihalomethanes'; 'THMs', and 'drinking water and cancer'. While we would have liked to have used 1975 as our base point, the Canadian News Index did not

begin cataloguing news stories until 1977, hence that is the earliest year for which we have data. The CBCA computer searchable database only goes back as far as 1984. Given that the CBCA index search yielded both newspaper articles and articles that came from the Canadian Press Newswire service, we only included articles published in newspapers as these represented the 'news' to the public.

To reiterate, the purpose of this research is to examine media stories by focusing on story frames and metaphors as a way of constructing the chlorinated disinfection byproducts and cancer issue in the public arena. Consequently, it differs from other studies on the media reporting of environmental risks (see Sandman et al., 1987) in that the paragraphs of stories are not individually counted and each paragraph is not categorized as the 'presence' of a risk or the exposure to a 'risk'. Moreover, the relevance of noting the sources of issues, events, or items contained within the print media differed. We were concerned with how scientific evidence is presented and interpreted by the media as well as government officials who ultimately may use that scientific evidence as one element in the policy decision making process. It was not necessary for our analysis to code the 'official source' for each individual paragraph of media stories as outlined by Sandman and colleagues (1987).

The process of including articles from the print media involved any article making an explicit reference to potential adverse health effects of chlorine, chlorinated byproducts (broadly defined as drinking water byproducts like trihalomethanes, or individually identifying specific byproducts, e.g. chloroform)

and cancer outcomes. This included print media stories which had a primary focus on toxic chemicals in public water supplies (i.e., broader water quality articles) due to industrial discharge and improper disposal practices (of, for example, PCBs, TCE) provided that chlorinated disinfection byproducts in drinking water were also mentioned in the article as a human health hazard. While it is recognized that chlorinated disinfection byproducts were not the main focus of those broader water quality stories, they were identified as another source of environmental exposure to a contaminant in the drinking water supply. Moreover, all of the contaminants mentioned in those stories were explicitly categorized as suspected carcinogens by the print media. All other drinking water or non-chlorinated disinfection byproduct exposure stories were excluded from this analysis if they did not meet the above criteria. In total, 76 articles were selected for analysis from January 1977 to December 2000.

Specifically, media stories, particularly those relating a cancer fear due to exposure to chlorinated drinking water supplies, were read for metaphors and story frames (i.e., chlorine saves lives vs chlorinated drinking water is causing cancer). To explore how the issue was being framed, we examined if scientific evidence was being presented in the articles, how that evidence was presented, and if there were any suggestions being communicated to the public as to how to cope with the risks presented by chlorinated byproducts in drinking water. The 'source' of those messages (i.e., scientist, regulator, industry, or activist) was noted to see what impact that source had on the story framing.

In presenting the data from this media analysis in subsequent sections, a representative article of all newstories published each year was selected to be included in table format to demonstrate how the chlorine and cancer issue in drinking water was presented in the media over time. An article was deemed 'representative' if each story for that year framed the issue in a similar manner (i.e., followed one of the two dominant story frames outlined in the introduction). If, within a given year, news stories represented both story frames, or a story frame not captured by these dominant frames, they were also included in the table. In selecting a 'representative' article, we made the assumption that news stories which framed the issue early in the story (i.e., leading sentence or leading paragraphs) would be more powerful at capturing a reader's interest, than a story which framed the issue near the end of the article.

5.3 Main Findings

5.3.1 Framing the Debate - The Perspectives of Key Informants

From the perspective of key informants, the different definitional frames attached to this issue all fall under the umbrella frame that 'chlorine disinfection of drinking water saves lives'. Within that dominant frame, there are three different definitional frames. There is the 'luxury concern of the first world' frame, the 'balancing risks' frame, and the 'single bad actor vs complex mixture' frame. From the perspective of many respondents, including academic scientists, public health scientists, regulators, and industry representatives, this issue has been

framed as a 'luxury concern of the first world'. In other words, we, in countries like Canada and the United States, should be grateful that we can afford to be worried about potential negative health effects associated with the disinfection of drinking water supplies, as opposed to being concerned about *getting* water, let alone, clean disinfected water. Dr. Calderon, of the US EPA, comments: "I was at an international meeting in November, and it was funny to be at this conference where you had people from countries where less than 10% of the country has piped water, and here we are talking about disinfection byproducts. So, for them, they can't even get water to people, much less be concerned about the quality of it" (Calderon, pers.com.). Economic concerns enter this framing, in terms of what we, as a society and government, are able to afford to pay for water with lower byproducts when there are so many other issues that are of greater public health significance (Calderon, DeAngelo, Murphy, pers.com.).

The second frame, that of 'balancing risks' was one of the most predominant issue frames. The basic argument here is that chlorination is one of the most cost-effective disinfection treatment options available to control microbial contamination of drinking water supplies. Risks must be balanced to ensure water utilities keep the disinfection byproduct levels as low as possible without compromising that microbial protection. The majority of key informants (e.g. Giddings, Green, Jenkins, Thomas, Mills, Murphy, Craun, Douglas, Ellison, Hall, Hunter, Macfarlane, Bull, Cantor, King, Calderon, Christman, Eisler, Jones, McCarty, Gohier, Arbuckle) made this distinction. As a representative of the

Chlorine Chemistry Council in the United States, Keith Christman argued that it was critical to educate the public about how chlorine is essential to public health:

> Frankly it's very important that people understand some of the benefits of our products. And in the case of disinfection it's very clear that there are great benefits and there is no good substitute for it. Also, it's a good place for having people consider what the trade-offs are. Lots of times you'll hear people call for a ban on a certain chemical and Greenpeace has called for a ban on chlorine consistently. If you ever dig into a ban on a product in any application you'll get into the hard issues of substitutions and what risks you're creating by banning a compound. In the case of disinfection it's very clear that if you try to ban chlorine you would endanger public health. There is no substitute for chlorine in drinking water. You could use other disinfectants for primary disinfection, but there is nothing else you can use in a distribution system to help maintain the water quality when it goes from the treatment plant to peoples' taps. So when you tell people that and they understand that, it's easier for them to understand some of the trade offs you get into with some of the other applications (Christman, pers.com.).

However, not all key informants agreed with this assessment. Only one individual did not explicitly frame the issue in 'balancing risks' terms. Erik Olson, of the Natural Resources Defense Council (an environmental NGO in the US) argued that we need to examine the chlorinated disinfection byproducts issue in conjunction with microbial risk protection, but not as a function of balancing these risks. He argued there is no need to rely on chlorination as a primary disinfectant to protect against microbial risk. Other primary disinfection treatment technologies could be equally effective, where only a small amount of chlorine would be required before the water entered the distribution system to ensure a proper chlorine residual. In this way, water utilities could control the level of byproduct formation by using a different primary disinfection process (i.e., ozone,

UV radiation). Another option could be to remove the majority of the organic material (i.e., filtration) prior to primary disinfection (Olson, pers.com.).[1] Dr. Melnick, of the US National Institute of Environmental Health Sciences, agrees: "People always talk about trade-offs between microbial disease and chemical risks. To me that should never be an issue. There is never an intent, as far as I can see, to allow microbial risk to increase. The issue should be, yes, you have to reduce microbial risk, but are there other means of eliminating chemical risk. I believe that is very much possible" (Melnick, pers.com.).

The third frame, 'single bad actor vs complex mixture', has been primarily forwarded by scientists, the chlorine industry and water utility representatives. While scientists argue that we need to balance the risks of disinfection, they also argue that there is a concern with respect to the type of byproducts formed in drinking water supplies. The existing scientific evidence can only demonstrate a statistically significant relative risk of bladder cancer in humans, though several studies have been conducted to examine exposure with other cancer sites (e.g. colon, rectal, brain), as well as studying adverse reproductive and developmental outcomes (Mills et al., 1998; Cantor et al., 1999; Dodds et al., 1999).

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[1] The current practice in most large water utility operations is that the surface source water is chlorinated (primary disinfection), filtered, and then chlorinated again (secondary disinfection) before the water enters the distribution system. Because the water is not filtered until after primary disinfection, there is the risk of considerable byproduct formation from, and depending upon, the amount of organic material present in that raw water supply, and the use of multi-media filter beds (including a charcoal layer removing DBPs) (Ellison, pers.com.).

Consequently, while the relative risks and odds ratios are low, and the evidence is equivocal, the majority of the population are exposed to chlorinated surface water supplies. In other words, there are few resources which affect entire populations like drinking water (e.g. air).

Hence, some scientists, primarily toxicologists, argue that we should be searching for the 'single bad actor'; that is, that byproduct which may be causing these negative health effects. Other scientists, primarily epidemiologists, argue that because drinking water is a complex mixture, there may be a synergistic effect because of 'multiple bad actors'. These different scientific frames are not surprising. Toxicologists are able to study individual compounds by looking for a one-to-one relationship by controlling all possible confounders. Toxicologists have largely eliminated chloroform as a 'bad actor' (see ILSI, 1997) and are trying to refocus their research agenda (see Driedger and Eyles, 2001a,) onto other disinfection byproducts, such as the brominated species and haloacetic acids (Bull, DeAngelo pers.com.), as well as the formation of nitrosamines in drinking water (Bull, pers.com). By contrast, while epidemiologists cannot detect the effects of single compounds in a complex mixture, such as disinfection byproducts, with sufficient knowledge about the nature of mixtures, they can evaluate risk associated with various types of mixtures (i.e., mixtures with high or low brominated compound content, or with high or low haloacetic acid content.) This may provide important insights into the toxicological nature of the mixture (Cantor, King, Wigle, pers.com.).

To illustrate, representatives of the Canadian Chlorine Coordinating Committee (C4) and the US Chlorine Chemistry Council (C3) have played a role in trying to isolate the 'single bad actor'. For example, C3 has played a prominent role in a recent judicial battle against a regulation that the US Environmental Protection Agency set for chloroform (see Driedger and Eyles, 2001b), arguing that the 'best available evidence' shows that chloroform is not likely the bad actor in cancer studies (Christman, pers.com.). By contrast, in countering the chlorine industry's 'single bad actor' frame, Erik Olson, of the Natural Resources Defense Council (NRDC) argued that while chloroform may not be the individual bad actor, when it is combined with other 'bad actors', it forms a 'cocktail effect'. Consequently, several byproducts individually may not be harmful, but the combination poses 'multiple bad actors' (Olson, pers.com.). The Executive Director of the Canadian Water and Wastewater Association (CWWA) is not convinced. Ellison commented that "trihalomethanes have been studied a great deal because they are really verifiable and believed to be a good indicator of the presence of other DBPs. What we need to consider is the role of other DBPs, such as the brominated compounds and haloacetic acids, that scientists think might actually present greater risks to human and reproductive health. Why study the surrogate (i.e., trihalomethanes) when other issues need to be studied?" (Ellison, pers.com.).

Hence, to capture these different frames into one overall frame, scientist key informants (i.e., toxicologists, epidemiologists, public health scientists,

microbiologists), define the issue as: 'chlorine disinfection protects us from microbial risks, with a possible adverse consequence of that protection.' The possible adverse consequence of microbial protection that is afforded by chlorine is not sufficient to warrant a switch in disinfection treatment technologies. The underlying issues are that: 1) there is an insufficient database on potential adverse health effects associated with byproducts created from ozonation, ultra-violet radiation, granular activated carbon systems, or other forms of disinfection; 2) there is at least a limited database for adverse health effects associated with chlorinated disinfection byproducts; 3) it would take at least twenty-five years or longer to establish a health database for alternative technologies; and 4) while many European countries, and some North American cities, have switched to ozonation as the primary disinfection treatment, there has not been any concerted effort to compare the health risks of those communities with communities that rely solely on chlorination. In many respects, it is this latter issue that would be the most relevant to a policymaker having to render a risk management decision.

5.3.2 Framing the Debate - Media Presentations of Science

With respect to the chlorinated disinfection byproducts issue, key informants felt that for the most part, the media has been relatively balanced in presenting scientific information (Findlay, Hunter, King, Ellison, Douglas, pers.com.). Nonetheless, some felt that the media has been somewhat incomplete when it has covered the issue because there has been a tendency to focus on the cancer risks

due to chlorination and less on the microbiological risks if there is insufficient chlorination (Jenkins, Henry, Morris, Stone, Ellison, DeAngelo, Arbuckle, pers.com.). Table 5.1 illustrates how the media has presented scientific information and knowledge regarding the disinfection byproducts and cancer issue.

The quotes included in Table 5.1 were largely (but not always) extracted from the first three paragraphs or leading sentence of the article. In many later articles, particularly from 1999-2000, journalists frequently referred back to key studies or reviews (e.g. Marrett and King, 1995; King and Marrett, 1996; Mills et al., 1998), though not by name. Overall, scientists were able to convey to the media that the benefits of chlorination outweigh the potential adverse cancer risk. In media stories this was reflected only after some statement was made about 'chlorine in drinking water causes cancer'. For example, in 34 of the 76 cancer related articles (i.e., 45%) the journalist would indicate somewhere in the article that chlorination is necessary to protect drinking water supplies against waterborne diseases. However, in 27 cases (35%), the journalist only indicated that chlorine is used to kill bacteria in water without a clear distinction being made about the necessity of pathogen-free water, and in 15 cases (20%), there was no mention of the benefits of chlorine as a water disinfection treatment. This is particularly interesting in that the framing of the issue places a greater emphasis on the negative aspects of chlorination (i.e., cancer), rather than the positive aspects (i.e., microbial protection). We will return to this idea further in the discussion section.

Table 5.1: Media Presentations of Scientific Evidence of Chlorine and Chlorine Compounds in Water

Year (n)	Comments (emphasis added to demonstrate story frames)
1977 (n=9)	"Chlorine used to purify drinking water may be related to incidence of cancer in humans, but ***the benefits of chlorine in combating water-borne diseases far outweigh any risk of cancer***, says a scientist who completed a study of Ohio water, but found a higher rate of cancer mortality among consumers of surface water in Ohio than those who drank groundwater" (Associated Press, 1977)
	"A survey of seventy Canadian communities has found that Canadian drinking water, like that in the United States, contains significant amounts of a ***potential cancer-causing chemical*** formed when water is disinfected with chlorine" (Sun Science Writer, 1977)
1978 (n=2)	"Mysterious deaths of fish in laboratories have triggered extensive testing of tap water. Some scientists have turned to bottled water and distilled supplies for personal use. Erving Diener, head of the University of Alberta medical faculty's immunology department is skeptical of the official assurances and is having an independent check done. '***The city fathers believe that because nobody dies right away, there is no problem***...they don't realize that the damage may not show up in the body for 20 years" (Jaremko, 1978)
1985 (n=2)	"Animal studies have demonstrated the consumption of large doses of ***chloroform*** results in the development of malignant tumors. And this suggests that the ***ingestion*** of even low amounts ***by humans may produce*** some incidence of ***cancer***." (Dennis, 1985)
1987 (n=4)	"Long term drinking of ***chlorinated water*** appears to ***increase*** a person's ***risk of developing bladder cancer*** as much as 80 per cent, according to a major new study (by Ken Cantor)." (Newhouse News Service, 1987)
1988 (n=2)	"***The greatest threat to drinking water*** consumed by millions of Canadians ***comes from the chlorine that is used to purify it***, says a Quebec researcher. Ayotte stressed in an interview that the risk is small, but still deserves attention since chlorination is so widely used to kill bacteria in water" (Canadian Press, 1988)
1989 (n=2)	"Decades of research have demonstrated chlorination's benefits in limiting outbreaks of typhoid fever and other acute diseases from microbial contaminants. However, four groups of federal researchers report that these ***benefits may come at the expense of a small added risk of chronic disease - most likely heart disease or cancer***." (Raloff, 1989)
1990 (n=4)	"***A chemical that may cause cancer*** is more prevalent in Canadian drinking water than anywhere else in the western world, a US study obtained by the CBC at Six shows. Trihalomethane, a chemical created when chlorine is used to kill bacteria in water, has been linked to high cancer levels in America, says Dr. Ken Cantor" (Canadian Press, 1990)
1992 (n=5)	"A Harvard University study found that ***chlorine*** used in municipal water supplies to kill germs may create ***chemical compounds*** that make people more ***susceptible to cancers*** of the bladder and rectum. It evaluated the possible source of cancers reported in 10 research projects published between 1966 and 1987" (Associated Press and Reuters, 1992)
1994 (n=4)	"A new Finnish study adds to the controversy over chlorinated drinking water, showing ***byproducts*** in that water may slightly ***increase people's risk of bladder and kidney cancer***. US scientists emphasized that any risk is minuscule compared with that from smoking, high-fat diets and other common unhealthy habits, but said it is ***enough concern for governments to act***" (Associated Press, 1994)
1995 (n=2)	"An overview of the research published three years ago speculated that ***byproducts might cause 6,500 cases of rectal cancer*** (18% of new cases) each year, as well as ***4,200 cases of bladder cancer*** (9% of new cases). A few studies also suggest that ***pregnant women exposed to chlorination byproducts*** have a slightly higher chance than unexposed women of ***delivering babies with rare birth defects***" (Unnamed, 1995)
	"One in 10 cases of bladder or colon ***cancer*** in Ontario may be ***caused by*** decades of drinking and bathing in ***chlorine-treated water***, a study suggests" (Canadian Press, 1995)
1996 (n=3)	"***Drinking water treated with chlorine could be causing more than 500 cases of cancer and about 140 deaths in Ontario each year***, a health study reveals" (McAndrew, 1996; Derfel, 1996)
1998 (n=9)	"A new federal analysis concludes that ***chlorinated drinking water may pose a cancer risk*** to humans, particularly the risk of bladder cancer" (Canadian Press, 1998; Ward, 1998; Evenson, 1998)
	"***You can drink your tap water without fear***, scientists say. Recent headlines that chlorinated water can increase the risk of cancer are all wet. The ***benefits far outweigh the potential health problems***" (Barlow, 1998)
2000 (n=11)	"The studies are fairly consistent in showing a ***slight increase in the risk of bladder cancer for people who use chlorinated water***. But we are looking at a very small relative risk" said King (Nichols, 2000)

By contrast, Table 5.2 outlines media presentations of the government assessment of the science concerning the chlorine and cancer in drinking water issue. The media presents a much less balanced story when reporting on the government assessment of the scientific evidence. Comments attributed to government officials in 1977 to 1980 are relatively cautious, in that officials are trying to allay public fears about drinking water. However, with some exceptions (see 1987, 1992, 1998) media presentations from about 1981 on, appear to manipulate conclusions made in reports to appear more definitive than they really are.

For example, in 1992, the statement from two articles reflecting two opposite story frames (see Table 5.2) is referring to the broader review of drinking water guidelines by the Federal-Provincial Subcommittee on Drinking Water (DWS). The DWS, comprised of representatives from federal and provincial ministries of health, is the regulatory body that establishes drinking water guidelines in Canada. In 1992, the DWS initiated an extensive public consultation process with various national organizations regarding Canada's guideline for trihalomethanes (THMs). While the DWS originally proposed a reduction in THMs to 50 ppb from the original guideline of 350 ppb, the guideline eventually agreed upon in 1993 was 100 ppb. While there were many reasons for adopting a higher guideline than originally proposed (see Driedger and Eyles, 2001c) the media, it seems, never reported on this change in Canadian guidelines in 1993. This is not surprising. The 'hot' chlorine issue of 1992 to 1994

Table 5.2: Media Presentations of the Government Assessment of Scientific Evidence

Year (n)	Comments in leading paragraph/sentence (emphasis added to demonstrate story frames)
1977 (n=9)	"***Highly toxic organic materials*** are contaminating the drinking water supplies in some Ontario communities, but there is ***no real danger to inhabitants***, a Ministry of Environment report says" (Malarek, 1977)
	"American health officials may limit the use of chlorine to purify drinking water because the process promotes the formation of ***chloroform, a suspected cancer-causing agent***, according to a group of chemists" (Troyer, 1977)
1980 (n=1)	"***Trihalomethanes***, which also ***may or may not be carcinogenic***, are a class of substances derived from chlorine interacting with certain organic material in water and have been detected in Winnipeg water at 50 micrograms per litre" (Allan, 1980)
1981 (n=1)	"Twenty years ago we never would have through chlorine would be a problem," says Dr. Donald Wigle, head of Health and Welfare's noncommunicable disease section. "***But anything that is reactive enough to kill bacteria can do other things too.***" (O'Hara, 1981)
1983 (n=2)	"***Is the water*** from Lake Ontario or from a number of industrially polluted areas across Canada, ***safe to drink*** for a lifetime? The short answer is that there are no clear answers. A senior Environment Canada official says that while there is no evidence that drinking tap water from Lake Ontario will harm anyone over a couple of years, '***the risk becomes greater as you extend the time***'". (Keating, 1983)
1984 (n=2)	"The use of ***chlorine***, the most widespread water disinfectant in North America, poses ***potential cancer and genetic risks*** when used in drinking water a Toronto board of health study says. The study, released yesterday, cited another inquiry of Great Lakes water which concluded that chlorinated water is two to ten times more likely to cause genetic damage than raw lake water. 'This ***suggests that chlorination is the largest single source of potentially hazardous chemicals to drinking water***'" (Canadian Press, 1984)
1985 (n=2)	"***Chlorine*** added to drinking water to kill bacteria ***may be creating a health hazard*** by combining with organic matter to produce ***cancer-causing chemicals***, a federal government scientist says" (Mitchell, 1985)
1987 (n=4)	"Drinking ***tap water*** in Metro and 67 other municipalities ***carries no health risk***, says a report by Ontario's environment ministry." (Temple, 1987)
1992 (n=5)	"The water purification process used in Canadian cities since the turn of the century should be improved to eliminate the growing ***risks of cancer linked with chloroform***, the Health Department says" (Associated Press and Reuter, 1992)
	"***The risk of cancer from chlorinated drinking water is all but non-existent*** in Manitoba despite an alarming report last week, an official with the provincial Environment Department says." (Flood, 1992)
1993 (n=1)	"Concerns are growing about traces of ***carcinogenic material***. Trihalomethanes are definitely a concern said Doug Jamieson, chief production engineer for city waterworks" (Lowey, 1993)
1994 (n=4)	"Medical health officials say they prefer chloramination because of the ***danger of carcinogens in chlorine***. Ministry of environment and fisheries officials prefer chlorination. So do environmentalists and fish hatchery workers because of the danger chloramine poses to fish habitats" (Gram, 1994)
1998 (n=9)	"***Chlorinated tap water*** contains chemicals that ***may give people bladder cancer and cause birth defects***, a Health Canada panel says" (Spears and Toneguzzi, 1998)
	"The municipal ***water we drink*** and wash in Hamilton-Wentworth ***is among the safest*** in Canada, and you certainly ***won't get cancer from it***" (Barlow, 1998)
1999 (n=8)	"Thousands of residents in the province (Nova Scotia) have ***a higher risk of getting cancer because of the water they drink***, says a new provincial survey" (Camus, 1999a)
	"People in 18 Nova Scotia communities that have a ***cancer-causing chemical compound in tap water shouldn't panic***, says the province's chief medical officer" (Camus, 1999b)
	"It's added to water to make it safer, but growing questions about a ***possible link between chlorine and cancer*** have prompted the federal government to launch a major study" (Lawton, 1999)
2000 (n=11)	"About a third of 197 public water supplies tested in Newfoundland since 1985 contained high levels of ***potentially dangerous chemicals***, the province revealed Monday" (MacDonald, 2000)

was the various calls being made from international organizations to ban chlorine use in industrial practices (see Driedger and Eyles, 2001d).

There appears to be an absence of the news media soliciting a government assessment of scientific evidence regarding the chlorinated disinfection byproduct issue between 1994 and 1998, in spite of a major Ontario study being revealed in 1995 (as a government document, see Marrett and King, 1995) and again in 1996 (as a peer-reviewed publication, see King and Marrett, 1996). Only three articles (appearing in 1996 in Ontario newspapers, and in the national *Globe and Mail*) were directly related to the Marrett and King (1995) study of bladder, colon and rectal cancer in Ontario. However, this study was referred to an additional twelve times in subsequent years when media articles commented on the disinfection byproducts and cancer issue. The three articles reporting the results of this study were, on the whole, balanced. By contrast, in 1998, when Health Canada released its expert panel report which examined the health effects of chlorinated disinfection byproducts, including both cancer and reproductive effects, the media reported on the study nine times across the country, and referred back to the report an additional four times from 1999 to 2000. The reason for the greater media attention dedicated to the Health Canada study is largely due to the more 'sensationalist' language used in a position paper written by a Health Canada scientist.

To accompany the publication of the expert panel report (Mills et al., 1998), Don Wigle was asked to produce a written editorial to provide a public

health perspective and to update the issue given that almost a year and a half had passed since the workshop was convened and the publication of the consensus report in the peer-reviewed *Chronic Diseases in Canada* journal. The panel report was cautious in its presentation of the evidence. The editorial was only to represent Wigle's personal opinion on the issue, and not reflect official Health Canada policy. However, because his paper was too long to be considered an 'editorial', it was labeled a 'position paper' (Wigle, pers. com.).

In the abstract of Wigle's position paper, he argues that on the assessment of the evidence for cancer that:

> there is an urgent need to resolve this and to consider actions based on the body of evidence, which at a minimum, suggests that lowering of CBP [chlorinated byproducts] levels would prevent a significant fraction of bladder cancers. In fact, given the widespread and prolonged exposure to CBPs and the epidemiologic evidence of associations with several cancer sites, *future research may establish CBPs as the most important environmental carcinogens in terms of the number of attributable cancers per year* (Wigle, 1998: 103, emphasis added).

The media reaction to the release of the expert panel report and the position paper focused more on the latter because it appeared to make more definitive (rather than cautious) statements. The statements in the newspaper articles were largely based on quotes from Wigle. Moreover, the media typically credited Wigle as the author of the expert panel report. The release from the Canadian Press, picked up by the *Globe and Mail* and the *Toronto Star* (Canadian Press, 1998) the *Montreal Gazette* and *Halifax Chronicle Herald* (Bueckert, 1998), and the *Vancouver Sun* (Ward, 1998) writes:

> Despite the undisputed benefit of chlorination in controlling infectious diseases, "the epidemiological evidence now available clearly suggests that CBPs pose a cancer risk to humans" says the study..."Given the wide and prolonged exposure of Canadians to this risk, public health authorities must decide if the available evidence warrants actions to at least reduce exposure of Canadians to this risk."... In addition, epidemiological studies — based on data about large numbers of people — indicate an elevated incidence of bladder cancer among those who have been exposed to chlorinated drinking water for long periods. "If you put these two lines of evidence together, I would say it comes out as a probable link (between chlorinated water and cancer)," says Health Department expert Donald Wigle, who wrote the review (November 21, 1998).

A few days following the release of the report, the story was picked up an additional two times by the *National Post* (Evenson, 1998) and the *Calgary Herald* (Spears and Toneguzzi, 1998). The statements become even more sensationalist:

> Prepared with the help of leading epidemiologists, toxicologists, public health specialists and water quality experts, the study hints that even showering or swimming in chlorinated water poses a risk. Research may prove that these chemicals "may establish (the chlorine byproducts) as the most important environmental carcinogens in terms of the number of attributable cancers per year" Dr. Wigle writes (November 24, 1998).

Only one newspaper article presents a balanced view on this issue, and was covered in a newspaper not catalogued by the CBCA. The *Hamilton Spectator* article focused more on the benefits chlorine affords in protecting public health from microbial risks than the very small relative risk associated with disinfection byproducts and cancer outcomes (Barlow, 1998, see Table 5.2).

From 1999 to 2000, the major focus of the media is on the elevated rates of trihalomethanes found in drinking water supplies of many communities in both Nova Scotia and Newfoundland. Many of the headlines refer to these

trihalomethanes as a "cancer-causing chemical" (see Table 5.2). Ellison, of the Canadian Water and Wastewater Association comments:

> When the Nova Scotia study was released in December, it generated a fair amount of excitement, but it died down within 2 days. When the Newfoundland study came out, which actually showed a far worse situation than Nova Scotia, Newfoundland handled it a lot better. They had a proper press announcement which put the health risk in perspective and addressed specifically the issue of chronic cancer risk compared to other health risks as they'd seen what happened in the case of Nova Scotia and the initial lead story, which was issued on the Friday night prior to the press announcement being made on Monday actually was very, very well written. In many respects, reading these stories, I kept thinking to myself, 'wow, they are doing a good job at trying to raise awareness of how many infrastructural improvements will be necessary, almost as a plea to the federal government to step in with some money'. That's what I thought they were really trying to do (Ellison, pers.com.).

In summary, this section has demonstrated how the chlorinated disinfection byproducts and cancer issue has been treated in the media, both in terms of how the media has reported on scientific evidence, and how the media has reported on government assessment of that evidence. Contrary to how the key informants have framed the issue ('chlorine disinfection saves lives'), the media has largely framed the issue as 'chlorine is causing cancer'. In only a few stories does it raise the issue of alternative technologies, and rarely does the media report on suggestions for the public to avoid exposure. In fact, disinfection alternatives to chlorine are only mentioned eleven times from 1977 to 2000, and in only thirteen instances over the same period does the media report on suggestions such as granular activated charcoal filters, Brita filters, bottled water, or storing water in the refrigerator overnight. In many respects, this demonstrates the low

importance of the chlorine and cancer issue as being nothing more than a 'flash in the daily pan'. Media reports on the cancer studies, occasionally incorporate reaction from government officials, but then move onto another story after a day or two.

5.3.3 Findings: Constructing Metaphors

A series of different metaphorical concepts emerge from the media presentations of scientific evidence in terms of the construction of the different story frames. Lakoff and Johnson (1980) argue that metaphors serve to reveal hidden cultural constructs and perceptions of reality. To reveal these, Table 5.3 demonstrates the differences in the use of metaphorical constructs by both the print media in presenting scientific evidence, and the key informants who are responsible for the construction, assessment and evaluation of that evidence.

The print media does not frame the chlorinated disinfection byproducts and cancer outcomes debate with a focus on 'water' as a metaphor. Water appears to fuel the chlorine metaphors because it is the contamination of the water from chlorine that enables the media stories to sensationalize the issue. In only three news stories is the issue of water explicitly addressed as an entity on its own where it is expressed as a 'right' that is threatened by contamination. Similarly, cancer is also not treated metaphorically as an individual entity; it just 'is', with one exception. In that instance, cancer was framed as a 'deadly danger' of which environmental contamination is contributing to rising rates, as opposed to how

Table 5.3: Metaphorical Constructs by Source

Metaphor	Broad Metaphorical Constructs	Print Media Stories	Key Informant*
Water	Quality of life (threatened vs saved)	Our survival is threatened by unclean water (n=1)	Water is life/life force (DeAngelo, Douglas, Findlay, Gohier, Hall, Carr, Henry, Murphy, Robertson, Giddings, Green)
			Water is essential ingredient for living (Arbuckle, Hukowich, Morris)
	Equity	Water is a right (n=2)	Water is not a right, it is a resource (Calderon)
			Water is a public right (Ellison)
			Water is relaxation, recreation, pristine, and pure (Douglas, Gianfrancesco, Stone)
Chlorine	Saviour	Chlorine saves lives (n=37)	Chlorine saves lives (Jones, McCarty, Christman, Ellison, Eisler, Douglas, Findlay)
			Chlorine is a public health intervention/essential/ more beneficial than the hazard (Giddings, Green, Hall, Jenkins, Jones, Mao, Murphy)
	Death	Chlorine causes cancer/ cancer-causing chemical (n=76)	
		Chlorine is the 'hearse' option of disinfection (N=13)	
	Unnatural	Chlorine is a chemical with a personality like Dr. Jekyll and Mr. Hyde (n=1)	
	War	Chlorine is a dangerous time bomb/most toxic mixture known (n=12)	Chlorine is controversial and powerful (Findlay)
Cancer	Disfigurement /Death	Cancer is a deadly danger (n=1)	Cancer is scary/dread disease/involuntary risk (Arbuckle, Ellison, Jenkins, Thomas)

* Refers to how key informants view the public perception of water, chlorine and cancer

'cancer' was framed in metaphorical constructions regarding chlorine. Here the focus was always on the 'evils' of chlorine as a 'cancer-causing' chemical. The 'evilness' of chlorine is mediated in thirty seven articles which emphasize that chlorine disinfection is essential to protect against microbial risk, and the one article that specifically frames the chlorine issue as 'chlorine is a necessary public health intervention' (Barlow, 1998).

By contrast, key informants raised several issues regarding water, chlorine, and cancer. It is important to note that interview questions were not directed at obtaining these metaphorical constructs, with 'water' being the only exception. Several respondents were asked to comment on what they thought about 'water'. All of the chlorine and cancer metaphorical constructs, and some of the water metaphors were revealed inductively during the interview conversation by the respondents themselves. Overall, water is a physical (i.e., essential to life), social (i.e., a right) and environmental (i.e., recreation, resource) construct. The metaphorical constructs of chlorine are consistent with the different frames that key informants used to describe the disinfection byproducts and cancer issue as described earlier in this paper. Four respondents specifically drew attention to the 'cancer' issue as a dread disease, and perceived to be an involuntary risk by the public when the exposure is from the 'environment' (Ellison, pers.com.).

5.4 Discussion and Conclusion

Douglas (1966) outlines the concept of 'purity' and 'danger' as metaphorical constructs, elements of which are found in Table 5.3. Concepts of 'purity' inspire thoughts of a pristine environment, where the largest threat or 'danger' comes from contamination or 'dirt'. In fact, Cresswell (1997) examines how the metaphor of 'dirt' is used to constitute people or actions as unwanted or 'out-of-place'. 'Water' symbolizes life. Consequently, 'water' is an extremely powerful metaphorical construct to capture sentiments of a 'lifesource', 'equity', and 'purity'. It is intended to epitomize 'naturalness', and yet, in this issue, we are talking about 'unnatural' water: it is microbiologically clean due to a disinfection process. The microbiological 'dirt' has been purified by use of a chemical, which for the most part in the print media is framed as 'danger' or 'death'. It is not the disinfected water which is 'out-of-place', it is the 'cancer-causing chemical' of chlorinated byproducts. Framed as the 'hearse' option, chlorine is characterized as unnatural or as the abomination: Mr. Hyde.

Similarly, the metaphor of 'war' is very predominant in media presentations of science, and in the government assessment of that evidence. The bolded and italicized words in Tables 5.1 and 5.2 demonstrate this concept of war: there are battles (e.g. 'chlorine combating water-borne diseases'), there are casualties (e.g. 'may cause cancer'; 'delivering babies with rare birth defects'), but many more lives are saved for a greater 'good' (e.g. 'the benefits far outweigh the potential health problems'). However, a study conducted for Health Canada to

evaluate health risk perception in Canada found that 74% of participants agreed with the statement that: "if even a tiny amount of a substance that can cause cancer were found in my tap water, I wouldn't drink it" (Krewski et al., 1994). This reflects an overall misunderstanding on the part of the public regarding the risks from microbial contamination.

The print media feeds into this metaphor of war as it seeks to 'arm' the 'public right to know' about as much, or as little, information as possible. Though self-evident, the media is 'selling' that which is the most sensational. Though globally, many more people die of diarrheal diseases (Craun, et al., 1994), our western, industrialized cultural bias views 'cancer' as one of the biggest fears. 'Cancer' is a highly emotionally charged word in the public domain. It is referred to as the big 'C'; people speak of 'cancer' in a whispered tone. It is viewed with dread as a 'horrible way to die'. Consequently, the small risk of cancer from chlorinated disinfection byproducts is viewed as an 'involuntary' risk by the public, even though the risk of microbiologically contaminated water is much higher.

Tied in with these conceptions of 'war' lies the metaphorical discourse of 'rights'. The public demands the 'right' to a safe environment and safe drinking water. For them, any exposure to a 'contaminant' is unacceptable; particularly in something as 'pure' and 'essential to life' as water. At the core lies the issue of who has the 'right' to make decisions regarding voluntary and involuntary risks. The public frequently engages in personal behaviour (i.e., voluntary) which is

much riskier than drinking water with chlorinated disinfection byproducts (i.e., involuntary), and yet, it is the byproducts that are 'risky'. There appears to be a perception that if drinking water is microbiologically contaminated and it causes sickness, that an individual can go see their doctor and the doctor will make them better. But, if they get cancer, their doctor is powerless to help (Green, pers.com.). Though many people were horrified by the seven deaths and many more illnesses created by microbiologically contaminated drinking water in Walkerton, Ontario (mentioned earlier), the cancer fear still prevails. At the same time, as part of a democratic society, we 'voluntarily' cede our 'rights' to elected officials and government bureaucrats to make decisions on the public behalf. This becomes especially controversial when decisions get made which affect public health. Here lies a continuum where the impacts range from low to high. The 'right' to decide becomes a contested issue. Though the public cedes its right to elected officials, there is still a certain degree of agency (e.g. electoral votes).

Although the media has largely switched its attention to the judicial inquiry that has been formed to investigate what happened in the breakdown of the water treatment in Walkerton, Ontario, once the inquiry is over, the media is likely to return to the 'tried and true': cancer-causing chemical contamination of drinking water supplies. A question was posed at the outset of this paper: 'do the mass media focus attention on some issues to the neglect of others or do they report attention rather than create it?' (Kingdon, 1995: 16). Duncan Ellison (pers.com.) of the Canadian Water and Wastewater Association comments that

"those who are promoting health programs and environmental programs have their life made, to some extent, easier (and occasionally more difficult) with appropriate headlines." The discovery of chloroform's carcinogenicity in 1976 led to several newspaper articles to be directed to the 'cancer-causing' chemical fear in 1977, of which nine media stories were written on the subject. While nine stories does not seem significant, the only other years to generate that kind of attention was in the last three years of this analysis. This started when Health Canada released its expert panel report in 1998, where predominantly the comments by Dr. Wigle's position paper were featured in the media presentations of science, until 1999 and 2000 when Nova Scotia and Newfoundland made public the trihalomethane levels in drinking water supplies.

In some respects, the media attention surrounding the cancer risks and the cancer science, however small, has helped contribute to the continued research agenda regarding the issue. The few media articles would often spur funding agencies to support scientific research that was exploring the disinfection byproducts and cancer relationship. In fact, Gunther Craun, formerly of the US EPA and involved in committees which established research priorities within the EPA for drinking water contaminants commented that: "my general impression was once the disinfection byproduct issue was identified in the mid-seventies it was pretty much recognized by most people in EPA as a high priority and sometimes at the expense of funding research on some of the microbial issues" (Craun, pers.com.).

In Canada, the media focus concerning Dr. Wigle's assessment of the issue was pivotal in pushing Health Canada to respond to the issue 'politically'. The Wigle position paper, while intended to reflect his personal opinion, was nonetheless written by a Health Canada official and published in a Health Canada peer-reviewed publication. Hence, the *appearance* was that Wigle's position reflected official policy, although this was not the case. Consequently, Health Canada had to be seen as doing something pro-active on the issue. Given that Health Canada could predict the nature of the media reaction to the issue (i.e., chlorine causes cancer), they established a Chlorinated Disinfection Byproducts Task Group four months prior to the expert panel report and the Wigle position paper being published. The mandate of the Task Group is to continue studying the issue and make some recommendations as to whether the Federal Provincial Subcommittee on Drinking Water (DWS) needs to re-open its guideline for trihalomethanes.

Establishing this Task Group has afforded the Drinking Water section of Health Canada a 'policy window' (Kingdon, 1995) in which to forward recommendations regarding a guideline for haloacetic acids (HAAs) which form the other most significant group of disinfection byproducts found in drinking water. (While the United States and the World Health Organization have developed standards/guidelines, respectively, for some of the HAAs, there is currently no Canadian guideline.) When the DWS revised its guideline for THMs in 1993, it had been years in the making with the DWS meetings, peer-review

assessment of the evidence, and the public consultation process. Much of these delays may now be avoided for HAAs if the Drinking Water section is able to amass the necessary evidence to submit to peer review along with the evidence for THMs when they make their report to the Task Group. However, there have been some serious interruptions to this process.

Though a number of stories were generated by the high trihalomethane levels in Nova Scotia and Newfoundland in 1999 and 2000 (see Tables 5.1 and 5.2), once the Walkerton e-coli tragedy which resulted in seven deaths broke out in May 2000, the media literally exploded with drinking water stories (n=534 from May 2000 to May 2001). However, the new predominant frames were concerned with microbial protection of public drinking water supplies and the government responsibility for water issues. The plethora of media coverage surrounding Walkerton is not surprising. The Walkerton tragedy created a very 'vivid' representation of the first e-coli outbreak to be linked to drinking water supplies in North American history. Since chlorine was adopted as a disinfection treatment in the early 1900s, very few deaths, in North America, have been attributed to water contamination (cryptosporidium outbreaks in various North American cities at various times being the exception). The key distinction between the cancer stories and the Walkerton tragedy is this: there were 'dead bodies' directly attributed to contamination of the water supply with Walkerton. Dave Green of Health Canada comments that:

> with chlorination disinfection byproducts and any chemical components, you have theoretical numbers for risks due to exposure to these byproducts in drinking water supplies. You can't show me a face, you can't show me a dead body. But with microbiological contamination, you can show me the body. Here's the body. Here's the dead child, whoever it might be. He died because of the microbiological contamination at the treatment plant (Green, pers.com.).

At a science-policy level difficulties arise in the 'definitional struggles'. Scientists and key informants who have participated in this research have largely framed the issue as a 'voluntary risk': we willingly adopt these potential cancer risks from chlorinated byproducts to protect ourselves from microbial contamination of our drinking water supplies which leads to certain death. Hence, a 'where are the bodies' frame becomes apparent. By contrast, the media and some environmental NGOs have framed the issue as an 'involuntary risk': chlorine disinfection is giving us cancer. While the media has not been advocating alternative technologies to any significant degree, some of the key informants (Olson, Morris, Melnick, Douglas, Wigle, Thomas, Gianfrancesco) did raise a preference for ozonation to be employed as the primary disinfection treatment, followed up with chlorination to ensure a proper chlorine residual in the distribution system. They mentioned this preference as a precautionary measure given that ozonation produces fewer byproducts than chlorination alone. The difficulty is that the involuntary risk frame is unable to 'show us the bodies'. However, working in favour of the 'involuntary risk' frame is that the 'chlorine causes cancer' frame achieves a high degree of public salience, and consequently, has the potential to generate political attention.

As it currently stands, the Walkerton tragedy seems to have completely derailed the activities of the Chlorinated Disinfection Byproducts Task Group. This Task Group had been scheduled to make recommendations by 2000-2001. However, given that so many members of the Task Group have also been involved in the Walkerton inquiry, there is a great deal of uncertainty as to when the Task Group will return to its activities. In our discussions with epidemiologists, the current science research program appears to be moving more towards studying the reproductive and developmental outcomes associated with exposure to disinfection byproducts. This is largely due to the high degree of uncertainty associated with cancer studies. Because scientists have not been able to establish better biomarkers of exposure to measure in a human population, new large scale cancer case-control studies are not being initiated until they are able to address the exposure issue. While this is also important in establishing a baseline of evidence for the reproductive and developmental outcomes, the reproductive evidence is still very much in the early stages. Reproductive and developmental studies have the advantage of being constructed retrospectively and prospectively, do not involve as long of a latency period, and hence data can be collected more quickly. We suggest that once the evidence becomes more readily available on the reproductive outcomes, this will serve to redirect media, and hence political, attention back to the disinfection byproducts issue.

In the meantime, post-Walkerton media attention is largely (and perhaps properly) directed at microbial risks, and ensuring protection against microbial

contamination, in drinking water supplies. Insufficient attention in the public's mind has been directed at microbial concerns in drinking water in the past. This is not to say that the cancer risks or the reproductive risks should not be studied. Quite the contrary. If there are genuine risks associated with these exposures, and there are alternative technologies which may be able to address those concerns, then research should be directed at that. However, there has been a tendency among the general public to demand a 'zero risk' for any environmental contaminant (Jenkins, pers.com.). It is important to reduce environmental exposures as much as possible, however, 'zero risk' is impossible. It should not be expected in a society where the general public demands many technological advancements that business/corporations supply, which unfortunately, come with a price.

We hypothesized at the beginning of this paper that the public may view risks associated with chlorinated disinfection byproducts as involuntary (causes cancer), but controllable (alternatives exist), unfair, chronic (cancer) and acute (reproductive effects), focused in time and space (present in water supplies), delayed (latency), difficult to detect (measurement problems), but still within the realm of human mitigation; alternative technologies can be used, but whose health effects are equally uncertain. Residents of Erickson, British Columbia have been battling with their provincial government against chlorination plans of their groundwater supplies. The community residents of Erickson have been largely afraid of the cancer risks associated with chlorination byproducts. The medical

officer of health for the region is afraid that Erickson is a 'Walkerton in the waiting'. For these residents, ozonation is the 'saviour' and chlorination is the 'hearse'. For government officials in British Columbia, ozonation represents the 'Cadillac' option. Only time will tell.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

6.1 Introduction

This research examined the social construction and communication of risk in science-policy, using chlorinated disinfection byproducts (CDBPs) and cancer outcomes as a case study. Particularly, this thesis explored the contested nature of how cancer risk from chlorinated disinfection byproduct (CDBP) exposure in drinking water was assessed and framed by different actors. Two dominant framings have stemmed from this analysis. The first framing is that chlorine disinfection protects public health from microbial pathogens, and while this may carry a small relative risk of cancer, the overall risks must be balanced such that microbial protection is not compromised. This framing can be broadly characterized as a 'voluntary risk'; that is, we choose to disinfect with chlorine to protect our health. Hence, we voluntarily accept the small elevated cancer risk for a guaranteed protection against microbial contamination which carries with it greater risks for public health.

The second framing is that given the potential cancer health risk due to longterm exposure to chlorinated disinfection byproducts, alternative water treatment technologies should be adopted. Within this frame, what constitutes

alternative water treatment technologies differs. For some, it means infrastructural changes to existing treatment plants such that water is filtered before primary disinfection, thereby removing the majority of the organic and inorganic material with which chlorine reacts. For others, it means changing disinfection treatment plans altogether. Here, ozonation (usually the preferred option), ultra violet radiation, membrane technology, and granular activated carbon systems are advocated. The health effects which may be associated with some of these alternatives are largely unknown. This framing can be broadly characterized as an 'involuntary risk'; that is, given that chlorinated byproducts may cause cancer, alternative technologies should be adopted as a precautionary measure. Implied within this frame is that the public has never been given the option to choose a 'preferred' disinfection treatment plan; the decision to chlorinate water supplies has been 'imposed' by public health and water treatment authorities.

This research combined multiple qualitative methods in the analysis of key informant interviews and scientific, legal, and policy documents. The combined approaches were based on: social problems research through a focus on claimsmaking activities; political science in the application of interpretive policy analysis and agenda-setting issues; and linguistics analysis with a focus on language, stories, and metaphors. The primary objectives of the research were as follows:

1. To examine the construction of scientific knowledge and evidence concerning the relationship between chlorine as a drinking water disinfectant and possible human health effects, exclusively cancer.
2. To investigate how the science is communicated and contested within the scientific community and transformed to a level of accepted 'scientific fact' as 'authorities', by exploring how scientists have publically framed the issue in published documents as compared with private reflections on the nature of the evidence.
3. To assess what impact these contested scientific authorities may have on the policymaking process in terms of setting guidelines, regulations, policies, and standards in both Canada and the United States.
4. To investigate media presentations of scientific evidence as compared to framings by scientists, regulators, the chlorine industry, water utility representatives and non-governmental organizations of the CDBP issue.

6.2 Summary of Findings

6.2.1 Objectives One and Two: Construction of Scientific Knowledge and Contested 'Authorities'

Chapter two demonstrated that once the 'fateful moment' (Giddens, 1991) of chloroform's carcinogenicity was demonstrated in toxicological studies in 1975 (NCI, 1976) the scientific research agenda was directed at further study of the CDBP issue. Policymakers recognized the CDBP issue as a research priority,

sometimes at the expense of other water quality research such as microbial contamination. This was evidenced by increased research activity at the US Environmental Protection Agency (EPA) and Health Canada, as well as by other research scientists (academic, industry) given that the identification of the 'cancer risk' was one of the motivators of funding agencies. In examining the construction of scientific knowledge as 'authorities' in the CDBP and cancer issue, a number of challenges were made.

The first challenge was against the Morris meta-analysis (Morris et al., 1992). For a time, the risk estimates calculated by Morris were favourably received by the Environmental Protection Agency (EPA). However, some disagreed with the methodology used in the meta-analysis, and others argued that the 'cancer fear' it created was at least partly responsible for the cholera outbreak in Peru. The second challenge was grounded in toxicology where disputes centered around a US expert panel report (ILSI, 1997) and the competing hypothesis of a scientist at the National Institute of Environmental Health Sciences. This challenge was visible in a legal battle pitting the chlorine industry against the US EPA, as outlined in Chapter four. The last challenge broadly highlighted tensions between toxicology and epidemiology regarding differing interpretations of the weight of evidence.

These tensions raised an interesting finding from this research. The differing assessments of the evidence among toxicologists and epidemiologists, as represented in published documents, did not always coincide with personal

reflections on the evidence from interview conversations. Epidemiologists, toxicologists and public health scientists all rank the chemical risks from CDBPs much lower than microbial risks from inadequately protected drinking water supplies. Public health scientists, however, have been unsuccessful at redirecting the research agenda to microbial concerns. Hence it has been the 'public' face of epidemiologists and toxicologists, through expert panel reports which has promoted policy commitments to more research. This has overridden the 'private' preference of public health scientists operating in that regulatory arena.

This raises another important finding, in that it is necessary for scientists to preserve a level of 'uncertainty' in order to secure continued research funds. As Jamieson (1996) argues, there needs to be a balance of uncertainty in science and policy. Toxicologists, by 'closing the door' on the chloroform hypothesis, seem to have been successful in moving the 'uncertainty' level to a different domain: the study of other, perhaps more important, disinfection byproducts such as the brominated species or the haloacetic acids. Epidemiologists, finding themselves at a 'standstill' in terms of undertaking new cancer research, have decided that they need to re-analyze existing datasets of the more recent stronger case-control designed studies. At a policy level, the continued uncertainty of science resulted in no change in regulations, but had the potential to redirect funds away from the CDBP agenda. Hence, in addition to these re-analysis studies, some epidemiologists have switched to focus on the reproductive effects. This has served to redirect the nature of uncertainty to a domain of 'more research is

necessary' and the construction of 'new' scientific authority. However, uncertainty in science-policy debates can create a paradox, in that, while some uncertainty is necessary to secure research funds, uncertainty can also be used in science and policy claimsmaking activities when issues are brought to the levels of the Courts, as was seen in Chapter four.

6.2.1.1 Graphic Presentation of Objectives One and Two

Graphically, Figure 6.1 demonstrates how 'authorities' have been contested. It demonstrates the inter-relationships between science, industry, and government in the CDBP science-policy arena. Within this policy subsystem each group holds their own particular epistemic 'authorities', as outlined in Chapter one. In the CDBP and cancer outcomes issue, science holds the domain of 'truth' which carries with it the power to define and explain reality as an epistemic authority. Industry holds an epistemic authority over the domain of business, economy and growth. Government holds as an epistemic authority the power to decide what is in the best interest of public protection and public good.

In the science-industry sphere, lies an area of contested and competing knowledge over what constitutes appropriate 'scientific fact'. Here lies the competing hypotheses regarding CDBPs (e.g. chloroform; individual species; dominant byproduct of concern vs complex mixture), tensions over the strength of the evidence (e.g. between toxicology and epidemiology), and tensions regarding 'credible' sources (e.g. industry funded research vs research funded by arms

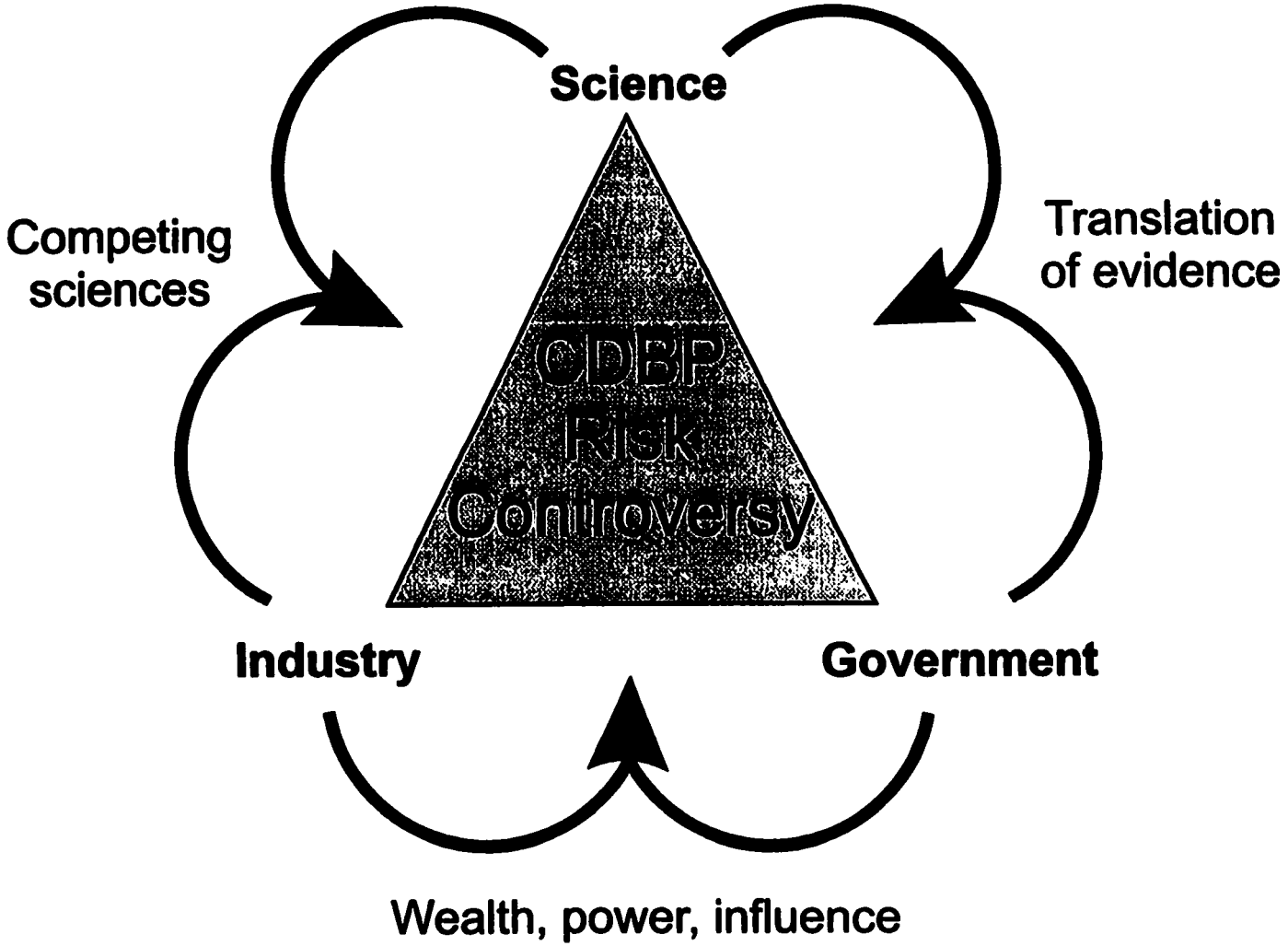

Figure 6.1 Contested 'Authorities' in CDBP Controversy

length organizations with no vested interest in outcome). Within the science-government sphere lies the difficulty in translating scientific evidence to the policy domain. Microbial risks are of greater concern than the cancer health risks, but government appears to have focused more on the latter. Moreover, at another level, for a policy-relevant translation of scientific evidence to occur, it would require studies comparing exposures and health outcomes between communities relying on surface water, which use chlorine as the primary disinfection treatment, and others which use ozonation. In the industry-government sphere lies the role of wealth and power which can influence government decision making. This was evident in Chapter four when the chlorine industry used the scientific claims of the ILSI expert panel report against the EPA's policy decision regarding chloroform in the courts. In this case, industry's wealth, power and influence was mediated through the courts by grounding its arguments in science. This demonstrates a shift in the traditional strategies employed by industry to influence policy. Usually, industry relies on economic arguments, framed in terms of job losses, if the government proceeds with a particular policy initiative. For example, this was the case with chlorine use in pulp and paper bleaching practices in Ontario (see Driedger and Eyles, 2001).

6.2.2 Objective Three - Impact of Science in Policy: Canada and the United States

Chapter three demonstrated that in Canada, it is the scientific evidence which has shaped the agenda. The 'focusing event' for the CDBP and cancer issue in Canada occurred when the Marrett and King (1995) study was presented to Health Canada. This led to the bi-national expert panel report (Mills et al., 1998) and the establishment of the Chlorinated Disinfection Byproducts Task Group to continue reviewing the evidence. The mandate of the Task Group is to make recommendations to the Federal Provincial Subcommittee on Drinking Water (DWS), that body which is responsible for setting Canadian drinking water guidelines. However, it is not likely the cancer science that will drive regulatory change with respect to the CDBP issue. This thesis hypothesizes that it will be the reproductive effects which may 'tip' the issue because the issue would become reframed as an acute risk (i.e., reproductive effects) versus a chronic one (i.e., cancer). The reason for this speculation is twofold. First, reproductive and developmental evidence, while still in the early stages, can be collected more quickly as the latency period between exposure and outcome is much shorter. Second, while some articulate a concern over the cancer risks associated with CDBP exposure, any regulatory changes that are motivated by evidence of reproductive and developmental effects, would effectively remove (or at least reduce) the cancer risk. In the meantime, the CDBP Task Group is potentially affording the Drinking Water section of Health Canada a 'policy window' in

which to forward for recommendation a guideline for haloacetic acids; a byproduct that scientists argue may be of greater concern to human health.

By contrast, chapter four argued that in the United States, it was the chloroform 'science war' that served as the 'focusing event'. Overall this 'war' removed the contested nature of the competing sciences from the laboratory and peer-reviewed journals to the courts. The nature of the 'boundary-work' (Gieryn, 1999) demonstrated in this science-war pitted threshold-proponents (i.e., those who argue chloroform is safe at low doses) against threshold-opponents (i.e., no dose is safe). However, in credibility contests, it is numbers and reputations that count. There was an unequal power relationship between threshold-proponents and threshold-opponents. Threshold-proponents were greater in number and had several powerful organizations on their side: ILSI; the chlorine industry; some EPA scientists. Threshold-opponents were largely represented by the EPA, the NRDC (an environmental NGO), and Dr. Melnick of the National Institute of Environment and Health Sciences in the US National Institutes of Health. While the latter, too, could arguably be characterized as powerful organizations, they do not have the same financial base from which to draw. Melnick's counter-hypothesis regarding chloroform's carcinogenicity was only truly 'heard' in court, and it did not carry any weight with the court's decision. In this legal challenge, scientific uncertainty concerning chloroform (i.e., Melnick's challenge vs ILSI) was not used to justify non-decision making. Rather, the court interpreted the ILSI

panel's scientific claims to represent the 'best available science'. Regardless of whether or not the EPA wanted to follow additional measures to ensure that the ILSI panel evidence was indeed the 'best available', the court argued that the scientific process itself (i.e., the possibility of falsification at a later date) would resolve the issue. Hence the courts adopted a construction of 'knowledge' closer to that of science, than the legal system (i.e., usually relies on standards of 'reasonable doubt').

6.2.3 Objective Four - Media Presentations of Science

'Out-of-place' metaphors (Cresswell, 1997) were present in media presentations of science covered in Chapter five. Chloroform's 'fateful moment' led to several print media articles directed to the 'cancer causing' chemical fear in 1977. This media response was partly credited with the level of attention policymakers attached to CDBPs in the United States. The media response following the release of Health Canada's expert panel report in 1998 featured prominently the comments by Dr. Wigle's position paper, and credited Wigle as the author of the expert panel review. Consequently, the media response could be partly responsible for why Health Canada deemed it necessary to establish a CDBP Task Group with a mandate to make recommendations regarding drinking water guidelines. The way in which the media framed news stories (i.e., chlorine causes cancer) did not reflect the dominant framings of key informants (i.e., chlorine disinfection

protects public health). While the e-coli outbreak in Walkerton, Ontario shifted media attention towards microbial issues, the high THM levels reported in Nova Scotia and Newfoundland meant the cancer framing was not lost. The implication for public risk perception is that the cancer fear may remain paramount with drinking water concerns.

6.2.3.1 Graphic Presentation of Objectives Three and Four

Figure 6.2 provides a graphic representation of objectives three and four. Objectives one and two (represented by Figure 6.1) demonstrated that scientists, policymakers, and industry have largely framed the CDBP issue as a 'voluntary risk' and each hold as a belief, concern for public health. Their approaches, however, may differ. Chlorine disinfection of drinking water is one of the most positive applications of chlorine. Industry representatives use the example of drinking water as a way to demonstrate to the public that not all chemicals are 'harmful'. Many scientists view the issue as a 'luxury of the first world' where they are not completely convinced there is an adverse cancer relationship. This is particularly the case among toxicologists, at least given the byproducts that have been studied. Public health scientists are much more concerned with 'balancing the risks', and favour chlorine as the preferred treatment option because alternative technologies are expensive. Though public health scientists would be more in favour of 'prudent' options, they operate within a government framework

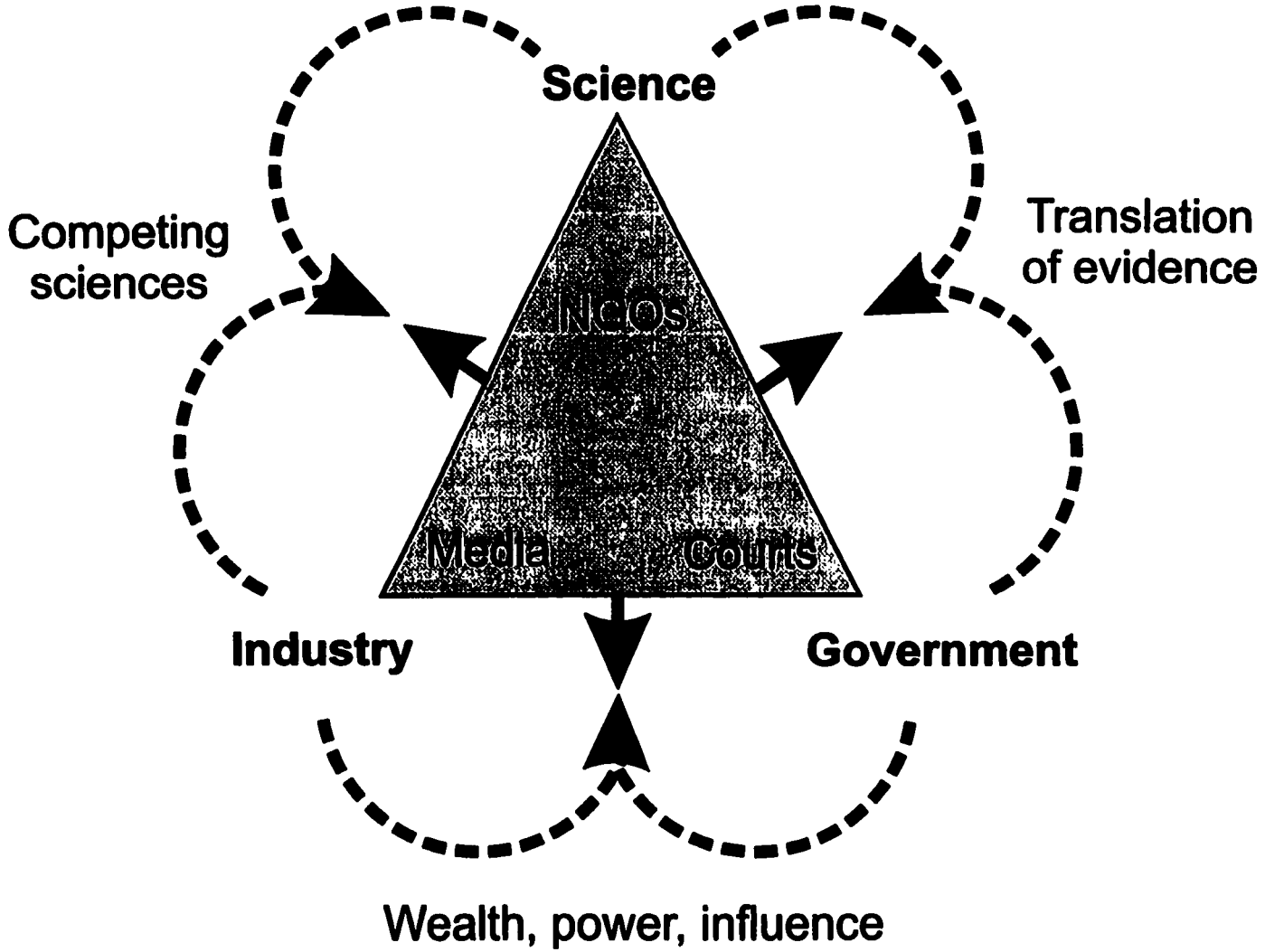

Figure 6.2 Modifying Influences that Challenge 'Authorities'

of limited resources. Hence, they try to achieve the 'greatest public health bang for each public health dollar spent'.

However, Figure 6.2 demonstrates how the courts, the media and NGOs have provided an arena for modifying and contesting the 'authorities' of science, industry and government. Non-governmental organizations and the media have both largely framed the issue as an 'involuntary risk' due to the 'cancer fear'. Pollution Probe has established itself as the Canadian 'watchdog' of the CDBP issue, participating in the CDBP Task Group and in promoting its water concerns through multi-stakeholder meetings (e.g. Water We Drink conference in November 1998). The NRDC, in the US, was instrumental in challenging the basis of the scientific claims forwarded by the chlorine industry. The courts, at least within the US, sided with the authorities of science and industry prompting the EPA to make some regulatory changes. Notably absent in this issue has been the public. It has been only the media which has been closest to creating public attention through news stories. Media attention surrounding CDBPs seems temporary, and quickly moves out of the sphere of attention.

6.3 Contributions of the Study

6.3.1 Theoretical Contributions

The theoretical contribution of this research lies primarily in its development of a conceptual and analytic framework by which to investigate how environmental

health issues are constructed and contested within a discourse of uncertainty. Figures 6.1 and 6.2 show an evolving image of how the CDBP and cancer issue developed. These figures can be further extended to build an understanding of the parameters of environmental health decision making as shown by Figure 6.3. Concepts outlined in this figure resonate with policy literatures that have examined the role of facts, values and interests in the policy arena (e.g. Sabatier, 1987; Weiss, 1983). The contribution of this research extends those concepts into a broader framework for examining science-policy issues; particularly in an environment and health context.

Figure 6.3 shows a three-sided pyramid of industry, science, and government resting on a 'public' base. Mediating the science-government-industry 'authorities' are the courts, the media and NGOs. These relationships are multidirectional within the 'public' domain, where not all actors in the policy subsystem are active in all cases. To illustrate, Table 6.1 complements the graphic presentation of Figure 6.3 by demonstrating how facts, values and interests vary in a policy arena.

Figure 6.3 and Table 6.1 create insights into how information is transformed by science, constructed into evidence within the scientific community, and how it is communicated to policy makers and socially (re)constructed by them given 'outside' influences (industry, media, NGOs, courts). Each of these actors seek to achieve a level of 'credibility' which will

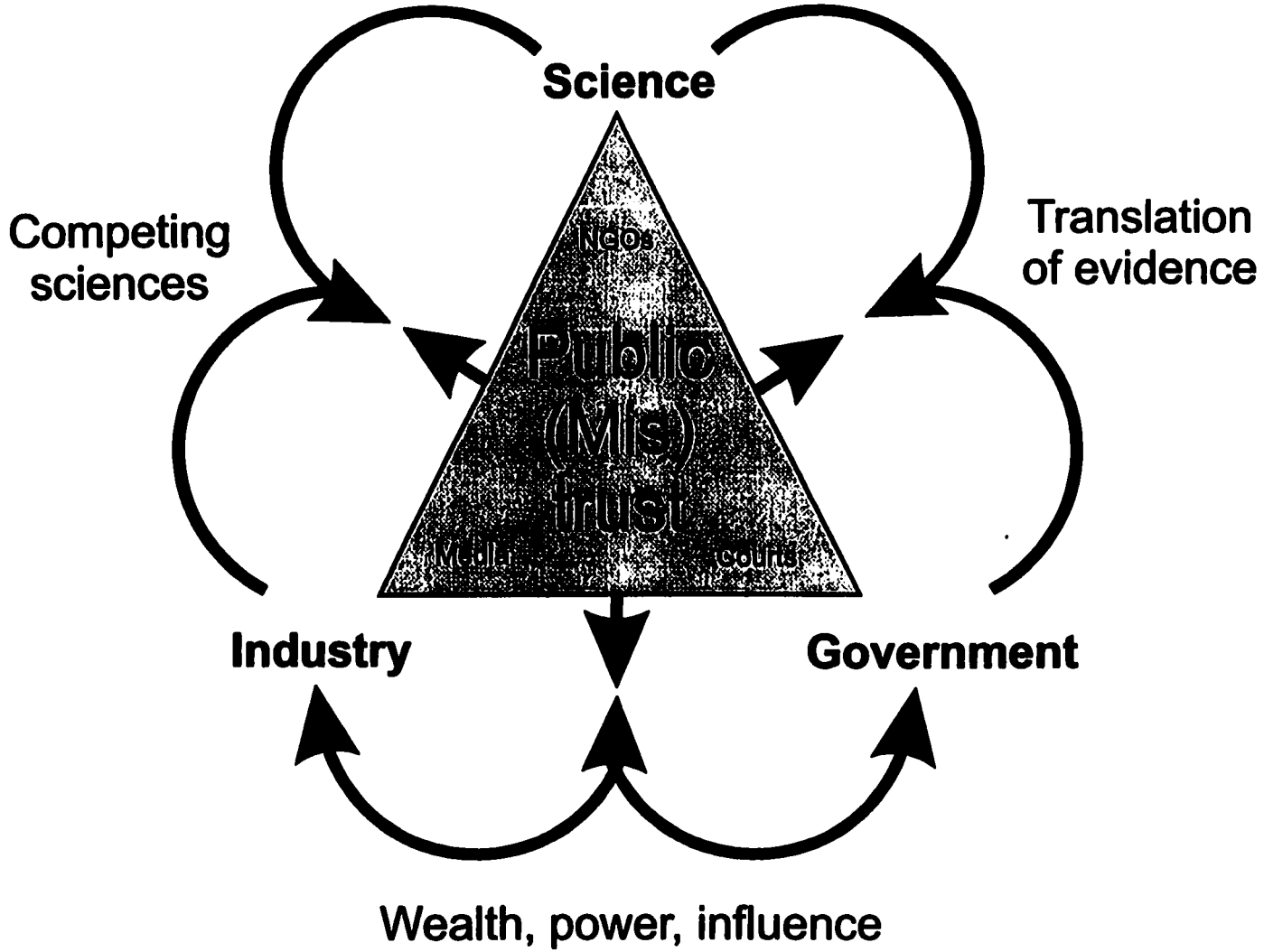

Figure 6.3 Contested 'Authorities' and Modifying Influences in Risk Issues

Table 6.1 Facts, Values, and Interests of Policy Actors in Environmental Risk Issues

Policy Actors	Facts	Values	Interests
Science	evidence (95% CI)	burden of objective truth	professional careers
Government	fluctuates with interests and pressure (public health facts may be overpowered by cost factors)	fluctuates depending on who is in power	re-election imperative
Industry	unequivocal evidence	free-market	profits
Public	status-quo but zero-risk	no-risk society	environmental protection but with low taxes, high quality of life
Environmental NGOs	fluctuates with interests	precautionary preferences	environmental agenda, decreasing industry power
Media	fluctuates with interests	freedom of press/ public right to know	profile, careers, salience through selling
Courts	evidence - beyond reasonable doubt	justice	careers, unchallenged decisions

resonate with public values in risk issues. Mismanagement of risk issues has led to a mistrustful public. Figure 6.3 reveals the role of other actors within the policy subsystem, namely 'industry' which broadly represents corporate interests, business, individual resource utilities (e.g. nuclear power vs hydroelectric power interests; water utilities; industrial manufacturers; etc.), as well as the judiciary. While the judiciary plays a strong role in the US given its legislative and judicial traditions, the courts have not played as strong a role in Canada. However, with the introduction of Environmental Bills of Rights, that Ontario has recently adopted, more avenues for challenging science-policy decisions may be opened.

To illustrate these contributions, a key finding of this research is that though the hegemony of science is challenged in the new 'risk society' (Beck, 1992), the interpretation and use of scientific claims by actors (who arguably are advancing their own individual interests and values) within the policy subsystem, are important in establishing authority and credibility in environmental health policy issues. Industry representatives, broadly defined, are funding scientific research, both to present themselves as good corporate citizens by taking interest in studying what impact their products may be having on the environment and on human health, but also to protect their interests. They have significant resources to fund original research. Thus, they rely on scientific evidence as 'facts' to support their interests of continued profits, and still maintain an underlying value of preservation of the free-market (see Table 6.1).

Given that government organizations and external research granting organizations (e.g. National Institutes of Health in the US, or Federal Research Councils in Canada) do not have the same resources at their disposal, in a 'mandated science' (Salter, 1988) sphere, industry science gets used, or at least evaluated, in standards setting. This carries with it significant implications for the use of science in policy. It also raises important questions as to whose responsibility it should be to conduct these scientific studies for regulatory decision making purposes. Some would argue that this responsibility should lie with government bodies, as it is their primary mandate to establish guidelines and standards to protect public health; that is, their epistemic authority. While other scientific bodies, through the academe and industry may add to this body of knowledge, issues of credibility are paramount, particularly if a goal of policy actors is to ever regain public trust in risk issues.

Moreover, given the uncertain nature of epidemiological science, and the difficulty of interpolating animal data to humans, regulatory bodies have placed a greater reliance on government appointed expert panel committees to evaluate large bodies of evidence concerning exposure-outcome relationships. This shift towards drawing from evaluations of 'expert' panels carries significant implications for the translation of scientific evidence within a policy domain. Because 'careers' are at stake, the construction and membership of these 'expert' panels can be pivotal in shaping the outcome (Aronson, 1984). These experts have

a vested intellectual and professional interest in securing their interpretation and results from falsification. This is not to claim that these experts would necessarily exclude competing information outright. However, if there was only a small minority arguing against the dominant scientific interpretation of evidence, it would take a critical mass before the 'minority' position could make a legitimate challenge. Such interests are very similar to the nature of paradigm shifts in science as outlined by Kuhn (1962).

Moreover, the membership of these expert panels is often mixed. That is, they can have representatives from industry, academe and government in order to present a 'unified' group. While such a mixed membership might make the consensus conclusions more acceptable to these different bodies of 'authority', they may not automatically generate higher levels of credibility with NGOs, experts not participating on the panel, or the public. This demonstrates another avenue for the role of the courts in interpreting and mediating science-policy disputes.

Demonstrating the applicability of this framework to other science-policy issues is important. For example, environmental NGOs are increasingly drawing on scientific evidence to advance their claims within the policy subsystem. In the 1990s, environmental NGOs were raising awareness of elevated breast cancer rates worldwide arguing that environmental contaminants could account for some of the unknown risk factors (Thornton, 1993). The 'facts' were premised as

organochlorines contribute to breast cancer. In the organochlorine-breast cancer issue (see Driedger and Eyles, 2001), scientific claims and counterclaims were generated by NGOs, scientists, and industry, each reflecting their differing facts and values. At a policy level, while a number of international organizations were calling for a ban on chlorine, the Ontario (Canada) provincial government did make some policy changes regarding chlorine discharge in pulp and paper mills. (The policy decision changed with the election of a new governing party). Unlikely supporters of the chlorine industry, such as the American Public Health Association, agreed with the counterclaims generated by industry in that there was a need to ground policy decisions in 'good science'. Thus, even though the hegemony of science is being challenged, science remains the 'objective' arbiter in science-policy debates. The challenge lies in how that science is used and interpreted.

Another example can be drawn from a different science-policy issue that does not closely resemble the chlorine situation: genetically modified (GM) foods. There are three countries that produce most of the GM crops in the world: the United States; Argentina; and Canada. The Canadian government has established a regulatory process for approving GM foods by assessing risks both in terms of safety for human consumption and the environment. Canada has approved GM varieties of canola, corn, and soybeans. However, there is no mandatory labelling system for GM foods in Canada. European countries have been much more

resistant to the acceptance of GM foods, particularly for import. A recent report produced for the Ministerial Group on Biotechology in the United Kingdom has concluded that many of the concerns raised about genetically modified foods also exists for foods produced by conventional means (e.g. potential nutritional imbalances, allergic effects) (Donaldson and May, 1999). Nonetheless, the European Union, having approved some varieties of GM foods, has placed a moratorium on further approvals in order to better assess the risks (i.e., interests change based on public pressure). Within a science domain, there are tensions among the construction of risks. It will be interesting to monitor the type of claims that are generated by public health, academic and industry scientists concerning the human health risks associated with GM foods.

In summary, the actors involved in a policy subsystem vary in their application of scientific claims to justify their facts, values and interests (Table 6.1). These will also vary depending on the risk issue, and to what extent each actor may play in constructing knowledge claims (Figure 6.3). The application of Figure 6.3 and Table 6.1 provides a model by which other environmental issues can be compared to determine what role scientific uncertainty is playing in the environmental health policy process, based on which facts, values and interests resonate with the actors. The theoretical contributions lie in the extension of such policy concepts into the environment and health domain.

6.3.2 Substantive Contributions

The substantive contributions come from a detailed case study of a single uncertain and complex issue that links the environment to health: CDBP in drinking water and cancer outcomes. It is important to understand how transnational environmental issues are filtered through national and local political contexts. This thesis presented an analysis of how the CDBP and cancer issue developed and took shape in public health regulatory standards setting environments in both Canada (through Health Canada) and the United States (through the EPA). Understanding the construction of knowledge and authorities in the two different regulatory environments, and the mechanism of issue resolution, is increasingly important. Environmental health issues which transcend boundaries often involve differing interpretations of the same issue and evidence which can result in different regulatory outcomes. Moreover, this research adds to the literature of public-private discourses. There has been insufficient attention paid to the potential differences in scientific interpretations of evidence and directed research programs as represented in published documents (public) against personal reflections (private) of the same issues. It also contributes to the public's understanding of risk, at least based on how the media presents scientific evidence and government positions regarding issues of risk. Lastly, this study provides an example of the necessity to move away from the strict 'objective' scientific interpretation of an issue in order to examine it through a more contextual lens.

Risk controversies are not going to disappear, nor will they develop in the same manner in all political contexts, in all places. Hence, broader theoretical and analytical understandings will be required.

6.3.3 Methodological Contributions

Methodologically, this thesis relied on multiple qualitative approaches. In dealing with complex issues, it is pivotal that researchers do not remain fixed on only one method of analysis. To understand the underlying social, political, and cultural context, this research required the adoption of many analytical tools. It incorporated the approaches of social problems research through a focus on claimsmaking activities, political science in the application of interpretive policy analysis and agenda-setting issues, and linguistics analysis with a focus on language, stories and metaphors. When woven together, these mixed methods assisted in the reconstruction of the CDBP and cancer 'story'. Hence, methodologically, this research adds to contemporary policy analysis that currently dominates the environmental health literature by focussing on the meaning of policy; that is, what is said, how it is said, and who is the audience. This supports recent calls made in the policy literature for a more interpretive approach to policy discourse and policy paradoxes.

6.4 Future Research Directions

This research has provided a focus on process-oriented issues in an area of scientific and regulatory 'uncertainty', as opposed to representing a complete reconstruction of 'what happened'. A number of research directions flow from this analysis. Within the same topic area, it will be beneficial to monitor if the reproductive outcomes are more powerful to 'tip' the regulatory process, as speculated by this project, than the cancer science. The United States will be promulgating Stage 2 Final Rules for Disinfection and Disinfectant Byproducts in May 2002. Similarly, the CDBP Task Group has yet to table their final report with recommendations for action in Canada. Once the Walkerton inquiry has been resolved, the Task Group will be able to return to their mandated activities.

The framework developed in this research needs to be further tested against other science-policy issues governed by discourses of uncertainty. Some examples, like organochlorines and genetically modified foods, have been forwarded, though an examination of issues such as air quality will be important as this carries with it a greater global health impact. Other examples include the application of concepts like 'sustainable development' or 'population health' which are prominent in the language of policy documents, but difficult to put into practice. There is a critical need to understand what motivates different stakeholders in a policy subsystem to act, and what conditions in the local community are necessary to marshal opposition and concern in that subsystem.

Risk controversies are not going to disappear. Instead, what is going to be required is an individual, contextual understanding of risk issues within specific areas in order to address local concerns. Past mismanagement of risk issues has left the public distrustful of 'expert' opinion, regardless of source (science, industry, government). In order to regain that trust, it will require decades of appropriate and sensitive action on the part of scientists, policymakers, and industry representatives. The public is no longer content to remain an idle, silent partner in risk issues. This is increasingly evident as the public trusts their own 'experts' over the supposedly more 'credible' experts. While global understanding of risks will remain important, it is the interpretation and perception of these risks at the local level that is likely to guide decision making processes.

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APPENDIX A

List of Documents

List of scientific, policy and legal texts

Science Documents:
ILSI. 1997. *An evaluation of EPA's proposed guidelines for carcinogen risk assessment using chloroform and dichloroacetate as case studies: Report of an expert panel.* International Life Sciences Institute and Health and Environmental Sciences Institute.

Mills, C.J., Bull, R.J., Cantor, K.P., Reif, J., Hrudey, S.E., Huston, P., and an Expert Working Group. 1998. Health risks of drinking water chlorination byproducts: Report of an expert working group. *Chronic Diseases in Canada.* 19(3): 91-102.

Policy Documents:
Science Advisory Board. 2000. *Review of the Draft Chloroform Risk Assessment by a Subcommittee of the Science Advisory Board.* April 2000. EPA-SAB-EC-00-009.

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Legal Documents:
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Respondents Brief, US EPA, 1999. Chlorine Chemistry Council et al v. US EPA, 206 F.3d 1286. Nos. 98-1627, 99-1053 and 99-1056).

APPENDIX B

Interview Timetable

Name	Interview Date	Organization	Interview Type
Arbuckle, Tye	March 27, 2000	Health Canada	Epidemiologist (Reproductive) - Public Health
Bull, Richard	October 15, 1999	Batelle Research Labs	Toxicologist
Calderon, Rebecca	September 5, 2000	USEPA	Epidemiologist, Public Health
Cantor, Ken	November 18, 1999	National Cancer Institute, US	Epidemiologist
Christman, Keith	October 20, 2000	Chlorine Chemistry Council, US	Chlorine Industry
Craun, Gunther	October 24, 2000	former USEPA	Epidemiologist, Public Health
DeAngelo, Tony	September 6, 2000	USEPA	Toxicologist, Public Health
Douglas, Ian	February 17, 2000	Ottawa-Carleton	Water Treatment Engineer
Eisler, Hugh	December 11, 2000	Former Executive Director, C4	Chlorine Industry
Ellison, Duncan (1) (2)	February 18, 2000 March 24, 2000	Executive Director, CWWA	Water Utility Representative
Findlay, Rick	February 18, 2000	Director, Water Program, Pollution Probe	Environmental NGO
Gianfrancesco, Mike	November 14, 2000	Waterloo Region	Public health unit concerns
Giddings, Michele and Green, Dave	February 23, 2000	Health Canada, Drinking Water Section	Microbiologists, Public Health
Gohier, Leo	November 29, 2000	Former Hamilton Director of Environmental Services	Public health concerns, Water service delivery issues
Hall, Rob	November 22, 2000	City of Hamilton	Public health concerns

Hamdy, Yousry and Carr, Dan	October 27, 2000	MOE, Water Policy Branch	Ontario policy issues
Henry, Dale	December 6, 2000	MOE, Associate Director, Former Drinking Water Standards, ON	Ontario policy issues
Hrudey, Steve	August 20, 1999	University of Alberta	Risk Assessment
Hukowich, Alex	November 30, 2000	Medical Officer of Health Haliburton/ Cawartha	Public health concerns
Hunter, Bill	October 27, 2000	MOH, Environmental Health and Toxicology	Public health concerns
Jenkins, Goff	August 30, 2000	MOE, Ontario rep for FPDWS; Drinking Water Specialist	Public health and regulatory science concerns
Jones, Allan and McCarty, Lynn	October 19, 2000	C4, Executive Director and Research Scientist	Industry
King, Will	March 2, 2000	Queen's University, Community of Health and Epidemiology	Epidemiologist
Lachmaniuk, Patricia	November 8, 2000	MOE, Formerly of Drinking Water Surveillance Program (DWSP)	DWSP program background
MacFarlane, Ronald	December 14, 2000	MOH, Toronto	Public health concerns
Mao, Yang	August 19, 1999	Health Canada, LCDC	Epidemiologist, Public Health
Melnick, Ronald	January 16, 2001	National Inst. of Env. Sciences, EPA	Toxicologist
Mills, Christina	August 18, 1999	Health Canada, LCDC	Public Health

Morris, Robert	November 20, 2000	Tufts University	Epidemiologist, Meta-Analysis
Murphy, Patricia	October 16, 2000	USEPA	Epidemiologist
Poole, Charles	August 31, 2000	University of North Carolina, School of Public Health	Meta-Analysis, Epidemiology
Olson, Eric	January 4, 2001	Natural Resources Defense Council	Intervener in legal case for EPA
Robertson, Will	February 23, 2000	Health Canada	Microbiologist
Stone, Jim	November 21, 2000	North Bay	Public health concerns
Thomas, Barry	Sept. 27, 1999	Formerly of Health Canada	Toxicologist
Wigle, Don (1) (2)	August 19, 1999 Sept. 27, 1999	Health Canada, LCDC	Epidemiologist

APPENDIX C

Interview Checklist

Summary of Interview Checklist

General Questions — regarding background, job position, organization background, etc.

LCDC (Mills et al., 1998) Report — asked of report authors, and other scientists who may have been familiar with it. Issues surrounded their assessment of the report, did they think anything was omitted, etc.

CDBP Task Group — asked of Canadian scientists, NGOs, policymakers, task group members when possible. Issues surrounded their knowledge of the activities of the Group, did they feel that such a group was necessary, expected timeline for completion of their activities, etc.

Assessment of Evidence — asked of almost everyone. What was their assessment of the toxicology/epidemiology evidence (individually), the assessment of the overall evidence on CDBPs, were they convinced that there was a problem or concern, did respondents know of any ongoing studies, how would they rank the CDBP issue as a public health concern, etc.

Toxicology vs Epidemiology Tension — asked of scientists working in the area. Issues surrounding discrepancies in the data, which evidence base seemed stronger, etc. Often these questions tied in with the assessment of the evidence issues.

Water Safety Concerns — asked of everyone. Issues surrounding whether they felt the water was safe, were there any major concerns, were they worried about the evidence, what level of government did they feel was ultimately responsible, etc.

Issue Importance — asked of everyone (but questions varied based on respondent). Whether chlorine disinfection was a concern (generally and as a public health issue), how did it rank among the department's list of concerns, evidence assessment issues, etc.

Policy — asked of those who would be involved in policy aspects (even among government scientists who are not involved in policy specifically but they have opinions). If it was an important policy area, where did it rank in their list of concerns, who were the stakeholders involved in the debate, who/what has been shaping the policy agenda, what did they think would emerge in the short-medium term in policy.

Science-policy — issues surrounding what role scientific evidence should play in policy decisions. Asked of everyone. Issues also included what hinders evidence-based policy decisions.

Risk Communication — again took up themes of science-policy issues, role of communication strategies in allaying public fears, if their organization engaged in such activities, etc.

Public Perception — this was intended to try and get at metaphor issues surrounding drinking water, the media coverage, etc. Asked of everyone. Questions here were very indirect; usually focused around how they thought the public perceived the issues.

* Please note that not all categories of potential questions were asked, as this depended on who the audience was. And in many instances, the prepared questions were never asked as respondents raised the issues on their own. In other instances, new lines of questions were generated at the time of interview based on new knowledge being forwarded by respondents.

APPENDIX D

NVivo Coding Tree

NVivo Coding Tree

(18)	/Agenda Setting
(18 3)	/Agenda Setting/CDPs
(18 9)	/Agenda Setting/chlorine interests
(18 10)	/Agenda Setting/EPA funding
(18 1)	/Agenda Setting/miscommunication
(18 4)	/Agenda Setting/opposition
(18 11)	/Agenda Setting/policy importance
(18 2)	/Agenda Setting/promoting
(18 8)	/Agenda Setting/public
(18 6)	/Agenda Setting/science
(18 7)	/Agenda Setting/silent
(18 5)	/Agenda Setting/US
(18 12)	/Agenda Setting/zero tolerance mentality
(20)	/Bill 14
(20 2)	/Bill 14/Opposition
(20 1)	/Bill 14/Position
(26)	/C3
(26 2)	/C3/major concerns
(26 1)	/C3/role
(25)	/C4
(25 4)	/C4/budget
(25 2)	/C4/chlorine use
(25 5)	/C4/formed
(25 3)	/C4/influence of 3
(25 1)	/C4/role
(6)	/CDBP Task Group
(6 1)	/CDBP Task Group/background
(6 6)	/CDBP Task Group/Decision Analysis
(6 5)	/CDBP Task Group/economics
(6 8)	/CDBP Task Group/members
(6 10)	/CDBP Task Group/micro
(6 3)	/CDBP Task Group/policy
(6 7)	/CDBP Task Group/public involvement
(6 9)	/CDBP Task Group/rec time frame
(6 4)	/CDBP Task Group/role
(6 2)	/CDBP Task Group/science
(4)	/CDBPs
(4 5)	/CDBPs/brominated compounds
(4 4)	/CDBPs/chloroform

(4 4 1) /CDBPs/chloroform/counter hypothesis
(4 4 2) /CDBPs/chloroform/ignoring human
(4 4 3) /CDBPs/chloroform/scenario
(4 12) /CDBPs/complex mixture~
(4 10) /CDBPs/DCA
(4 3) /CDBPs/evidence
(4 3 5) /CDBPs/evidence/appropriate action
(4 3 4) /CDBPs/evidence/changing devils
(4 3 2) /CDBPs/evidence/epi
(4 3 2 2) /CDBPs/evidence/epi/Doyle paper
(4 3 2 1) /CDBPs/evidence/epi/Morris paper
(4 3 11) /CDBPs/evidence/limitations
(4 3 11 1) /CDBPs/evidence/limitations/repro
(4 3 13) /CDBPs/evidence/measurement problems
(4 3 13 1) /CDBPs/evidence/measurement problems/exposure misclassification
(4 3 13 1 1) /CDBPs/evidence/measurement problems/exposure misclassification/repro
(4 3 13 1) /CDBPs/evidence/measurement problems/potential solutions
(4 3 8) /CDBPs/evidence/modelling problems
(4 3 7) /CDBPs/evidence/ongoing studies
(4 3 7 3) /CDBPs/evidence/ongoing studies/industry generated
(4 3 7 2) /CDBPs/evidence/ongoing studies/repro
(4 3 7 1) /CDBPs/evidence/ongoing studies/tox
(4 3 10) /CDBPs/evidence/repro
(4 3 12) /CDBPs/evidence/showering
(4 3 6) /CDBPs/evidence/sufficient
(4 3 6 3) /CDBPs/evidence/sufficient/overall
(4 3 6 2) /CDBPs/evidence/sufficient/politically
(4 3 6 1) /CDBPs/evidence/sufficient/scientifically
(4 3 1) /CDBPs/evidence/tox
(4 3 9) /CDBPs/evidence/tox vs epi
(4 3 3) /CDBPs/evidence/ways to improve evidence base
(4 11) /CDBPs/exceedance problems
(4 7) /CDBPs/general problems
(4 2) /CDBPs/guidelines
(4 2 2) /CDBPs/guidelines/HAAs
(4 2 1) /CDBPs/guidelines/study process
(4 9) /CDBPs/monitoring data
(4 8) /CDBPs/MX
(4 1) /CDBPs/proxy uncertainty
(4 6) /CDBPs/THMs

(16) /CWWA
(16 6) /CWWA/Costs
(16 6 2) /CWWA/Costs/political realities
(16 6 1) /CWWA/Costs/public utilities
(16 5) /CWWA/DBP position
(16 1) /CWWA/function
(16 2) /CWWA/funding
(16 4) /CWWA/governing structure
(16 3) /CWWA/member associations
(1) /Demographic
(1 1) /Demographic/job title
(1 1 1) /Demographic/job title/drinking water responsibilities
(1 1 2) /Demographic/job title/reproductive health
(21) /DWSP
(21 1) /DWSP/database
(21 3) /DWSP/role
(21 2) /DWSP/sampling
(23) /Epi Exposure Meeting
(23 1) /Epi Exposure Meeting/Agenda-Context
(15) /Events
(15 5) /Events/cryptosporidium
(15 1) /Events/Milwaukee
(15 2) /Events/Ottawa
(15 3) /Events/Peru
(15 4) /Events/Walkerton
(5) /FPDWSC
(5 3) /FPDWSC/CDBPs
(5 3 1) /FPDWSC/CDBPs/guidelines
(5 3 1 1) /FPDWSC/CDBPs/guidelines/HAAs
(5 3 1 2) /FPDWSC/CDBPs/guidelines/other compounds
(5 3 1 1) /FPDWSC/CDBPs/guidelines/study process
(5 2) /FPDWSC/Guideline Process
(5 2 2) /FPDWSC/Guideline Process/Ontario
(5 2 2 1) /FPDWSC/Guideline Process/Ontario/NDMA
(5 2 2 2) /FPDWSC/Guideline Process/Ontario/tritium
(5 2 1) /FPDWSC/Guideline Process/tradeoffs
(5 4) /FPDWSC/microbiological concerns
(5 1) /FPDWSC/province
(3) /Great Lakes 1995
(3 1) /Great Lakes 1995/background
(3 3) /Great Lakes 1995/feasibility study
(3 4) /Great Lakes 1995/GL Health Effects Program

(3 4 1) /Great Lakes 1995/GL Health Effects Program/role
(3 2) /Great Lakes 1995/study design
(3 2 1) /Great Lakes 1995/study design/limitations
(3 5) /Great Lakes 1995/study purpose
(3 5 1) /Great Lakes 1995/study purpose/agenda issues
(8) /Health Canada
(8 4) /Health Canada/Cancer Bureau
(8 2) /Health Canada/EHD Mandate
(8 2 1) /Health Canada/EHD Mandate/Drinking Water Guidelines
(8 3) /Health Canada/EHD project planning
(8 3 1) /Health Canada/EHD project planning/water issues
(8 1) /Health Canada/LCDC Mandate
(2) /LCDC workshop
(2 8) /LCDC workshop/background
(2 4) /LCDC workshop/CDBP context
(2 6) /LCDC workshop/evidence
(2 6 1) /LCDC workshop/evidence/collection and assessment
(2 6 1 1) /LCDC workshop/evidence/collection and assessment/dispute
(2 6 3) /LCDC workshop/evidence/conclusion
(2 6 2) /LCDC workshop/evidence/exposure misclassification
(2 3) /LCDC workshop/meeting objective
(2 2) /LCDC workshop/member selection
(2 9) /LCDC workshop/personal objective
(2 10) /LCDC workshop/position paper
(2 1) /LCDC workshop/preliminary discussion
(2 7) /LCDC workshop/recommendations
(2 7 2) /LCDC workshop/recommendations/guideline
(2 7 1) /LCDC workshop/recommendations/skepticism
(2 5) /LCDC workshop/report construction
(2 11) /LCDC workshop/report dissemination
(12) /Metaphor
(12 4) /Metaphor/bottled water
(12 5) /Metaphor/cancer
(12 6) /Metaphor/chlorine
(12 2) /Metaphor/Chlorine is essential
(12 3) /Metaphor/Numbers
(12 1) /Metaphor/water
(12 7) /Metaphor/water as conservation
(28) /MOE
(28 2) /MOE/Lab closures
(28 2 1) /MOE/Lab closures/public health concerns
(28 1) /MOE/New Standards

(28 1 3) /MOE/New Standards/chlorination
(28 1 1) /MOE/New Standards/communication process
(28 1 2) /MOE/New Standards/quality assurance issues
(19) /Pollution Probe
(19 4) /Pollution Probe/CDPs
(19 3) /Pollution Probe/LCDC report
(19 1) /Pollution Probe/mandate
(19 2) /Pollution Probe/Water Conference
(19 2 3) /Pollution Probe/Water Conference/Action
(19 2 3 3) /Pollution Probe/Water Conference/Action/consumer confidence
(19 2 3 1) /Pollution Probe/Water Conference/Action/full cost pricing
(19 2 3 2) /Pollution Probe/Water Conference/Action/Groundwater
(19 2 1) /Pollution Probe/Water Conference/Context
(19 2 2) /Pollution Probe/Water Conference/Report
(29) /Public Health
(29 10) /Public Health/agenda issues
(29 2) /Public Health/chlorine concerns
(29 2 1) /Public Health/chlorine concerns/problem recognition
(29 8) /Public Health/Haliburthon-Cawartha
(29 8 1) /Public Health/Haliburthon-Cawartha/water supply
(29 4) /Public Health/Hamilton
(29 9) /Public Health/Health Protection Promotion Act
(29 5) /Public Health/new ON standards
(29 7) /Public Health/North Bay
(29 3) /Public Health/relationship with province
(29 6) /Public Health/Safe Water Program
(29 1) /Public Health/Waterloo
(29 1 2) /Public Health/Waterloo/changes under new reg
(29 1 1) /Public Health/Waterloo/Water supply
(13) /Public perception
(13 2) /Public perception/bottled water
(13 9) /Public perception/chlorine
(13 6) /Public perception/DBPs
(13 7) /Public perception/government
(13 8) /Public perception/micro
(13 3) /Public perception/Reality
(13 4) /Public perception/Risk analysis
(13 5) /Public perception/treatment alternatives
(13 1) /Public perception/water
(7) /Risk Assessment
(7 1) /Risk Assessment/Cancer RA
(7 1 2) /Risk Assessment/Cancer RA/EPA Model

(7 1 1) /Risk Assessment/Cancer RA/problems
(7 1 1 1) /Risk Assessment/Cancer RA/problems/policy implications
(7 1 1 2) /Risk Assessment/Cancer RA/problems/potential solutions
(7 2) /Risk Assessment/Non-Cancer RA
(10) /Risk Communication
(10 7) /Risk Communication/chloroform scenario
(10 6) /Risk Communication/comm of evidence
(10 1) /Risk Communication/dissemination
(10 1 2) /Risk Communication/dissemination/C4
(10 1 1) /Risk Communication/dissemination/media
(10 2) /Risk Communication/Keeners
(10 3) /Risk Communication/Problems
(10 3 1) /Risk Communication/Problems/DBPs vs micro
(10 5) /Risk Communication/public education
(10 4) /Risk Communication/role of science
(14) /Risk Management
(14 1) /Risk Management/Balancing Risks
(14 3) /Risk Management/Costs
(14 2) /Risk Management/Engineering Science
(14 4) /Risk Management/public consultation
(11) /science-policy
(11 4) /science-policy/Canada-US differences
(11 1) /science-policy/culture
(11 1 1) /science-policy/culture/public perception
(11 2) /science-policy/evidence-based
(11 2 2) /science-policy/evidence-based/championing causes
(11 2 1) /science-policy/evidence-based/hindering
(11 3) /science-policy/ontario
(11 5) /science-policy/other science
(11 6) /science-policy/pure vs public health science
(17) /toxic substances
(17 3) /toxic substances/agenda issues
(17 1) /toxic substances/chloramines
(17 1 1) /toxic substances/chloramines/process
(17 2) /toxic substances/policy implications
(24) /US
(24 3) /US/court challenge
(24 1) /US/EPA regs
(24 2) /US/Stage1+2
(27) /Water Policy Branch
(27 1) /Water Policy Branch/CAP
(27 2) /Water Policy Branch/Enforcement of Standards

(9) /water treatment
(9 1) /water treatment/alternatives
(9 1 2) /water treatment/alternatives/chloramine
(9 1 1) /water treatment/alternatives/ozone guidelines
(9 1 3) /water treatment/alternatives/preferred
(9 1 4) /water treatment/alternatives/UV
(9 3) /water treatment/history
(9 2) /water treatment/implementing changes