



# KEEPING DRINKING WATER SAFE AND ECONOMICALLY SUSTAINABLE

*By Ketra A. Schmitt and Ryan S.D. Calder*

**DELIVERING POTABLE WATER** to citizens is an essential role of government. In Canada, this responsibility is shared among federal, provincial and municipal governments, with a federal role that often serves in an advisory capacity. While Canadian drinking water is generally of a very high quality, emerging contaminants such as disinfection by-products and nano-materials threaten its safety. Historically, federal and provincial water policies have been reactive, responding in a piecemeal way to emerging threats and scientific advances. The Canadian Federal Water Policy calls for more anticipatory, comprehensive and efficient water policy (Environment Canada, 1987), but this has largely failed to happen. With a few tragic exceptions, current Canadian water policy does deliver safe water to the public. However, the slow reaction time and lack of legal force behind drinking water guidelines at the federal level may leave Canadian water supplies vulnerable to emerging contaminants.

Canada has 9 per cent (Environment Canada, 1987) of the world's fresh water, but the more appropriate figure to consider is Canada's level of renewable supply, which is about 6.5 per cent of the world's supply. Since only 40 per cent of this water is accessible to population centres, the actual amount of water available to Canadians is 2.6 per cent of the world's supply (Sprague,

## [ POLICY ENGAGEMENT ]

2006). Canada does have enough water, but the popular perception of its water wealth is overblown and dangerous for policy considerations. Still, the biggest issue facing Canadian water supply is quality, not quantity. In this regard, Canada faces the same drinking water challenge as much of the developed world: Can the technology that is increasing the number of potential drinking water contaminants keep pace with our ability to detect and remove them?

At the same time that technological advances cause potential complications, science and water policy coexist in an important feedback loop. A change in our understanding of a contaminant's toxicity or an increased ability to detect a contaminant at low levels often leads to a drinking water policy response. Drinking water policies and regulators play a leading role in setting scientific research priorities. As each side is spurred on by the other, the landscape of drinking water policy and science grows more complex and more costly. This approach has mostly worked for us so far; our water is generally safe, and water treatment costs are not yet overwhelming municipal budgets. Unfortunately, the rate of change in emerging contaminants and increasing toxicological knowledge (and the need for subsequent research) means that our current approach is unlikely to continue to keep us safe at a reasonable cost.

Take for example perchlorate, a widely dispersed contaminant with a clear toxicological effect, but not a clear safe dose. Lower detection limits allowed the extent of contamination to be realized and created a research need for identifying health effects at lower exposure levels. While Health Canada's more flexible regulatory guideline system has allowed a guideline to be produced for perchlorate, the US Environmental Protection Agency (EPA) has been mired in both scientific and political controversy and eventually decided not to issue a drinking water rule. Much of the debate on perchlorate could have been circumvented by structuring a forward-looking science policy approach focused on identifying potential contaminants and responding to those threats quickly. Without consideration of the interaction of science and policy—treating them as a unit in an explicitly identified regulatory framework—we will be stuck in this pattern, unable to move forward with a rational, predictive drinking water policy.

### DRINKING WATER LANDSCAPE

The current water delivery paradigm consists of underground pipes providing highly purified potable water, of which just 5 per cent is consumed by humans (Natural Resources Canada, 2009). While roughly half of municipal water is used in homes, the top residential water uses are bathing, toilets and laundry (Environment Canada, 2001). Only 10 per cent is used for cooking, and even less is consumed.

Water distribution infrastructure stretches back to the early 1800s. While components have been updated throughout the intervening 200 years, water's physical delivery has remained the same, leading to corrosion, water loss, contaminant leakage into the environment and, with chlorination technology, the inclusion of disinfection by-products. While the advent of hygienic public water supplies is universally hailed as one of the modern miracles of public health, delivery of high-quality water supplies via a system of underground pipes might not be the obvious choice if water systems were introduced today, particularly in view of the popularity of alternative water-supply systems, such as bottled water, home water purification systems, rainwater catchment systems, and grey

water re-use systems. New delivery systems may also include distributed water treatment systems, desalination systems, or point-of-use water treatment, thereby avoiding potential post-treatment contamination.

The fact that traditional systems continue to be built even in new developments may have more to do with the concept of infrastructure as destiny. In other words, some large-scale infrastructure choices have permanent impacts on communities, spaces and technology.

In 1987, the federal government created a water policy designed to safeguard water resources of all kinds. The new policy highlighted the need for increased coordination and co-operation with the provinces, the need for considering the life cycle of potential contaminants, as well as the need for water policy to be effective, efficient and anticipatory, rather than reactive to emerging threats. Fifteen years later, Quebec developed its own policy, echoing the need for co-operation with neighbouring states and provinces, as well as the need to implement the precautionary principle in dealing with emerging water threats (Government of Quebec, 2002).

More recently, Ontario's *Water Opportunities and Water Conservation Act, 2010* specifically addresses the need for innovative solutions to water issues in the province.

Canadian drinking water policy is unique among most of the industrialized world in that the federal government has no legal power to enforce water contaminant limits. Thus, Canada's water policy has been augmented by provincial water policies.

Current strategies to address issues of drinking water quality and availability include adapting new treatment technologies as well as new approaches to policy and delivery. Policy solutions include adopting the precautionary principle, such as the European Union's Regulation for Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), which requires that chemicals be proven safe before use. Chemical alternatives analysis uses a decision-making framework and focuses on products throughout their life cycle, forcing end-users to evaluate multiple input needs and trade-offs associated with those choices. In contrast, the US EPA employs the more traditional "safe until proven otherwise" approach.

Available treatment technologies vary widely in cost and level of cleanliness delivered. Each, from basic filtration, flocculation and chlorination technologies, to sophisticated reverse osmosis and ultraviolet (UV) light treatment, has

specific risks and benefits. For example, chlorination technologies are cost-effective and widely used, but disinfection by-products impose risks on users. UV and reverse osmosis methods deliver highly purified water free of by-products (at a high cost), but do not provide resistance to post-treatment contamination.

## **POLICY AND TOXICOLOGY BACKGROUND**

What drives water policy regulation? Is there likely to be more and more regulation as science advances? If so, is the current method of supplying drinking water the most economical, long-term approach? While actors in both drinking water science and drinking water policy study and react to the other in the context of a conventional water distribution infrastructure, there has been very little study of the overall landscape, implications for the future, or alternatives to the current infrastructure-oriented model. Substantial investments in public drinking water quality when only a tiny portion of that water is used for human consumption may be an indicator that our infrastructure-oriented approach is not in our long-term best interests.

Current water policies derive from the ad hoc relationship between drinking water science and specific measures to keep water safe. They are the result of discrete public health discoveries and the ensuing patchwork of policy fixes. The current scientific and regulatory landscape has thus been carved out in a piecemeal way with little effort at predicting costs and benefits beyond the horizon of a particular issue. Furthermore, substantial lags exist between the discovery of new water quality challenges and appropriate policy responses, for example, in addressing disinfection by-products, chemical mixtures and nano-materials. And technology-based responses tend to default to the existing water distribution infrastructure, missing creative opportunities for improving overall efficacy and efficiency.

A technology policy perspective can make for better drinking water policy through an improved understanding of the drivers and outcomes of regulatory change. In particular, such an approach can help us understand how different regulatory constructs respond to emerging drinking water challenges and assess the efficacy and efficiency of current water distribution technology alternatives. The results can help policy-makers adopt more effective and efficient drinking water policy.

Insights into the regulatory drivers of such policies are crucial to understanding the cur-

rent regulatory framework and how it deals with unanticipated challenges. Only then can it be compared with alternative water delivery and regulatory systems to predict their success. While alternative water delivery systems are often viewed as solutions for low water-availability issues, they need to be considered as potential solutions for reducing drinking water costs and risks in conventional settings as well. An ability to expect the unexpected will be the defining characteristic of a successful holistic and predictive scientific-regulatory framework for drinking water.

Significant academic and government resources have been devoted to creating and evaluating the impacts of individual water regulations. Conversely, little research exists to assess the drivers and outcomes of water quality regulations as a whole. A look back at the environmental movement demonstrates that it has succeeded in triggering new regulations over time, but the specific determinants of environmental regulation have not been widely treated as an academic subject and, as such, are not well understood.

Further, we don't understand with any certainty how these regulations actually protect public health, due to the lack of information about contaminant toxicity at very low doses. An increased understanding of the public health benefits of advances in detection and treatment technology can help regulatory decision-making become more responsive to emerging threats.

Our understanding of the toxicology of drinking water contaminants is in rapid evolution. Identification of new exposure pathways and the increased ability to detect contaminants at low levels can lead to new regulations. Take the case of arsenic, whose safe regulatory level in Canada and the US as a result of new testing was lowered in 2006 to 10 micrograms/litre from 50 micrograms/litre (Health Canada, 2010; EPA, 2001).

Emerging contaminants can be defined as "chemicals or materials that have evolving science (e.g. beryllium); new or unknown exposure pathways (e.g. trichloroethylene and nano-materials); and new detection capabilities (e.g. perchlorate) that can be reasonably anticipated to lead to regulatory changes" (Cunniff and Asiello, 2009). Other definitions of emerging contaminants exist, but there has been little research to determine what drives regulatory action. Much of the existing literature focuses on the role of quantitative risk assessment (Cothorn and Marcus, 1984).

However, statistical analysis has been used in reviewing EPA decision-making in pesticide regulation and corporate influence through comments on proposed new administrative rules. For our part, we have begun to examine the drivers of regulatory change by evaluating the role of detection ability in prompting new drinking-water regulations (Calder and Schmitt, 2010). We are also in the process of assessing the regulatory significance of uncertainty in the toxicological model (our knowledge of the dose-response relationship between exposure and disease based on animal studies) in cancer estimates. We hypothesize that model uncertainty may play a large role in determining the regulatory level for contaminants in opposite ways, by leading to more stringent standards and by delaying the decision to regulate. Other important drivers of drinking water policy include: comprehensive approaches in which emerging issues are treated as a connected system, as called for in Canada's water policy; life cycle-based approaches that evaluate a product's potential environmental and human health, as well as social and

## [ POLICY ENGAGEMENT ]

economic impacts throughout their life cycle; the precautionary principle, which requires that products are proven safe, rather than waiting for products to be demonstrated to be unsafe; anticipatory approaches that seek to identify and appropriately address emerging issues before problems become entrenched; and the polluter pays principle, which shifts the burden of environmental damage onto polluters.

Clearly, understanding these drivers is the first step to ensuring that contaminants are being regulated to the appropriate level. This is crucial to good governance—excessive regulation causes an unnecessary burden on industry, while insufficient regulation can cause human health and environmental harm. Once we understand what drives regulation, we can consider the impacts of regulation and begin crafting better drinking water policies.

### CHOOSING THE RIGHT TOOLKIT

Existing policies can only be improved once we understand the impact of the current policy landscape. Evaluating the impacts of a regulatory and infrastructure system as pervasive as drinking water delivery requires robust and flexible methodologies. Cost-benefit analysis is one such analytical technique, widely used in fields as disparate as health-care delivery, education and transportation. Broad analyses and frameworks exist for establishing the costs and benefits of large-scale water systems, sanitation projects, and source water delivery (Baffoe-Bonnie, 2007; Hutton et al., 2007). Regulatory impact assessment determines how well regulations do the job they were designed to do. We are currently addressing the impact of regulatory structure by developing a comparative study of water regulations in Canada and other nations, assessing the risks and benefits in sub-national regulation.

More than the right methodology is necessary to develop an effective anticipatory policy solution. A water delivery framework and a realistic understanding of human behaviour are also required.

Drinking water clearly requires both a solid scientific understanding of water delivery as a system and social science training in policy and human behaviour.

### SPECIFIC RESEARCH RECOMMENDATIONS

Addressing Canada's drinking water delivery first requires a theoretical understanding of the water regulatory system as it pertains to water quality and distribution. That understanding is needed to develop an anticipatory framework to better address new regulatory challenges in a more comprehensive manner. Such a new framework requires a coherent set of measures to assess regulatory and water delivery systems and that these measures be tested against existing and novel water distribution systems. Specifically, research is needed to:

1. identify the drivers of drinking water regulation and characterize how they influence drinking water policy;
2. evaluate the outcomes of different regulatory constructs for influencing drinking water quality and distribution; and
3. assess and recommend technology policy scenarios for successful delivery of drinking water, where success is measured in effectiveness, efficiency and adaptability.

With a few exceptions, Canadian water delivery systems work well, delivering high-quality water to the vast majority of citizens. While the current

regulatory and infrastructure framework is successful, advances in science and technology are already beginning to alter this reality, both by making us more aware of (and able to remove) existing water contaminants and by contributing to increased and more sophisticated contaminants. Our current infrastructure and regulatory approach cannot serve our drinking water needs forever. Our increasing ability to identify, understand and treat emerging contaminants will necessarily lead to increased water treatment cost in the short run. In the long run, it is not clear that our current infrastructure approach can provide water that satisfies the public's desire for quality.  $\Sigma$

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Ketra Schmitt is an assistant professor in the Centre for Technology, Innovation and Society (general studies unit) of Concordia University's engineering and computer science department. Ryan Calder is a graduate student in the department of building, civil and environmental engineering at Concordia University.