

The drinking water crises of Flint and Havelock North: a failure of public health risk management

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ABSTRACT

Between 2014 and 2016, there were two severe community water system (CWS) failures in Flint, Michigan (MI), USA and Havelock North, Hawkes Bay, New Zealand. These events had profound implications for public health in their respective countries. While the nature of both crises was different, certain aspects of the failings were strikingly similar. These included:

- failure of authorities to protect the integrity of their source water,
- 'wait-and-see approach' to address problems if and when they occurred,
- negligent approach to regulatory oversight and responsibility,
- substandard facilities and lack of knowledge and training of staff,
- failure of consultants and advisory services engaged by suppliers, and
- failure of government agencies to enforce regulations.

The lessons from both incidents must be learned, or similar tragic events are likely to reoccur. The six principles identified in the Government Inquiry into the Havelock North outbreak are an essential first step. The next step is to implement them throughout the drinking water sector.

Key words: drinking water, lead, pathogens, public health crisis, treatment, water supply

HIGHLIGHTS

- The drinking water crises in Flint, MI and Havelock North, NZ are compared.
- The failings in these crises were found to be strikingly similar.
- The crises in both locations involved a disregard for public health.
- The six principles laid out in the Government Inquiry into Havelock North incident can be broadly applied worldwide to protect human health.

GRAPHICAL ABSTRACT



INTRODUCTION

This article analyses two severe failures of community water systems (CWSs) that occurred between 2014 and 2016. Both occurred in Organization for Economic Co-operation and Development (OECD) countries, had profound implications for public health in their respective communities, and resulted in high-level independent investigations. While the nature of both cases was quite different, the widespread nature of the failings was strikingly similar, as found in each of the inquiry reports commissioned by the governments of Michigan (*Flint Water Advisory Task Force 2016*) and New Zealand (*Government Inquiry into Havelock North Drinking Water 2017a, 2017b*).

In the City of Flint, Michigan (MI), USA, the decision to switch from purchasing treated water from the Detroit Water and Sewage Department (DWSD) (later Great Lakes Water Authority) to treating water using an almost 50-year-old plant that had stood essentially idle since 1967 significantly impacted public health in Flint (*Hanna-Attisha et al. 2016; Masten et al. 2016; Rosen et al. 2017; Ruckart et al. 2019; Brooks & Patel 2021*). The change resulted in three boil water alerts in the Summer of 2014 due to the detection of total coliform bacteria in the distribution system, high levels of trihalomethanes (chlorinated disinfection by-products) in 2014 and early 2015, and high lead concentrations at the consumer taps (*Pieper et al. 2017*). In addition, the water was often discoloured and foul-smelling, undersaturated with respect to calcium carbonate, and corrosive (*Flint Water Advisory Task Force 2016; Masten et al. 2016; Pieper et al. 2017*). There is evidence that it also resulted in an increase in legionellosis, although the connection to the water supply has never been confirmed (*Schwake et al. 2016; Rhoads et al. 2017; Byrne et al. 2018; Zahran et al. 2018; Garner et al. 2019; Martin et al. 2020*). Schwake *et al.* (2016) speculated that the lack of corrosion control and the release of iron nutrients and depleted free available chlorine residual in the distribution system promoted a high level of *Legionella* bacteria. *Smith et al.* (2019) provided evidence that the Genesee County, MI outbreak in 2014, resulted from exposure at a local hospital, at homes from Flint water, and from cooling towers. However, they speculate that cases in 2015 resulted from exposure at the local hospital.

The town of Havelock North in the Hawkes Bay region of New Zealand (NZ) experienced an acute and severe outbreak of campylobacteriosis due to the contamination of the water supply in August 2016 (*Gilpin et al. 2020*), which affected up to 39% of the town's population of 14,000 (*Government Inquiry into Havelock North Drinking Water 2017a*). The town

drew its water from an aquifer through bores in an area of intensive farming. In accordance with NZ regulations, as the Te Mata aquifer was incorrectly believed to be confined and the bores secure, the supply was not chlorinated.

Both crises were preventable if the most fundamental principles of public health had been implemented. The conditions leading up to each crisis were in place well before the events occurred, along with a general disregard for the potential consequences of a lack of due diligence. There appeared to be a misguided belief (in Flint) that interim water supplies did not have to meet the same rigour in the protection of public health that would be expected from a permanent supply. However, email correspondence from the Michigan Department of Environmental Quality (MDEQ) engineers from 2013 suggests that the plant needed to meet all Federal and State Drinking Water regulations. Supervisors of the Flint Water Treatment Plant expressed concern to the MDEQ that the treatment plant and staff were not ready to begin complete treatment ([Flint Water Advisory Task Force 2016](#)). These concerns were ignored with a likely belief that any issues would be dealt with, if and when, they occurred. Likewise, in the Havelock North supply, 'significant history of transgressions' (i.e., positive *Escherichia coli* results ([Government Inquiry into Havelock North Drinking Water 2017b](#))) were considered acceptable events that would be dealt with as and when they occurred. Both were serious human-made disasters in recent times in their respective countries. One member of the [United States House of Representatives \(2016\)](#) stated that the crisis in Flint was the greatest catastrophe since New Orleans and Hurricane Katrina.

BACKGROUND

The City of Flint has endured a troubled and beleaguered history, plagued by poverty, and a cascade of difficulties ([Sadler & Highsmith 2016](#)). The population peaked in the 1960s at almost 196,940. With a booming industrial base, the Flint River no longer could provide sufficient water to the city, and in 1967, the city shuttered its water treatment plant and began purchasing treated water from the DWSD under a long-term contract ([Masten *et al.* 2016](#)).

However, with the decline of the automotive and associated industries, the population of Flint is now approximately half what it was in the 1960s, resulting in oversized water and wastewater infrastructure, dwindling revenue base, and a city in financial crisis. The industrial boom left Flint with a legacy of soil and water contamination issues ([Leonardi & Grundi 2001](#); [Rosner 2017](#)).

Flint was placed under emergency management by the Michigan State Governor from 2011 to 2015 ([Flint Water Advisory Task Force 2016](#)). As documented by [Paine & Kushma \(2017\)](#), after the City of Flint entered the Karegnondi Water Authority (KWA) in 2013, negotiations between the City and the DWSD broke down, and the emergency manager decided to switch to treating Flint River water in the shuttered plant until the Karegnondi pipeline would be complete in 2016. Between 2013 and April 2014, only about US\$5M of upgrades were made to the plant to ready it for full-time operation, despite the recommendation in an engineering study of almost US\$50M in upgrades that were needed before plant operation could begin ([Lockwood, Andrews, & Newman Inc. 2011](#)). Additionally, despite several red flags from a state official warning of 'some big potential disasters down the road', and Mike Glasgow, water quality supervisor at the Flint plant, that 'if water is distributed from this plant in the next couple of weeks, it will be against my direction', the city began treating and distributing Flint River water on 25 April 2014 ([Fonger 2016](#); [Masten *et al.* 2016](#)).

As described in [Masten *et al.* \(2016\)](#), almost immediately after the switch, serious health concerns with the treated water began emerging, the first being rashes. Despite widespread complaints, the city, under the direction of the emergency manager, persisted in distributing treated Flint River water from the Flint River. In October 2014, the General Motors Flint Engine Operations Facility negotiated a switch to another water supply due to corrosion of metal engine parts. At about the same time, the State of Michigan installed bottled water coolers in their offices in Flint, city and state officials claimed that the supply was safe and dismissed any reports to the contrary ([Kennedy 2016](#)). In February 2015, very high lead levels were detected in the distributed water. Data collected from July 2014 to June 2015 for the Federal Lead and Copper Rule showed increasing 90th percentile lead levels. Independent lead testing of premise plumbing by faculty and students from Virginia Tech in the summer of 2015 also revealed very high water lead levels ([Edwards 2015](#)). Only after Dr. Mona Hanna-Attisha reported that the blood lead level in Flint children were elevated was the true nature of the problem verified and confirmed ([Hanna-Attisha 2015](#)) and did the State corroborate openly that there was a significant problem. On 16 October 2015, the City of Flint switched back to purchasing water from the DWSD, notwithstanding previous statements that this was impossible because 6 miles of the pipeline connecting Flint to the DWSD distribution main had been sold. On 14 December, 2015, Flint Mayor Karen Weaver declared a State of Emergency, resulting in the City and Genesee

County Health Department issuing a health advisory. Genesee County declared an emergency on 4 January 2016, and the State followed suit the next day. On 12 January 2016, the Michigan Governor activated the National Guard to assist with bottled water and faucet filter distribution. Two days later, President Obama signed an Emergency Declaration for Michigan, which authorised FEMA to identify, mobilise, and provide, at its discretion, equipment, and resources necessary to alleviate the impacts of the emergency (U.S. Department of Health and Human Services 2016).

In contrast to Flint, Havelock North, located in the Hawkes Bay region of New Zealand, is a relatively high income and desirable residential community set in a picturesque setting. The town of 14,000 residents is part of the Hastings District Council. The town's water supply is drawn from the Te Mata aquifer below an intensely farmed area with sheep grazing near several extraction bores. A pond and stream are present in a field near several bores. During the wetter times of the year, the level of the pond water would rise, indicating a hydrological 'losing connection' between the pond stream and the aquifer, meaning that the aquifer was not confined or secure. There were also 'a considerable number of bores that penetrate the aquitard', along with 'sewage pipes in close proximity to abstraction points' (Government Inquiry into Havelock North Drinking Water 2017a). Nevertheless, the supply was not chlorinated based on the premise that the aquifer was confined and protected from contamination, and the bores were secure. While disinfection was not mandated under the Drinking Water Standards (Ministry of Health 2008), the system was required to have a higher level of monitoring and surveillance than one providing continuous disinfection.

In August 2016, several days after a heavy storm in the Hawkes Bay region, numerous residents presented with gastroenteritis due to *Campylobacter* infection. The Governmental Investigation into Havelock North Drinking Water (2017a) found that the heavy rain contaminated with sheep faeces probably inundated the paddocks close to the bores and subsequently entered the aquifer from which the water was drawn. By the time the monitoring regime detected the presence of pathogens, a significant number of residents had been affected. An estimated 5,500 residents, or 39% of the town's population, were infected.

The investigation found that it was possible that contaminated water entered the chamber, rising above the bore head cable holes, seeping around the loose cable seals, and travelling down the cables into the water supply. However, this scenario was considered less likely than contamination via the pond. The report also documented a history of contamination and transgressions that had not been addressed by the supplier, including an earlier, potentially severe outbreak of Campylobacteriosis in 1998, similar to the 2016 outbreak. As a result of the 1998 incident, an investigation by Clark (1998) found that water probably leaked through a power supply cable gland. Clark questioned whether the Te Mata aquifer was confined and recommended an investigation. However, it appears that none was done, although some improvements were made. As noted in the 2017(a) report, while the headwork chambers of bores 1 and 2 were raised to the above ground level, the headworks were not raised. Although the third bore was reported to have a concrete apron surrounding the casing, this was not the case for bores 1 and 2. The investigation into Havelock North Drinking Water (2017a, 2017b) found that little had been learned from this earlier outbreak, which was not taken seriously enough to implement systemic changes.

PARALLEL FAILURES

Upon examining both cases, the commissioned reports, and associated documents, the following parallel failures of primary importance apply to both incidents.

Failure to protect the integrity of the source waters

The failure to protect the integrity of the source waters is perhaps the greatest failing in both cases because all other failures stemmed from this.

City of Flint

The Federal Safe Drinking Water Act (SDWA) requires a thorough and comprehensive evaluation of a source water prior to treatment and distribution. In the case of Flint, the failure to fully evaluate and protect the source water as a designated water source led to a cascade of problems. Under the SDWA Long-Term 2 Enhanced Surface Water Treatment Rule, 24 months of source water testing for *Cryptosporidium*, *E. coli*, and turbidity were required before switching to Flint River water. However, apparently because MDEQ staff believed the Flint River was only a temporary source (MDEQ email conversations), this testing was never done. In addition, the U.S. Geological Survey had identified the Flint River as highly susceptible to contamination, which was not surprising as the river had been used for decades as an open sewer into which industrial

chemicals, urban runoff, and municipal sewage were discharged. River sediments were known to be contaminated by coal tar (Christian 2017), inorganics, including arsenic, chromium, lead, and zinc, organics, including benzo[a]pyrene, benzo[b]fluoranthene, chrysene, and pyrene (U.S. EPA 2007). Emails between MDEQ staff from March 2013 reveal that staff members were aware that the use of the Flint River as opposed to treated Lake Huron water '[p]ose[d] an increased microbial risk to public health, increased risk of disinfection by-product (carcinogen) exposure to public health, and would trigger additional regulatory requirements under the Michigan Safe Drinking Water Act' (Bridge Michigan 2016).

In addition, the water quality in the Flint River is much more variable than that in Lake Huron, the source water for DWSD. The highly variable temperature, turbidity, organic matter content, and bacteria levels make the water challenging to treat. In addition, the chloride levels in the untreated and treated Flint River were much higher than those in the DWSD water. Orthophosphate was not added to the Flint River water after treatment, unlike the treated Lake Huron water. After treatment, the Langelier Saturation Index, a measure of the degree to which a water is undersaturated with respect to calcium carbonate, was highly negative. In addition, the chloride-to-sulphate mass ratio greatly exceeded recommended values. The change in water quality would be expected to disrupt the passivation layer that protects the internal pipe network from corrosion (Masten *et al.* 2016).

The above led back to the failure to adequately address concerns regarding the integrity of the Flint River water as a designated source of human drinking water.

Havelock North

The Havelock North Inquiry found that the water supplier had failed to properly service and maintain the extraction bores and protect the aquifer. The equipment was in such poor condition and so poorly constructed that a vacuum test to check water tightness could not be performed. Contaminated surface water, especially during storm events, was able to leak into the aquifer. The recommendations of a specialist made in 1988 had not been addressed (Clark 1998). Hrudehy (2017) stated, in evidence prepared as a submission to the [Government Inquiry into Havelock North Drinking Water \(2017a, 2017b\)](#), '*The greatest risk to consumers of drinking water are pathogenic microorganisms. Protection of source waters and treatment are of paramount importance and must never be compromised!*' It was clear from the inquiry that this fundamental principle had been ignored.

Wait-and-see operations

Both the Flint and Havelock North water suppliers took a '*wait-and-see approach*' in dealing with any problems in the apparent belief that all problems could be rectified once they occurred.

It was striking that both the [Flint Water Advisory Task Force \(2016\)](#) and the [Government Inquiry into Havelock North Drinking Water \(2017a, 2017b\)](#) reports found an essentially identical problem of a minimalistic approach to regulatory and oversight responsibility, which compromised the protection of public health.

City of Flint

One of the significant and often overlooked issues regarding Flint is that neither the city nor the water treatment plant was in control of financial decisions since 2011, when then Governor Snyder appointed the first of a series of emergency managers. Under Public Act 4 (commonly known as the Emergency Manager Act), all expenditures greater than US\$10,000 per year needed the approval of the Michigan Department of Treasury, which resulted in delays that would have a detrimental impact on public health during the Flint Water Crisis. The approval process also put the decision-making authority upon those who were not trained or experienced in water treatment and on those whose purpose was to reduce expenditures to restore fiscal solvency.

Water supplied from the DWSD contained optimised phosphate corrosion control to inhibit lead leaching from the aged infrastructure into the distribution system. The addition of phosphate was discontinued upon the switch to the Flint River source, presumably because the process equipment and the phosphoric acid would need to be purchased. The decision to determine if phosphate addition was needed for corrosion control, based upon subsequent lead and copper testing, appeared to be grounded on advice from MDEQ staff (who misinterpreted this U.S. EPA requirement) ([Flint Water Advisory Task Force 2016](#); [Shelson 2016](#); [USEPA 2018](#)). While the lack of corrosion control resulted in the release of lead into the distribution system ([Flint Water Advisory Task Force 2016](#); [United States House of Representatives 2016](#)), [Masten *et al.* \(2016\)](#) predicted that the addition of phosphate for corrosion control may not have been effective due to the highly corrosive

nature of the treated water. The potential for lead leaching from the piping network should have been thoroughly investigated before any decision was made to treat Flint River water.

There were numerous other examples of *'wait-and-see approaches'*, from determining the required disinfectant doses to ensure chlorine residuals throughout the distribution system, to determining the effect of variations in turbidity on coagulant doses, to determining the effective anionic and cationic polymer doses to ensure adequate sedimentation of the lime softening floc.

Havelock North

E. coli was regularly detected in Havelock North's source water, yet the same *'wait-and-see approach'* was taken. The [Government Inquiry into Havelock North Drinking Water \(2017a, 2017b\)](#) was particularly critical of this approach as the supplier had ample warning from as far back as 1988. Nevertheless, little to nothing was done to protect the source water from contamination.

Substandard facilities and lack of staff training

Flint public works

As documented by [Masten *et al.* \(2016\)](#), the Flint Water Treatment Plant was woefully unprepared to treat and distribute water. Among many inadequacies were insufficient supplies of polyelectrolyte (secondary coagulant), incomplete upgrades of the SCADA¹ system, non-functioning head loss monitors on the filters and no online chlorine residual monitors in the treated water wetwell. As a result, residual chlorine levels could only be determined by intermittent grab (jar) samples with water taken from a plant tap, which did not comply with federal law.

[Masten *et al.* \(2016\)](#) concluded that Flint Public Works' plant operators either did not understand or lacked important information about the treatment needed. There were no studies on treatment to determine chemical dosages until late August 2015, and personnel were left to address the many complex water treatment issues by trial and error. Significant doses of chemicals were changed without apparent reason ([Masten *et al.* 2016](#)). We can only conclude that this was a 'hit-and-miss' operation with under-qualified staff, desperately trying anything they could to resolve a cascade of mounting problems. The [Flint Water Advisory Task Force \(2016\)](#) found that the staff were undertrained, inexperienced with full-time plant operation, and ill-prepared to address complex chemistry issues. As the events unfolded, concerns raised by staff members were dismissed, while the operators were utterly overwhelmed as they tried to resolve the many ongoing problems. While the Flint Task Force could not excuse the abject failure of the MDEQ, it reported that Flint Public Works Division appeared to be an organisation in crisis with inexperienced personnel struggling to meet enormous and untenable responsibilities. The 1996 Amendment to the U.S. [Safe Drinking Water Act \(1974\)](#) greatly expanded the scope of this legislation to include source water protection, operator training, funding for water system improvements, and to ensure public health safety from the source to tap. The Flint water supply operation was in multiple serious breaches of this Act.

Havelock North

The [Government Inquiry into Havelock North Drinking Water \(2017a\)](#) found that the construction of the bores was substandard with the bore heads located below the ground level. The bores were poorly maintained and in substandard condition. The bore chambers were dirty, with debris and cables lying on the floor. The cable seals were loose, allowing water to travel down the cables and into the water supply. Cable glands or seals on one of the bores were in such poor condition that a vacuum test for water tightness could not be performed. The investigation revealed with a high degree of confidence that the bores in question were non-compliant with the NZ Drinking Water Standards. It was also known that the water supply is in an unconfined aquifer zone, but the water system operated as if it were in a confined aquifer.

Failure of contracted consultants and advisory providers

City of Flint

The Flint Task Force ([Flint Water Advisory Task Force 2016](#)) raised concerns about the competence of resident consulting engineers, Lockwood, Andrews, and Newman (LAN) regarding the treatment of the Flint River water. LAB's contract was

¹ *Supervisory Control and Data Acquisition*. This is a computer-controlled system used at many water and wastewater treatment plants that allows the control of the plant and processes from a PC onsite and remotely.

sole-sourced and approved by the emergency manager. The emergency managers who followed did not seriously consider abandoning the Flint River operation because the consultants (LAN), Council staff, and the MDEQ all advised that the problems were manageable, and the water was safe to drink. The return to DWSO water was deemed too costly. The 2013 KWA financing contract signed by the former Flint Mayor Dayne Walling, under the authority of then emergency manager Ed Kurtz, allowed KWA to seize Flint's water assets and revenue-sharing funds if Flint defaulted on the contract (Egan & Dolan 2016).

We would further argue that in their unstoppable drive to switch to treating Flint River water without adequate investigation, everything else became secondary to saving money. In fact, Flint's financial situation at the time was so dire that it threatened KWA's ability to issue bonds and begin construction of the pipeline to Lake Huron. However, that problem was solved when bond language was inserted into an MDEQ-issued administrative consent order to upgrade softening sludge lagoons (Egan 2016). We cannot emphasise how unusual this was, especially since it appears from email records that KWA's bond attorneys insisted on the bond language that was inserted in the ACO, linking the entire KWA project to a relatively small plant improvement project. In addition, it appears that neither the heads of MDEQ's Drinking Water Division nor their Water Resource Division wanted to sign off on the ACO, as it was eventually handed off to the Office of Waste Management and Radiological Protection.

As a result of the financial concerns and the need for Flint to help finance the KWA project, it appears that the responsible parties would not have accepted the need for a comprehensive treatability study over several years. Nor would they have agreed to face the inevitable resistance to properly regulate and control all discharges and clean-up costs necessary to designate the Flint River as a safe, reliable source of drinking water. As a result, the parties failed to address or did not understand the complexities involved in treating the Flint water or the potential implications of the change in water to the distribution network (Flint Water Advisory Task Force 2016; Masten *et al.* 2016).

Havelock North

The [Government Inquiry into Havelock North Drinking Water \(2017a, 2017b\)](#) was critical of two contracted engineering consultants. In June 2014, the Hastings District Council contracted MWH, an engineering consultant, to assess the security of the bore for compliance. Reports done in 2014 and 2016 were defective at the face value and should have been challenged. Most of the inspections were conducted by a junior engineer with insufficient experience to be described as 'an expert in the field', as was required by the Drinking Water Assessors (i.e., enforcement agency). Inspectors did not enter the maintenance holes that housed the bores and fixtures. Instead, the inspections were conducted from outside the maintenance holes. As a result, the inspector failed to determine if the seals and glands (through which electric cables passed) were watertight. The Inquiry further alleged that the inspector appeared to have limited knowledge of the Drinking Water Standards, nor did they appreciate the importance of the compliance work they were required to undertake. The Inquiry was especially critical that the inspector was instructed to undertake tasks with inadequate training and supervision. Furthermore, reports which followed were wanting, and in one case, seriously negligent, as statements were made about the compliance of one of the bores that had not been inspected.

The Inquiry was also critical of the consultants, Tonkin and Taylor, who were commissioned to investigate the contamination events in 2013 and 2015. After an initial meeting early in 2016, progress was slow with no output until the outbreak in August 2015 when an unfinished draft report was produced. The investigation did not consider this an adequate response considering the emerging issues.

Failure of the regulatory authorities

In both cases, widespread multi-level failures by the regulatory agencies resulted in illness and death.

Flint

The [Flint Water Advisory Task Force \(2016\)](#) found that the MDEQ Office of Drinking Water Quality and Municipal Assistance bore primary responsibility and that a culture inside the organisation prevented it from protecting the health of the Michigan residents. Particularly noteworthy was the failure to apply the legal requirements for corrosion control in the distribution system. The MDEQ stalled for months before accepting expertise from the U.S. EPA regarding the lead crisis. The staff of the MDEQ were found to be unresponsive, obstructive, and dismissive. Furthermore, advice and assistance given to the City of Flint were deeply flawed, resulting in short-sighted enforcement of the laws to protect public health (Flint Water Advisory Task Force 2016).

The task force also stated that the MDHHS failed to provide leadership and coordinate efforts in Flint and across Michigan regarding child lead exposure. It did not comprehend its data on lead levels in children. They prolonged the crisis by frustrating the attempts of others and were reluctant to share data with two key independent professionals investigating the water quality and blood lead levels in children. The coordination between MDEQ and MDHHS to address the public health issues was inadequate with infrequent communication and a dogmatic default position that health problems could not be related to the state of the Flint water supply ([Flint Water Advisory Task Force 2016](#)).

Local and state public health staff also failed to adequately communicate with the public regarding the number of cases of legionellosis from 2014 to 2015. Concerns about the quality and safety of the water supply should have resulted in the coordination of public agencies to promptly and thoroughly investigate the situation. While a definitive course of the outbreak is uncertain, there was enough evidence by association for a precautionary and timely approach ([Flint Water Advisory Task Force 2016](#)).

State governor's office and state-appointed emergency managers. The Governor's office staff appeared to have relied on incorrect information provided by the MDEQ and the MDHHS and continued to do so despite mounting evidence from outside experts that the information was incorrect and notwithstanding numerous citizens' complaints. This highlights the risk of an almost exclusive reliance on a few staff members in one or two departments (without adequate questioning or seeking peer review) for information leading to critical decisions. Statements and communications about the Flint water crisis were at times found to be inappropriate and unacceptable ([Flint Water Advisory Task Force 2016](#)). One must question if the advice supplied was on the premise of what the Governor and his staff expected to justify a decision that was controversial from the start.

The Governor of Michigan and a former emergency manager were cross-examined at the congressional hearings investigating the crisis held in Washington, DC in March 2016 ([United States House of Representatives 2016](#)). Both came under intense scrutiny and, at times, sustained attack from elected representatives for placing financial concerns above everything else. Much of the blame was placed on the Governor-appointed emergency managers charged with financial reform and the Governor himself. The Governor's statement that he ran the state of Michigan like a business was also roundly condemned when it resulted in harm to residents, especially children ([United States House of Representatives 2016](#)). Elected representatives found it difficult to comprehend that while the impending crisis was being reported to his Chief of Staff, it was not subsequently communicated to the Governor himself. In response, the Governor admitted the failings and said he had relied on incorrect and often misleading information from agency personnel ([United States House of Representatives 2016](#)). The [Flint Water Advisory Task Force \(2016\)](#) concluded that emergency managers often do not have the necessary expertise to manage the non-financial aspects of government and recommended improvement to the relevant law to ensure that public health is not compromised in the name of a financial crisis. The task force suggested that the lack of transparency of the emergency management structure made it difficult for residents to know what decisions were made and why. It also meant that residents were unaware of water testing results in a timely fashion. Finally, governmental agencies failed to take their residents' complaints seriously.

The U.S. Environmental Protection Agency. The [Flint Water Advisory Task Force \(2016\)](#) and congressional hearings ([United States House of Representatives 2016](#)) found that the U.S. EPA failed in its oversight capacity to exercise its authority properly and doubted its willingness to enforce the SDWA. The agency only acted in the face of widespread public outrage. The U.S. EPA tolerated the intransigence and belligerence of MDEQ personnel ([Flint Water Advisory Task Force 2016](#)). Two key agency members (one of whom resigned over the Flint water crisis) appeared before the congressional hearings ([United States House of Representatives 2016](#)), drawing sustained criticism from many elected representatives. The chairperson of the congressional committee stated, 'What's sickening about this is it was totally avoidable. It's almost unbelievable how many bad decisions were made' ([Dolan & Spangler 2016](#)). They condemned statements made by agency personnel, the lack of response to the Flint Water Crisis, the condoning of widespread and testing practices that did not comply with the LCR and served to disguise the lack of optimised corrosion control and the resulting water lead levels, and the failure of the agency to revise the outdated Lead and Copper Rule.

Furthermore, the chairperson and some elected representatives were outraged at the evasive answers given by the EPA Administrator, along with the silencing and the handling of a staff member who had identified and prepared a report documenting the high water lead levels and the lack of optimised corrosion control. Some elected representatives called on the

Administrator to take responsibility and resign. However, the Administrator persistently denied that the agency had done anything seriously wrong. She disagreed that the agency should have taken enforcement action against the MDEQ and claimed to have strived to work cooperatively with the MDEQ, which turned out to be fruitless (United States House of Representatives 2016).

Hawkes Bay Regional Council

The protection of a water source is the first and most critical barrier to contamination. Under the New Zealand all-encompassing environmental law, the Resource Management Act 1991, much of the responsibility for the protection of air, water, land, and sea falls under the jurisdiction of Regional Councils. The Hawkes Bay Regional Council, which has regulatory authority over Havelock North, grants permits (resource consents) for water extraction and imposes conditions. It appears that the 'letter of the law' was followed. The consultants had signed off the Havelock bores as secure. GNS Science, New Zealand's leading provider of Earth, geoscience, and isotope research and consultancy services, and the Ministry of Health Drinking Water Assessors (i.e., enforcement agency) completed their audits and assessments. The Council deemed the groundwater as secure and MWH completed their assessment of bores 1 and 2, reporting them to be secure. All seemed copacetic.

Unfortunately, the situation was anything but copacetic, and the situation clearly spotlights the fundamental flaws in the implementation of the regulations. The [Government Inquiry into Havelock North Drinking Water \(2017a, 2017b\)](#) found that the Regional Council's knowledge and awareness of catchment contamination risks fell well below the required standard. The Regional Council failed to correctly identify and mitigate aquifer contamination risks arising from the extraction process, even though such risks were identified. The Regional Council knew about the depletion effect on the pond and stream (during extraction), which alluded to a possible hydraulic connection.

The Regional Council neglected to address the contamination risk from the nearby uncapped unused or non-consented (non-regulated) and risky bores near the extraction bores. Had the Regional Council paid more attention to the situation, they would have learned that the three bore heads were located below the ground level and in chambers that readily allowed surface water to flow into the bores, especially during floods. The Council would have identified that other important defence mechanisms such as sumps, pumps and alarms were prone to failure. They would have required compliance with the safe and serviceable condition of the water permit granted to the Hastings District Council.

The [Government Inquiry into Havelock North Drinking Water \(2017a\)](#) found that the Regional Council process for investigating, monitoring, and requiring mitigation of risks was severely deficient. The Inquiry found that their excuses for not ensuring the safety of the water were grossly inadequate. The Regional Council either lacked enforcement personnel, or the personnel were insufficiently trained. Senior personnel did not question the report submitted by a Regional Council officer that claimed that pathogens would not survive the transport from the field to the bore despite scientific evidence to the contrary. The Regional Council claim that contamination of the surface pond was localised and would not impact that groundwater was summarily dismissed by the Inquiry, which found that even small amounts of animal faeces (less than 1 kg) were sufficient to cause widespread contamination of the aquifer.

The Ministry of Health and Drinking Water Assessors (New Zealand). Drinking water Assessors have a statutory role under New Zealand [Health Act 1956](#) (Part 2A – Drinking Water). While employed by the District Health Board, they are designated officers to the Director General of Health and fulfil the Ministry of Health functions as the regulatory authority in the provision of safe drinking water. The Act requires that a water supplier take all practicable steps to comply with the Drinking Water Standards ([Ministry of Health 2008](#)). The [Government Inquiry into Havelock North Drinking Water \(2017a\)](#) found that these officers took a 'hands-off' approach in dealing with the District Council as a water supplier. Too often, the Drinking water assessors would try to coax or cajole the Hastings District Council into compliance, which essentially never happened despite any assurances given. The Inquiry found that drinking water assessors were entitled to expect co-operation from the District Council, which was not forthcoming. It was clear from the evidence presented to the Inquiry that the consultative approach was not working, and the District Council readily exploited the collaborative approach. Stage 2 of the Inquiry documented that the levels of compliance should have been escalated to the enforcement provisions in the [Health Act 1956](#) (Part 2A – Drinking water).

The Ministry of Health endured severe criticism in Stage 2 of the Government Inquiry report as it encouraged a 'softly softly' approach even when there was ongoing persistent non-compliance. As a result, no enforcement provisions of the

Act were ever implemented. The Inquiry detailed provisions in the [Health Act \(1956\)](#) that were likely to be problematic in court proceedings. However, the argument could be raised that no case law was developed nor legal precedents set because no provisions were ever tested in a court of law. The Inquiry acknowledged the difficulties in the provision of the Act, which would give some justification to a cautious approach to enforcement. However, it found that the complete disregard of the use of prosecutions was, without a doubt, unjustifiable and unacceptable.

The Medical Officer of Health had the authority under the Act to serve a Compliance Order on the Hastings District Council if they believed it was necessary to prevent, remedy, or mitigate any risk to public health. There was ample evidence to justify this action prior to the 2016 outbreak. The Inquiry raised serious questions over the Ministry's reluctance to promote the use of compliance orders, which are a form of legal requisition or improvement notices set out clearly in the provisions of the Act. Such enforcement provisions were vital in this case as the Hastings District Council treated compliance as a discretionary activity (to be done, if and when, resources were available) rather than a mandatory requirement. While a water utility supervisor may agree that work is needed, expenditures may not be approved by upper management or elected officials if the work is not required by law.

There was much confusion over the Ministry of Health's enforcement policy concerning drinking water supplies. A senior official stated that policy had been changed in 2014 to strengthen enforcement activities. The Inquiry found that few officers knew this policy shift, which was apparently given at a training session. The investigation attempted to clarify the Ministry's position by requesting copies of materials given in training sessions where the policy change was supposedly disseminated. From the materials and evidence supplied, the Inquiry was unable to discern any evident policy change and, in doing so, found that testimony given to this effect was *'unpersuasive and unreliable'*.

Following criticism of the enforcement policy which emerged in Stage 1 of the Inquiry, the Ministry provided lengthy written advice to the managers of drinking water assessors and medical officers of health. Stage 2 of the Inquiry found this advice to be verbose, convoluted and could not find any statement that the former lenient policy was to be replaced with more vigorous enforcement. The Inquiry described this attempt by the Ministry to communicate an effective enforcement policy to be inept.

RECOMMENDATIONS

An expert panel advising the Government Inquiry into the Havelock North outbreak proposed six fundamental principles for the provision of safe drinking water ([Government Inquiry into Havelock North Drinking Water 2017b](#)). The principles are based on WHO's water safety plans, which involve system assessment, monitoring, and management and communication ([World Health Organization 2017](#)). They also provide the framework on which the Australian Drinking Water Guidelines (ADWG) ([NRMCMC 2011](#)) are based. These principles reflect good international practices, and we have used them to provide recommendations for protecting public health from hazards related to unsafe drinking water.

Much of the testimony given in the U.S. congressional hearings examining the Flint water crisis was especially critical of the U.S. EPA and the MDEQ in the discharge of their regulatory responsibilities ([United States House of Representatives 2016](#)). Some elected representatives even suggested that some key personnel negligently carried out their duties and concealed the truth and should be charged with criminal liability. A number of these key personnel have since been indicted on felony charges. Under the U.S. [Safe Drinking Water Act \(1974\)](#), the people of Flint, like all U.S. residents on CWSs, have a fundamental right to know the quality of the water they are drinking, what it contains, the source, and how it is treated ([U.S. EPA 2004](#)). The same is true for the citizens of Havelock North under section 69O(1) of the [Health Act 1956](#) and the Drinking Water Standards for New Zealand 2005 (Revised 2018). The [Government Inquiry into Havelock North Drinking Water \(2017b\)](#) found that the Ministry of Health failed to promulgate or articulate an effective policy of enforcement, thus endangering the lives of the very people it serves to protect.

Although the characteristics of each crisis were very different, the multi-level failures and the lack of due diligence evident in both cases resulted in severe consequences for their respective communities. While the city of Flint was impoverished, both incidents occurred in countries that 'have the economic and technical resources to prevent them' ([Hrudey & Hrudey 2019](#)). In both cases, there was a belligerent and cavalier attitude to embracing the fundamental principles for the provision of safe and wholesome drinking water. As stated in ***Principle 1: A high standard of care must be embraced***. Complacency and a lack of competence, vigilance, diligence, and enforcement led to unsafe water in both Flint and Havelock North. Proper training of all personnel is mandatory, along with a culture that values a high standard of care to protect public health. This also includes

administrative personnel responsible for approving financial decisions. As was clearly the case both in Flint and Havelock North, management lacked the expertise and training needed to make financial decisions regarding water treatment and conveyance. Finally, it is important for water treatment personnel to have the necessary skills to effectively communicate the funding needs to management and administrators.

As outlined in **Principle 2: Source water protection is of supreme importance**. Because source water protection provides the first line of defence, it is the most significant barrier against contamination and illness. In Flint and Havelock North, source water protection, which was essential to ensuring high-quality water, was severely compromised. Risks to source waters must be understood, managed, and adequately addressed.

Evidence presented in the congressional hearings (United States House of Representatives 2016) raised the issue that many communities across the USA face high lead levels in drinking water due to aged and crumbling lead service pipes and infrastructure. Despite the knowledge that chronic exposure to low-level lead exposure is detrimental to human health and development (e.g., see Bellinger & Dietrich 1994; Mendelsohn *et al.* 1999, 1998; Bellinger 2008; Boskabady *et al.* 2018, Maloney *et al.* 2018), few CWSs in the USA have completely replaced all lead service lines. While the Lead and Copper Rule focuses efforts on optimising corrosion control to reduce lead levels below the 15-ppb action level, corrosion control is a poor substitute for lead pipe replacement, as corrosion of metal distribution pipes is thermodynamically favourable and cannot be completely arrested. New Zealand's efforts focus on a flush a mug campaign, encouraging their residents to not drink the first mug of water from premise plumbing first thing in the morning or after long stagnation. It should be noted that although lead service lines were not used in New Zealand, lead is present in many plumbing fixtures and cast iron pipes with lead joinings are present in the reticulation systems of many communities. In New Zealand, the Australian and New Zealand Standard (AS/NZS) 4020 *Testing of Products for Use in Contact with Drinking Water* (Australian/New Zealand Standard (AS/NZS 4020:2018) still allows for up to 6% (by weight) of lead to be used in some plumbing materials in contact with drinking water (Australia Building Codes Board 2021). This is despite a scare in a south Otago where, in early 2021, water lead levels were found to be almost 40 times (Uwins-England & McKenzie 2021), the maximum acceptable level of 10 µg/L set under the 2018 Drinking Water Standards for New Zealand (Ministry of Health 2018). Sadly, the sole recommendation made by Ministry Officials was to urge people to flush at least 500 mL of water from their taps each morning (McNeilly 2021).

On the contrary, the USA has passed several laws and regulations to reduce lead content in drinking water plumbing materials. The 2011 Reduction of Lead in Drinking Water Act (RLDWA) revised the definition of lead-free by lowering the maximum lead content of the wetted surfaces of plumbing products from 8% to a weighted average of 0.25%. In 2020, the U.S. EPA published the final regulation, 'Use of Lead-Free Pipes, Fittings, Fixtures, Solder, and Flux for Drinking Water,' requiring manufacturers or importers to certify that their products meet the requirements under the RLDWA. Similar regulations are necessary for New Zealand and elsewhere to protect public health.

Six to ten million homes in the USA (ASCE 2020) are believed to still receive water through lead service lines, with more than 5.5 million US residents receiving water from CWS that exceed the 15-ppb action level (NRDC 2020). Despite the 1991 Lead and Copper Rule requirements that CWSs exceeding the 15-ppb lead action limit must replace 7% of their lead service lines each year or complete full replacement within 14 years, few if any CWSs have been required to do so. The 1991 LCR was recently amended in 2020 by extending the 14-year replacement requirement to 33 years and allowing smaller CWSs (serving 10,000 people or less) to replace corrosion-control technology with point-of-use treatment such as water filters (Eyal 2021). This pushes the treatment responsibility from the CWS to the individual homeowner.

The failure to implement any capital plan to upgrade the infrastructure over time progressively is a serious missed opportunity (Roy & Edwards 2019). Had this been implemented in the early 1980s when lead was progressively removed from household paint, gasoline, the food canning industry (soldered seams), and from food implements such as cutlery and containers, the replacement would be complete by this time. In addition, it was reported in the congressional hearings that aged distribution systems result in problems, such as numerous breakages and leakages, so replacement is inevitable. While the U.S. EPA has been criticised for protracted delays in upgrading the Lead and Copper Rule for optimised corrosion protection, the reality is that there may be no ideal solution short of complete replacement of leaded service pipes.

Consistent with the **third principle: Multiple barriers against contamination must be maintained**, corrosion control is simply an interim measure, and the elimination of lead in distribution and premise plumbing must be achieved (Roy & Edwards 2019). In addition, CWSs must develop and implement source water protection plans, secure distribution systems, monitor effectively, and respond promptly to any adverse signs and signals. A 'source to tap' approach is required to ensure that the consumers receive safe drinking water.

In both the Flint and Havelock North situations, the governmental authorities, engineers, operators, and public health officials failed to understand and appreciate the level to which environmental conditions (in the case of Havelock North) and changes in water source would impact public health. Consistent with **Principle 4: Change precedes contamination**, the change of any kind (including personnel, governance, equipment, process, and environmental conditions) should raise a red flag. Therefore, any such change must be monitored and responded to with due diligence.

The Inquiry into the Havelock North crisis criticised the notion that required expertise could be contracted. They also found that the system used for such engineering consulting services was cumbersome and did not meet the Ministry of Health's needs and that of the water treatment sector. **Principle 5: Suppliers must own and embrace the safety of their drinking water** is essential to the protection of public health. CWS, regulatory organisations, engineering consultants, and city officials must have a personal sense of responsibility, commitment, and dedication to providing consumers with safe water. The greatest assurance is provided by competent, knowledgeable, experienced, committed, and responsive personnel. As such, adequate training and continuing educational opportunities, along with well-funded internships and apprenticeships, are recommended for all personnel involved in purveying safe drinking water. This is consistent with the conclusions of [Hrudey & Hrudey \(2014\)](#) who wrote that 'in many cases, smaller communities have evident deficiencies in facilities and resources for staffing those facilities'. This not only includes staff training, but also proper funding of these facilities, which in many cases is sorely lacking.

Principle 6: Applying a preventive risk management approach is critical to protecting public health as preventive risk management is the best safeguard against illness. In the Flint and Havelock North crises, officials lacked an appreciation of the range of risks involved in delivering safe drinking water and failed to take responsibility for such delivery. It is imperative that CWSs systematically assess risks throughout their supplies, effectively manage and mitigate those risks, perform monitoring of each barrier, promptly analyse the data generated, and, lastly, develop and continue to revise a Water Safety Plan (Public Health Risk Management Plan) to address risks as they become apparent. A roadmap for developing such plans is provided by [Hrudey & Hrudey \(2014\)](#) and serves as the framework for the Australian Drinking Water Guidelines.

Clearly, despite the very different nature of each crisis, essential and significant lessons should be learned from examining both crises. These lessons have significant implications for drinking water providers, regulatory authorities, consultants, and governments worldwide. Both inquiries ([Flint Water Advisory Task Force 2016](#) and the congressional hearings; [Government Inquiry into Havelock North Drinking Water \(2017a, 2017b\)](#)) have echoed the proclamation that each of these disasters must not ever happen again. The lessons from both incidents must be learned, or similar tragic events are likely to reoccur. The six principles identified in the Government Inquiry into the Havelock North outbreak are an essential first step. The next step is to implement them throughout the drinking water sector.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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