**EPA Research Programme 2014–2020**

# Economic Assessment of the Waterborne Outbreak of *Cryptosporidium hominis* in Galway, 2007

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## EPA Research Report

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# Executive Summary

Water is a limited and precious resource and is being consumed worldwide at unsustainable levels. According to the United Nations World Water Development Report, 47% of the world's population will be living in areas of high water stress by 2030 (UN, 2012). "Hidden water" is water used to produce consumable items that do not obviously contain water (Emmott, 2013). For example, it is estimated that it takes 72,000 L of water to produce a microchip to power a laptop computer (UN, 2012). Water is one of the most critical environmental resources that people depend on. It is therefore essential to place an economic value on this precious resource. Good access to water supports health in many ways, including drinking, food production, hygiene and health care. Although Ireland has abundant water resources, problems with the quality of water cause illnesses in Ireland, as elsewhere in the world. Problems with water quality may be caused by contamination with chemicals or microorganisms. Compromised water quality can have adverse effects on industry, particularly the tourism and agricultural sectors, as well as having significant impacts on public health.

*Cryptosporidium* is a protozoan parasite that lives in the intestinal tract of infected humans and animals. It is shed in faeces, thereby contaminating waters and soils, and may be present in inadequately treated drinking water. Infection can be asymptomatic in some cases, but more frequently results in watery diarrhoea, stomach cramps, bloating, vomiting and fever. Although usually a self-limiting illness in otherwise healthy people, it may be associated with chronic gastrointestinal sequelae in some people and may be fatal for those with impaired immune function. In Ireland, cases of cryptosporidiosis are usually associated with *Cryptosporidium parvum* and are predominantly rural in occurrence. Endemic disease generally occurs in spring (peaking in April). *Cryptosporidium parvum* is primarily a parasite of ruminant animals with incidental human infection associated with farming activities or interactions with animals. *Cryptosporidium hominis* is primarily a parasite of primates, including humans, and is less common in Ireland. Epidemiological data reveal that exposure to drinking water from private supplies represents a high risk for cryptosporidiosis.

In March 2007, the largest outbreak of cryptosporidiosis since surveillance began in Ireland was identified, and was associated with contamination of the water supply serving Galway City and surrounding areas. The outbreak lasted for 5 months, by which time there were 242 confirmed cases of cryptosporidiosis, although it is likely that the actual number affected was far higher. A boil water notice was put in place for the duration of the outbreak and affected approximately 120,000 people living in the area, all of whom required an alternative water supply. A key challenge in managing the risk of waterborne infection associated with *Cryptosporidium* spp. is that the parasite is not inactivated by chlorination. Chlorination is the mainstay of water treatment and the only treatment applied in many rural areas in Ireland (Callaghan *et al*., 2009). A number of technologies are available to remove or inactivate *Cryptosporidium* spp. during water treatment. These include filtration and ultraviolet (UV) light treatment systems. *Cryptosporidium* spp. have become recognised as an important cause of waterborne infection, so existing water treatment systems will require additional investment to enhance treatment systems to manage this risk.

The outbreak ended in August 2007 following major investments by local authorities in water treatment infrastructure and major disruption to residents and local businesses.

The goal of this research was to place a monetary value on the costs and inconvenience imposed by the 2007 Galway outbreak on the public, local businesses, the healthcare system, local authorities, national agencies, tourism and other water-dependent sectors. The research also examined the relationship between the investment needed to mitigate risk of contamination with *Cryptosporidium* and the benefits that would arise from such an investment. Water quality incidents such as the 2007 outbreak may have negative impacts on the public's confidence in the water supply, and may also negatively affect confidence in other public bodies. Although challenging, this research also explored these effects on confidence by the distribution of a survey among residents of Galway City and County.

This study represents the first of its kind in Ireland and posed some challenges. The estimation of costs posed a particular challenge, particularly for the private sector where the study was limited by data availability.

Key findings from this project include:

1. The overall cost of the waterborne outbreak of cryptosporidiosis that occurred in Galway in 2007 was estimated to amount to €19 million or €120,000 per day of the outbreak.
2. The estimated total cost to households in the affected area was approximately €3.9 million. This translates into an average cost of almost €88 per household (or €0.55 per household per day of the outbreak) in the boil notice zone over the 23 weeks (158 days) while the boil water notice was in effect.
3. The estimated cost to lodging and care businesses amounted to almost €8 million or €50,000 per day of the outbreak.
4. Almost €6 million of the total cost of the outbreak was the cost of mitigation actions by the local authorities. This included €388,000 for the installation of a UV treatment facility that effectively inactivates *Cryptosporidium* oocytes in water, thus preventing waterborne transmission.
5. When the capital investment necessary to accommodate the installation of a UV treatment system was taken into account, the total cost was €1,674,000. If we consider that this investment made prior to the outbreak would have prevented the outbreak, the potential saving per euro invested amounts to €11.

# 1 Introduction

Water is a limited and precious resource and is being consumed worldwide at unsustainable levels. According to the United Nations (UN) World Water Development Report, 47% of the world's population will be living in areas of high water stress by 2030 (UN, 2012). "Hidden water" is water used to produce consumable items that do not obviously contain water (Emmott, 2013). For example, it is estimated that it takes 72,000 L of water to produce a microchip to power a laptop computer (Emmott, 2013). It is therefore essential to place an economic value on this precious resource. The UN Statistical Commission has developed a framework for monitoring the impact of social and economic development on the environment and, specifically, water – the System of Environmental Economic Accounts for Water (SEEA-Water; UN, 2011). It is estimated that over 50 countries are compiling or are planning to compile water accounts. In 2004, the Department of the Environment, Heritage and Local Government (DEHLG) commissioned an economic analysis of water use in Ireland. The report estimated the annual value of water in the domestic, agricultural and industrial sectors at €201,565,415, €122,991,821, and €75,374,122 respectively (DEHLG, 2004). Compromised water quality can have adverse effects on industry, particularly the tourism and agricultural sectors, as well as having significant impacts on public health. Within the European Union (EU), water quality is generally good, although pathogenic microorganisms remain a hazard in drinking and recreational waters. Of particular concern in Ireland is the level of non-compliance for microbiological parameters found in some drinking water supplies and bathing waters (EPA, 2015a,b). Provision of potable water "fit for human consumption" requires compliance with strict standards set for 48 microbiological, chemical and indicator parameters by the European Union (Drinking Water) Regulations, 2014. Most recent data for the year 2014 indicate that the drinking water quality in Ireland's public water supplies continues to improve (EPA, 2015a). These improvements have been attributed to investment in the physical infrastructure of water treatment plants, examples of which include the provision of chlorine monitors and alarms at all public water supplies and the installation of appropriate *Cryptosporidium* barriers. Significant improvements have also been made in the provision of up-to-date information to users of public water supplies through the development of dedicated websites that are updated on a regular basis. Despite the documented improvements in water quality in Ireland in recent years, a number of incidents have occurred in which the quality of water available to the community has been compromised because of contamination. The Environmental Protection Agency (EPA) maintains a Remedial Action List of public water supplies to ensure compliance with drinking water standards (EPA, 2016). Most recent data for the first quarter of 2016 indicate that eight water supplies serving approximately 39,740 people were on a boil water notice or other water restriction. Furthermore, these data also reveal that 20 water supplies serving approximately 85,948 people did not have a *Cryptosporidium* barrier in place. The continuing risk to public health from *Cryptosporidium* in drinking water is clear from the 2015 outbreak in Westport, County Mayo.

*Cryptosporidium* is a protozoan parasite that lives in the intestinal tract of infected humans and animals. It is shed in faeces, thereby contaminating waters and soils. It may be present in inadequately treated drinking water. Infection can be asymptomatic in some cases, but more frequently results in watery diarrhoea, stomach cramps, bloating, vomiting and fever (Vijgen, 2007; Mead *et al*., 1999; Dietz *et al*., 2000). Although usually a self-limiting illness in otherwise healthy people, it may be associated with chronic gastrointestinal sequelae in some people and may be fatal for those with impaired immune function (Garvey, 2007). In Ireland there is a strong urban–rural divide in relation to notified cases of cryptosporidiosis with a crude incidence rate (CIR) of 1.4 cases per 100,000 in the Health Services Executive (HSE) east region as compared with CIRs of 15.5, 15.5 and 15.2 cases per 100,000 in the HSE north-west, HSE south and HSE midlands regions, respectively (HPSC, 2015a). The highest incidence rates are consistently reported for children under 5 years of age, and contact with farm animals is recognised as a significant risk factor (HPSC, 2015a). In Ireland, cases of cryptosporidiosis are usually associated with *Cryptosporidium* *parvum* and are predominantly rural in occurrence. This species is primarily a parasite of ruminant animals, with incidental human infection associated with farming activities or interactions with animals (Garvey, 2007; Callaghan *et al*., 2009). *Cryptosporidium hominis* is primarily a parasite of primates, including humans, and is less common in Ireland. Endemic disease generally occurs in spring (peaking around April), coinciding with the calving season (Garvey, 2007; HPSC, 2015a). Significantly, the data also reveal that exposure to drinking water from private supplies represents a higher risk for cryptosporidiosis (HPSC, 2015a).

Internationally, a number of large waterborne outbreaks of cryptosporidiosis have been reported (Corso *et al*., 2003; Bridge *et al*., 2010; HPSC, 2015b). In 1993, contamination of the municipal water supply affected an estimated 403,000 people in Milwaukee, WI, USA (Corso *et al*., 2003). In March 2001 in North Battleford, SK, Canada, an estimated 7,000 people became unwell as a result of contaminated water (Jameson, 2008). A key challenge in managing the risk of waterborne infection associated with *Cryptosporidium* spp. is that it is not inactivated by chlorination. Chlorination has been the mainstay of water treatment for many years and remains the only method of treatment applied in many rural areas in Ireland (Callaghan *et al*., 2009). A number of technologies are available to remove or inactivate *Cryptosporidium* spp. during water treatment. These include filtration and ultraviolet (UV) light treatment systems. As *Cryptosporidium* spp. have become recognised as an important cause of waterborne infection, existing water treatment systems have required additional investment to manage this risk. Protection of source waters from contamination with *Cryptosporidium* spp. and other pathogens is also an important process in managing risk.

In March 2007, the largest outbreak of cryptosporidiosis since surveillance began in Ireland was identified, and was associated with contamination of the water supply serving Galway City and surrounding areas. The outbreak lasted for 5 months, by which time there were 242 confirmed cases of cryptosporidiosis, although it is likely that the actual number affected was far higher. A boil water notice was put in place for the duration of the outbreak and affected approximately 120,000 people living in the area, all of whom required an alternative water supply. The outbreak ended in August 2007, following major investments by local authorities in water treatment infrastructure and major disruption to residents and local businesses.

In addition to direct impacts on human health, water quality incidents such as the outbreak of cryptosporidiosis in Galway in 2007 lead to economic losses (Corso *et al*., 2003; Ailes *et al*., 2013) and may undermine public confidence in the safety of water supplies (Ailes *et al*., 2013). Many international studies have estimated the economic costs of infection related to microbial contamination of drinking water supplies (Corso *et al*., 2003; Hutton *et al*., 2007; Halonen *et al*., 2012; Safe Drinking Water Foundation, 2015). However, there is no standard method for performing such analyses. For example, Halonen *et al*. (2012) calculated the cost of the lost workdays by the employees in the public sector residing in clean and contaminated areas in Finland (Halonen *et al*., 2012). In the study by Corso *et al*. (2003), a wide range of costs were included in the calculations, including medical costs and the loss of productivity related to the *Cryptosporidium* outbreak in Milwaukee, Wisconsin in 1993 (Corso *et al*., 2003). A similar approach was used in a Canadian study by the Safe Drinking Water Foundation (2015), which conducted a full cost–benefit analysis of the outbreak associated with microbial contamination of the water supply in Walkerton, ON (Safe Drinking Water Foundation, 2015). Irrespective of the approach used by the researchers, there is agreement in existing international literature that the cost of outbreaks is very significant and the benefits of the preventative measures need to be examined (Hutton *et al*., 2007; Halonen *et al*., 2012; Safe Drinking Water Foundation, 2015).

## 1.1 Project Aims and Objectives

The overall aim of this project was to assess the economic impact of the waterborne outbreak of cryptosporidiosis that occurred in Galway in 2007.

***Specific objectives included:***

- to review studies that have placed an economic value on major water quality incidents;
- to place a monetary value on the costs and inconvenience imposed on the public, business and production sectors, local authorities and government agencies;
- to assess the costs and benefits arising from remedial actions taken;

- to investigate means of assessing the immediate and long-term costs associated with loss of trust by communities in the public water supply and more general loss of trust in public services;
- to identify key knowledge gaps that limit evaluation of the economic impact of the outbreak with a view to developing a template for real-time data collection in future incidents.

# 2 Estimation of Direct and Indirect Costs Associated with the Outbreak

The costs associated with the waterborne outbreak of cryptosporidiosis that occurred in Galway in 2007 have a multi-level structure and include costs incurred by those individuals directly affected; households and local businesses affected by water restrictions; and governmental organisations (local authorities, HSE, EPA and other public service agencies). The structure of the costs included is depicted in Figure 2.1. In line with previous research and traditional health economic frameworks, both direct and indirect costs were included in calculations (Ailes *et al*., 2013). Direct costs include medical and healthcare costs, the cost of providing an alternative water supply and response costs. Indirect costs include loss of income, loss of business and productivity loss, among others (Ailes *et al*., 2013). The costs included are consistent with those included in previous economic assessments of waterborne outbreaks of infectious diseases (Corso *et al*., 2003; Safefood, 2003; Ailes *et al*., 2013).

## 2.1 Data Sources and Assumptions

The data used in this analysis came from different sources, as outlined in Table 2.1. Where the data were unavailable or did not exist, assumptions were made and these are also outlined in Table 2.1. Shortly after the outbreak, the HSE western area commissioned Ipsos MORI to carry out a post-outbreak survey to gain insights into the effect of the outbreak on residents of the area affected by the boil water notice, and on those visiting the area for work or recreational activities (commuters and tourists). Although the findings of this survey remain unpublished, the results of the survey were available to this study and data generated were used in this economic assessment. The data, its sources, and the assumptions (if any) that were made in estimating the costs are listed in Table 2.1. The Stata statistical software package (StataCorp, 2011) was used to complete the analysis.

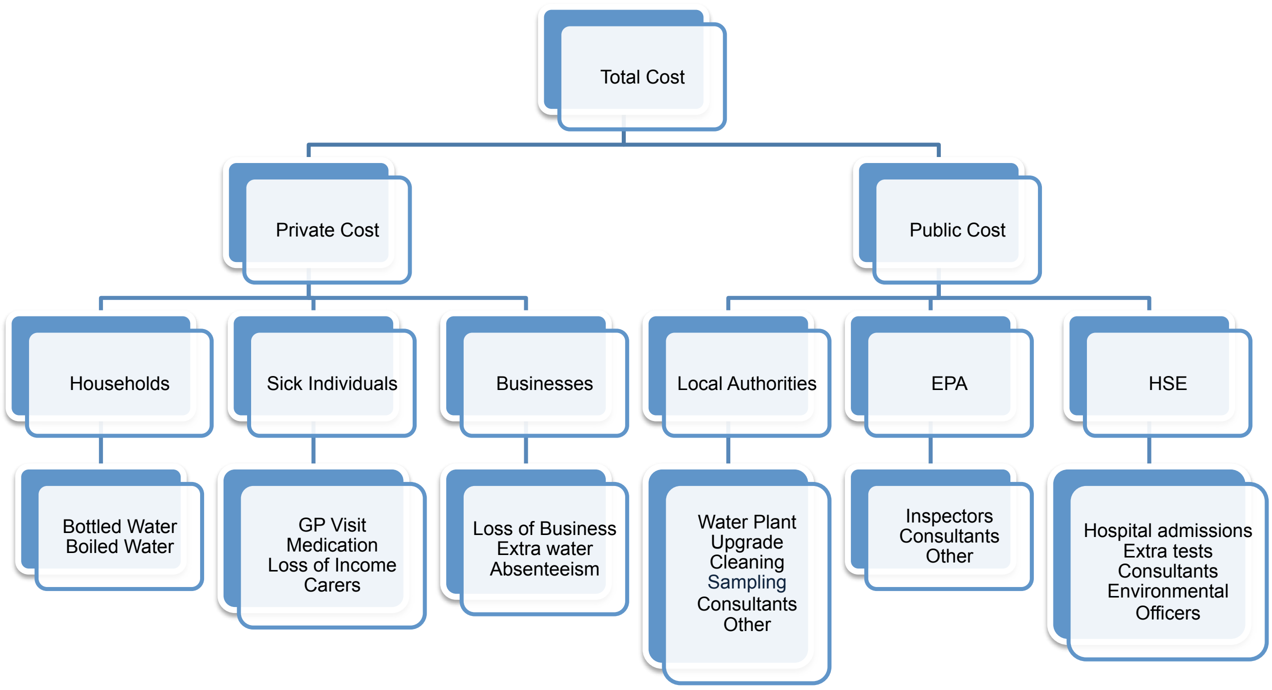



**Figure 2.1. Structure of the costs associated with the outbreak.**

**Table 2.1. Costs included by category, data sources and assumptions applied**

| Costs | Data and assumptions | Source |
|---|---|---|
| *Costs to symptomatic (reported and non-reported) individuals* | | |
| Number of notified cases | 242 | Public health data for period of outbreak, 2007 |
| Number of non-reported cases | 497 cases, 70.8% are not reported | Public health data for period of outbreak, 2007; Safefood (2003) |
| GP visits | €50 per visit, one GP visit per confirmed case; all reported cases consulted GP; GMS cost is €50.46, assume to be €50 | HSE primary care reimbursement service data for 2008 |
| Self-medication | Antidiarrhoeal medication: €9.26; oral rehydration solution (1 packet): €6.99. 30% self-medication (reported); 17.6% self-medication (non-reported) | Pharmacy prices (Corso *et al.*, 2003) |
| Loss of income | €122.85 per day; 5 days of work missed; 10 days of work missed for hospitalised patients | CSO data for 2007; public health data for period of outbreak, 2007 |
| Loss of income for carers | €122.85 per day; children under 15 and those over 65: a carer took 5 days off work; 10 days off work for hospitalised patients | CSO data for 2007 (Garvey, 2007), public health data for period of outbreak, 2007 |
| Cost of missing college/school | €69.20 per student per day; under 21 is either in school or college (reported). 19% took time off school/college (non-reported); 5 days missed (10 for hospitalised) | CSO data for 2007; Safefood, (2003); public health data for period of outbreak, 2007 |
| *Costs to households* | | |
| Number of households | 45,160 | O'Donoghue (2012) |
| Cost of bottled water | 48% reported buying bottled water; 80% increased bottled water consumption from 3.2 L to 16.1 L; 20% from 3.2 L to 20 L | Public health data for period of outbreak, 2007 |
| | Cost of bottled water: €0.50 per litre | Estimated bottled water retail price |
| Cost of boiling water | Usage of boiled water (per HH): drinking ≥ 12% (2.1 L per adult, 1 L per child); cooking ≥ 30% (2 L per HH); dishwashing ≥ 43% (5–10 L per HH); hygiene ≥ 14% (250ml per person per day) | Ailes *et al.* (2013) |
| *Public sector costs* | | |
| EPA | €20,000 | EPA data |
| Emergency Department cost | €100; 1.3% of reported cases went through A&E, €100 A&E admission charge | HSE data (Fitzgerald *et al.*, 2004) |
| 5810 extra lab tests for *Cryptosporidium* detection | €46.06 | HSE data (number of laboratory tests) and commercial service provider (cost) |
| 3000 extra faecal lab culture tests | €59.58 | |
| Hospital admissions | €753 per person per day; 35% admitted to the hospital; 10 days stay | HSE data, public health data for period of outbreak, 2007 |
| Galway City Council | €3,388,840 | Galway City Council data |
| Galway County Council | €2,272,837 | Galway County Council data |
| *Response team* | | |
| Opportunity cost of labour | €356 per staff member per meeting; 16 people, 28 meetings | Institute of Public Administration report |
| *Private sector costs* | | |
| Cost to businesses: productivity loss | €134 per person per day; 5 days on average (10 days for hospitalised) affected and carers | Health & Safety Times (2011) |

**Table 2.1. Continued**

| Costs | Data and assumptions | Source |
|---|---|---|
| *Hospitality industry (hotels, B&Bs, hostels)* | | |
| Extra water | 4.2 L per room per day | |
| Cancellations | 13% cancellation rate | Ipsos MORI survey |
| *Care industry (nursing homes and crèches)* | | |
| Bottled water | 2.1 L per person per day | The Sphere Project (2011) |
| Boiled water | 1.5 L per person per day | |

**HH, household; B&B, bed and breakfast**

### 2.1.1 Reported cases

The assumptions about the costs to reported cases are presented in Table 2.1. It was assumed that all confirmed cases visited a general practitioner (GP) at least once at an estimated cost of €50. The same cost was assigned irrespective of private or public patients [or General Medical Services (GMS) patients] as the GMS GP claim for out-of-house services is €50.64 (HSE, 2008). It was assumed that 30% self-medicated (Corso *et al*., 2003) by taking an antidiarrhoeal agent (e.g. loperamide) and an oral rehydration solution. It was assumed that each patient purchased one packet of antidiarrhoeal medication and one packet of oral rehydration solution. The reported cases missed on average 5 days of work, and those who were hospitalised (35% of reported cases) missed an average of 10 days, based on findings of the Ipsos MORI survey. Due to uncertainty about employment status and sector of the individuals under consideration, it was assumed that everybody aged 22–65 was in employment at the average industrial wage for the region and was not getting paid for days of work missed through illness. It was assumed that dependants [symptomatic children (under the age of 15) and the elderly (65 years old and older)] would require a full-time carer for the duration of their illness – 5 days for non-hospitalised cases and 10 days for hospitalised cases. The loss of income (for both reported and non-reported cases) was estimated at an average industrial wage rate in 2007 of €122.85 per day, based on census data. Moreover, those who were under the age of 21 (reported and non-reported cases) were assumed to either attend college/school or to be unemployed. In line with previous research by Safefood (2003), the opportunity cost of the time they were ill was assigned at a minimum wage rate in 2007 of approximately €69.20 per day for an 8-hour working day based on census data.

### 2.1.2 Unreported cases

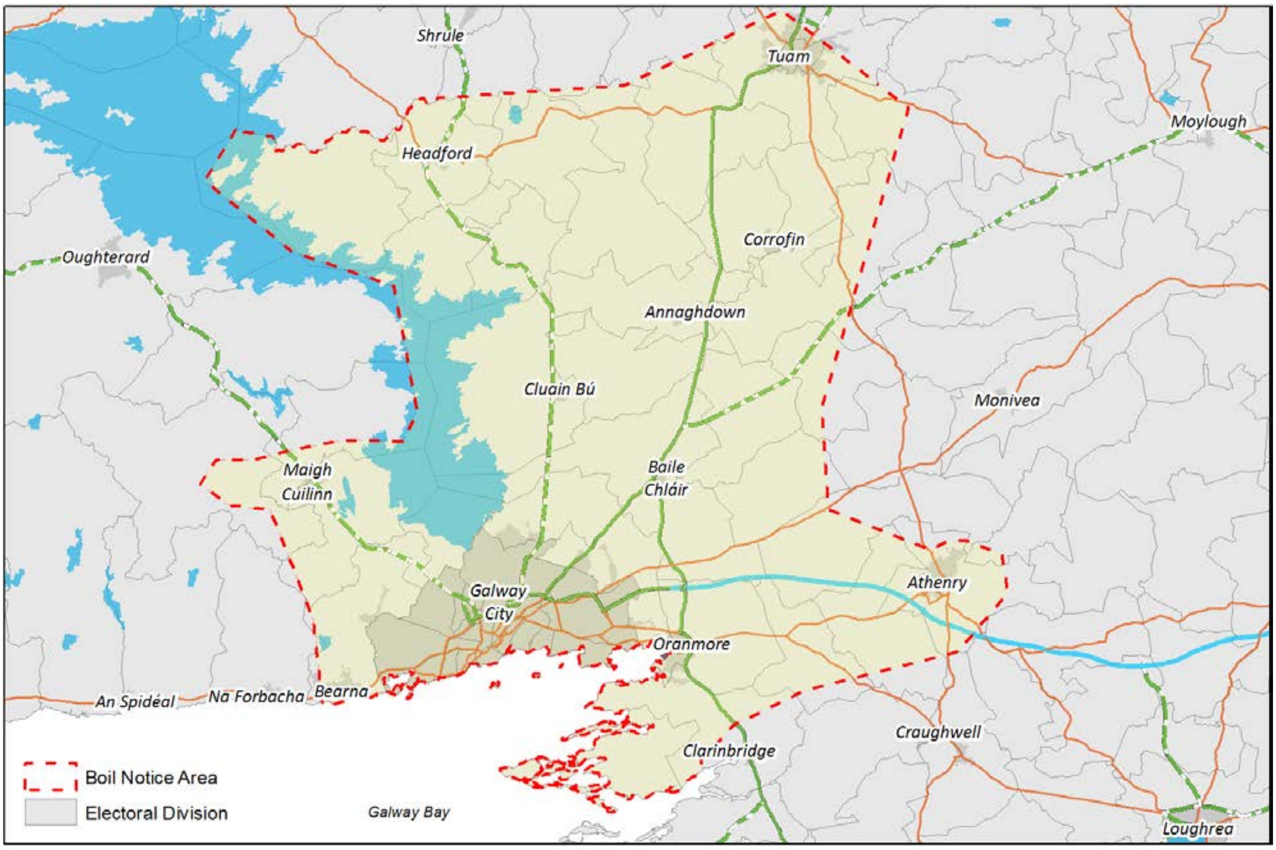
A variety of studies indicate that there is variation with regard to the number of unreported cases of gastroenteritis that occur in outbreak settings (Safefood, 2003; Corso *et al*., 2003; Fitzgerald *et al*., 2004; Ailes *et al*., 2013). Fitzgerald *et al.* (2004) reported that 71% of those whose health was affected did not report as cases (Fitzgerald *et al*., 2004), while Corso *et al.* (2003) estimated that during the outbreak of cryptosporidiosis in Milwaukee in 1993, 25% of the population in the area were affected and 88% of these did not report (Corso *et al*., 2003). If an estimate of 25% of the population affected was applied in this study, the number of non-reported cases would have been estimated at 25,291. For the purposes of this economic assessment we adopted the more conservative approach and assumed that 71% of those with symptoms did not report as cases. In addition, it was assumed that non-reported cases would fall into the less vulnerable population aged 5–64 (approximately 101,000 or 84% of total population in the area as estimated using the Simulation Model of the Irish Local Economy (SMILE) (O'Donoghue, 2012). Therefore, based on the number of reported cases, it was estimated that 497 people who were unwell did not present for healthcare treatment or their cases were not notified. The costs estimated here are based on the most conservative figure, but we acknowledge that there is substantial uncertainty regarding the number of people infected and the actual number may be significantly higher. It was assumed that all confirmed cases visited a GP at least once at an estimated cost of €50. The same cost was assigned irrespective of private or public patients (or GMS patients) as the GMS GP claim for out-of-house services is €50.64, based on HSE primary care reimbursement service data for 2008. It was assumed that 30% of reported cases and 17.6% of non-reported cases self-medicated (Corso *et al*., 2003) with an antidiarrhoeal agent and an oral rehydration solution. It was assumed that each patient purchased one packet of antidiarrhoeal medication and one packet of oral rehydration solution (Table 2.1).

It was estimated that 17.4% of non-reported cases missed on average 5 days of work (Ipsos MORI survey), and those who were hospitalised (35% of reported cases) were absent from work for an average of 10 days. Due to uncertainty about employment status and sector of the individuals under consideration, it was assumed that all individuals aged 22–65 were in employment, receiving an average industrial wage and were not paid for days of work missed due to illness. It was assumed that dependants [symptomatic children (under the age of 15) and the elderly (65 years old and older)] would require a full-time carer for the duration of their illness – 5 days for non-hospitalised cases and 10 days for hospitalised cases.

### *2.1.3 Households*

In order to estimate the household costs, SMILE data (O'Donoghue, 2012) were used, as absolute data were not available. The SMILE model is a synthetic dataset that is spatially representative of households and farms at an electoral district (ED) level. SMILE data were used to determine the number of households located within the boil water notice area and their socio-economic characteristics. In the context of the present analysis, SMILE data for the year 2008 were used to identify households located in the boil water notice zone (Figure 2.2) and to estimate the numbers of people within various age groups that reside in this area.

The costs incurred by all the households in the boil water notice zone included the cost of bottled water bought and the cost of boiling water (Table 2.1). Based on the Ipsos MORI survey results, it was assumed that 48% of households bought extra bottled water, 80% of these increased bottled water consumption from 3.2 L per week to 16.1 L per week, with the remaining 20% increasing consumption of bottled water to 20 L per week. Based on the average price of 1 L of bottled water, it was assumed that €0.50 was paid per litre of bottled water purchased. It was also assumed that, for their household needs, the households boiled water




Data: EEA Corine CLC 2012; OpenStreetMap contributors, Includes Ordnance Survey Ireland Generalised ED and Settlement data. All rights reserved. Licence number NUIG230615. © Ordnance Survey Ireland 2015.

**Figure 2.2. Area affected by the boil water notice.**

during the boil water notice period. Based on previous research by Ailes *et al.* (2013) it was assumed that 12% of households boiled water for drinking, 30% boiled water for cooking, 43% boiled water for dishwashing and 14% boiled water for personal hygiene purposes (Ailes *et al*., 2013). The further assumptions about the number of litres boiled for each of these purposes are reported in Table 2.1. It takes approximately 133 W to boil 1 L of water (Energy Association, 2013) and the cost per litre was estimated at €0.01 based on Electricity Supply Board tariffs reported in 2007 (ESB, 2007).

### *2.1.4 Public sector costs*

The cost to the public sector that resulted from the outbreak of cryptosporidiosis in 2007 consists of the healthcare cost, cost to local authorities and the cost of the response team. The healthcare cost includes the cost of accident and emergency (A&E) attendances, which is assumed to apply to 1.3% of reported cases (Fitzgerald *et al*., 2004) at €100 per visit, which is the sum normally charged to private patients in Ireland based on current rates. The cost of a hospital stay is taken at a rate of €753 per day reported by the HSE, with 35% of patients reportedly hospitalised (Garvey and McKeown, 2007) for 10 days on average during this outbreak, based on the Ipsos MORI survey data.

Costs incurred by Galway City Council and Galway County Council included costs of chemical treatment, consultants' fees, advertising, mechanical plant maintenance, metering, payroll, water sampling, waterworks refurbishment, water routine operations, sludge management, loss of revenue due to concessions given to businesses and households, and other costs. These amounted to €3,388,840 and €2,272,837, respectively. A response team was formed to manage the outbreak, which consisted of 16 representatives of HSE West, Galway City Council, Galway County Council, EPA and others. The time spent by these highly skilled specialists was considered an opportunity cost – time diverted from other activities. There were 28 meetings held during the course of the outbreak, representing an estimated opportunity cost that was assigned as €356 per person per meeting. The opportunity cost was assigned based on the HSE senior management pay scale that ranges from €110,000 to €150,000 per annum with an average €130,000 assigned pro-rata per meeting (HSE, 2013). Although the actual pay of the response team members is not available for confidentiality reasons, nor were the response team members paid overtime, it was decided to assign an opportunity cost to the time taken away from their day-to-day duties to deal with the outbreak.

### *2.1.5 Private sector costs*

The costs to the private business sector in the area proved to be more challenging to estimate because of a lack of available data. In particular, it proved difficult to obtain reliable data on costs incurred by restaurants and to make assumptions on the costs that resulted from the outbreak. Thus, it was decided to exclude these costs from calculations. The remaining business costs (hotels and the care sector, e.g. crèches and nursing homes), sources and assumptions are outlined in Table 2.1.

Absenteeism is costly for private businesses and was estimated to be on average €134 per person per day (Health & Safety Times, 2011). The cost of absenteeism for both reported and non-reported cases, and for carers was included in the cost of the outbreak with 5 days for non-hospitalised cases (for both symptomatic cases and their carers) and 10 days for hospitalised cases (for both symptomatic cases and their carers).

One of the private sectors affected by the outbreak was the hospitality sector, i.e. hotels, guest houses, bed and breakfasts (B&Bs) and hostels. These businesses were affected in a number of ways: they had to provide water for their guests for drinking, as well as experiencing higher than average numbers of cancellations. The assumption was made that hotels, B&Bs and hostels provided 4.2 L of bottled water per room per day (based on the daily water intake requirement of 2.1 L per adult with an assumption of two adults sharing a room). The list of the registered lodging businesses for the area affected, including the number of rooms per business, was obtained from the Fáilte Ireland website (www.failteireland.ie) and the current listings were used to estimate numbers for 2007. The cancellations due to the outbreak were assumed to be 13% based on the survey conducted by Ipsos MORI. The price per room was estimated from the average of prices reported on the Trivago.ie website (Trivago.ie, 2015) at €66 per hotel room, €65 per B&B room and €17 per hostel room, with an occupancy level of 57% for the relevant period of 2007 taken from the Fáilte Ireland report on tourism data (Fáilte Ireland, 2010).

The care industry was also affected: in particular, nursing homes and crèches had to provide alternative drinking water to persons in their care. The number of nursing homes in the affected area was obtained from HSE (HSE, 2015). Eighteen of these nursing homes were located in the area affected by the boil water notice. These 18 nursing homes were contacted and the number of residents determined. It was assumed that nursing home residents were provided with 2.1 L of drinking water per day and 1.5 L per resident per day was boiled for other purposes.

Details of crèches and childminders registered in the area were obtained from the Child and Family Agency, Tusla, and 129 crèches were found to be located within the boil water notice zone. A random selection of 20 crèches was surveyed to ascertain the number of children they cater for, and an average of this number was used for calculations. It was assumed that during an outbreak, crèches provided 1 L of bottled water per child per day, and 1.5 L per child was boiled for other purposes. The assumption was based on the average weight of a child and the recommended 30 mL of water per kilogram of body weight per day, as cited by EPA and HSE (2011).

## 2.2 Results

The overall cost of the waterborne outbreak of cryptosporidiosis that occurred in Galway in 2007 was estimated to amount to €19 million or €120,000 per day of the outbreak. The costs are broken down by category in Table 2.2. The estimated cost to households in the affected area is approximately €3.6 million. This translates into an average cost of almost €95 per household (or €0.55 per household per day of the outbreak) in the boil water notice zone over the 23 weeks (158 days) during which the boil water notice was in effect. This is consistent with the recent study by Ailes *et al*. (2013), which estimated that households spent on average $87 during an outbreak of waterborne salmonellosis in Alamosa, CO, USA in 2008. The loss of income to the households with symptomatic individuals is estimated at €287,000. This cost includes the wages of those unwell as well as the wages of the carers of patients who reported their sickness.

The costs to non-reported cases amounted to €74,000. The total wage loss and expense of water to households during the outbreak were estimated to have been €4,310,000. Assuming that average household income in the boil water zone was €27,251 per annum (as estimated using SMILE data) or €11,796 in 158 days, the loss has translated into 0.8% of household income in the affected area.

**Table 2.2. Estimated costs per category**

| Cost category | Estimated costs (€) |
|---|---|
| *Public authorities* | |
| Galway City Council | 3,388,840 |
| Galway County Council | 2,472,837 |
| EPA | 20,000 |
| Response team | 159,488 |
| A&E visit | 315 |
| Hospital | 637,791 |
| Total public authorities' costs | 6,679,271 |
| *Households* | |
| Bottled water | 3,552,299 |
| Boiled water | 401,011 |
| Total household costs | 3,953,310 |
| *Costs to non-reported cases* | |
| Self-medication | 1418 |
| Wages | 52,973 |
| Carers' income loss | 17,689 |
| School days lost | 1922 |
| Total non-reported costs | 74,002 |
| *Costs to confirmed cases* | |
| Self-medication | 1180 |
| Wages | 36,339 |
| Carers' income loss | 161,544 |
| GP | 12,100 |
| School days lost | 89,074 |
| Total confirmed case costs | 300,236 |
| *Costs to businesses* | |
| Lodging industry cancellations | 5,374,115 |
| Lodging industry bottled water | 1,734,285 |
| Crèche and nursing homes | 525,929 |
| Carers' productivity loss (reported) | 176,206 |
| Symptomatic (non-reported) productivity loss | 57,781 |
| Carers' productivity loss (non-reported) | 19,294 |
| Symptomatic (reported) productivity loss | 36,554 |
| Business costs | 7,924,164 |
| Total estimated cost | 18,930,983 |

It was estimated that the cost to lodging and care businesses amounted to almost €8 million or €50,000 lost per day of the outbreak. It was estimated that almost €5.4 million was lost due to cancellations, with a further

€1.7 million required to provide an alternative supply of water to customers. Care businesses were estimated to have provided safe water to people in their care with a total cost of €526,000.

Almost €6 million of the total cost of an outbreak was the cost of the mitigation of an outbreak by the local authorities. This cost includes €388,000, which represented the cost of installation of a UV treatment system that effectively inactivates *Cryptosporidium* oocytes in water, thus preventing waterborne transmission. The percentage breakdown of costs is depicted in Figure 2.3.

In terms of comparing the total cost of the outbreak with the cost of a UV treatment system, the analysis shows the potential savings of €48 per unit of investment. However, when the capital investment necessary to accommodate installation of the UV treatment system (€1,674,000) is taken into account, the potential saving per euro invested amounts to €11.

In addition to the cost of installation of the UV treatment systems, the research group was advised that there were additional costs amounting to €5,126,000 related to decommissioning of the Old Terryland water treatment plant and other works. This research team did not consider that this additional cost was strictly related to the prevention of cryptosporidiosis infection and therefore did not include this as a cost necessary to prevent the outbreak. However, an argument may be made to include this cost. If this cost is included, then the cost of those measures, which, if taken, would have prevented the outbreak, is €6,800,000, and the cost of the outbreak is €24,056,000, giving a saving per €1 invested of €4.

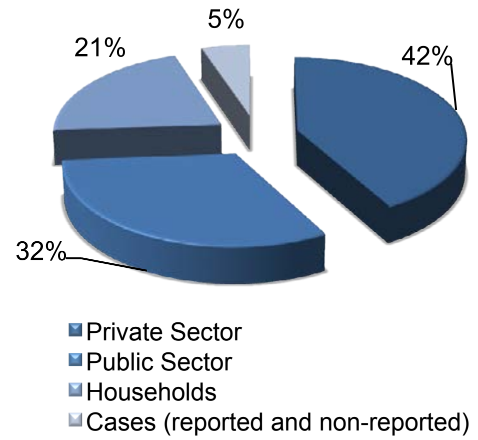



**Figure 2.3. Cost composition.**

# 3 Assessment of Cost Benefits Arising from Remedial Actions Taken

A number of scenarios were considered in an attempt to assess the cost benefits of remedial actions taken.

## 3.1 Cost–Benefit Analysis

Completion of a full cost–benefit analysis in line with the approach adopted previously by the World Health Organization (WHO) was originally considered. This approach would have involved (1) using data on notifications of human cryptosporidiosis and gastrointestinal illness, and assessing the economic benefits to the healthcare system due to decreases in illness as a result of remedial actions taken, (2) estimating the cost saving in both the operational and the capital cost categories using an appropriate market interest rate and depreciation rate, respectively, and (3) using the net present value method to estimate the stream of benefits [as the deviation of the average income (cash flows) or output in the last few years without the incident to the average income (cash flows) or output during the episode] to local business, tourism and the production sectors.

Unfortunately, this approach was not feasible. An accurate estimation of the probability of a similar outbreak occurring and the reduction in the number of people affected as a result of preventative measures taken is required. Moreover, the decreased number of cases of illness as a result of remedial actions needs to be known. This information was not possible to determine with accuracy for the following reasons: (1) since cryptosporidiosis became a notifiable disease in 2004, only one large waterborne outbreak of infection associated with *Cryptosporidium hominis* has been recorded, therefore it was not possible to determine the probability of a similar outbreak happening again; (2) a review of international literature did not assist with determining a probability of a repeat occurrence with accuracy; and (3) data on the number of cases of cryptosporidiosis before and after an outbreak were reviewed (HPSC, 2015a) and no change in the baseline number of cases of cryptosporidiosis in the region under investigation was apparent after remedial actions were completed. There was no expectation that the improved water treatment for the city supply would impact on the annual seasonal occurrence of infection with *Cryptosporidium parvum*, as this is spread through animal contact and through water supplies that service small groups or single households.

## 3.2 What-If Analysis

In order to provide a useful insight to stakeholders of the relationship between investment needed and the benefits that would arise from such an investment, we calculated a ratio ($R$) of the cost of upgrading a water treatment system necessary ($I$) to eliminate *Cryptosporidium* from the water supply and the cost ($C$) that could have been avoided if the 2007 outbreak had been prevented (Equation 3.1).

$R = C/I$ (Equation 3.1)

Such an analysis allows the evaluation in monetary terms of a possible saving per euro of expenditure necessary to inform public investment decisions.

In terms of comparing the total cost of the outbreak and the cost of installation of a UV treatment system, the analysis shows a potential saving of €48 per unit of investment. However, when all the capital investment necessary to accommodate the UV treatment system installation (€1,674,000) is taken into account, the potential saving per euro invested amounts to €11.

In addition to the cost of installation of the UV treatment systems, the research group was advised that there were additional costs amounting to €5,126,000 related to decommissioning of the Old Terryland water treatment plant and other works. This research team did not consider that this additional cost was strictly related to the prevention of cryptosporidiosis infection and therefore did not include this as a cost necessary to prevent the outbreak. However, an argument may be made to include this cost. If this cost is included, then the cost of those measures, which, if taken, would have prevented the outbreak, is €6,800,000, and the cost of the outbreak is €24,056,000, giving a saving per €1 invested of €4.

# 4 Assessment of the Immediate and Long-Term Costs Associated with Loss of Public Trust in Public Services

A survey of the public's (residents of Galway City and County) knowledge concerning their drinking water was carried out in summer 2014 through a Health Research Board (HRB) summer student scholarship.

The aim of this survey was to gain an insight into what people know about where their drinking water comes from and their awareness of its quality. The survey was administered face-to-face, house-to-house and online between 26 June and 23 July 2014. This survey included questions relating to costs associated with bottled water use, the public's memories of the outbreak of cryptosporidiosis that occurred in Galway in 2007, and what effect, if any, it had on them (Appendix 1).

In total, 487 responses were received in the 4-week period of the survey. Analysis revealed that 387 respondents (79.5%) drink tap water, while 93 (19%) do not, with the predominant reason for not drinking water from the tap being concern about water safety.

One hundred and ninety-six (40%) respondents buy bottled water for drinking purposes at home and 100 (21%) filter tap water at home using a jug filter prior to drinking. Of those who purchase bottled water, 39 (20%) buy up to 2 L per week, a further 24 (12%) buy up to 20 L per week and 12 (6%) respondents indicated that they buy more than 20 L of bottled water per week.

The primary reasons for buying bottled water were taste (96 respondents) followed by water safety (89 respondents), convenience (67), catering (6), and other reasons (21).

The respondents were asked to state on a scale of 1 to 5 (1 – lowest, 5 – highest) how much trust they had in their drinking water, with the majority of respondents indicating a moderate level of trust (Table 4.1).

**Table 4.1. Level of public trust in drinking water (percentage of residents)**

| Level of trust | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 8.21 | 12.7 | 29.6 | 29.2 | 17.4 |

Knowledge of water supply type was relatively low, with 264 (54%) of the respondents indicating that they knew what kind of water supply they were served by. In addition, only one-third (158 respondents) were aware of whether or not their water supply was routinely monitored for microbial contamination.

When asked about what, if any, problems respondents encountered with their drinking water supply in the previous 10 years, the primary issue was bad taste [137 respondents (28.1%)] followed by low pressure [132 respondents (27.1%)], presence of sediment [87 respondents (17.9%)], discoloration [79 respondents (16.2%)] and bad smell [66 respondents (13.5%)]. Overall, 39 respondents (8%) brought these issues to the attention of their water supplier, and the majority of these [29 respondents (74%)] indicated that they had received a satisfactory reply.

In total, 240 respondents (49%) indicated that their drinking water supply had been the subject of a boil water notice/restriction in the previous 10 years. The majority of those affected [229 respondents (95%)] reported that they understood the reason for the boil water notice/restriction and 144 (60%) felt that they were updated adequately during the restriction period. Just under 46% of these people (110 respondents) indicated that being subject to a boil water notice/restriction had no impact on their use of drinking water.

Overall, 414 respondents (85%) remembered the waterborne outbreak of cryptosporidiosis that occurred in Galway in 2007. In total, 212 (43%) of these were affected by the boil water notice during this outbreak; 24 (5%) respondents reported being ill during the outbreak and nine of these reported also having a family member that became ill; and 15 (3%) respondents reported a loss of income during the outbreak. In total, 128 respondents (or 60% of those affected by the outbreak) indicated they had changed the way they use their drinking water as a result.

These findings suggest that incidences such as the waterborne outbreak of cryptosporidiosis that occurred in Galway in 2007 undermine the public's trust in their drinking water supply.

# 5 Development of a Template for Real-Time Data Collection in Future Incidents

As outlined in Chapter 2, it was not possible to include all costs to the private sector in the calculations, and a number of assumptions had to be made to estimate the remaining costs because of limited data availability. Owing to the extent of the lack of data relating to certain aspects of the local economy, our estimation was not devoid of statistical uncertainty. For instance, it is very likely that the businesses in the area had sustained financial losses during the outbreak that are not systematically recorded. Therefore, owing to the extent of the unavailability of such data, our estimations reflect an underestimation of the possible impact of the outbreak of waterborne cryptosporidiosis under investigation.

In Table 5.1, we present the type of data that would be useful for future analyses. If capacities are created to collect real-time data, it would be immensely helpful to monitor the outbreak and positively intervene through relatively faster policy solutions. Moreover, collecting data outlined in Table 5.1 would help to estimate the costs with greater certainty, would provide better information to stakeholders and policymakers, and would certainly help the relevant governing authorities to make informed decisions about public investment in safe water provision in Ireland.

**Table 5.1. Data required and sources for estimation of costs in future similar incidences**

| Cost category | Data required | Source |
|---|---|---|
| Cases (reported and non-reported) | Number of reported cases | HSE, survey, business, Central Statistics Office (CSO) |
| | Number of people who self-medicated | |
| | Number of people who sought healthcare, source and number of visits | |
| | Number of people who needed a carer and duration of care in days | |
| | Duration of illness in days | |
| | Number of reoccurrences of illness | |
| | Number of A&E visits | |
| | Number hospitalised | |
| | Length of hospital stay, tests completed | |
| | Cost of A&E visit | |
| | Cost of hospital stay | |
| | Cost of lab tests | |
| | Loss of income due to illness | |
| | Loss of income of carers | |
| | Number of people in full-time education | |
| | Number of people employed/unemployed | |
| Households | Map of boil water notice area with cases mapped | Households, HSE, local authorities |
| | Number in affected households | |
| | Number of extra litres of water bought/week | |
| | Number of litres of water boiled/day for drinking, cooking, washing, hygiene | |
| | Number of household members who experienced symptoms | |
| | How many household members visited the GP | |
| | Cost of bottled water | |
| | Loss of household income due to an outbreak | |
| | Cost of boiling water | |

| Cost category | Data required | Source |
|---|---|---|
| Businesses | Number of businesses in the boil water notice zone (hotels, restaurants, food processors, nursing homes, crèches, etc.) | Representative associations, HSE, local authorities, Irish Water |
| | Arrangements put in place due to an outbreak | |
| | Customers/revenue loss | |
| | Absenteeism | |
| | Other costs related to outbreak | |
| Public Sector | Chemical treatment | Irish Water, local authorities, HSE, EPA |
| | Consultant fees | |
| | Advertising | |
| | Mechanical plant maintenance | |
| | Metering | |
| | Payroll | |
| | Water sampling | |
| | Waterworks refurbishment | |
| | Water routine operations | |
| | Sludge management | |
| | Loss of revenue due to concessions given to businesses, households | |
| | Other costs | |
| | Response team costs | |
| | Cost of EPA monitoring | |
| | Lab overtime cost | |

# 6 Discussion and Conclusions

The waterborne outbreak of cryptosporidiosis that occurred in Galway in 2007 resulted in 242 notified cases of illness, with a conservative estimate of 497 additional cases that were not reported. The outbreak also generated considerable costs to residents, visitors, public bodies and local businesses. This study highlights the economic importance of a safe drinking water supply by reporting both public expenditure on mitigating the results of the outbreak and private costs to households and businesses in the area. The outbreak is believed to have occurred because the lake that serves as the source of drinking water for the city became contaminated with *Cryptosporidium hominis*, and the treatment process in place at that time was not sufficient to eliminate or inactivate the parasite before this water was distributed in the municipal supply.

Considering the fact that an investment of €1,674,235 (updating waterworks and installing a UV water treatment system) could have prevented viable parasites from entering the water supply, we calculated that a cost of €11 would have been avoided for each euro invested in implementing this additional treatment step. Thus, the results indicate that there are economic benefits of investing in safe drinking water supplies and water treatment enhancement. This is consistent with the findings of Hutton *et al.* (2007), who reported between US$5 and US$46 return per dollar invested in water and sanitation improvements, with all water improvement interventions examined in their study being cost-beneficial (Hutton *et al*., 2007).

We recognise a significant limitation in our approach to assessing relative costs. There is no basis upon which to estimate the frequency of occurrence with which a source water contamination event will be likely to result in a comparable outbreak. If such a contamination event occurs frequently (for example annually), the cost of implementation greatly outweighs the associated costs of infection. If such an event occurs every 100 years, then the situation may be reversed. In the context of a municipal supply based on a large surface water body where source protection is challenging, we believe that it is reasonable to suppose that contamination is likely to occur relatively frequently. Methods to define more precisely the annual probability of a major contamination event for a particular water supply would be of value.

The costs assessed for this evaluation related to the period of an outbreak. However, there is reason to believe that some economic impacts continued for years afterwards, related to the undermining of public trust in the water supply, and affected the Galway area and local businesses as a result of fewer visitors. As many as 13% of survey respondents to the Ipsos MORI survey indicated that they were less likely to return to the Galway area due to the outbreak. Thus, the economic impact may be far larger.

In addition, cryptosporidiosis can be potentially fatal, with a fatality rate cited in international literature ranging between 0.05% (Mead *et al*., 1999) and 0.6% (Dietz *et al*., 2000). Fortunately, there were no fatalities associated with the 2007 outbreak in Galway; however, if there had been, the costs are likely to have been much higher. Thus, preventative measures can prove to be economically beneficial.

Limited data is one of the obstacles that resulted in the number of assumptions made in this study. Thus, the results reported here should be interpreted with care and careful examination of the assumptions is advised before drawing conclusions. The lack of data related to businesses in the area and the impact the outbreak had on their operation prevented us from accounting for these impacts in our calculations. Also the lack of regional input–output data is a major drawback in terms of estimating the intersectoral feedback arising from the forward and backward linkages between and within the business and household sectors. This highlights the need for real-time data collection, and the lack of various other data, including the sectoral feedback data, only indicates that the costs may have been much higher than reported here. Moreover, there is an uncertainty about the number of people who were unwell as a result of the outbreak but did not seek help.

Notwithstanding the limitations of the analysis discussed here, this study provides a useful insight into the possible magnitude of the costs that can result as a result of compromised drinking water quality and indicates that preventative measures are economically beneficial. However, further analysis is needed to determine the magnitude of these benefits.

# 7 Recommendations

- The economic benefits of investment in safe drinking water supplies and water treatment enhancement, as well as the benefits to public health, should be considered by decision-makers.
- Methods to define more precisely the annual probability of a major contamination event for a particular water supply should be developed.
- Appropriate data should be collected in real time during incidences and outbreaks such as the waterborne outbreak of cryptosporidiosis in Galway in 2007.
- Investment should be made in the development of data collection software/applications that could capture all costs in real time.
- Methods should be investigated to better define the number of people who are unwell as a result of an outbreak such as this but do not seek help.

# References


Ailes, E., Budge, P., Shankar, M. *et al*., 2013. Economic and health impacts associated with a *Salmonella* Typhimurium drinking water outbreak – Alamosa, CO, 2008. *PLoS One* 8: e57439.

Bridge, J.W., Oliver, D.M., Chadwick, D. *et al*., 2010. Engaging with the water sector for public health benefits: waterborne pathogens and diseases in developed countries. *Bulletin of the World Health Organisation* 88: 873–875.

Callaghan, M., Cormican, M., Prendergast, M. *et al*., 2009. Temporal and spatial distribution of human cryptosporidiosis in the west of Ireland 2004–2007. *International Journal of Health Geographics* 8: 64.

Corso, P.S., Kramer, M.H., Blair, K.A. *et al*., 2003. Cost of illness in the 1993 waterborne *Cryptosporidium* outbreak, Milwaukee, Wisconsin. *Emerging Infectious Diseases* 9: 426–431.

DEHLG (Department of the Environment, Health and Local Government), 2004. *Economic Analysis of Water Use in Ireland.* Available online: www.wfdireland.ie/docs/35_Economics/Economic%20Analysis%20of%20Water%20use.pdf

Dietz, V., Vugia, D., Nelson, R. *et al*., 2000. Active, multisite, laboratory-based surveillance for *Cryptosporidium parvum*. *American Journal of Tropical Medicine and Hygiene* 62: 368–372.

Emmott, S., 2013. *Ten Billion*. Penguin Group, London.

Energy Association, 2013. *Cost - Boiling a Kettle*. Available online: www.energy-association.com/public/faq-boiling-a-kettle/

EPA (Environmental Protection Agency), 2015a. *Drinking Water Report 2014*. Available online: www.epa.ie/pubs/reports/water/drinking/dwreport2014.html

EPA (Environmental Protection Agency), 2015b. *The Quality of Bathing Water in Ireland 2014*. Available online: www.epa.ie/pubs/reports/water/bathing/thequalityofbathingwaterinireland2014.html#.VaTixkDfV8E

EPA (Environmental Protection Agency), 2016. *EPA Drinking Water Remedial Action List for Q1 of 2016*. Available online: http://www.epa.ie/pubs/reports/water/drinking/Q1_2016_RALforweb.pdf

EPA and HSE (Environmental Protection Agency and Health and Safety Executive), 2011. *Joint Position Statement. Trihalomethanes in Drinking Water.* Available online: www.hse.ie/eng/services/Publications/Environmentalhealth/Joint%20Position%20Statement%20Trihalomethanes%20in%20Drinking%20Water.pdf

ESB (Electricity Supply Board), 2007. *ESB Customer Supply Tariff Methodology Statement. Tariff Period November 2007 to September 2008*. Available online: www.cer.ie/docs/000067/cer07108.pdf

European Union (Drinking Water) Regulations, 2014. Statutory Instrument 122 of 2014. Government Publications, The Stationery Office, Dublin.

Fáilte Ireland, 2010. *Tourism Facts, 2010*. Available online: www.failteireland.ie/FailteIreland/media/WebsiteStructure/Documents/3_Research_Insights/3_General_SurveysReports/Tourism-Facts-2010-FINAL-v2.pdf?ext=.pdf

Fitzgerald, M., Scallan, E., Collins, C. *et al*., 2004. Results of the first population based telephone survey of acute gastroenteritis in Northern Ireland and the Republic of Ireland. *Eurosurveillance*: 8.

Garvey, P. and McKeown, P., 2007. *Epidemiology of Cryptosporidiosis in Ireland, 2007*. Health Protection Surveillance Centre, Dublin, Health Service Executive. Available online: www.hpsc.ie/A-Z/Gastroenteric/Cryptosporidiosis/Publications/EpidemiologyofCryptosporidiosisinIrelandAnnualReports/File,3475,en.pdf

Halonen, J.I., Kivimaki, M., Oksanen, T. *et al*., 2012. Waterborne outbreak of gastroenteritis: effects on sick leaves and cost of lost workdays. *PLoS One* 7: e33307.

Health & Safety Times, 2011. *Absenteeism is Proving a Costly Business.* Ocean Publishing. Available online: www.oceanpublishing.ie/health_safety/images/featuredarticles/workplace%20absenteeism.pdf

HPSC (Health Protection Surveillance Centre), 2015a. *Annual Epidemiological Reports on Cryptosporidiosis in Ireland.* Available online: www.hpsc.ie/A-Z/Gastroenteric/Cryptosporidiosis/Publications/EpidemiologyofCryptosporidiosisinIrelandAnnualReports/

HPSC (Health Protection Surveillance Centre), 2015b. *HPSC Annual Epidemiological Report 2014.* Available online: www.hpsc.ie/A-Z/Gastroenteric/Cryptosporidiosis/Publications/EpidemiologyofCryptosporidiosisinIrelandAnnualReports/File,15317,en.pdf

HSE (Health and Safety Executive), 2008. *Schedule of Fees and Allowances Payable to Doctors Participating in the General Medical Services Schemes and Other Community Schemes*. HSE Finance Shared Services Primary Care Reimbursement Service, Dublin.

HSE (Health and Safety Executive), 2013. *Consolidated Salary Scales in Accordance with Clause 2.32 of the Haddington Road Agreement.* HSE.

HSE (Health and Safety Executive), 2015. *Cost of Care in Approved Facilities.* Available online: www.hse.ie/eng/services/list/4/olderpeople/nhss/costs.html

Hutton, G., Haller, L. and Bartram, J., 2007. Global cost–benefit analysis of water supply and sanitation interventions. *Journal of Water and Health* 5: 481–502.

Jameson, P.B., Hung, Y-T, Kuo, C.H. *et al*., 2008. *Cryptosporidium* outbreak (water treatment failure): North Battleford, Saskatchewan, Spring, 2001. *Journal of Performance of Constructed Facilities* 22: 342–347.

Mead, P.S., Slutsker, L., Dietz, V. *et al*., 1999. Food-related illness and death in the United States. *Emerging Infectious Diseases* 5: 607–625.

O'Donoghue, C., Ballas, D., Clarke, G. *et al.*, 2012. *Spatial Microsimulation for Rural Policy Analysis*. Springer, Berlin and Heidelberg.

Safe Drinking Water Foundation, 2015. *Cost–Benefit Analysis: Treat the Illness or Treat the Water?* Available online: www.safewater.org/PDFS/resourcesknowthefacts/CostBenefit_Analysis_Treat.pdf

Safefood, 2003. *Acute Gastroenteritis in Ireland: A Telephone Survey.* Available online: www.safefood.eu/SafeFood/media/SafeFoodLibrary/Documents/Publications/Research%20Reports/Acute_Gastroenteritis.pdf

Statacorp, 2011. *Stata Statistical Software: Release 12*. College Station, TX: StataCorp LP.

The Sphere Project, 2011. *Humanitarian Charter and Minimum Standards in Humanitarian Response.* Available online: www.sphereproject.org/resources/?search=1&keywords=&language=English&category=22&subcat-22=23&subcat-29=0&subcat-31=0&subcat-35=0&subcat-49=0

Trivago.ie, 2015. *County Galway.* Available online: www.trivago.ie/galway-42401/hotel

UN, 2011. *Monitoring Framework for Water.* UN World Water Assessment Programme (UN WWAP) and UN Statistics Division (UNSD). Available online: *unstats.un.org/unsd/envaccounting/WWAP_UNSD_WaterMF.pdf*

UN, 2012. *Managing Water under Uncertainty and Risk.* UN World Water Development Report 4. Available online: www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/wwdr4–2012

Vijgen, S.M.C., Mangen, M.J.M., Ortbeek, L.M. *et al*., 2007. *Disease Burden and Related Costs of Cryptosporidiosis and Giardiasis in the Netherlands*. RIVM Report 330081001. Available online: https://www.researchgate.net/publication/27453554_Disease_burden_and_related_costs_of_cryptosporidiosis_and_giardiasis_in_the_Netherlands

# Abbreviations

| | |
|---|---|
| **CIR** | Crude incidence rate |
| **CSO** | Central Statistics Office |
| **DEHLG** | Department of the Environment, Heritage and Local Government |
| **EPA** | Environmental Protection Agency |
| **GMS** | General Medical Services |
| **HSE** | Health Services Executive |
| **SMILE** | Simulation Model of the Irish Local Economy |
| **UN** | United Nations |

# Appendix 1  Survey Questionnaire

# Do You Live in Galway City or Galway County and Drink Water?

If yes, we would appreciate it if you could take 10 minutes to complete the following 4-page survey. This research is being carried out by the Discipline of Bacteriology, School of Medicine, NUI Galway, to get a better understanding of what people know about where drinking water comes from and their awareness of its quality. This project is funded by the Health Research Board. Results of this survey will help inform the general public, providers of water and governing bodies on how to improve communication with the general public on water related issues. If you would like further information, please find website and contact details at the end of the survey.

Please tick □ appropriate response:

**Q1. Do you live in?**

| | |
|---|---|
| Galway City | |
| Galway County – Town | |
| Galway County – Countryside | |
| Other | |

***If other, please do not complete the rest of this survey, as we are only looking for survey respondents from Galway City and Galway County, but thank you for your time.***

**Q2. Do you drink water from the tap at home?**

| | |
|---|---|
| Yes | |
| No | |

***If No:*** *Why not? (Please choose all options that apply)*

| | |
|---|---|
| Taste | |
| Smell | |
| Colour | |
| Previous problem with water quality | |
| Worry about water safety | |
| Other (please specify) : | |

**Q3. Do you use a jug filter for drinking purposes at home?**

| | |
|---|---|
| Yes | |
| No | |

**Q4. Do you buy bottled water for drinking purposes at home?**

| | |
|---|---|
| Yes | |
| No | |

**If No: Proceed to Q5.**

***If Yes*****:** *Please estimate how much your household buys and what it costs to the nearest € each week?*

| **Volume (in litres)** | **Cost** |
|---|---|
| | |

***If Yes*****:** *Why do you buy bottled water?*

| | |
|---|---|
| Worry about water safety | |
| Catering (e.g. guest use) | |
| Taste (e.g. sparkling water) | |
| Convenience (e.g. lunchbox) | |
| Other (please specify) : | |

**Q5. If you were worried about your drinking water where would you go to find out more information?** *Please tick all options that apply*

| | |
|---|---|
| EPA | |
| Local Authority | |
| Group Water Scheme | |
| Local T.D. | |
| Local newspaper | |
| Local radio | |
| Internet | |
| Facebook | |
| Twitter | |
| Don't know | |
| Other (please specify) : | |

**Q6. On a scale of 1–5 how much do you trust your drinking water?** *(1 being not trusting it at all and 5 being trusting it completely)*

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| | | | | |

**Q7. Do you know if your drinking water supply is tested routinely?**

| | |
|---|---|
| Yes | |
| No | |
| Don't know | |

**Q8. Do you know what type of drinking water supply you use at your home?**

| | |
|---|---|
| Yes | |
| No | |

***If Yes:*** *Please specify*

| | |
|---|---|
| Connection to a public main | |
| Connection to a Group Water Scheme with a Local Authority source of supply | |
| Connection to a Group Water Scheme with a private source of supply (e.g. lake, borehole, etc.) | |
| Connection to other private source (e.g. well, lake, rain water tank, etc.) | |
| No piped water supply | |

**Q9. Do you know if any treatment is applied to your water supply to prevent contamination with bacteria and other organisms?**

| | Yes | No | Don't know |
|---|---|---|---|
| Chlorine | | | |
| UV | | | |
| Filter | | | |

**Q10. In the last year have you had any of the following problems with your water supply?**
(Please choose all options that apply)

| | Yes | No |
|---|---|---|
| Discoloration | | |
| Bad smell | | |
| Bad taste | | |
| Presence of sediment in your water | | |
| Low pressure | | |

**If No to all: Proceed to Q11.**

***If Yes:*** *Have any of the above problems happened more than once?*

| | Yes | No |
|---|---|---|
| Discoloration | | |
| Bad smell | | |
| Bad taste | | |
| Presence of sediment in your water | | |
| Low pressure | | |

***If Yes:*** *Have you brought these problems to the attention of your water supplier?*

| | |
|---|---|
| Yes | |
| No | |

***If Yes:*** *Were you satisfied with the response you received?*

| | |
|---|---|
| Yes | |
| No | |

**Q11. In the last 10 years has your drinking water supply been subject to a boil water notice/restriction?**

| | |
|---|---|
| Yes | |
| No | |
| Don't know | |

**If No: Proceed to Q12.**

***If Yes:*** *How did you find out about the boil water notice/restriction?*

| | |
|---|---|
| T.V. | |
| National radio | |
| National newspaper | |
| Local radio | |
| Local newspaper | |
| Internet | |
| Twitter | |
| Facebook | |
| Leaflet drop | |
| Other (please specify) : | |

***If Yes:*** *Did you understand the reason for the boil water notice/restriction?*

| | |
|---|---|
| Yes | |
| No | |
| Don't know | |

***If Yes:*** *Did you feel you were updated enough during the boil water notice period/restriction?*

| | |
|---|---|
| Yes | |
| No | |
| Don't know | |

***If Yes:*** *What difference did this make to your use of drinking water at home after the boil water notice/restriction ended?*

| | |
|---|---|
| Changed to only drinking bottled water | |
| Use jug filter for drinking water | |
| Now, I always boil tap water to drink it | |
| No impact | |
| Other (please specify) : | |

**Q12. Do you remember the 2007 outbreak of cryptosporidiosis in Galway City and surrounding areas?**

| | |
|---|---|
| Yes | |
| No | |

***If Yes:*** *Please specify how this outbreak affected you: (tick all the options that apply to you)*

| | |
|---|---|
| Boil water notice was put in place in the area in which you live | |
| Became ill with cryptosporidiosis | |
| You were absent from work/school | |
| Family member ill and absent from school/work | |
| Business owner affected by boil water notice | |
| Place of work affected by boil water notice | |
| Not affected | |

**Q13. Did you suffer a loss of earnings due to the 2007 outbreak of cryptosporidiosis?**

| | |
|---|---|
| Yes | |
| No | |
| If Yes please estimate your loss of earnings: | |

**Q14. Has the way you use drinking water changed since the cryptosporidium outbreak in 2007?**

| | |
|---|---|
| Yes | |
| No | |

***If Yes:*** *Please indicate in what way*

| | |
|---|---|
| Changed to only drinking bottled water | |
| Use jug filter for drinking water | |
| I always boil tap water to drink it | |
| No impact | |
| Other (please specify) : | |

**Q15. Sex:**

| | |
|---|---|
| Male | |
| Female | |

**Q16. Age:**

| 18–24 | 25–34 | 35–44 | 45–54 | 55–64 | 65+ |
|---|---|---|---|---|---|
| | | | | | |

**Q17. What is the highest level of education you have completed to date?**

| | |
|---|---|
| No formal education | |
| Primary education | |
| Second level education | |
| Third level education – Non-degree | |
| Third level education – Primary degree | |
| Third level education – Postgraduate qualification | |

**Q18. What is your nationality?**

| | |
|---|---|
| Irish | |
| Other | |
| If other, please specify: | |

**Q19. What is your main language?**

| | |
|---|---|
| English | |
| Irish | |
| Other | |

**Q20. How would you describe your present principal status?**

| | |
|---|---|
| Employed | |
| Unemployed | |
| Student/pupil | |
| Looking after home/family | |
| Retired from employment | |
| Unable to work due to permanent sickness or disability | |

***If employed:*** *Do you work for a public service organisation?*

| | |
|---|---|
| Yes | |
| No | |

**Q21. Does your household own or rent the house you live in?**

| | |
|---|---|
| Owns | |
| Rents | |
| Local Authority housing | |
| Other | |
| If other, please specify: | |

**Q22. How many people live in your household including yourself?**

| |
|---|
| |

## Thank you for taking the time to complete this survey.

For further information please contact:

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http://www.nuigalway.ie/bac/water_survey.html

**Note:** The EPA recently launched a public awareness campaign on private wells. Please feel free to take the attached leaflet For more details see following website: http://www.epa.ie/water/dw/hhinfo/protprivwell/