3

Rainwater harvesting – an HIA of rainwater harvesting in the UK

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3.1 INTRODUCTION

Rainwater harvesting is a very simple concept, where rain falling onto a roof surface is collected and subsequently used as a source of water. It has been in use in some areas (e.g. Israel, Africa and India) probably since 2000 BC and is now used in both developing and developed countries where it provides both potable (e.g. Australia, Canada, USA) and non-potable supplies (e.g. Germany).

As the predicted use of rainwater harvesting in the UK is for domestic non-potable use (i.e., toilet flushing, laundry use, garden watering etc.) most of the discussion here is related to non-potable supplies, although experience from potable systems is drawn upon in assessing possible health effects (through inadvertent or deliberate consumption of harvested rainwater).

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The simplest rainwater collection method, and the one with the longest history in the UK, is the garden water butt. More complex constructed household rainwater harvesting systems can, however, increase the amount of water 'saved'. They are probably most easily accommodated into new build designs. In the UK, in-house systems typically consist of an underground storage tank, a filter to prevent the entry of leaves and large solids, a smoothing inlet to stop sediment on the bottom of the tank being disturbed, a pump for distributing the harvested water (either to a header tank or directly to appliances) and a suction filter to prevent the uptake of any floating material as the water is drawn up for use. Systems also have an automatic mains top-up device which, depending upon the system, may supply the storage tank, a header tank or the actual appliances with mains water if harvested supplies run short.

3.2 RISK ASSESSMENT

For the purposes of this health impacts examination the following scenario has been considered:

- Each property has a household rainwater system, with an underground tank (such as that shown in Plate 3.1), collecting rainwater from the roof via downpipes, passing through a filter on entry to the tank. The tank receives top up supplies from the mains water when it is running low and the supplies are used for toilet flushing and garden watering. The system operation and its maintenance are the responsibility of the individual householder.

3.2.1 Possible hazards associated with rainwater harvesting

A health hazard is anything that can potentially cause harm (with harm being loss of life, injury, illness and so on). The following hazards have been identified:

- drowning and near-drowning;
- injury; and
- infection.

3.2.2 Exposure assessment

The HIA was conducted on a hypothetical population based on a newly built estate in the South of England, as outlined in Chapter 2 (section 2.5).

Plate 3.1. Typical tank design (Photo: L. Fewtrell)

3.2.2.1 Drowning and near-drowning

This will, to some degree, depend upon the type of tanks used. In some countries, Australia for example, above ground rainwater harvesting tanks are common (Cunliffe 1998). In the UK, however, tanks tend to be underground. All such tanks have manhole covers and some prevent actual access to the water by the positioning of the filter (Plate 3.2). Thus, it has been assumed that there can be no exposure and hence no risk of drowning.

3.2.2.2 Injury

The scope for injury is determined by user behaviour during maintenance, especially during gutter clearing and tank inspection and cleaning. The former would require ladder access and the latter may present a confined space access risk. There is also the possibility that the manhole cover could be removed during inspection or left unsecured following inspection.

Falls are the most common cause of both fatal and nonfatal unintentional injury (accidents) in the home environment (Dowswell *et al*. 1999; Marshall *et al*. 2005). An important component of this statistic is made up by falls from

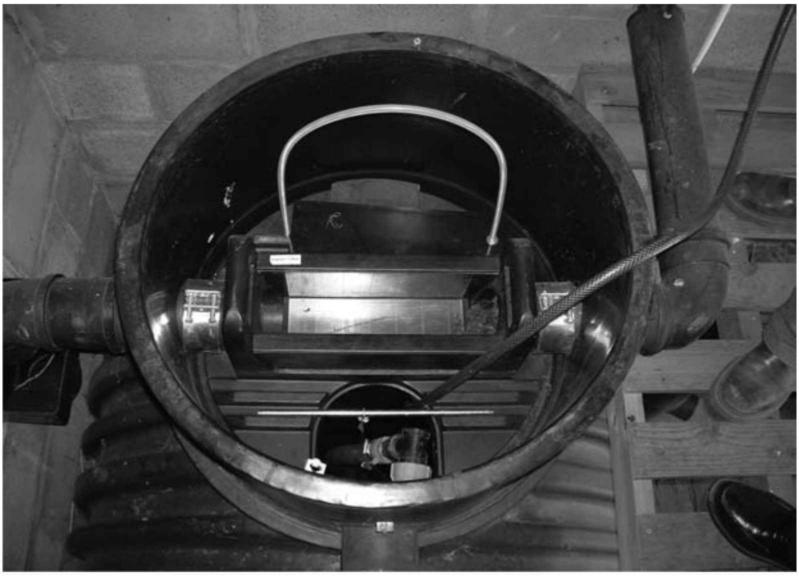

Plate 3.2. Manhole access showing filter (Photo: L. Fewtrell)

ladders (and scaffold), usually as a result of incorrect ladder placement or from excessive reaching (Partridge *et al*. 1998). Examining the risk of injury per hour of exposure to various consumer products, Hayward (1996) found that ladders and scaffolding rated highly, with between 10 and 65 accidents per million hours of use (with scaffold being second in the list, behind electric hedge-trimmers). Ladders and scaffolding were also among the products associated with the longest mean duration of incapacity, with an average incapacity per accident of 18.8 days (Hayward 1996).

In Australia, a study looking at the nature, severity and outcome of injuries sustained from ladder falls found that 83% of those presenting in hospital as a result of a ladder fall were male and that 78% were injured in a non-occupational setting (Tsipouras *et al*. 2001). Over 40% of the accidents were caused by ladder instability. Most of the patients had mild or moderate injuries, but 13% had severe trauma, usually with head, chest or spinal injury. In Denmark, a similar study found that the mean annual rate of ladder falls was 1.18 per 1,000 in males and 0.41/1,000 in females (Faergemann and Larsen 2000). A rise in the annual incidence rates for both men and women was seen with increasing age. About 20% of injuries resulted in hospitalisation for a median of seven days. 50% of the injuries were contusions (bruises) or sprains and about 30% were fractures or dislocations.

In the UK, good surveillance data are available relating to falls including those from ladders. In 1994 and 1995, 73 and 67 people respectively were killed as a result of falling from a ladder or scaffolding in England and Wales. Of these fatalities over 50% occurred at home (as opposed to being occupational injuries) and the percentage of home fatalities was found to increase by age (Dowswell *et al.* 1999). The Home Accident Surveillance System (HASS) maintained by RoSPA is a UK database holding details of home accidents (up to 2002) that were serious enough to warrant a visit to hospital. Data are derived from a sample of admissions to between 16 and 18 hospital accident and emergency departments in the UK, and national estimates are made based on this sample. The data for falls on/from ladders/stepladders for 2000 to 2002 are shown in Table 3.1.

Table 3.1. Incidents involving falls from or onto ladders and stepladders in the home 2000 to 2002 (DTI 2003)

	Number of incidents		
Year	Sample data	National estimate	Multiplier∗
2000	1816	32,216	17.64
2001	1903	33,969	17.85
2002	1721	35,281	20.50

∗ The multiplier was not given in the report, but was calculated from the national estimate and sample data for each year.

Examination of data for 2000 to 2002 revealed 187 incidents involving the use of ladders to access gutters (135 of these were specifically related to cleaning gutters). Using an average of the multipliers (Table 3.1) this suggests that on average 840 people each year will injure themselves cleaning their gutters. As only one of the patients was under the age of 16, the incidence has been calculated based on the adult population (48,047,425 – National Statistics 2005), giving an incidence rate of 0.017/1000 population. From the annual incidence rate it is estimated that 0.062 people per year at the case study site will injure themselves as a result of examining or cleaning their guttering. It has been assumed that householders are aware of their rainwater harvesting system and a proportion of them may clean their gutters more frequently than before as a result of perceived maintenance needs. Thus 20% of incidents have been attributed to rainwater harvesting, resulting in an estimate of 0.012 people sustaining injuries.

Confined space qualitative estimate

A confined space is any space of a substantially closed nature where there is a risk of death or serious injury from hazardous substances or dangerous conditions (e.g. lack of oxygen). Some confined spaces are fairly easy to identify; enclosures with limited openings, such as an underground rainwater harvesting tank (HSE 1997). Data on morbidity and mortality relating to exposure to confined spaces in non-occupational circumstances are not readily available. It is likely that incidents relating to confined spaces (including those arising from occupational exposure) would be coded as W81[1] (confined to or trapped in a low-oxygen environment) or W84 (unspecified threat to breathing). During the three year period (2001 – 2003) there were three deaths coded as W81 in England and Wales and 99 coded as W84 (National Statistics 2001, 2002, 2003), representing annual incidence rates of 0.018/million population and 0.62/million population respectively. Neither of these codes, however, is very specific (e.g., W81 includes 'accidentally shut in refrigerator or other airtight spaces, diving with insufficient air supply' – WHO 2003). The type of tank in the case study is designed to prevent entry (Plate 3.2), so it has been assumed that there is no risk of confined space entry. As with some tank designs, however, entry may be possible a qualitative estimate of (−) has been given to this hazard.

3.2.2.3 Infection

Infection relating to rainwater harvesting could occur via a number of routes, namely:

- Inappropriate ingestion/contact: through ingestion of aerosols produced as a result of toilet flushing; direct ingestion via the garden tap; direct contact through using the garden tap to fill up paddling pools, hot tubs, swimming pools etc., inadvertent ingestion/contact through contamination of drinking-water supplies as a result of cross connections.
- Inhalation of microorganisms within an aerosol: via toilet flushing.
- Microbial contamination of the environment: and subsequent ingestion of garden produce contaminated as a result of watering with rainwater.
- Vector-borne illness: stored water could become a breeding site for mosquitoes.

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[1] i.e. according to the International Classification of Disease, version 10 (WHO 2003)

The principal pathogen source in harvested rainwater in the UK is likely to be from bird faeces. From an examination of the literature it is clear that a number of different bird species carry a variety of human pathogens, which could be deposited on roofs and washed off into harvested rainwater supplies. The two most commonly studied are *Salmonella* spp. and *Campylobacter* spp. (typically *Campylobacter jejuni*). A recent review (Fewtrell and Kay 2007) suggested that a number of human enteric pathogens have been isolated from rainwater supplies; including *Campylobacter* spp., *Salmonella* spp., *Cryptosporidium* spp. and *Giardia* spp. *Campylobacter* spp. and *Cryptosporidium* spp. were chosen here to quantify the risks of infection. While it is acknowledged that other pathogens may be present in the water the choice of these pathogens is generally conservative (with *Campylobacter* having a lower infectious dose than *Salmonella*, and *Cryptosporidium* having a similar infectious dose to *Giardia*) and the risk from these pathogens was felt to be indicative of infection risk with bacterial and protozoan pathogens.

The following possibilities of infection were examined:

- ingestion of *Campylobacter* spp. from aerosol formed during toilet flushing;
- ingestion of *Campylobacter* spp. and *Cryptosporidium* spp. due to direct ingestion of harvested rainwater or through contamination of drinking water supplies via cross connections; and
- ingestion of garden produce contaminated with *Cryptosporidium* spp.

3.2.2.3.1 Campylobacter spp.

Campylobacter spp. is a bacterial pathogen capable of causing human infection, which is commonly carried by birds such as blackbirds, starlings and gulls (Moore *et al*. 2002; Waldenstrom *et al*. 2002; Broman *et al*. 2002) and has been detected in harvested rainwater supplies (Savill *et al*. 2001; Albrechtsen 2002). *Campylobacter* is the most commonly reported bacterial cause of infectious intestinal disease (gastroenteritis) in England and Wales (HPA 2005). The illness, campylobacteriosis, is characterized by severe diarrhoea and abdominal pain. In some cases chronic sequela (secondary adverse health outcomes), such as Guillain-Barré syndrome, may occur as a result of *Campylobacter* infection (Mead *et al*. 1999).

Dose-response is the quantitative relationship between dose and outcome (e.g. ID_{50} is the number of microbes required to initiate infection in 50% of the exposed population). A dose-response (β-poisson) model for *Campylobacter* spp. has been developed by Medema *et al*. (1996), based on the experimental data reported by Black *et al*. (1988). A duration of 6 days, with a severity weight of 0.086 has been assumed for uncomplicated campylobacteriosis (based on a weight of 0.067 for the majority of cases and 0.39 for the 6% of cases expected to visit their general practitioner). Where there are complications a severity weight of 0.28, with a duration of 365 days has been assumed (adapted from Havelaar *et al*. 2000). A total of 30% of infections are assumed to cause clinical illness and 0.5% of clinical illness is considered to be severe or complicated (based on the rate for campylobacteriosis hospitalisation cited by Mead *et al*. 1999). The case fatality rate for campylobacteriosis is 0.005% (Mead *et al*. 1999), with a median age at death of 78 years (Havelaar *et al*. 2000).

Exposure to Campylobacter spp. through toilet flushing

The data required to estimate the exposure of the case study population to *Campylobacter* through the use of harvested rainwater supplies for toilet flushing are shown in Table 3.2.

It has also been assumed that each day has the same likelihood of *Campylobacter* contamination and that the microorganisms are suspended homogenously in water.

Exposure to Campylobacter spp. through direct ingestion (external tap use)

It has been assumed that during the summer months, and in particular the six week school holiday period, some children may drink water from the garden tap (supplied by harvested rainwater). This assumes that any signs relating to the water not being for drinking are ignored and there is access to the taps. It has also been assumed that children under the age of 5 are either supervised or could not turn on the tap. The data requirements for this analysis are shown in Table 3.3.

Exposure to Campylobacter spp. through cross connections (contaminated potable supplies)

There are no data on the number of cross connections that result from having a dual supply (potable and non-potable) system within the household in the UK. It has, however, been seen in other countries in relation to large scale recycling schemes (e.g. Murray 2005). Thus, it remains a possibility, despite the best efforts of system installation engineers and designers to clearly differentiate between the systems on the basis of pipe colour, dimensions and incompatible fittings. The data requirements for this analysis are shown in Table 3.4.

Table 3.2. Exposure to *Campylobacter* spp. through toilet flushing

Data requirements	Comments
The concentration of *Campylobacter* in the harvested rainwater	Very few studies have attempted to quantify levels of *Campylobacter* spp. in harvested rainwater (presence/absence data only). Savill *et al*. (2001), however, did quantify levels and found a maximum concentration of 0.56 MPN/100ml.
The frequency of contamination of rainwater supplies with *Campylobacter* spp.	Albrechtsen (2002) reported *Campylobacter* spp. in 20% of samples, while Holländer *et al*. (1996) did not detect it in over 140 samples analysed. For this analysis it has been assumed to occur between 0 and 10% of the time (with no allowance made for seasonal variation).
The fraction of these organisms capable of initiating infection	Dose-response model of Medema *et al*. (1996), where α=0.145 and β=7.59
Amount of water swallowed	Flushing a toilet produces an aerosol. The volume of water ejected during a 'typical' flush is unknown but is likely to be small and probably between 1 and 2ml. Only a proportion (say a tenth) of this is likely to reach a susceptible host.
Number of flushes per day	Frequency of toilet use is assumed to be between 3 and 6 times/day, with the range accounting for home workers and those who work away from home (MTP 2006). Children under the age of 3 are not thought to be exposed as they are unlikely to be toilet trained (AAP 2000).
The frequency with which people are exposed to contaminated flush water	It has been assumed that people will be exposed to aerosol 5% of the time (1 flush in 20)

3.2.2.3.2 Cryptosporidium spp.

Cryptosporidium spp. is a protozoan pathogen capable of causing human infection. Cryptosporidiosis commonly produces self-limiting diarrhoea which can sometimes include nausea, vomiting and fever. Although it usually resolves within a week in otherwise healthy people, it can last for a month or more. The severity of illness depends on age and immune status; infections in immunocompromised people can be severe and even life-threatening. The most

Table 3.3. Exposure to *Campylobacter* spp. through direct ingestion (external tap use)

Data requirements	Comments
The level of contamination with *Campylobacter* spp.	See Table 3.2
The frequency of contamination of rainwater supplies with *Campylobacter* spp.	See Table 3.2
The fraction of these organisms capable of initiating infection	See Table 3.2
The amount of un-boiled water consumed	A UK report on water consumption (MEL 1996) reported that the average amount of tap water consumed daily was 1138ml of which un-boiled water accounted for 16.7% (or 190ml)
The number of children likely to drink from external taps	It has been assumed that during the 6 week summer holiday period between 0 and 5% of children aged between 5 and 14 drink from the outside tap on an occasional basis (between 0.5 and 2 times a week) and consume between 50 and 250ml on each occasion

Table 3.4. Exposure to *Campylobacter* spp. through cross connections

Data requirements	Comments
The likely number of households to be affected by cross connections, and the duration of the problem	It has been assumed that between 0 and 0.1% of households are affected each year and that the problem lasts for between 10 and 60 days. Other households are assumed not to be affected.
The level of contamination with *Campylobacter* spp.	0.28 MPN/100ml based on a 50% reduction in the concentration reported by Savill *et al*. 2001 (see Table 3.2) to account for the dilution effect of the drinking water supply
The frequency of contamination of rainwater supplies with *Campylobacter* spp.	See Table 3.2
The fraction of these organisms capable of initiating infection	See Table 3.2
The amount of un-boiled water consumed	See Table 3.3

commonly used dose-response relationship is an exponential model (Teunis *et al*. 1996; WHO 2002) based on data from DuPont *et al*. 1995. A duration of 6 days, with a severity weight of 0.054 has been assumed for the immunocompetent ('normal') population (with 71% of infections progressing to illness), while a duration of 47 days and a severity weighting of 0.13 has been assumed for AIDS patients, where all infection progresses to illness (Havelaar *et al*. 2000). As almost 90% of the case study population classified their health as good, a rate of 0.05% HIV/AIDS prevalence has been assumed, rather than the estimated UK national level of 0.2% (CIA 2005).

Exposure to Cryptosporidium spp. through direct ingestion (external tap use)

Many of the data requirements are the same as those for *Campylobacter* spp. detailed above. The data requirements are outlined in Table 3.5.

Table 3.5. Exposure to *Cryptosporidium* spp. through direct ingestion (external tap use)

Data requirements	Comments
The concentration of *Cryptosporidium* in the harvested rainwater	Albrechtsen (2002) reported *Cryptosporidium* concentrations ranging between 0 and 50/l
The frequency of contamination of rainwater supplies with *Cryptosporidium* spp.	0–10% – as for *Campylobacter*
The fraction of these organisms capable of initiating infection	Dose-response model of Teunis *et al.* (1996) applies, where r = 0.004
The amount of un-boiled water consumed	See Table 3.3
The number of children likely to drink from external taps	See Table 3.3

Exposure to Cryptosporidium spp. through cross connections (contaminated potable supplies)

The requirements to determine the risk from exposure to *Cryptosporidium* spp. as a result of cross connections are shown in Table 3.6.

Table 3.6. Exposure to *Cryptosporidium* spp. through cross connections

Data requirements	Comments
The likely number of households to be affected by cross connections	See Table 3.4
The level of contamination with *Cryptosporidium* spp.	As Table 3.5, but by reduced by 50% to account for dilution by drinking water supply
The frequency of contamination of rainwater supplies with *Cryptosporidium* spp.	See Table 3.5
The fraction of these organisms capable of initiating infection	See Table 3.5
The amount of un-boiled water consumed	See Table 3.4

Exposure to Cryptosporidium spp. through contaminated garden produce

It has been assumed that people in the case study population growing their own fruit and vegetables will water their produce using rainwater supplies, which could on occasion be contaminated with *Cryptosporidium* spp. The products considered to present the greatest risk are salad plants, as the food part of the plant (which is subsequently eaten raw) will be watered directly and, in addition to possible root uptake, may retain any contamination (at least for a period of time). Data requirements for this analysis are outlined in Table 3.7.

No account has been taken of pathogen removal with washing, or of people other than the householders who are growing the produce eating contaminated salad crops (i.e. no assessment of risks from householders who give away some of their produce has been made).

3.2.2.3.3 Other infections and qualitative estimates

Inhalation of microorganisms via aerosols, contact and dermal exposure to rainwater supplies and vector-borne illness were not subject to quantitative microbial risk assessment. *Legionella pneumophila* would be expected to be the principal pathogen of concern in aerosol inhalation, however, this is rarely found in rainwater samples in Europe (e.g. Holländer *et al*. 1996; Albrechtsen 2002; Birks *et al*. 2004) and is unlikely to multiply at the temperatures recorded in underground tanks. Thus this hazard has been given an estimate of (−).

Although there is a possibility that people could be exposed to *Pseudomonas aeruginosa* via rainwater supplies (Holländer *et al*. 1996; Albrechtsen 2002), this is an opportunistic pathogen (Hardalo and Edberg 1997) which only

Table 3.7. Exposure to *Cryptosporidium* spp. through consumption of contaminated garden produce

Data requirements	Comments
The level of contamination with *Cryptosporidium* spp.	See Table 3.5
The frequency of contamination of rainwater supplies with *Cryptosporidium* spp.	See Table 3.5
The fraction of these organisms capable of initiating infection	See Table 3.5
The number of households using harvested rainwater to water food plants eaten raw (e.g. salad crops)	A MORI poll, commissioned by the Royal Horticultural Society estimated that 41% of people grow their own fruit and vegetables (410/1000) and that over a 2-year period 12% of these have attempted to grow lettuce (MORI 2004; RHS 2004). Thus is has been assumed that each year 6% of the fruit and vegetable growing population grow lettuce (i.e. 25/1000). This figure has been applied on a household basis to the study population.
The consumption of such home grown produce	Figures from Northern Ireland (NFS 2005) suggest an average weekly lettuce (and leafy salad) consumption of 25.9 g/person. It has been assumed that families who grow their own vegetables will eat double this amount of their own produce between June and October (i.e. a five month season).
The level of contamination of salad crops	It is assumed that any contamination resulting from watering in the final week of growth will remain on the produce during harvesting

occasionally causes skin problems in healthy people (usually in association with hot tubs or similar facilities – Rasmussen and Graves 1982; CDC 2000) and has, thus, been given a qualitative estimate of (−).

It is unlikely that nutrient levels within an underground rainwater tank would be adequate for the development of mosquito larvae; therefore rainwater harvesting systems are unlikely to play a role in vector-borne disease.

3.2.3 Risk characterization

The estimates relating to injury are determined by multiplying the number of occurrences by the severity weight and duration to calculate the years lived with a disability. Where an occurrence is fatal it has been assumed to occur at the age of eight in children and 45 in adults (unless otherwise noted). The years of life lost are calculated by subtracting the age of death from the UK average (79 based on rounded figures of 77 in men and 81 in women – GAD 2007).

3.2.3.1 *Injury*

The analysis of exposure (3.2.2.2) estimated that 0.012 people would be injured on an annual basis as a result of cleaning their gutters to maintain their rainwater harvesting system. It has been assumed that no fatalities occur, but that people suffer either from hospitalisation (20%), fractures/dislocations (20%) or bruises/sprains (50%). Table 3.8 shows the severity weights and durations attributed to each of these outcomes (WHO 2005; Stouthard *et al.* 1997).

Table 3.8. Severity weights and duration of incapacitation for ladder-related injuries

Outcome	Severity weight	Duration (days)	Comments
Hospitalisation	0.25	120	Based on double the figures for fractures
Fractures/dislocations	0.125	60	Severity weight based on the average of a break of the radius, ulna, hand bones, ankle, foot bones and dislocation. Duration considered to be three months.
Bruises/sprains	0.064	14	Severity weight based on figures for sprain

Applying these figures to the number of injuries gives a DALY score of 0.0003.

3.2.3.2 *Infection*

Where possible, parameters for the individual infection exposures were entered into @Risk (Palisade Corporation 2002) as probability distributions rather than point estimates, in order to examine the effects of uncertainty and the assumptions to which the estimate was most sensitive. The data for severity weights and each of the infection exposures are summarised as a series of Tables in the Appendix (Tables A3.1–A3.7).

3.2.3.3 *Summary of risk characterization*

Table 3.9 summarises the risk characterization for each of the identified hazards applied to the case study population.

Table 3.9. Risk characterization summary (rainwater harvesting)

Hazard	Exposure	Group	Estimate	Annual cases	DALYs
Drowning		All		0	0
Injury	Gutter-related incident				
		Adults		0.012	0.0003
	Confined space incident				
		All	Qualitative		(−)
Illness	Campylobacteriosis from toilet flushing				
		All	Min	3.2×10^{-5}	9.7×10^{-8}
			Mean	0.015	4.6×10^{-5}
			Max	0.11	3.4×10^{-4}
	Campylobacteriosis from direct ingestion (external tap)				
		Children	Min	2.2×10^{-4}	6.8×10^{-8}
			Mean	0.006	1.8×10^{-5}
			Max	0.038	1.1×10^{-4}
	Cryptosporidiosis from direct ingestion (external tap)				
		Children	Min	3.3×10^{-5}	2.9×10^{-8}
			Mean	0.004	3.4×10^{-6}
			Max	0.035	3.1×10^{-5}
	Campylobacteriosis from cross connections				
		All	Min	0	0
			Mean	0.003	9.9×10^{-6}
			Max	0.022	6.5×10^{-5}
	Cryptosporidiosis from cross connections				
		Norm pop	Min	0	0
			Mean	0.002	1.9×10^{-6}
			Max	0.024	2.4×10^{-5}
		Immunocomp	Min	0	0
			Mean	1.4×10^{-6}	2.3×10^{-8}
			Max	1.7×10^{-5}	2.8×10^{-7}
	Respiratory illness via aerosol				
		All	Qualitative		(−)
	Skin infection via dermal contact				
		All	Qualitative		(−)
	Cryptosporidiosis from ingestion of garden produce				
		Norm pop	Min	2.2×10^{-4}	2.2×10^{-7}
			Mean	0.08	8.0×10^{-5}
			Max	0.47	4.6×10^{-4}
		Immunocomp	Min	1.2×10^{-7}	2.0×10^{-9}
			Mean	4.3×10^{-5}	7.3×10^{-7}
			Max	2.5×10^{-4}	4.2×10^{-6}
	Vector-borne illness				
		All		0	0

Norm pop: Normal population   Immunocomp: Immunocompromised population
Min: minimum estimate   Mean: mean estimate
Max: maximum estimate   (−): minor health impact

Figure 3.1 shows a graphical representation of the results of the mean estimate.

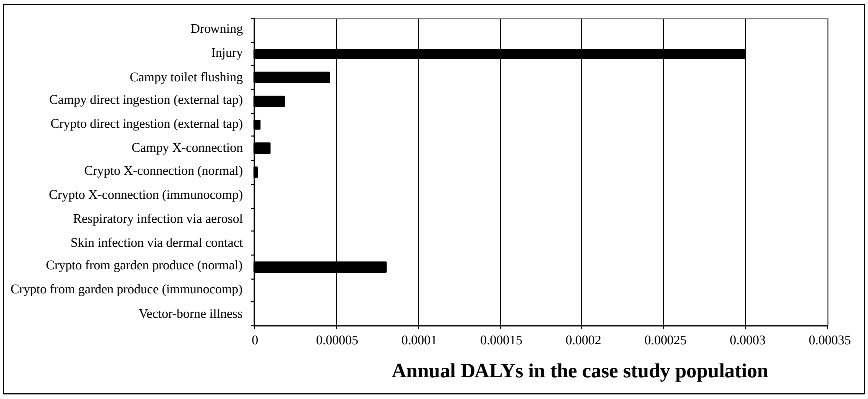

Figure 3.1. Annual DALYs by possible hazard (rainwater harvesting system)

It can be seen from Figure 3.1 that injury has the greatest DALY score, followed by cryptosporidiosis from eating contaminated garden produce and campylobacteriosis from toilet flushing. This information could be used to prioritise risk management strategies, such as an estate rainwater harvesting package where an external company services the system each year, eliminating the need for households to attempt cleaning their gutters. Such a package could actually have in an additional health benefit as, presumably, it would remove the need for any householder to clean their gutters (for what ever reason), which could prevent an additional 0.05 incidents (equivalent to 0.001 DALYs).

3.3 HEALTH IMPACT STATEMENT

This brings together all of the identified health impacts summarised in Table 3.9 (mean estimates) and presents the results on the basis of an overall DALY score.

Total DALY score: 4.59×10^{-4}

Qualitative estimate: 3(−)

3.4 DISCUSSION

The estimated DALY scores from both the mean estimate and the maximum estimate fall well within the screening level and the WHO reference level of risk outlined in Chapter 2. This is clearly shown in Figure 3.2, which compares the annual DALY estimates and the reference levels, on a case study population basis, on a $\log_{10}$ scale.

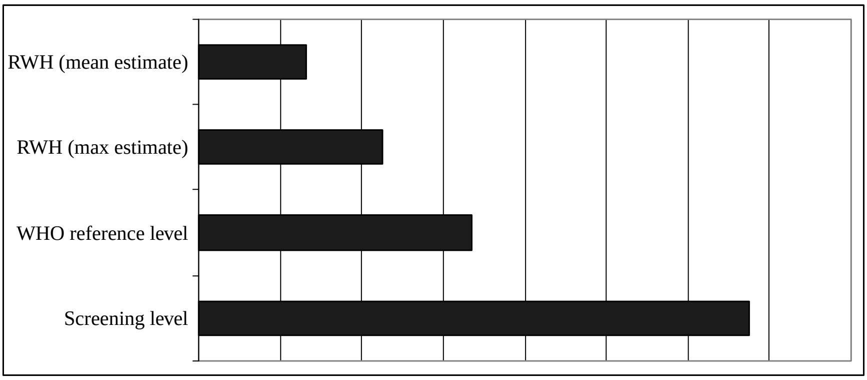

Figure 3.2. Summary of DALY scores ($\log_{10}$ scale)

In order to conduct the HIA, it was necessary to make a number of assumptions, such as the number of people likely to be injured while cleaning their gutters. As far as possible, these were based on data in the literature. Where no data were available (such as the number of children likely to drink from an external tap) documented estimates were made which enable the assumptions to be challenged and (if appropriate) alternatives to be investigated.

For the QMRA, ranges of data were incorporated into the estimates with Monte Carlo analysis used to derive minimum and maximum values. As noted above, even the maximum estimate falls well within both reference levels of risk. It is however, possible to test further some of these assumptions by deliberately choosing elevated levels. For example, ingestion of aerosolized toilet flush water could be increased to 10ml per flush (surely a noticeable and hopefully infeasible amount) and the individual DALY score for that aspect of the assessment still falls within the reference risk levels. Similarly, if the *Campylobacter* spp. concentration of the toilet flush water (derived from the harvested rainwater) is increased to 100/100ml (a level not dissimilar to that seen in polluted river water), the individual DALY score reaches 3.4×10^{-6}, slightly greater than the WHO reference level, but less than the screening level.

3.5 REFERENCES

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APPENDIX 3.1 SUMMARY OF INFECTION PARAMETERS

Table A3.1 shows the severity weights, durations and incidence for various forms of infection for both *Campylobacter* spp. and *Cryptosporidium* spp. taken from Havelaar *et al*. (2000a,b) and Mead *et al*. (1999). The remaining Tables outline the @Risk input values and sensitivity analysis data.

Table A3.1. Severity weights, duration and incidence

Infection	Severity	Duration (days)	Incidence*	Age at death
Uncomplicated campylobacteriosis	0.086	6	30%	–
Complicated forms of campylobacteriosis	0.28	365	0.5%	–
Fatal cases of campylobacteriosis	1		0.005%	78
Cryptosporidiosis (normal population)	0.054	6	71%	–
Cryptosporidiosis (immunocompromised)	0.13	47	100%	–
Fatal cases of cryptosporidiosis	1		0.022%	78

* Incidence for uncomplicated campylobacteriosis and cryptosporidiosis in the normal and immunocompromised populations relates to the percentage of people in whom infection goes to clinical illness. The other incidence figures are a proportion of those showing clinical illness.

Campylobacter spp. through toilet flushing

Table A3.2. @Risk input values and sensitivity analysis

Input	Distribution	Mean	Range	Regression value
Volume ingestion (ml)	Normal	0.1	0–0.25	0.59
Campylobacter concentration (/ml)	Log Normal	0.001	0–0.00056	0.46
Frequency of contamination of harvested supplies	Normal	3	0–10	0.42
Number of flushes	Discrete		3–6	0.31

Campylobacter spp. through direct ingestion (external tap use)

Table A3.3. @Risk input values and sensitivity analysis

Input	Distribution	Mean	Range	Regression value
Percentage of children exposed	Normal	2.5	0–5	0.52
Campylobacter concentration (/ml)	Log Normal	0.0025	0–0.0056	0.52
Frequency of contamination of harvested supplies	Normal	3	0–10	0.49
Frequency of drinking from external tap	Normal	7.5	3–12	0.29
Volume ingested (ml)	Normal	125	50–250	0.17

Campylobacter spp. through cross connections (contaminated potable supplies)

Table A3.4. @Risk input values and sensitivity analysis

Input	Distribution	Mean	Range	Regression value
Households affected by cross connections	Discrete		0–2	0.78
Campylobacter concentration (/ml)	Log Normal	0.00125	0–0.0028	0.35
Frequency of contamination of harvested supplies	Normal	3	0–10	0.31
Length of cross connections (days)	Normal	33	10–60	0.03

Cryptosporidium spp. through direct ingestion (external tap use)

Table A3.5. @Risk input values and sensitivity analysis

Input	Distribution	Mean	Range	Regression value
Cryptosporidium concentration (/l)	Log Normal	3	0–50	0.63
Percentage of children exposed	Normal	2.5	0–5	0.45
Frequency of contamination of harvested supplies	Normal	3	0–10	0.42
Frequency of drinking from external tap	Normal	7.5	3–12	0.24
Volume ingested	Normal	125	50–250	0.15

Cryptosporidium spp. through cross connections (contaminated potable supplies)

Table A3.6. @Risk input values and sensitivity analysis

Input	Distribution	Mean	Range	Regression value
Number of households affected by cross connections	Discrete		0–2	0.70
Cryptosporidium concentration (/l)	Log Normal	1.5	0–25	0.43
Frequency of contamination of harvested supplies	Normal	3	0–10	0.29
Length of cross connections (days)	Normal	33	10–60	0.02

Cryptosporidium spp. through contaminated garden produce

Table A3.7. @Risk input values and sensitivity analysis

Input	Distribution	Mean	Range	Regression value
Cryptosporidium concentration (/l)	Log Normal	3	0–50	0.80
Frequency of contamination of harvested supplies	Normal	3	0–10	0.52
Residual water (ml)	Normal	3.75	3–4.5	0.11
Volume of lettuce ingested (g/week)	Normal	51.9	30–90	0.04

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