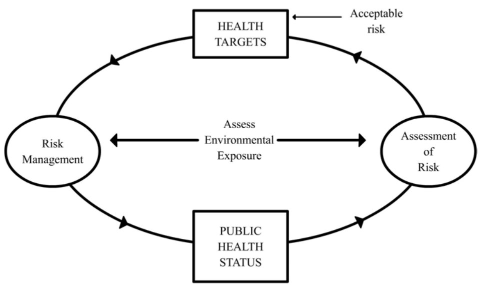

18

Framework for guidelines development in practice

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This chapter outlines a series of hypothetical studies that demonstrate the use of the proposed framework for guidelines development in practice. Examples are taken from each of the water-related guideline areas, namely: drinking water, recreational water and wastewater use.

18.1 INTRODUCTION

The proposed harmonised framework for guidelines development, in terms of water-related microbiological risk, was developed during a five-day WHO workshop held in Stockholm in September 1999. Many of the chapters in this book have developed and expanded upon issues and concepts relating to the framework that arose during the meeting. During the workshop an initial attempt was made to 'trial' the framework by working through hypothetical examples for each of the guideline areas of interest. All the workshop participants were involved in this process. These examples are designed to be illustrative and, for the purposes of the exercise, a number of assumptions was made based upon the participants knowledge of each area. Clearly, for a 'proper' iteration of the framework it will be necessary to evaluate, and document, the relevant literature.

The trial studies are outlined, one by one, along the lines of the framework, although the specific approach taken within the bounds of the framework was determined by sub-group participants. Each group's starting point was a health target and acceptable risk level to be considered in relation to a specific pathogen. Health outcomes were expressed as acute gastrointestinal infection (AGI) equivalents. The following sections outline the trial studies and the reader is referred back to earlier chapters for specific details, if required.

18.2 DRINKING WATER

The drinking water group worked through the framework using *Campylobacter* sp. as their reference pathogen. The tolerable burden was considered to be one case of AGI per person during a 10-year period. Due to possible chronic sequelae *Campylobacter* infection was considered to be 2.5 times worse than AGI, resulting in a tolerable risk of one *Campylobacter* infection per person during a 25-year period. An additional requirement was that there should be an avoidance of a detectable rise in morbidity (i.e. an outbreak) due to *Campylobacter* arising from the water source.

18.2.1 Trial study setting

In order to direct the group's thinking a water supply scenario was defined. The water supply system was taken from a surface water river. This was collected into a reservoir, disinfected, and passed into a reticulated water supply that included balancing storages. One of these balancing storages was uncovered.

18.2.2 Assess environmental exposure

Human infectious *Campylobacter* were considered to be potentially present wherever warm-blooded animal faeces contaminate water. However, they were not considered to be free-living in typical environmental waters. Therefore, any surface water or storage basin that could be subject to bird, animal or human faecal contamination could have a potentially unacceptable exposure. Groundwater protected from recent faecal contamination should not pose a significant risk. Therefore, a sanitary survey was proposed as a means of identifying the water source and the potential for faecal impacts.

18.2.2.1 Predictive assessment

For the example, the water supply system was taken from a surface water source that was assumed, from the sanitary survey, to be subject to animal and human faecal contamination. This was collected into a reservoir and passed into a reticulated water supply that included balancing storages, one of which was uncovered and was, therefore, subject to faecal contamination from birds. In conclusion, the supply was subject to a potentially significant *Campylobacter* exposure and further analysis was required.

18.2.2.2 Measured assessment

Monitoring methods do enable quantification of *Campylobacter* for exposure assessment. However, many laboratories and jurisdictions would not have access to such tests, preventing the direct assessment of exposure. In addition, quality may vary widely, requiring high sample numbers in order to properly assess exposure. Since sources of *Campylobacter* are also sources of *E. coli* and enterococci, these were reasoned to be suitable measures as indicators of general faecal contamination levels. It was noted, however, that all monitoring methods are subject to limitations due to the potential for a variation in densities of *Campylobacter* relating to:

- variations in the presence of animal and human hosts and defecation patterns
- variations in the prevalence and nature of infections carried by hosts
- variations in the origins of water reaching the sampling point due to hydrological variation.

These three factors can vary greatly both temporally and spatially and, therefore, so can exposure. The sanitary survey was considered the most important part of the exposure assessment process. Monitoring was thought to be useful as a means of verification of the level of faecal contamination. A statistically valid long-term monitoring regime was recommended. *E. coli* or enterococci were considered to be preferable alternatives to *Campylobacter* for exposure assessment to support the sanitary survey. This is because:

- The presence of these indicators is less subject to host carriage rate variation.

- Indicators are easier to detect and are typically present in higher densities within hosts than pathogens.
- Indicators are useful because although their presence does not mean *Campylobacter* are present and that the supply is unsafe at a point in time, it implies that the water has the potential to become unsafe.

For this example, monitoring results taken weekly from the reservoir water and analysed for *E. coli* and enterococci were assumed to have demonstrated the frequent presence of these organisms at a concentration greater than 1 per 100 ml. This indicated the presence of faecal contamination from warm-blooded animals at densities of potential significance.

18.2.3 Assessment of risk

In practice, it is likely that different strains of *Campylobacter* will have different infection probabilities and also that the health outcome following infection may vary according to the population. Furthermore, the level of acceptable risk may be different in individual countries according to specific national circumstances. The following is illustrative, therefore, only for the trial study.

For waterborne exposures in relatively clean water, faecal contamination would be likely to be very dilute and pathogen densities low. Therefore, the relevant dose–response relationship is found by extrapolating from human feeding trials to the lower doses.

It was assumed that the probability of ingestion leading to both infection and AGI was 0.1%. The severity of symptoms following infection can be converted to Disability-Adjusted Life Years (DALYs) (see Chapter 3) to enable a more general comparison, although that has not been done here and health outcomes are enumerated as AGI equivalents. This was assumed to give a consequence of infection of 2.5 AGI equivalents per infection (average).

18.2.4 Acceptable risk and health targets

Health targets in this example were two-fold:

- One AGI per 10 years from *Campylobacter* for long-term exposure.
- The avoidance of a detectable rise in morbidity (an outbreak) resulting from the water source due to *Campylobacter* arising from an acute exposure period.

An acceptable long-term risk level for the case study community for the water supply was set at one AGI per person per 10 person-years (ppy) from

Campylobacter. This equated to one *Campylobacter* infection per 25 years or, based on the assumed infection rate of 0.1%, 1000 exposures per person per 25 years. On the assumption that people drink 2 litres (l) of water per day, over a 25-year period an individual would be exposed to over 18,000 litres of water. This can be translated into an acceptable exposure concentration of 1 *Campylobacter* per 18 l by equating to 1000 exposures over the same time period.

The acute exposure limit set for short-term occasional high exposures was calculated differently. In the trial study community considered, there was assumed to be a background rate of 0.4% per person-year of notified campylobacteriosis. The surveillance system in place was assumed to be capable of detecting a 10-fold increase in the rate of campylobacteriosis after one week duration as an outbreak. This would equate to a case rate of 4% ppy for a period of one week. It turns out that, in this example, this is equivalent to the acceptable rate for long-term exposure and thus the acute exposure limit for periods up to one week is also 1 *Campylobacter* per 18 l.

18.2.5 Risk management

18.2.5.1 Basic control approaches

There may be a number of immediate actions that can be taken to give rapid reductions in exposure. These may, for example, be infrastructural. In our hypothetical trial, vermin-proofing grills on water tanks were assumed to be damaged. However, these were thought to be quickly and cheaply repairable to reduce avian faecal contamination during reticulation. Other examples could include land-use issues. In our example, the sanitary survey suggested that livestock faeces was heaped in storage piles near a watercourse that ran into the reservoir. It was assumed to be a simple matter for the land manager to store this at the other extremity of the land area farthest away from the river. This would reduce the risk of direct runoff and increase the amelioration effects of sub-surface and overland flow. Taking these simple, and often highly effective, measures can lead to rapid reductions in risk. This illustrates the importance of implementing basic controls while the more detailed risk assessment and management cycle gets underway.

18.2.5.2 Water quality objectives

Water quality objectives are designed to describe the desirable water quality for exposure. For our example, 1 *Campylobacter* per 18 l provides an exposure that is consistent with short- and long-term health objectives. This requires faecal contamination to be very dilute since even 1 g of faeces from an infected host (which could contain millions of *Campylobacter*) could contaminate many megalitres of water to beyond this limit. Such water would also be expected to contain even greater concentrations of indicator bacteria. For our example we have assumed that *Campylobacter* would be present in concentrations at least 1000-fold lower than *E. coli*, and that it has a lesser environmental persistence (it is also more sensitive to disinfectants than indicator bacteria). Therefore, a water quality objective of an average of less than one *E. coli* per 100 ml was thought to represent an appropriate monitoring target both for long- and short-term (outbreak) exposures.

18.2.5.3 Other management objectives

The next step is to set system management objectives to ensure that the system meets the water quality objectives and any other objectives required of the system. These objectives might include technical system management aspects as well as training of staff and education and communication with stakeholders and customers. In our trial example, this involved ensuring water quality objectives were met under normal circumstances and preventing gross contamination during unusual events, such as system failures, to meet those same water quality objectives. This involved influencing a number of identifiable groups. Some groups have roles that are not related to water supply, such as those that manage land-uses that could impact on reservoir water quality. Education, guidelines and regulation are tools to influence such groups. Others are internal, such as utility staff for whom training and appropriate resourcing would be used to ensure the supply of the best quality reservoir water, management of the disinfection system and protection of the reticulation system.

18.2.5.4 Current condition

Measures and interventions to manage the risk involve assessing the environmental exposure by systematically analysing the system from contamination source(s) through to the point(s) of consumption. Possible points of entry of hazards (i.e. *Campylobacter* spp.) would be identified along with any points of removal or inactivation. In the study example, the group was interested in the possible points of entry of faecal contamination from warm-blooded animals and birds. It considered the storage of water for a prolonged period (as a removal and inactivation barrier) and a disinfection system (as an inactivation barrier).

18.2.5.5 Key risk points and audit procedures

The key preventative measures to minimise contamination and barriers to inactivate and control contamination are to be identified and their effectiveness assessed by audit.

In the study example, point sources of faecal contamination were thought to represent a high priority hazard that required audit to ensure that the best reasonable and practicable measures were being taken to prevent faecal material entering the water. For example, for faecal material from agricultural facilities, storage in heaps for elevated temperature composting, storage as far away from the water source as possible and the use of wastewater treatment systems were examples of preventative measures aimed at reducing contamination. The selective harvesting of water from the rivers to the reservoir was another area of potential intervention. The group concluded that since this system drew water from a river into a reservoir, harvesting of water would cease after events in which fresh contamination would run into the river, such as heavy storms or a notified wastewater treatment system failure upstream. The point from which water is drawn into supply from the reservoir could be positioned to maximise the quality of water withdrawn. Turbidity could be used as a surrogate for likely bacterial contamination. The disinfection barrier, if properly applied, was thought to represent the most significant critical control point as it was assumed to provide very large reductions in *Campylobacter* densities (residual disinfectant levels also provide protection within the distribution system). Effectively, the heavy reliance on the disinfection barrier results in a 'fragile' system and suggests the need for an automatic cut-off if the disinfection process fails.

Vermin and bird-proofing in the storages, systems to prevent backflow, careful attention to the location and maintenance of pumps and suction lines, and the use of maintained/continuous positive system pressures were further points of attention recommended to prevent recontamination in the reticulation system. A longer-term intervention that may be considered in the study system was the covering of the open storage.

18.2.5.6 Analytical verifications

The key analytical monitoring and verification procedures are focused on the major preventative measures and critical control points. In the case study example, monitoring points were proposed throughout the system. Point sources of faecal contamination could be inspected regularly to ensure that appropriate waste management practices were being adhered to. The frequency of inspection would be proportional to the likely rate of change of practices at the site as well as the level of risk presented and inspectors would need to be properly trained. Where effective management measures were not being adhered to, corrective actions would need to be taken, such as advising the landholders on appropriate management measures or enforcing regulations. The decisions on selective harvesting of water from the river to supply the reservoir could be linked to a water quality monitoring programme. Action could be triggered by results from water quality parameters monitored instantaneously, such as turbidity, or by rainfall itself. Long-term monitoring could be used to understand the relationship between those factors that can be measured early enough to use as cues for preventative action (such as rainfall) and those that cannot (such as bacterial indicator readings). A system for monitoring and notifying major treated wastewater discharges could be included to enable the avoidance of water harvesting after treatment system failures. Within the reservoir, the water quality could be monitored at a range of depths and at regular intervals to ensure that the point of offtake from the reservoir is optimal for water quality. The disinfection barrier could include an alarm to enable rapid corrective actions to be taken in response to malfunctions measured in terms of pH, chlorine or turbidity. In the short term, triggering of the alarm could result in an automatic redirection of the flow to waste. Corrective actions could include repair or engaging of backup disinfection systems. Engineered items such as tanks, pumps and suction lines and reticulation system backflow preventors need to be appropriately designed and could be carefully monitored at appropriate intervals with repairs made where problems are found. Where system pressures are found to have been lost, potentially leading to ingress, such as after the repair of bursts, an appropriate flushing regime could be used to remove contamination prior to resumption of supply.

A process for verification would be used to ensure that training is up to date and that people are performing their tasks as required. Regular water quality monitoring for *E. coli* would be performed to verify that the concentration of faecal bacterial contamination is acceptably low and that the management approach is working.

18.2.6 Public health status

Public health verification through surveillance would take place and would be designed to test for significant associations between consuming water and morbidity. In the study system, there was assumed to be no evidence of associations between water consumption and morbidity although it was assumed that monitoring found *E. coli* occasionally downstream of the open storage to suggest an average concentration above 1 per 100 ml. Since this leads to the exceedance of the water quality objectives, it was felt appropriate that an intervention should be undertaken. This was because it was reasoned that the concentration of *E. coli* demonstrated the presence of faecal material at a concentration that could foreseeably lead to a campylobacteriosis community infection rate greater than the public health target. It was assumed that this would occur should the population of animals or birds excreting the faeces into the storage become heavily infected with a human infectious *Campylobacter* strain. Options for intervention were put forward, such as disinfection downstream of the open storage or covering and vermin-proofing of the storage.

18.3 RECREATIONAL WATER

In contrast to the other two case studies, the recreational water group was asked to focus on the avoidance of acute gastrointestinal infection rather than a specific pathogen. The health target was set as 1 case of AGI per 80 exposures to a recreational water, along with no detectable outbreaks attributable to the recreational water during a summer bathing period. These levels were chosen to relate to present regulatory discussions and the draft guidelines relating to recreational water.

18.3.1 Trial study setting

The group decided that the best means of illustrating the framework was to apply it in a trial study format using real data. Beach A is a 4 km-long embayment with several compliance locations, set in a northern European location. One of the compliance locations passes the Guide standard and the others pass the Imperative criteria specified in the EC Bathing Water Directive. The bay takes most of the surface drainage from a community with a winter population of about 80,000 and a peak summer population of approximately 110,000. The local wastewater treatment works comprises an activated sludge plant with final settlement and ultra-violet (UV) disinfection of the treated wastewater producing an effluent of excellent microbiological quality. This effluent is discharged through a short outfall within the inter-tidal zone and represents nearly half of the freshwater input to the Bay.

In addition to the effluent treatment investments, considerable attention has been devoted to limiting the discharge of partially treated storm waters and untreated (but dilute) effluent from the combined sewerage system. The storage capacity has been designed to such a level that intermittent discharges following rainfall events have been virtually eliminated. Despite these measures, the beaches in the receiving waters do not all reliably achieve the Guide standards of the Bathing Water Directive and it has been proposed that stream inputs draining from agricultural catchments containing livestock and hinterland communities may be responsible.

18.3.2 Assess environmental exposure

In this example, data considered to be representative of the whole of Beach A are shown in Table 18.1.

Table 18.1. Microbiological data representative of Beach A

Environmental exposure data	
No. of samples	20
Geometric mean – faecal streptococci (/100ml)	12
Geometric mean – total coliform (/100ml)	215
Geometric mean – faecal coliform (/100ml)	71
Log_{10} standard deviation (faecal streptococci)	0.624
Log_{10} standard deviation (total coliform)	0.429
Log_{10} standard deviation (faecal coliform)	0.599
Bather number per year (i.e. no. of exposures)*	100,000

* Estimated based on the assumption that the average beach visitor population is 25,000 per fortnight over a 16-week summer period (i.e. 200,000 visitors per annum) and that 50% will bathe in the sea and swim once during their holiday.

Additional points, in relation to environmental exposure, are as follows:

- The effluent receives secondary (biological, activated sludge) treatment with tertiary UV disinfection. The geometric mean (GM) faecal coliform organism concentration in the discharged effluent after UV treatment is generally <50/100ml.
- The discharge point is in the inter-tidal zone via a short outfall.
- There is excellent storm-flow management of the combined sewerage system. High flow events are retained in the system through enhanced volume and storm retention. The spill frequency for this system is <1 in 5 years.
- There are significant inputs from diffuse sources causing episodic bacterial inputs to the bathing water which have been quantified. The potential exists for the application of a ‘diffuse sources’ prediction model to identify hot spots as part of a critical control point analysis.
- Streams draining an adjacent urban area through culverts may have cross connections causing minor but persistent microbiological loadings.
- There is an adjacent harbour with recreational craft that may produce intermittent bacterial discharges through inappropriate toilet discharges.

- The site has an average gull population and is not a major sea bird roosting area.

18.3.3 Assessment of risk

The assessment of risk is based upon the assumption that the visitor population is 25,000 per two-week period over a 16-week holiday period, with 50% of the visitors swimming in the recreational water. Previous epidemiological studies have investigated the risk of gastrointestinal infection from sea bathing and have demonstrated a dose–response relationship between faecal streptococci levels measured at chest depth and gastrointestinal illness (see Chapters 2 and 7). Using a disease burden approach (as outlined in Chapter 2) a risk of 43 cases of gastrointestinal infection/1000 population is derived. Over the summer season this equates to 4300 cases in 16 weeks or 269 cases of AGI attributable to sea bathing per week.

18.3.4 Acceptable risk and health targets

The health targets were based upon observing no outbreaks of illness attributable to a recreational water during a bathing season and one case (or less) of AGI per 80 exposures.

The assessment of risk, outlined in the previous section, found that the current level of illness was 4300 cases of illness from 100,000 bathing events. This equates to 1 case of illness in 23 exposures – clearly somewhat worse than the acceptable level.

In terms of outbreak detection, it is assumed that the local surveillance system will pick up a 15-fold increase above the background rate of gastrointestinal illness. The background rate of AGI is taken to be one case/person/year, which equates to 0.038 cases per two week period (or 0.019 cases/week) and hence a background rate of 480 cases per week in the visitor population ($0.038 \times 25,000$ in a two-week period). The background rate in the local population is assumed to be the same and therefore adds an additional 1520 cases of illness/week ($0.019 \times 80,000$), resulting in a total background rate of 2000 cases/week. The cases of illness attributable to sea bathing would, therefore, not be detected as an outbreak.

18.3.5 Risk management

An early stage in the risk management process is the setting of water quality objectives that are designed to allow the health target to be achieved. Following on from that, the harmonised framework requires that verifiable measures, interventions and key risk points (critical control points in HACCP terminology) should be defined. The approach taken by the recreational water group is outlined in the following sub-sections.

18.3.5.1 Water quality objectives

Based upon the desired health target, the water quality objective was set such that the faecal streptococci 95 percentile level should not exceed 50/100 ml during samples taken during the bathing season (for more details see Chapter 2).

18.3.5.2 Audit measures

- Microbiological concentrations in the bathing water and resultant compliance assessment.
- Final effluent quality monitoring for microbiological parameters and/or real time measurements of physico-chemical parameters in the effluent stream to facilitate instantaneous prediction of effluent microbiological quality.
- Combined sewer overflow (CSO) and storm spill volume monitoring and recording in real time.
- Diffuse source catchment modelling to predict the time and concentrations of diffuse source inputs.

18.3.5.3 Intervention measures

- Control of beach usage (time and/or space). Advisory notices could be posted to limit use to a specific area or restrict use for a specified time period.
- Adjustment of sewage treatment regime. The potential exists for plant optimisation and/or flow volume adjustment using the in-built storage to minimise faecal indicator loadings. It should be noted here that the science base describing the influence of management interventions within the activated sludge process on faecal indicator and enterovirus concentrations in the final effluent is very weak. It is stronger for interventions within the UV or microfiltration disinfection systems.
- Stream input quality. This may be adjusted by remedial solutions such as reed beds for small streams. Larger inputs would require some form of catchment management to control diffuse sources. Effort can best be targeted through the identification of pollution 'hot spots' informed by diffuse sources modelling.

- Compliance modelling. This could be used to predict the timing of elevated bacteriological concentrations for appropriate 'real time' intervention. This can take the form of simple statistical models that use antecedent conditions described by commonly available variables (such as sunlight, stream-flow, tidal state, wind speed and direction etc.) to provide a prediction of bacterial concentration at the compliance point.
- Removal of cross-connections between the sewage and storm-water systems. Such removal is as essential as the remediation of the catchment diffuse sources from agriculture. Almost universally, all surveys of inappropriate connections (i.e. of foul drains to surface-water drains and streams that are often culverted in urban areas) identify previously unknown problems.

18.3.5.4 Verification information

The need for the following verification information was identified. Points followed by an asterisk indicate that such data is currently already acquired in a number of countries.

- Compliance data.* Microbiological data acquired under the monitoring requirements of the Bathing Water Directive or other national/regional legislation or regulations.
- Spill volume data.* Acquired from telemetric monitors in the sewerage infrastructure. It is worth noting that some coastal sewerage systems are subject to marine water ingress causing siltation during high tides. This makes flow and level monitoring data difficult to interpret. In such circumstances, modelled flow data may be a more appropriate measure of CSO discharge, although such CSO modelling does require good spatial resolution and precision in the available rainfall data to drive the model.
- Effluent quality data.* Acquired though routine plant monitoring, this may not always include the microbiological parameters which should be placed on the suite of routine determinands.
- Stream water quality data. This is rarely available and, where data have been acquired, sampling is often biased towards low-flow conditions. The reason for this is the logistics of sampling within the working day and the requirement to get samples to a laboratory for analysis within the working week. However, samples collected under low flow conditions are almost worthless in characterising the impact of streams and catchment diffuse sources on bathing

waters because most of the bacterial delivery from streams and rivers occurs during high flow events.

- Beach usage rate data. Again, good quality data are rarely available for this parameter. Surveys offer one empirical means of data acquisition but broad estimates of usage from commonly acquired tourist data such as bed-night occupancy may be the best data available.

18.3.6 Public health status

Although there will be no detectable outbreaks of illness relating to the use of Beach A during a bathing season, the level of risk is currently greater than the acceptable level. The following table (Table 18.2) outlines a number of possible interventions along with the estimated health gain from each proposed measure. Such estimates could be used in a cost-benefit analysis, which may then lead to reconsideration of the level of acceptable risk.

Table 18.2. Interventions and health gain estimates

Intervention	Estimated health gain
Control of beach usage to prevent access to polluted water after episodic inputs from diffuse sources.	4000+ cases of AGI (assuming perfect prediction and control).
Adjustment of present sewage treatment regime.	Very little, as effluent quality is already very good.
Improvement of stream input quality to 'no effect' level.	Given the low effluent bacterial loadings – 4000+ cases of AGI. (A 'high flow' bacterial budget calculation is needed to underpin this calculation.)
Compliance model to predict the timing and/or spatial extent of peak bacterial indicator concentrations to facilitate appropriate advisory notices and/or beach zoning. (The utility of this approach should be judged on the basis of the model explained variance).	Given the low effluent bacterial loadings – 4000+ cases of AGI.
Remediation of all cross-connections in the hinterland catchments and adjacent urban areas.	Probably a small loading, maybe >300 cases of AGI.

18.4 WASTEWATER REUSE

The wastewater reuse group was asked to apply the framework to vegetable irrigation with wastewater. The reference pathogen was hepatitis A virus (for which there is no direct analytical method in environmental samples). The tolerable burden of disease was to be equivalent to 1 case of AGI per 10 people per year. Infection with hepatitis A was considered to be equivalent to 200 cases of AGI.

18.4.1 Trial study setting

The scenario chosen by the group related to furrow or flood irrigation of a lettuce crop with untreated wastewater.

18.4.2 Assessment of environmental exposure and risk

In order to determine environmental exposure a number of assumptions were made in relation to the concentration of hepatitis A virus in faeces and wastewater and also the residual level of wastewater on the lettuce crop. The approach taken was based upon inputs from epidemiological studies and risk assessment models. For the purposes of the exercise the assumptions shown in Table 18.3 were made (based loosely on the literature).

Table 18.3. Assumptions and data inputs

Data required	Assumptions
Concentration of hepatitis A in faeces	10^4/g of faeces
N_{50} (median infectious dose)	0.5 g of faeces
Wastewater production	150 litres/person/day 5.5×10^4 litres/person/year
Faeces production	250 g/person/day 9.1×10^4 g/person/year
Prevalence of hepatitis A shedding	2% of the population – i.e. 0.02
Duration of shedding	7 days/year – 0.0192
Residual water on the lettuce crop	0.11 ml/g of lettuce
Lettuce consumption	100 g/person/day

These assumptions lead to an estimate of the daily hepatitis A intake from lettuce consumption. The virus production can be estimated by multiplying faeces production by prevalence in the population, duration of shedding and by the concentration of hepatitis A in the faeces.

$$9.1 \times 10^4 \times 0.02 \times 0.0192 \times 10^4 = 3.5 \times 10^5 \text{ hepatitis A virus/person/year}$$

The concentration of hepatitis A virus in wastewater is, therefore, calculated from the amount of virus produced per person and amount of wastewater production.

$$\frac{3.5 \times 10^5}{5.5 \times 10^4} = 6.4 \text{ hepatitis A virus/litre (i.e. } 6.4 \times 10^{-3} \text{ /ml)}$$

The actual daily intake of hepatitis A virus by lettuce consumption is a function of the concentration of the virus in the wastewater per ml, the volume of wastewater in the lettuce consumed and the per capita lettuce consumption (assuming no removal of pathogens through washing of the lettuce prior to consumption).

$6.4 \times 10^{-3} \times 0.11 \times 100 = 7 \times 10^{-2}$ hepatitis A virus/person/day

18.4.3 Acceptable risk and health targets

The acceptable risk was defined to the group as being 1 case of AGI per 10 people per year, with the AGI equivalent for hepatitis A being 200. This, therefore, equates to 0.005 cases of AGI per 10 people/year or 5×10^{-4} cases/person/year.

Since exposure is based on intake, it is also necessary to convert the acceptable level of illness to an intake. The acceptable level of hepatitis A virus intake is a function of the acceptable risk, the N_{50} value and the concentration of hepatitis A virus in faeces. If N_{50} is expressed as concentration of hepatitis A virus (0.5×10^4), this can be related to acceptable daily intake (ADI) as follows:

$$ADI = -N_{50} \times \ln\left(1 - \frac{5 \times 10^{-4}}{365}\right)$$

where 5×10^{-4} is the acceptable annual risk and 365 is the number of days per year. Acceptable daily intake thus equals 6.9×10^{-3} hepatitis A virus/person/ day. It can be seen from this calculation that the assessment of exposure is an order of magnitude greater than the level of acceptable risk and therefore requires a risk management strategy that would yield at least a 10-fold reduction in hepatitis A virus intake.

18.4.4 Risk management

It has been found for this hypothetical, yet realistic, example that the actual risk of contracting hepatitis A infection is somewhat greater than that deemed acceptable. In human wastewater reuse there are four measures that may be implemented individually or combined to reduce the risk of transmitting excreta-related infections:

(1) Treatment of waste.
(2) Choosing suitable methods of waste application.
(3) Restricting certain crops.
(4) Improved personal and domestic hygiene.

It has been assumed in this example that there is no legal restriction on crops to be grown or, if such restrictions do exist, either farmers do not respect them and/or they are not being enforced. Hence, as is often the case, particularly in developing countries, peri-urban farmers have chosen to grow vegetables. In an urban setting, these crops are likely to yield the highest cash income and contribute greatly to food security, for both the farmer and his family as well as for the urban populace.

The thrust for risk management, therefore, rests on treating the wastewater and adopting irrigation methods that reduce the risk of contaminating the crop. Improved hygiene practices would primarily help the farmer and his family.

18.4.4.1 Drip irrigation

Drip irrigation is likely to lead to a 100-fold (2-log cycle) reduction in the pathogen load contaminating irrigated vegetables when compared with spray or flood irrigation. Hence, if technically and financially feasible for the farmer, this measure alone would lower the risk to the consumer to below the acceptable level.

18.4.4.2 Wastewater treatment

There exist several treatment options to achieve a reduction in exposure to hepatitis A virus. In reality, the choice of a particular option will depend upon socio-economic, financial, technical and institutional criteria. Partial treatment in a waste stabilisation pond scheme (consisting of a facultative pond or an aerobic pond followed by a facultative pond) as well as conventional secondary treatment are both likely to comfortably satisfy the stipulated 10-fold reduction in hepatitis A virus levels. An upflow anaerobic sludge blanket clarifier, a new treatment option, currently popular in Latin American countries, may also satisfy the required reduction, although it still requires research on specific pathogens removal. Irrespective of the treatment option chosen, the expected/required performance can only be achieved if the systems are adequately designed, and properly operated and maintained.

18.4.5 Public health status

The final stage in the first iteration of the framework is an examination of 'public health status' as a verification that the measures put in place are adequate and appropriate. In the case study scenario it was found that with the introduction of partial waste treatment and drip irrigation, levels of hepatitis A fell to within the acceptable level within the urban community. There was a suggestion, however, that levels of hepatitis A infection within the farming community remained high and additional measures may be required to target the health of this group.

18.5 DISCUSSION

The trial examples, drawn from each guideline area using realistic hypothetical scenarios demonstrated that the proposed harmonised framework is a valuable tool. Data needs and availability vary between the three guideline areas and this was clear from the types of data adopted and the specific approaches taken by the individual groups. However, in each case the framework was sufficiently inclusive to allow the use of the best data available and also acted to guide the groups through the process in a logical fashion. The need for the framework to be seen as a series of iterations, rather than simply a one-off exercise, was demonstrated by each example. Given the short period of time available for these group discussions, elaboration on the 'public health status' aspect was limited and none of the groups was able to consider their scenario in terms of public health more generally. In terms of hepatitis A infection, for example, it may have been constructive for the wastewater use group to 'examine' the likelihood of hepatitis A infection from consumption of contaminated shellfish or even recreational water use.