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SURVEILLANCE AND OUTBREAK MANAGEMENT OF WATER-RELATED INFECTIOUS DISEASES ASSOCIATED WITH WATER-SUPPLY SYSTEMS



ABSTRACT

The Protocol on Water and Health to the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes is the key policy instrument for promoting better health through effective water management and water-related disease surveillance. Despite high access rates to improved water supplies, drinking-water supply systems are among the most important sources of water-related infectious diseases (WRID) posing a threat to public health in the pan-European region. This publication addresses surveillance and outbreak management of WRID associated with drinking-water supply systems, building on existing guidelines for infectious disease surveillance and outbreak response. It aims to help countries to build on and strengthen their systems by providing technical information on the specific features, activities and methodologies related to WRID surveillance and outbreak management.

KEYWORDS

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Contents

Acknowledgements	viii
Foreword	x
Abbreviations	xii
Background and introduction	1
Strengthening surveillance and outbreak management in the context of the Protocol on Water and Health	1
What is water-related infectious disease?	2
Pathogens transmitted through drinking-water	2
Drinking-water systems as a source of WRID	3
The public health importance of WRID in the pan-European region	6
Why strengthened surveillance and outbreak management capacity is needed	7
Scope and purpose of the publication	8
PART A. SURVEILLANCE OF WATER-RELATED INFECTIOUS DISEASE	10
Summary	11
Overview of WRID surveillance	13
Building blocks and types of surveillance	13
Attributes of different types of surveillance	19
How to set up, improve and maintain national systems for surveillance of WRID	24
Activity 1. Engage key stakeholders and identify their roles	25
Activity 2. Characterize the public health problem through a situation analysis and agree priorities for surveillance	25
Activity 3. Define the overall purpose, scope and objectives of the WRID surveillance system	28
Activity 4. Identify the outcomes for surveillance, the core surveillance dataset and design the system	29
Activity 5. Develop a methodology for collecting, managing and analysing the surveillance data	33
Activity 6. Develop processes for monitoring and evaluating the system	34
Enabling factors for strengthening and sustaining WRID surveillance	37
Approaches to WRID surveillance data analyses	39
Spatial analyses	39
Time-series analyses	40
Interlinkage of water-quality surveillance with WRID surveillance	44
Using surveillance data for advocacy	45

PART B. MANAGEMENT OF OUTBREAKS OF WATER-RELATED INFECTIOUS DISEASE	48
Summary	49
Introduction to outbreaks	52
Contingency planning	53
Considerations in contingency planning	53
Boil water notices	55
Revising and updating emergency response plans	56
Steps in outbreak management	57
Step 1. Detect and confirm the existence of the outbreak and confirm the causative agent	59
Step 2. Form the RRT	61
Step 3. Define cases	63
Step 4. Identify cases and obtain information	63
Step 5. Conduct a descriptive epidemiological investigation (time, place, person)	65
Step 6. Conduct additional studies and collect additional information (environmental, laboratory)	68
Step 7. Interview cases and generate hypotheses	72
Step 8. Evaluate the hypotheses	73
Step 9. Implement control measures	77
Step 10. Communicate findings, make recommendations and evaluate the outbreak response	79
Risk communication	82
Key elements of risk communication	83
Preparing public health messages	86
Partnership with stakeholders	86
Engaging with social media and the community	86
International frameworks for managing transboundary events and outbreaks	88
References	90
Annex 1. Glossary of terms	95
Annex 2. Useful resources	98
Annex 3. Template boil water notice	102
Annex 4. Legionella resources	103

Tables

Table 1.	Classification of WRID	3
Table 2.	Pathogens transmitted through drinking-water	4
Table 3.	Examples of hazardous events at different points of the drinking-water system	5
Table 4.	Types of indicator- and event-based surveillance and their relevance to WRID surveillance	15
Table 5.	Data commonly collected for different surveillance outcomes	31
Table 6.	Surveillance analyses to address specific surveillance objectives	39
Table 7.	Step-by-step specific actions for WRID outbreak management	50
Table 8.	Classification system for assessing the strength of the evidence linking an outbreak to water	75
Table 9.	Overview of the components of the chain of transmission and examples of associated target control measures for WRID	79

Figures

Fig. 1.	WRID transmission routes	2
Fig. 2.	Disease surveillance core activities	14
Fig. 3.	The epidemic intelligence framework through which outbreaks usually are detected	14
Fig. 4.	Patient pathway and timeliness and sensitivity of case ascertainment by surveillance systems based on clinical and laboratory diagnoses	20
Fig. 5.	Timeliness of outbreak detection using surveillance of: a) water-quality turbidity counts; b) customer complaints to the water provider; and c) laboratory reports of <i>Cryptosporidium</i> , Milwaukee, United States, 1993	21
Fig. 6.	Activities for developing and establishing a WRID surveillance system	24
Fig. 7.	Overview of the typical process for conducting surveillance	34
Fig. 8.	Surveillance systems: periodical evaluation against defined attributes	36
Fig. 9.	Overall process for the management of outbreaks	58
Fig. 10.	Signals for WRID outbreak detection	59
Fig. 11.	Integrated model for risk communication	85

Boxes

Box 1.	European Union surveillance case definition for cryptosporidiosis	30
Box 2.	Use of spatial analyses for WRID surveillance data analysis	40
Box 3.	Use of time-series analysis to investigate the association between rainfall and AGI	42
Box 4.	The 10-step approach for outbreak management	57

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Foreword

Having access to safe drinking-water and adequate sanitation are fundamental human rights that are essential to human health, well-being and development.

In the past decade, the pan-European region has seen good progress in providing people with adequate water and sanitation services. Yet the region continues to experience water-related infectious disease (WRID) outbreaks, impairing health, well-being and productivity of people and communities. WHO estimates that 14 people still die each day due to diarrhoeal disease associated with poor water, sanitation and hygiene. Nearly one fifth of all investigated outbreaks of infectious diseases were attributable to water.

To better protect human health through improved sustainable water management and to prevent, control and reduce water-related diseases, the United Nations Economic Commission for Europe (UNECE) and the WHO Regional Office for Europe coordinate the implementation of the Protocol on Water and Health.

The Protocol on Water and Health is a unique international legal instrument in the pan-European region that plays a vital role in attaining global and regional goals and commitments, particularly those of the 2030 Agenda for Sustainable Development

and the 2017 Ostrava Declaration on Environment and Health. It provides an effective framework to support countries in achieving United Nations Sustainable Development Goal (SDG) 6 to ensure access to safe water, sanitation and hygiene for all, the SDG 3 health targets to combat waterborne diseases and substantially reduce the number of deaths and illnesses from water contamination, and other water, sanitation and health-relevant SDG targets.

Establishing and maintaining vigilant and well functioning systems for surveillance and outbreak management of WRID is a core public health function. Parties to the Protocol on Water and Health therefore are required to strengthen their response capacities to prevent, control and reduce WRID. By building effective systems for WRID surveillance and outbreak management, Parties also contribute to the wider long-term global health security agenda and implementation of the International Health Regulations.

As part of our ongoing commitment to supporting the Parties to the Protocol in implementing the above obligation and complementing existing international guidelines, we are proud to present this practical tool on how effectively to address and integrate the specific aspects of WRID in existing systems. Its development has been inspired by the findings of the situation

assessment of WRID in the pan-European region (2016) and the needs expressed by countries cooperating under the Protocol. The tool will help countries identify gaps and areas for enhanced capacity and navigate the particular activities and techniques that need to be in place for effective WRID surveillance and management of outbreaks.

On behalf of the WHO European Centre for Environment and Health in Bonn, Germany, which coordinated the development of this



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Abbreviations

AGI	acute gastrointestinal illness
CDC	Centers for Disease Control and Prevention
CI	confidence interval
CISID	Centralised Information System for Infectious Diseases
DALY	disability-adjusted life-year
ECDC	European Centre for Disease Prevention and Control
EPA	Environmental Protection Agency
FWD	food and waterborne diseases
GIS	geographic information systems
ICD-10	International Statistical Classification of Diseases and Related Health Problems, 10th revision
IHR	International Health Regulations
M&E	monitoring and evaluation
NPHA	national public health agency
PCR	polymerase chain reaction
RRT	rapid-response team
SDGs	(United Nations) Sustainable Development Goals
TESSy	The European Surveillance System
UNECE	United Nations Economic Commission for Europe
WRID	water-related infectious disease
WS	water supply
WSP	water safety plan

Background and introduction

Strengthening surveillance and outbreak management in the context of the Protocol on Water and Health

The Protocol on Water and Health to the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1) (hereafter referred to as the Protocol) is the key policy instrument in the pan-European region¹ for promoting better health through effective water management and water-related disease surveillance. Specifically, Article 8 of the Protocol requires Parties to strengthen capacity for surveillance and outbreak management by ensuring that:

(a) Comprehensive national and/or local surveillance and early-warning systems are established, improved or maintained which will:

(i) Identify outbreaks or incidents of water related disease or significant threats of such outbreaks or incidents, including those resulting from water pollution incidents or extreme weather events;

(ii) Give prompt and clear notification to the relevant public authorities about such outbreaks, incidents or threats;

(iii) In the event of any imminent threat to public health from water-related disease, disseminate to members of the public who may be affected all information that is held by a public authority and that could help the public to prevent or mitigate harm;

(iv) Make recommendations to the relevant public authorities and, where appropriate, to the public about preventive and remedial actions;

(b) Comprehensive national and local contingency plans for responses to such outbreaks, incidents and risks are properly prepared in due time;

(c) The relevant public authorities have the necessary capacity to respond to such outbreaks, incidents or risks in accordance with the relevant contingency plan.

Article 6.2 of the Protocol requires that Parties to the Protocol establish and publish national and local health-based targets for the reduction of outbreaks and incidents of water-related disease. Targets can be set to:

- reduce incidents and outbreaks of water-related disease through preventive action, such as protecting water resources used for drinking-water, safely managing sanitation services and adopting the water safety plan (WSP) approach to ensure continuous safe management of the water-supply system, as such action can be more cost-effective than remedial action; and
- strengthen water-related disease surveillance and outbreak management systems.

Once targets have been adopted, progress towards achieving those targets and the degree to which their achievement has prevented, controlled and reduced water-related diseases is assessed and reported to

¹ This publication uses the term pan-European region to refer to the Member States of the WHO European Region and Liechtenstein. The WHO European Region comprises the following 53 countries: Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom and Uzbekistan.

the Meeting of the Parties to the Protocol on a regular basis (Article 7).

In accordance with Article 13 of the Protocol, Parties that border common transboundary waters should work together to prevent and control water-related disease outbreaks.

Article 2.1 of the Protocol defines water-related disease as, “any significant adverse effects on human health, such as death, disability, illness or disorders, caused directly or indirectly by the condition, or changes in the quantity or quality, of any waters” (1). These exposures may occur either through exposure to contaminated water through ingestion, inhalation or contact with the water, or due to hygiene-related behaviours associated with lack of access to clean water or poor hygiene practices (2). Water-related diseases can be infectious or non-infectious. This document focuses on water-related infectious diseases (WRID). It will support implementation of the Protocol by providing its Parties and other states working in its framework with information on best practices for monitoring, detecting and managing outbreaks.

What is water-related infectious disease?

Infectious diseases are classified as water-related based on their transmission route (Fig. 1).

Indirect exposure may occur through consumption of contaminated food, particularly food that has been cultivated, processed or produced using contaminated drinking-water, where there has been cross-contamination during food preparation, or where there has been insufficient access to safe water to ensure personal and food hygiene.

Classification systems have been developed for WRID and have been described elsewhere (2–6). The document uses the classification system proposed by Bartram et al. (5) and Bradley (7) (Table 1).

Pathogens transmitted through drinking-water

Contamination of water supplies with human and animal faeces can lead to the introduction of a variety of pathogens into the supply. Consumption of contaminated water supplies is associated with the largest proportion of cases of WRID. The WHO guidelines for drinking-water quality (8) provide detailed information on some of the most common pathogens that can be transmitted through drinking-water. Table 2, reproduced from the guidelines, provides an overview of these pathogens. Further information on the pathogens, including detailed fact sheets, is available in the guidelines for drinking-water quality, and information on how drinking-water

Fig. 1. WRID transmission routes

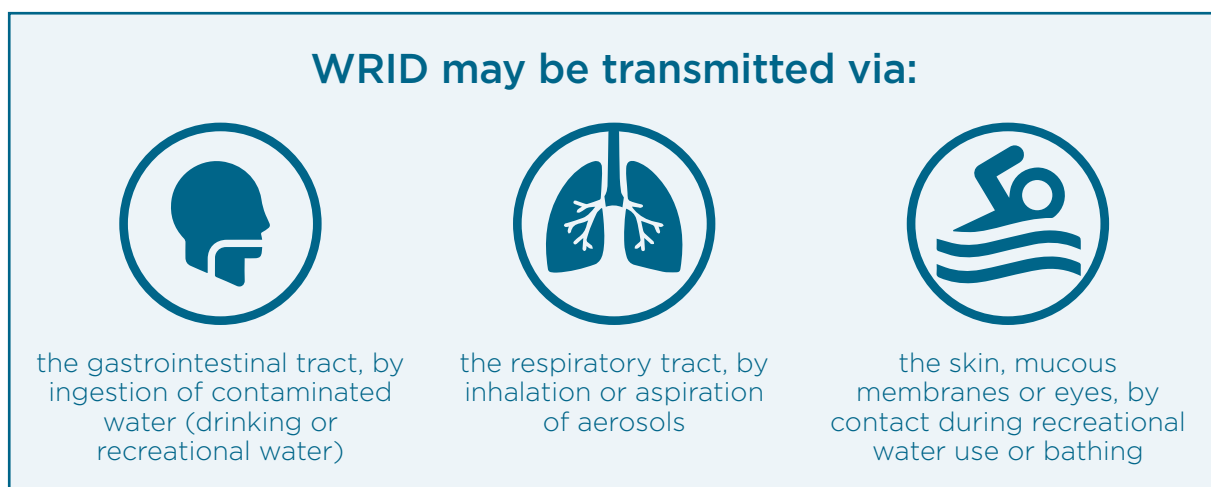


Table 1. Classification of WRID

Category	Description	Example diseases
Waterborne	Caused by ingestion of pathogens in contaminated water	Typhoid, legionellosis, poliomyelitis
Water-washed: (a) skin and eyes (b) diarrhoeal diseases	Transmission is due to poor personal and/or domestic hygiene as a result of lack of access to appropriate water	Scabies, trachoma, bacillary dysentery
Water-based: (a) penetrating skin (b) ingested	Diseases caused by infections of disease agents that must spend parts of their life cycles in aquatic environments	Schistosomiasis, ascariasis, taeniasis
Infections associated with water-related insect vectors: (a) biting near water (b) breeding in water	Diseases spread by insect vectors that breed in or bite near water	Malaria, trypanosomiasis, West Nile fever

Source: adapted from Bartram et al. (5) and Bradley (7).

systems can become contaminated can be found in the next section.

Waterborne pathogens can cause both acute and chronic health effects. Some can grow in the environment, while others, such as *Cryptosporidium*, can persist in water. They can aggregate or stick to solid particles in the water and their concentrations in the supply can vary over time. Temporal spikes in pathogens can lead to sporadic cases or outbreaks of disease. These temporal variations in the concentration of the pathogen in water also make its detection in the water supply difficult. Some pathogens can multiply in food and drinks, with the foods and drinks acting as secondary vehicles of infection. *Legionella* can grow in warm-water systems and water-distribution systems; it is transmitted not by consumption of the water, but by inhalation of infected droplets.

Drinking-water systems as a source of WRID

Drinking-water supply systems arguably are the most important source of WRID in the pan-European region.

These systems usually include the water source (surface or groundwater) and the water abstraction, treatment and distribution system up to the point of consumption. Smaller

community and single-household systems (like individual wells or springs) may have little or no treatment, and it is necessary to carry water home from community collection points in some parts of the pan-European region. Contamination can occur at any stage of drinking-water abstraction, treatment, distribution or at the point of use (4,8-10).

The quality of water reaching the consumer will be influenced by (9,10):

- the quality of the source water and the presence of sanitary protection zones;
- the adequacy and effectiveness of treatment processes;
- residual disinfectant levels in treated water;
- the integrity of storage reservoirs;
- the integrity of distribution systems, as influenced by the age and material of pipes, design (the presence of dead ends in the system, for instance), operational practices (such as managing constant pressure and residual chlorine levels) and maintenance practices (timely replacement of pipe sections and timely repairs of breaks, for example);
- transport of collected water from source to premises (for community point sources); and
- treatment of water at home, and handling and storage practices.

Table 2. Pathogens transmitted through drinking-water^a

Pathogen	Type species/ genus/group ^b	Health significance ^c	Persistence in water supplies ^d	Resistance to chlorine ^e	Relative infectivity ^f	Important animal source
Bacteria						
<i>Burkholderia</i>	<i>B. pseudomallei</i>	High	May multiply	Low	Low	No
<i>Campylobacter</i>	<i>C. coli</i> <i>C. jejuni</i>	High	Moderate	Low	Moderate	Yes
<i>Escherichia coli</i> - diarrhoeagenic ^g	-	High	Moderate	Low	Low	Yes
<i>E. coli</i> - enterohaemorrhagic	<i>E. coli</i> O157	High	Moderate	Low	High	Yes
<i>Francisella</i>	<i>F. tularensis</i>	High	Long	Moderate	High	Yes
<i>Legionella</i>	<i>L. pneumophila</i>	High	May multiply	Low	Moderate	No
Mycobacteria (non- tuberculosis)	<i>Mycobacterium</i> <i>avium</i> complex	Low	May multiply	High	Low	No
<i>Salmonella typhi</i>	-	High	Moderate	Low	Low	No
Other salmonellae	<i>S. enterica</i> <i>S. bongori</i>	High	May multiply	Low	Low	No
Shigella	<i>S. dysenteriae</i>	High	Short	Low	High	No
<i>Vibrio</i>	<i>V. cholerae</i> O1 and O139	High	Short to long ^h	Low	Low	No
Viruses						
<i>Adenoviridae</i>	Adenoviruses	Moderate	Long	Moderate	High	No
<i>Astroviridae</i>	Astroviruses	Moderate	Long	Moderate	High	No
<i>Caliciviridae</i>	Noroviruses, sapoviruses	High	Long	Moderate	High	Potentially
<i>Hepeviridae</i>	Hepatitis E virus	High	Long	Moderate	High	Potentially
<i>Picornaviridae</i>	Enteroviruses, parechoviruses, hepatitis A virus	High	Long	Moderate	High	No
<i>Reoviridae</i>	Rotaviruses	High	Long	Moderate	High	No
Protozoa						
<i>Acanthamoeba</i>	<i>A. culbertsoni</i>	High	May multiply	High	High	No
<i>Cryptosporidium</i>	<i>C. hominis/parvum</i>	High	Long	High	High	Yes
<i>Cyclospora</i>	<i>C. cayetanensis</i>	High	Long	High	High	No
<i>Entamoeba</i>	<i>E. histolytica</i>	High	Moderate	High	High	No
<i>Giardia</i>	<i>G. intestinalis</i>	High	Moderate	High	High	Yes
<i>Naegleria</i>	<i>N. fowleri</i>	High	May multiply	Low	Moderate	No
Helminths						
<i>Dracunculus</i>	<i>D. medinensis</i>	High	Moderate	Moderate	High	No

^a This table contains pathogens for which there is some evidence of health significance related to their occurrence in drinking-water supplies. More information on these and other pathogens is presented in Chapter 11 of the WHO drinking-water guidelines (8).

^b The type species listed (*L. pneumophila*, for example) are those most commonly linked to waterborne transmission, but other species may also cause disease.

^c Health significance relates to the incidence and severity of disease, including association with outbreaks.

^d Detection period for the infective stage in water at 20 °C: short, up to one week; moderate, one week to one month; and long, over one month.

^e Within pathogen species and groups, there are likely to be variations in resistance, which could be further impacted by characteristics of the water supply and operating conditions. Resistance is based on 99% inactivation at 20 °C where, generally, low represents a Ct99 of < 1 min.mg/L, moderate 1-30 min.mg/L and high > 30 min.mg/L (where C = the concentration of free chlorine in mg/L and t = contact time in minutes) under the following conditions: the infective stage is freely suspended in water treated at conventional doses and contact times, and the pH is between 7 and 8. It should be noted that organisms that survive and grow in biofilms, such as *Legionella* and mycobacteria, will be protected from chlorination.

^f From experiments with human volunteers, from epidemiological evidence and from experimental animal studies. "High" means infective doses can be 1-10² organisms or particles, moderate 10²-10⁴ and low > 10⁴.

^g Includes enteropathogenic, enterotoxigenic, enteroinvasive, diffusely adherent and enteroaggregative.

^h *Vibrio cholerae* may persist for long periods in association with copepods and other aquatic organisms.

Source: WHO (8).

Table 3 describes examples of events that can occur at different points in the drinking-water system that can lead to the supply of unsafe water.

The quality of raw water at the source is influenced by numerous factors, including weather events (heavy rainfall, thaw, flooding and drought), topography, geology, agricultural practices, wastewater and other point-source discharges. Surface waters and shallow aquifers are more susceptible to contamination. Contamination of groundwater can also occur at the point of extraction (9).

Water treatment can be a multistage process involving flocculation, filtration and disinfection (4,9). Failure during treatment can occur when the treatment process is overwhelmed by high turbidity during, for instance, heavy rain events and flooding, such that enteric organisms are not effectively removed and/or inactivated and can infiltrate

the treated water and distribution system, or when suboptimal filtration following filter backwashing allows pathogens to pass into the distribution system (4).

Distribution system failures cause outbreaks, primarily of waterborne enteric pathogens. It is likely that they also cause sporadic cases of disease which may or may not be detected by surveillance systems, as will be discussed further in Part B.

Environmental microorganisms, such as facultative pathogens, can grow and form biofilms in the pipes of distribution systems (particularly building water-distribution systems) and on outlets, mixing valves and washers (10,11). Biofilms can harbour pathogens such as *Legionella*, *Pseudomonas aeruginosa*, *Naegleria fowleri* and *Mycobacterium* species (non-tuberculosis). Microorganisms in biofilms are resistant to disinfection. Biofilms are more likely to form extensively when nutrients are

Table 3. Examples of hazardous events at different points of the drinking-water system

Point of contamination	Examples of hazardous events
Source water (surface or groundwater)	<ul style="list-style-type: none"> · Runoff of animal and human waste and sewage into source water during wet weather · Ingress of faecal material in karstic groundwater during wet weather · Leakage of faecal matter from on-site sanitation or damaged sewers
Treatment system	<ul style="list-style-type: none"> · Inundation of filtration beds with contaminated wastewater during flooding · Failures in coagulation and/or filtration processes · Failures in the disinfection or chlorination process
Distribution system	<ul style="list-style-type: none"> · Cracked or eroded pipes or damaged valves facilitating ingress of untreated/contaminated water from the environment, especially during pressure drops · Cross-contamination of drinking-water systems with non-potable systems (such as wastewater, process water and rainwater) · Resuspension of biofilms or sediments due to backflow from building distribution systems into the water-supply distribution systems · Contamination of water due to unhygienic conditions of water containers for carrying water from source to home
Storage system	<ul style="list-style-type: none"> · Faecal contamination of water stored in reservoirs or storage tanks from birds or animals that have entered the storage reservoir or tank · Biofilm growth in the tank
Building distribution systems	<ul style="list-style-type: none"> · Ingress of faecal-contaminated water due to poor plumbing design, such as through cross-connections with sewage systems · Biofilm growth in dead ends of the system and areas of water stagnation
Point-of-use system	<ul style="list-style-type: none"> · Contamination during household storage due to the use of unclean or inadequately covered storage vessels · Insufficient maintenance of home water-treatment devices

present in the source water and in the system, when there is corrosion or scale in the system, when the temperature of the water is warm, and when the flow rates are low or the water is stagnant, such as in dead ends of the system, storage tanks or during intermittent supplies.

Distribution-system contamination happens after treatment; consequently, pathogens introduced at this stage may flow directly to consumers if they are not inactivated by residual chlorine.

Contamination can also occur at the point of use in water systems within buildings, either due to the extension of contamination from the water-supply system into the building system, contamination events within the building water system itself (12), or contamination during household storage. For the purpose of this document, water-supply systems will include the source, treatment, distribution and point-of-use systems.

Delivery of safe water usually requires the presence of control measures, or hygienic barriers (ideally more than one), that effectively prevent or mitigate specific local threats to the water system. Such measures include protection of source waters and water treatment. The WHO guidelines for drinking-water quality (8) recommend WSPs as the most effective means of ensuring consistently the safety of a drinking-water supply. The WSP approach is based on a comprehensive risk-assessment and risk-management approach that encompasses all steps in the water supply, from catchment to consumer. The WSP approach draws on the multiple-barriers principle and focuses on whether operational monitoring of the barriers (control measures) are working effectively.

The public health importance of WRID in the pan-European region

Despite increased access to improved water supplies, WRID continue to pose a threat to public health in the pan-European region.

Although the true burden of disease is unknown, WHO estimates that 14 people daily die due to diarrhoea caused by inadequate water, sanitation and hygiene (13). The epidemiology of WRID in the pan-European region has been described elsewhere (14).

Between 2000 and 2010, 53 countries in the pan-European region reported over 400 000 cases of each of campylobacteriosis, hepatitis A, giardiasis and shigellosis to the Centralized Information System for Infectious Diseases (CISID). Between 2006 and 2013, 30 countries reported over 100 000 cases each for campylobacteriosis, giardiasis and hepatitis to the European Surveillance System (TESSy). CISID does not contain any information on whether water or food was the vehicle of transmission for these reported cases. TESSy only contains aggregated case counts, and the number and percentage of reported cases attributable to water is not known. Consequently, the number of cases that are water-related is not documented within these regional surveillance systems. Furthermore, an estimated 18% of outbreaks in the region that could be water-related and that were investigated during that time-period were associated with water (14). The highest proportion of outbreaks linked to contaminated water were those associated with leptospirosis, cryptosporidiosis, giardiasis and legionellosis. Many of these outbreaks were linked to water-supply systems.

Some of the organisms most frequently reported to European regional surveillance systems, such as *Campylobacter* species and *Giardia*, primarily are transmitted by the faecal-oral route, yet the greatest burden of mortality may be associated with organisms transmitted by other routes. Data from Germany and the United States of America indicate that the greatest burden of mortality is associated with environmental pathogens that grow in water-supply system biofilms, such as *Legionella*, *Pseudomonas* and non-tuberculous mycobacteria. In the United States, of 6939 deaths associated with 13

pathogens that can be transmitted by water, 6301 (91%) were associated with these three organisms (15). In Germany, it is estimated that more than three people die every day from legionellosis (16).

Important factors driving WRID in the region include the emergence and re-emergence of pathogens such as *Cryptosporidium parvum* and *Legionella pneumophila*, and the dissemination of water-related pathogens such as *Giardia lamblia* into new geographic areas due to climate change and international travel (3,17,18). Many communities, especially in rural areas, rely on community drinking-water supplies based on untreated or insufficiently treated groundwater or surface water. These community systems may be vulnerable to environmental contamination from livestock and agricultural practices (17,18). Changes in how water is used in industrial, commercial and domestic settings (in cooling towers, air conditioning and spas, for instance) is increasing the modes and opportunities for transmission of water-related pathogens (17,18). The increasing age of the population and the expanding numbers of people with reduced immunocompetence are heightening the susceptibility of populations to severe sequelae of infection (17,18).

Why strengthened surveillance and outbreak management capacity is needed

It is recognized that current capacity for surveillance and outbreak management in many countries in the pan-European region may be insufficient to control WRID (18). Surveillance practices vary widely across the region. Many countries rely on routine passive surveillance, which is based on the surveillance of a limited number of pathogens and will detect only a fraction of cases (14,18). The number of diseases and events covered by national notifiable-disease surveillance systems also varies widely. Many countries lack both a standard definition of an outbreak and thresholds for the number of cases

required to trigger an outbreak investigation (4,14). Surveillance systems may not contain a mechanism for reporting all water-related conditions (14), and there is variation in sampling and laboratory protocols and reporting practices (18).

Laboratories may routinely test human samples for only a limited range of enteric pathogens. A special request may need to be made to get the laboratory to test for anything beyond this routine range. Clinicians may not specify what to test for when sending samples, and if they do, they may only request testing for a limited number of pathogens. There is less testing of viruses and parasites (such as *Giardia* and *Cryptosporidium*) (19). Given this, cases caused by uncommon pathogens or those beyond the routine range of testing may be under-ascertained by surveillance. Furthermore, some countries have limited laboratory capacity for testing enteric pathogens. Analysis of the national summary reports under the Protocol (2016) (20) indicate that only a limited number of countries reported diseases caused by *Cryptosporidium*, *Giardia*, *Legionella* and/or viruses. These factors will influence the sensitivity of the system and the timeliness of reporting. A more uniform approach to case detection, diagnosis and surveillance practices across the region has been recommended (18).

Many surveillance systems focus on enteric pathogens or syndromes, such as acute gastrointestinal illness (AGI). Frequently, it is not possible to characterize these cases as water-related, as there are insufficient or no data on the source of infection. It can also be difficult to distinguish between cases of foodborne and waterborne disease. Food may be the vehicle of infection for a disease that is in fact water-related; for instance, if food is prepared using contaminated water, it will appear as if the food is the source of infection, while in fact it is the water.

As surveillance practices vary across the region, systematic, accurate and comparable information between countries is lacking, and

the true burden of WRID is unknown (14,18). Insufficient laboratory and epidemiological capacity and human and financial resources may limit country capacity to detect cases and outbreaks (14) and investigate outbreaks. There may be substantive underreporting of cases and underdetection or delayed detection of WRID outbreaks, such that the outbreak only becomes conspicuous when it already has affected many people. WRID can cause explosive outbreaks that affect thousands of people (21,22). This is most notable for waterborne pathogens contaminating public water supplies, where large populations are exposed in a short period of time. Such outbreaks have substantial health, social, economic and political consequences. Delayed detection of cases and outbreaks may result in bigger outbreaks causing greater public health, economic and social consequences than if the outbreak had been detected and control measures implemented earlier.

Communication and coordination between public health agencies and those who are responsible for monitoring water quality frequently is inadequate (18). Many countries have insufficient capacity for early-warning and response and for event-detection (14).

Data on the number of cases and outbreaks of WRID may reflect the ability of a surveillance system to detect these outcomes, rather than the actual number of outbreaks or cases (14). The source of infection in many detected outbreaks is not determined (3). There is less capacity for detecting outbreaks associated with smaller community water supplies and those associated with emerging WRID (18), so the pathogens and burden of disease associated with these sources is not always well known.

Suboptimal capacity for WRID surveillance and outbreak investigation hinders identification of the true burden of disease. Without accurate data on the burden of disease associated with water-supply systems, the need for investment to maintain and sustainably manage these

systems to ensure they do not cause disease and outbreaks, and the need for public health action to control WRID, are likely to be underestimated.

Scope and purpose of the publication

This publication addresses surveillance and outbreak management of WRID associated with drinking-water supply systems, including *Legionella*. The surveillance and management of outbreaks of water-washed, water-based and insect-vector-associated WRIDs are not covered, as the approach to their surveillance and control is different. Similarly, the surveillance and control of noncommunicable water-related diseases, such as chemical exposures and accidents, is beyond the scope of the document.

Most countries of the pan-European region already have systems in place for infectious disease surveillance and outbreak management. This document aims to help countries to build on and strengthen these systems, so the systems can address the particular challenges associated with WRID surveillance and control in drinking-water supply systems.

The document builds on guidelines for infectious disease surveillance and outbreak response (4,23–26). It provides technical information on the specific features, activities and methodologies related to WRID surveillance and outbreak management. This information can be adapted to the local context. It is suggested that the document be used together with the guidelines and with national protocols for disease surveillance and outbreak management.

This document aims to:

1. support countries to strengthen their capacities for WRID surveillance and outbreak management;

2. support countries to meet their requirements under Articles 8 and 13 of the Protocol;
3. support countries with implementation of the International Health Regulations (IHR) and the United Nations Sustainable Development Goals (SDGs); and
4. promote a harmonized approach in the pan-European Region to increase comparability of data between countries and generate more precise regional estimates on the burden of WRID.

In particular, the document provides technical information on:

1. how to develop and implement a surveillance system for WRID (Part A); and
2. how to investigate, respond to and manage outbreaks of WRID (Part B).

Part A targets public health professionals and others involved in WRID surveillance at all levels of the health system, as well as regulators responsible for ensuring the

safety of water-supply systems and the effective surveillance of WRID. Part B targets those involved in the management of WRID outbreaks, particularly public health and environmental health professionals, water providers and risk communicators.

The document is supplemented by a number of annexes:

- Annex 1. Glossary of terms used in the document;
- Annex 2. Resources related to water-supply systems, surveillance and outbreak management;
- Annex 3. Template boil water notice; and
- Annex 4. *Legionella* resources, including a case study for the investigation of an outbreak of Legionnaires' disease.

Illustrative case studies presented in parts A and B feature the imaginary central European country of Laguna. The case studies set out steps taken in Laguna to identify and counter WRID threats.

PART A. SURVEILLANCE OF WATER- RELATED INFECTIOUS DISEASE

This part provides practical information on how to set up, improve and maintain effective systems for the surveillance of WRID. It explains the key principles of surveillance and the different components that could be included in a surveillance system for WRID. It also includes an illustrative surveillance case study presented over six parts, which describes the activities undertaken in Laguna in developing a WRID surveillance system.

Part A is targeted towards public health professionals and others involved in WRID surveillance at all levels of the health system, and to regulators responsible for ensuring the safety of water supply systems and the effective surveillance of WRID.

Summary

WRID continue to cause a substantive burden of disease in the pan-European region. The true burden of WRID is unknown due to suboptimal capacity for WRID surveillance in many countries of the region.

Infectious diseases are classified as water-related based on their transmission route. WRID can be transmitted by ingestion of contaminated water, inhalation or aspiration of aerosols and contact during recreational water use or bathing.

Surveillance is the ongoing systematic collection, analysis and interpretation of health-related data for use in planning, implementing and evaluating public health policies and practices (27). It is important to embed WRID surveillance within existing national surveillance mechanisms, such as including relevant water-related pathogens into notifiable-disease surveillance systems.

Monitoring of health outcomes should be integrated with monitoring of environmental outcomes, such as drinking-water quality and environmental contaminants, for WRID surveillance to be effective. Strong coordination and collaboration between relevant stakeholders, including disease surveillance agencies, water service providers, regulators and environmental agencies, therefore is vital.

WRID surveillance systems usually operate at national, regional and local levels, with each level having different functions and objectives. WRID surveillance can have a number of specific objectives, including to:

- identify temporal trends in the incidence and prevalence of WRID;
- detect possible WRID outbreaks;

- identify new, emerging or re-emerging pathogens transmitted by water;
- estimate the burden of WRID;
- identify groups and communities who are at higher risk of WRID and target control and prevention measures;
- identify areas of the water system to target with resources;
- assess the effectiveness of control measures; and
- inform policies and regulations in relation to water quality and WRID.

The core activities of WRID surveillance are case detection, case-reporting, investigation and confirmation, analysis and interpretation, communication and taking actions such as public health response, policy development, and feedback to stakeholders.

The ability of a surveillance system to detect and investigate cases is influenced by a number of factors, including the clinical presentation of infection, health-care-seeking behaviour, diagnostic practices, laboratory capacity and practices, the types of pathogens under surveillance and availability of data.

A comprehensive WRID surveillance system includes both indicator-based surveillance approaches (such as notifiable disease, laboratory or sentinel surveillance) and event-based surveillance approaches (such as media monitoring), and thereby facilitates early warning of potential outbreaks and events. Different types of surveillance will have different attributes, such as timeliness and sensitivity to detect cases and events, that will make them more or less suitable to meet a range of surveillance objectives.

National public health agencies typically are responsible for developing an overall strategy

for surveillance, designing the surveillance protocol and supporting the local level with developing local procedures and implementing surveillance.

Developing and establishing a WRID surveillance system involves a number of activities, including:

1. engaging and building relationships with key stakeholders and assigning roles and responsibilities;
2. characterizing the public health problem through a comprehensive situation analysis and identifying surveillance priorities;
3. defining the purpose, scope and objectives of the surveillance system;
4. designing the system, including selecting and defining surveillance outcomes, a core surveillance dataset and data flows;
5. developing a methodology for the collection and management of the surveillance system; and
6. monitoring and evaluating the surveillance system periodically.

Essential actions to enable strengthening and sustaining WRID surveillance include establishing a legal framework, clearly defining surveillance procedures for WRID, securing adequate resources, putting in place infrastructure for surveillance (such as laboratory capacity, information technology, communication and data management) and developing capacity-building programmes for surveillance staff at all levels of the system.

The surveillance system can be designed to inform the setting of national and local health-based targets under the requirements of the Protocol.

Drinking-water supply systems are subject to routine verification (compliance) monitoring for faecal-indicator bacteria such as *E. coli* and enterococci and other indicators of contamination. Breaches of drinking-water quality standards and water contamination events should be notified to health authorities. As part of event-based surveillance, it is important to create procedures for reporting such events to the responsible health department to further investigate whether it is correlated with an increase in human cases of gastrointestinal illness or another health-related outcome under surveillance.

Spatial analyses and time-series analyses are particularly useful in the analysis of WRID surveillance data. Surveillance data can be used to estimate the societal and economic burden of WRID, which in turn can be used to identify priorities and advocate for resources for developing and maintaining water systems, and to inform the development of policies for WRID control.

In special situations, such as during flooding or natural disasters, it may be necessary to enhance a WRID surveillance system by, for instance, increasing the frequency of routine indicator-based reporting or enhancing the monitoring of social media or rumours.

Overview of WRID surveillance

Surveillance is the ongoing systematic collection, analysis and interpretation of health-related data for use in planning, implementing and evaluating public health policies and practices (27).

An important feature of WRID surveillance is that it integrates monitoring of health outcomes with monitoring of environmental outcomes, such as drinking-water quality and environmental contaminants.

Ideally, it involves strong coordination and cooperation between, among others, disease surveillance agencies (sometimes known as public health agencies), drinking-water service providers, regulators and environmental agencies. This is critical to ensure the timely mutual sharing of data on water-supply system incidents and possible water-related outbreaks.

Ideally, systems for WRID surveillance will be embedded within existing surveillance structures, either by building on existing surveillance systems or by expanding them to include WRID. Surveillance-system strengthening activities could, for instance, focus on updating the list of notifiable diseases and indicators under surveillance to reflect the water-related priority pathogens specific to the country, as well as enhancing capacity for detecting and reporting WRID.

WRID surveillance can have a number of objectives, including to:

1. identify temporal trends in the incidence and prevalence of WRID;
2. detect possible WRID outbreaks;
3. identify new, emerging or re-emerging pathogens transmitted by water;
4. estimate the burden of WRID;
5. identify groups and communities who are at higher risk of WRID;
6. target control and prevention measures to specific areas or populations;
7. identify priority needs towards improving drinking-water supply systems;
8. assess the effectiveness of existing control measures; and
9. inform policies and regulations in relation to water quality and WRID.

WRID surveillance systems operate usually at national, regional and local levels, with each of these levels having different functions and objectives. Surveillance at local or regional level may primarily be concerned with outbreak detection, identifying high-risk groups or communities, targeting control measures and resources, evaluating control measures and informing local policy. Surveillance at national level may primarily be concerned with monitoring trends, identifying new, emerging or re-emerging pathogens or pathogens being transmitted in water, estimating disease burden, targeting resources, and informing national priorities, policy and regulations.

The national level may support the local level in surveillance-system strengthening activities, including the development of local surveillance systems, as part of an overall national strategy for surveillance.

Building blocks and types of surveillance

Disease surveillance includes a number of core activities (25), as shown in Fig. 2.

A comprehensive surveillance system for WRID will include both indicator-based and event-based surveillance (Fig. 3) (28) and will incorporate an early-warning function,

Fig. 2. Disease surveillance core activities

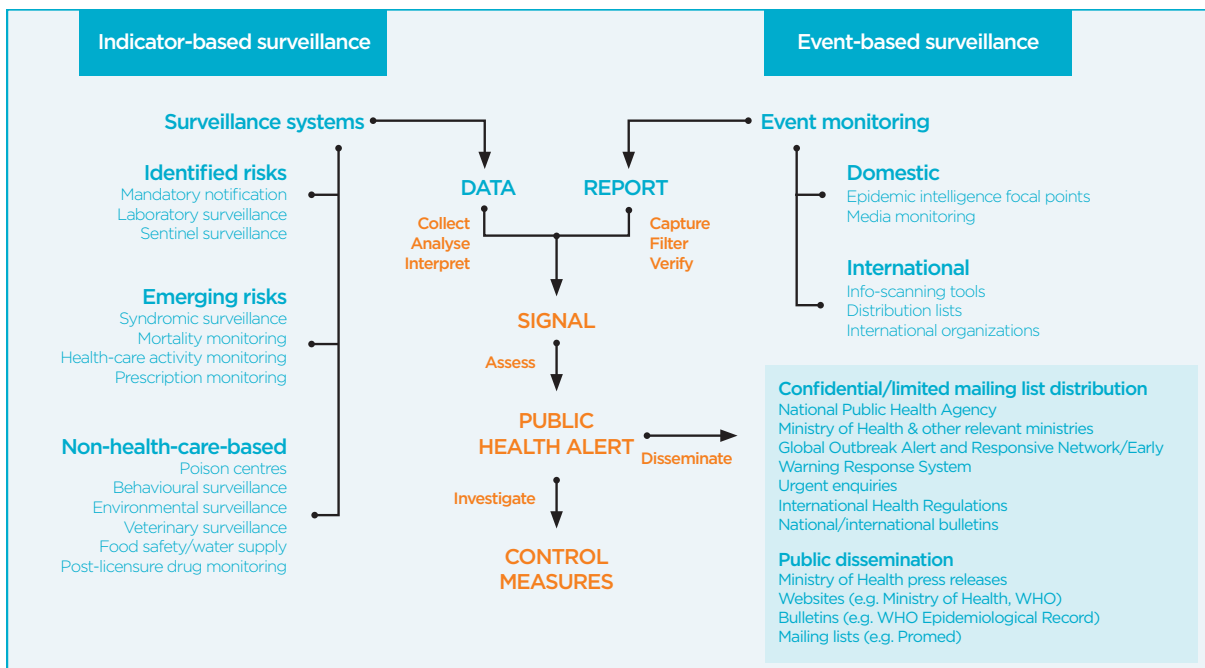


Source: Centers for Disease Control and Prevention (25).

in accordance with the requirements of the IHR (29) and emergence and reemergence of international disease threats and other health risks, the Fifty-eighth World Health Assembly in 2005 adopted the revised IHR. Fig. 3 details the different types of surveillance that can be used to detect outbreaks as part of an overall epidemic intelligence framework. Indicator-based surveillance is the reporting of structured standardized data, such as data on laboratory-confirmed infections or the number of cases meeting a syndromic case definition in a week collected through routine surveillance systems. It can also include surveillance of environmental indicators. Event-based surveillance is the collection of unstructured data from any source, such as media reports of problems with a water supply, or a health facility reporting a surge in the number of people presenting at the emergency department, or customer complaints to a water company.

Examples of types of indicator- and event-based surveillance for WRID and their relation to specific surveillance objectives are outlined in Table 4.

Fig. 3. The epidemic intelligence framework through which outbreaks usually are detected



Source: adapted from Kaiser et al. (30) (reproduced with permission from Eurosurveillance).

Table 4. Types of indicator- and event-based surveillance and their relevance to WRID surveillance

Type	Description	Source of data	WRID surveillance objectives addressed by the surveillance type	Examples of WRID surveillance indicators	Attributes/characteristics
Indicator-based surveillance					
Notifiable-disease surveillance	Legally mandated urgent reporting of serious diseases	All health facilities and diagnostic laboratories	<ul style="list-style-type: none"> Monitor WRID temporal trends Detect outbreaks Estimate WRID burden Identify and target high-risk groups and areas Implement and evaluate control measures 	<ul style="list-style-type: none"> <i>E. Coli</i> O157 H7 Legionnaires' disease Infectious bloody diarrhoea Hepatitis A <i>Campylobacter</i> species Cryptosporidiosis Giardiasis Shigellosis 	<ul style="list-style-type: none"> Highly specific (low degree of misclassification of cases) High positive predictive value Low sensitivity to detect unconfirmed cases and outbreaks, as only medically attended cases captured and the reporting cycle may preclude early detection of events No data on source of infection
Syndromic surveillance	Reporting of cases that comply with a syndromic case definition	Health facilities	<ul style="list-style-type: none"> Monitor WRID temporal trends Detect outbreaks Estimate WRID burden Identify and target high-risk groups and areas Implement and evaluate control measures 	<ul style="list-style-type: none"> Consultations for AGI or diarrhoea 	<ul style="list-style-type: none"> More sensitive and timelier than notifiable disease and laboratory surveillance due to syndromic case definition and because there is no waiting for laboratory results Less specific than notifiable and laboratory surveillance with lower positive predictive value due to syndromic case definition No data on source of infection
Laboratory surveillance	Reporting of isolation of specific organisms, number of requested tests	Laboratories	<ul style="list-style-type: none"> Monitor WRID temporal trends Detect outbreaks Identify new, emerging and re-emerging pathogens Identify what pathogens are transmitted by water 	<ul style="list-style-type: none"> <i>E. coli</i> (non-O157 H7 species) <i>Legionella pneumophila</i> Hepatitis A <i>Campylobacter</i> species Cryptosporidiosis Giardiasis Shigellosis Total submitted stool specimens 	<ul style="list-style-type: none"> Highly specific (low degree of misclassification of cases) High positive predictive value Low sensitivity to detect cases and outbreaks as only medically attended tested cases captured and the reporting cycle may preclude early detection of events No data on source of infection

Table 4 contd

Type	Description	Source of data	WRID surveillance objectives addressed by the surveillance type	Examples of WRID surveillance indicators	Attributes/characteristics
Sentinel surveillance	Surveillance from a selection of sentinel sites chosen to represent high-risk areas or high-risk groups More detailed collection of data, with or without sampling and laboratory testing of cases according to a defined sampling frame	Health facilities	<ul style="list-style-type: none"> - Detect outbreaks - Estimate WRID burden 	<ul style="list-style-type: none"> - AGI - Enteric pathogens - <i>Legionella pneumophila</i> 	<ul style="list-style-type: none"> - Timelier and more sensitive than notifiable disease and laboratory surveillance due to weekly reporting cycle and syndromic definition - Enables collection of higher-quality data on risk factors - More resource-intensive and higher workload due to extra data collection and sampling and stricter procedures - Not always representative of general population as only select health-care facilities participate
Environmental monitoring ^a	Legally mandated monitoring of key environmental indicators at set time intervals	Public health and environment agencies, water providers, municipal authorities	<ul style="list-style-type: none"> - Assess water quality - Identify hazards and assess risks in water-supply system - Identify contamination sources - Detect water-quality incidents - Identify high-risk areas and communities, - Target control measures and resources - Assess effectiveness of control measures 	<ul style="list-style-type: none"> - Drinking-water quality indicators (<i>E. coli</i> and <i>Legionella</i> monitoring, <i>P. aeruginosa</i> in health-care facility water supplies) 	<ul style="list-style-type: none"> - Early warning of contamination events - Low sensitivity, as the time of sampling may not correspond to the time of contamination events
Outbreak surveillance (for burden of disease estimation) ^a	Surveillance of outbreaks of WRID (confirmed outbreaks linked to water)	Public health agencies	<ul style="list-style-type: none"> - Estimate WRID burden - Monitor WRID temporal trends - Identify main causes and factors contributing to outbreaks 	<ul style="list-style-type: none"> - Number of outbreaks - Number of cases - Causative agents - Source of the outbreak - Contributing factors - Location 	<ul style="list-style-type: none"> - Useful in monitoring burden of WRID outbreaks - Not timely as outbreaks are reported after they are demonstrated to be water-related (at end of investigation) and often only quarterly or annual reporting - Low sensitivity since many outbreaks are not detected and many are not linked to water - Not representative (larger outbreaks more likely to be detected and reported)

Table 4 contd

Type	Description	Source of data	WRID surveillance objectives addressed by the surveillance type	Examples of WRID surveillance indicators	Attributes/characteristics
Other	<p>Surveillance of prescriptions or over-the-counter sales of drugs</p> <p>School absenteeism</p> <p>Calls to medical helplines</p>	<p>Insurances, pharmacies, schools, medical helplines</p>	<p>Detect outbreaks</p> <p>Monitor WRID temporal trends</p>	<ul style="list-style-type: none"> Types of prescribed anti-diarrhoeal medicines Health insurance claims 	<ul style="list-style-type: none"> Timely and sensitive for outbreak detection Early warning, prompts further investigation Less specific (prone to misclassification) Data influenced by external factors (such as promotions on anti-diarrhoeal medications, public awareness/perceptions of risk)
Event-based surveillance					
Outbreak surveillance ^a /direct notifications of clusters of disease and suspected outbreaks (for the purpose of early warning and outbreak detection)	<p>The public, clinicians, public health personnel may report clusters of cases, suspected outbreaks or unusual events such as mass absenteeism from schools or workplaces</p>	<p>Health facilities, the public</p>	<p>Detect outbreaks</p> <p>detection</p>	<p>Clusters of cases or suspected outbreaks</p>	<ul style="list-style-type: none"> Timely Can trigger rapid risk assessment of event and/or epidemiological investigation Low sensitivity (smaller outbreaks with milder illness less likely to be reported)
Direct notification of events related to the water system	<p>Water providers, municipal authorities or the public may report unusual events</p>	<p>Water providers, municipal authorities</p>	<p>Detect outbreaks and early warning of events that may pose a health risk to the public</p>	<p>Water contamination events</p>	<ul style="list-style-type: none"> Timely Can prompt environmental investigation of water supply Low positive predictive value
Media monitoring	<p>Surveillance of media reports of clusters of illness</p>	<p>Internet, radio, TV, newspapers, social media reports</p>	<p>Detect outbreaks</p>	<ul style="list-style-type: none"> Reports of problems with the water supply Clusters of cases 	<ul style="list-style-type: none"> Timely and sensitive for event detection Low specificity/low positive predictive value – many false positive reports Noisy data difficult to interpret

Table 4 contd

Type	Description	Source of data	WRID surveillance objectives addressed by the surveillance type	Examples of WRID surveillance indicators	Attributes/characteristics
Other					
Seroprevalence studies	Population-based surveys, convenience sampling of readily available samples (blood samples)	Public health agencies, laboratories, research institutes	Estimate burden of WRID	Secondary testing of blood samples collected from pregnant women	<ul style="list-style-type: none"> - Specific, as testing focuses on antigens to specific organisms - Convenient (if using readily available specimens) - Not timely - No data on source of infection - Usually representative of population subgroups rather than the general population
Environmental surveys	Ad hoc environmental surveys of readily available samples	Environmental agencies, research institutes	<ul style="list-style-type: none"> - Detect outbreaks - Assess environmental risks - Identify new, emerging and re-emerging pathogens - Identify what pathogens are transmitted by water - Estimate WRID burden 	Wastewater specimens	<ul style="list-style-type: none"> - Specific, as testing focuses on specific pathogens - Can be representative of general population - Not timely - Labour-intensive and costly

^a May be classified as either or both event-based or indicator-based, depending on the surveillance objective.

In reality, there can be some overlap between indicator- and event-based surveillance. How a particular type of surveillance is classified will depend on the associated objectives and so may vary from country to country. For instance, outbreak surveillance may be classified as both event- and indicator-based depending on the associated objectives of the system. If the outbreak surveillance system is oriented towards the receipt of reports of clusters of cases or suspected outbreaks for the purpose of outbreak detection, then it may be classified as event-based surveillance. If the objective of a WRID outbreak surveillance system is the collection of data on the number, size and location of WRID outbreaks and the associated causative agents, with a view to estimating the burden of disease and high-risk areas that are prone to outbreaks, then this would be classified as indicator-based surveillance.

Similarly, environmental monitoring may be classified as either indicator-based or event-based, depending on how this type of surveillance is organized in a particular country. Environmental monitoring primarily is conducted for the purposes of ensuring the provision of safe drinking-water. The detection of faecal indicators in the water supply, however, generally is notifiable to public health authorities and may prompt an investigation of a potential water incident by the public health authority and, if indicated, the implementation of control measures to protect public health. Following notification of the detection of faecal indicators in the water supply, the public health authority may request further water-quality data, such as data on turbidity from the water provider, to investigate a potential water incident.

A valuable addition to indicator- and event-based surveillance systems is ad hoc studies to estimate population-based exposure to WRID, or environmental surveys to characterize the organisms circulating in the environment. Population-based surveys (such as seroprevalence surveys) may be used to assess exposure to specific pathogens, such as *Campylobacter* or *Cryptosporidium*. This will

provide information on the burden of disease associated with these organisms, but not on the source of infection and whether the infections are water-related or not. Environmental surveys of wastewater have been used to identify enteric organisms circulating in urban populations and can be useful in outbreak detection (31,32).

In addition to the ad hoc studies listed above, public health agencies may choose to use surveillance data, such as case-based notifiable, laboratory or sentinel surveillance data, to undertake case-control studies. Such studies can be used to identify risk factors for infection, including water as a risk factor, and to estimate the burden of disease caused by a specific pathogen that is attributable to water.

Attributes of different types of surveillance

Surveillance types have different attributes, such as completeness, timeliness, usefulness, sensitivity, positive predictive value, specificity, representativeness, simplicity, flexibility, acceptability and stability. These attributes are described in further detail in the next chapter. It is important to consider the attributes of the different types of surveillance when deciding what types to include in a WRID surveillance system (as discussed in the next section) and when evaluating the system once it is established (as discussed in the next chapter).

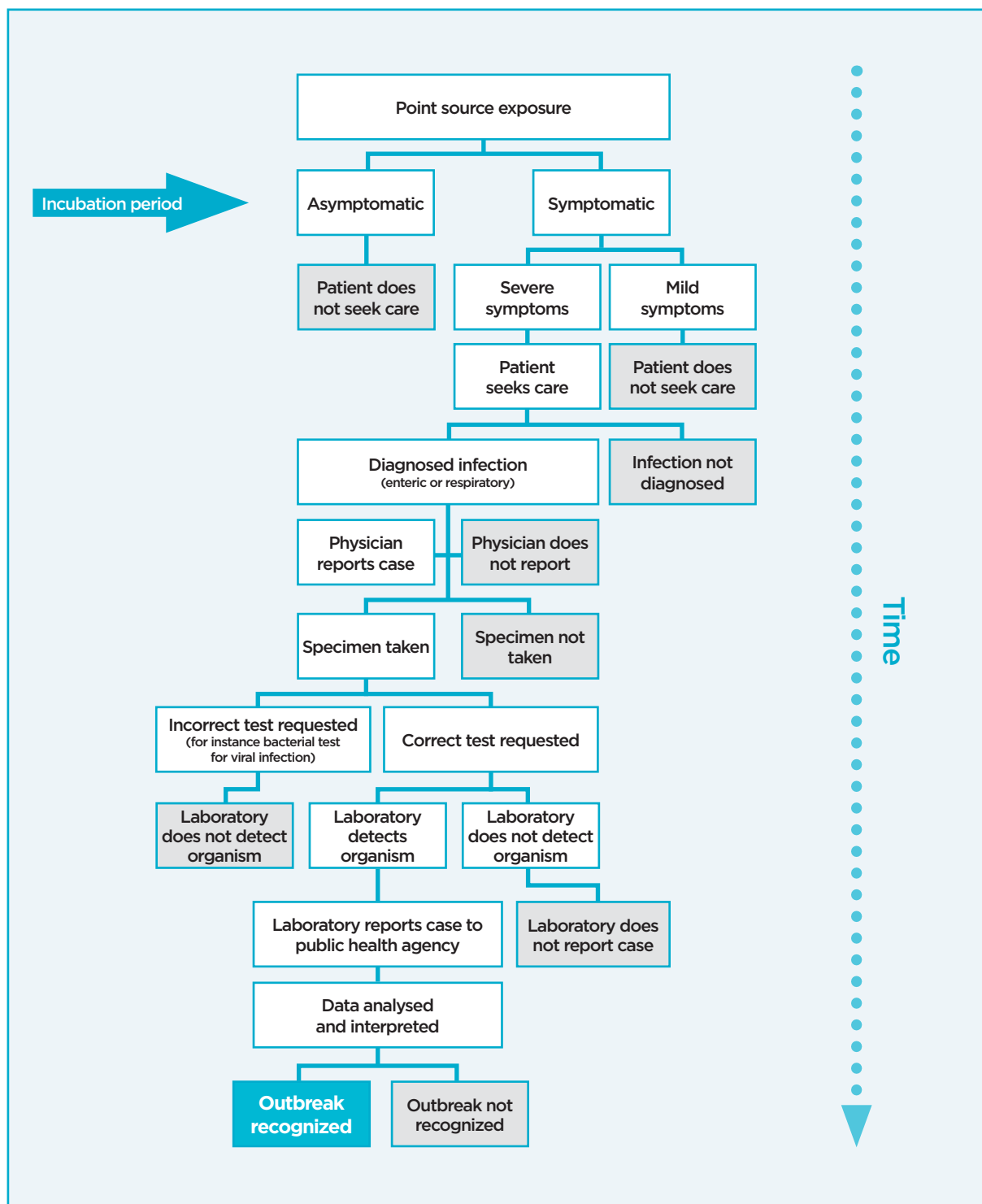
An overview of the attributes of different types of surveillance is presented in Table 4. Clinical and laboratory surveillance, for example, are highly specific for the detection of cases of WRID and so have a high positive predictive value for outbreak detection. These systems may have low sensitivity for the detection of WRID cases, however, and may not be representative of the general population, as only the limited number of pathogens that are included in the systems will be monitored and only medically attended cases are captured. The number of pathogens included in the systems are

often fixed. Consequently, these systems are relatively inflexible, as legislative change may be required to include new and emerging pathogens. There may also be considerable delay between the time of exposure and the time when public health authorities detect the case and identify whether an outbreak is occurring (Fig. 4). The source of infection

for these cases usually is not documented, so they cannot definitively be linked to water.

Undertaking this type of surveillance requires the engagement of clinical and laboratory staff. Participating in surveillance will inevitably increase their workload and may therefore not be very acceptable to staff, especially if they

Fig. 4. Patient pathway and timeliness and sensitivity of case ascertainment by surveillance systems based on clinical and laboratory diagnoses



cannot see how the data are used to prevent disease. Other types of surveillance will have similar attributes (Table 4).

Timeliness and sensitivity of surveillance

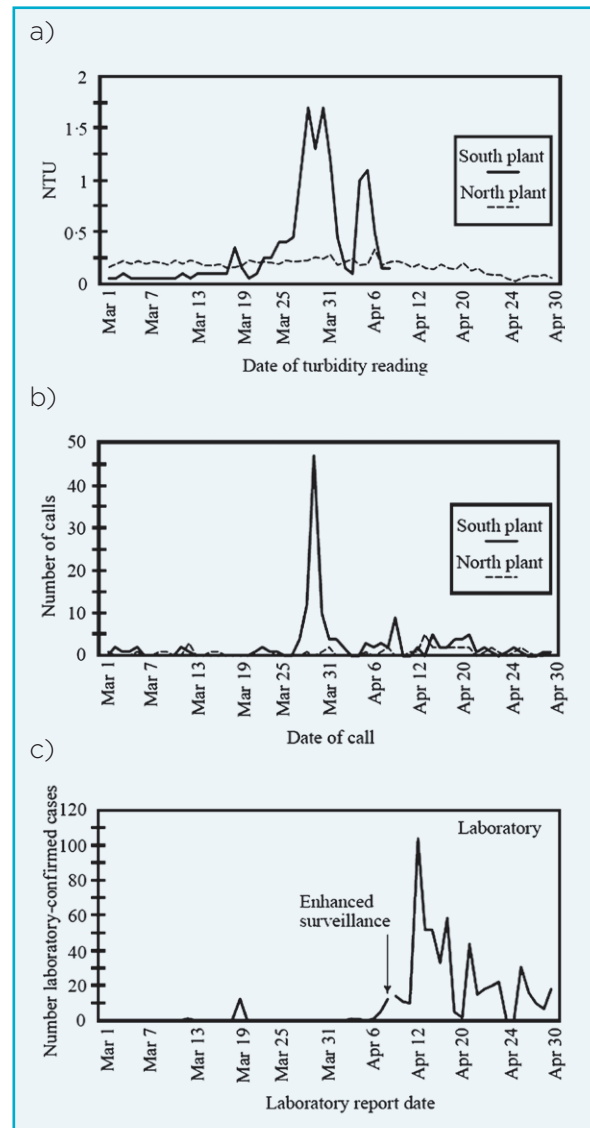
An exposure event like contamination of a water supply may manifest as a peak (signal) in associated outcomes (such as customer complaints) a day or two following the event. There may be a further delay in the detection of the signal by the indicator-based surveillance system. In a massive outbreak of *Cryptosporidium* in the United States, for instance, contamination of the water supply was reflected by a peak in complaints to the water company one day after the event, and this peak in complaints was detected by the customer-complaint surveillance system one day later (33). Conversely, a peak in laboratory notifications for *Cryptosporidium* was observed 15 days after the event, suggesting that in this instance, laboratory surveillance had limited utility for early outbreak detection (Fig. 5a–c). If the objective of the surveillance system is outbreak detection, then the timeliness of capture of surveillance data by the surveillance system can be as important as the timeliness of the occurrence of the signal in the surveillance data.

The ability of a surveillance system to detect cases is influenced by a number of factors (Fig. 2), including the clinical presentation of infection, health-care-seeking behaviour, diagnostic practices, health financing, laboratory capacity and practices, and the types of pathogens under surveillance. Sensitivity is particularly influenced by the fact that generally (34):

- not all cases are symptomatic;
- only a fraction of symptomatic cases seek care;
- stool samples are requested in only a fraction of those who seek care;
- samples are tested for a limited number of pathogens, so the sample may not be tested for the correct pathogen;

- laboratory tests are not 100% sensitive, so even if the pathogen is present, it may not be detected by the laboratory; and
- not all isolated pathogens are notifiable.

Fig. 5. Timeliness of outbreak detection using surveillance of: a) water-quality turbidity counts; b) customer complaints to the water provider; and c) laboratory reports of *Cryptosporidium*, Milwaukee, United States, 1993



Source: Proctor et al. (33) (reproduced with permission from Cambridge University Press).

The degree of laboratory testing may also be influenced by whether there is an associated cost to either the patient or the health facility. The type of tests conducted may be influenced by the practices of the individual laboratory (19). Generally, there is less testing of viruses and parasites than bacteria, and there is limited subtyping of specimens (19).

As an example of the impact of misdiagnosis on the detection and impact of an outbreak, the detection of an outbreak of legionellosis in Germany in 2013 (35) was delayed because the first cases of severe pneumonia were misdiagnosed by medical practitioners as a summer respiratory illness. *Legionella* was not included in the differential diagnosis. Had these cases been diagnosed correctly, the outbreak would have been detected earlier; the investigators estimated that 38 cases of *Legionella* could have been prevented.

How to decide what types of surveillance to include in a WRID surveillance system

When deciding what types of surveillance to include in a WRID surveillance system, national public health agencies will usually need to consider two factors:

- the objectives of the surveillance system; and
- the feasibility of conducting a particular type of surveillance.

The ability of a specific type of surveillance (such as sentinel or laboratory) to address a particular surveillance objective will depend on the attributes of the type of surveillance (such as its timeliness and sensitivity (as discussed in the section above on “Timeliness and sensitivity of surveillance”), completeness, representativeness and specificity (Table 4). Surveillance attributes are discussed further in the next chapter. Some types of surveillance, such as syndromic or event-based, will facilitate the earlier detection of outbreaks than other types, like notifiable-disease or laboratory surveillance, which usually have longer reporting cycles. Consequently, if one of the main objectives of the surveillance system is outbreak detection, national public health agencies may favour the inclusion of one or both of syndromic or event-based surveillance, as they will support the timely detection of outbreaks and will provide an early-warning function. If an objective

of the surveillance data is to monitor the seasonality and burden of WRID, the national public health agency (NPHA) may include laboratory and outbreak surveillance, as these types will provide highly specific data on both the temporal trends and burden of pathogens that may be water-related and water-related outbreaks. The attributes of the different types of surveillance, and the objectives that can be addressed by them, are detailed in Table 4.

Practical factors such as the availability of data, capacities (including laboratory or human resources) and cost will also influence what types of surveillance can feasibly be included. The ability and willingness of health workers to conduct different types of surveillance is an important consideration. For instance:

- notifiable-disease surveillance will only provide meaningful data if there is strong clinical diagnostic capacity and if diagnostic data can easily be captured by the system;
- effective syndromic surveillance will depend on the ability and willingness of health workers to use syndromic case definitions or on the use of automated data extraction from electronic medical records;
- laboratory surveillance will require minimum laboratory diagnostic capacity for water-related pathogens at national and subnational levels;
- sentinel surveillance will usually require the commitment of sentinel surveillance staff to undertake the extra work of sampling cases in accordance with a defined sampling strategy and collecting and reporting more detailed information on cases; and
- the use of prescription data, school absenteeism data or calls to medical helplines usually is only feasible if these data already are captured by an electronic database that can be shared with the NPHA.

When deciding what types of surveillance to include in a system, it is usually advisable to consider what types of surveillance are already conducted and what data are readily

available, as it usually is more feasible and cost-effective to build on existing systems than develop something from scratch.

How to set up, improve and maintain national systems for surveillance of WRID

This chapter provides practical information for building, improving and maintaining national surveillance and early-warning systems. It supports countries in implementing the core requirements of the Protocol and the IHR.

The chapter is informed by the following sources:

- WHO's technical guidance on water-related disease surveillance (4);
- WHO's manual on strengthening surveillance of, and response to, foodborne diseases (24);
- the WHO report on setting priorities in communicable disease surveillance (36);
- the *Field epidemiology manual: surveillance principles* of the European Centre for Disease Prevention and Control (ECDC)/European Programme for Intervention Epidemiology Training (37); and
- the third edition of the principles of epidemiology in public health practice from the Centers for Disease Control and Prevention (CDC) (25).

Ideally, the NPHA will:

- appoint a public health specialist (such as an epidemiologist) to lead surveillance-system strengthening activities;
- develop an overall strategy for surveillance and support activity at local level by developing local procedures and helping with implementation of surveillance;
- develop a short surveillance protocol to document the rationale, design and methodology for the system, especially if a new surveillance system is being

developed or if substantial changes to an existing system are required; and

- assemble an expert group or steering committee to guide the development of the system.

Developing and setting up a WRID surveillance system can involve a number of activities, as shown in Fig. 6.

Fig. 6. Activities for developing and establishing a WRID surveillance system



Activity 1. Engage key stakeholders and identify their roles

Engaging with and building relationships with key stakeholders, such as decision-makers and technical experts from organizations that will participate in surveillance, enables them to contribute their expertise and participate in the process of designing and implementing the surveillance system. Ideally, they should be engaged as early as possible by forming an advisory group to oversee and guide the development of the system. Additional stakeholders may be identified as the system evolves.

Ideally, those who will actively be involved in running the WRID surveillance system, including those who will provide data and will be tasked with responding based on the results of surveillance, will be engaged. Stakeholders may be engaged at national and local levels. A national advisory group may advise on the overall design and development of the system and can support identification of national priorities for WRID surveillance. At local level, those who will be tasked with operationalizing the system may form a local group.

Possible stakeholders to engage include, at national level:

- health ministry/NPHA;
- epidemiologists;
- water regulators;
- environment agencies;
- environmental health specialists;
- laboratory specialists;
- legal and data-protection experts;
- information technology specialists;
- media monitoring specialists/event-based surveillance specialists; and
- data managers.

At local level, potential stakeholders include:

- local public health specialists
- local epidemiologists
- local water providers

- representatives from local health facilities
- representatives from local laboratories
- local environmental health specialists.

Activity 2. Characterize the public health problem through a situation analysis and agree priorities for surveillance

It is helpful to undertake a situation analysis to describe the epidemiological situation for WRID in the country and current capacity for surveillance at national and local levels. Priorities for surveillance can be identified and agreed by the WRID surveillance advisory group based on the results of the situation analysis.

Situation analysis may include:

- the water-related pathogens of interest that are circulating in the country, including data on burden of disease and number of overall and water-related cases, prevalence and incidence during a defined time period (the past five or 10 years, for instance) and any trends in these data, overall and for each pathogen (these data may be obtained from a number of sources, including existing surveillance systems, laboratory records, outbreak investigation reports, published and unpublished research studies, and data from environmental surveys of wastewater and/or freshwater bodies);
- diseases caused by the pathogens, including their severity, long-term sequelae, fatality rate, incubation periods, modes of transmission and infectiousness;
- the propensity of each pathogen to cause outbreaks;
- the economic cost to the country associated with the pathogens;
- high-risk groups or high-risk areas for infection and disease;
- whether there is any public or political concern related to the pathogens;
- likely sources of the pathogens, including environmental and zoonotic reservoirs;

Surveillance case study: activity 1

Laguna

Laguna has a population of 10 million people and is located in central Europe. It is a mountainous country with many rivers and lakes. Sixty per cent of the population lives in urban centres, including 3 million people residing in the capital city.

Engage key stakeholders

To meet the requirements of the Protocol, the NPHA of Laguna is tasked with strengthening national capacity for WRID surveillance.

Stakeholders and their roles

The NPHA includes a Department of Disease Surveillance and Control, which is responsible for the surveillance and control of communicable diseases in Laguna. The department includes a team with primary responsibility for the surveillance and control of food and waterborne diseases. Clinical specimens are tested at laboratories attached to health facilities at district, regional or national levels, or sometimes private laboratories, depending on the facility and the type of test requested.

The Environmental Protection Agency (EPA) has overall responsibility for monitoring drinking-water and acts as the drinking-water regulator. Public water supplies in Laguna are provided by municipal authorities that undertake testing for drinking-water quality indicators. Drinking-water samples are tested at national and regional branches of the EPA laboratory service.

The head of the food and waterborne disease (FWD) team of the NPHA (the national lead for WRID surveillance) convenes a multidisciplinary national advisory group to steer the development of the WRID surveillance system in Laguna. The membership of the advisory group and their roles and responsibilities are detailed in Table CS1. The group includes representatives from the subnational branch offices of the NPHA who are responsible for implementing surveillance and forming local groups of relevant stakeholders at subnational level.

Table CS1. Membership of the Laguna advisory group and their roles and responsibilities

Person	Role/responsibility in surveillance system development and implementation
Head of the FWD team	Overall coordination and national focal point for surveillance
Principal epidemiologist from the FWD team	Protocol development, design of the system, development of data-analysis plan, data analysis and reporting
Statistician from the FWD team	Development of data-analysis plan, data analysis
Data manager from the FWD team	Database development and management
Head of event-based surveillance at the NPHA	Leads on expansion of existing event-based surveillance system to include WRID, management of WRID component of event-based surveillance and reporting of water-related events to the national focal point
Representatives from subnational level of the NPHA	Engagement with subnational level, implementation at subnational level
National programme manager for drinking-water quality of the EPA	Advises on how to use water-quality surveillance data and other useful data in surveillance and establishment of links between two systems
Representative from the National Reference Laboratory for Infectious Diseases	Advises on laboratory aspects of surveillance, leads on laboratory capacity-development for surveillance, engagement of local laboratories in surveillance
Representative from drinking-water service providers	Engagement of drinking-water service providers in the sharing of data and water-quality events
Specialist in environmental health	Advises on environmental monitoring for surveillance
Specialist in enteric and waterborne infections	Advises on clinical considerations, engages clinicians at national and subnational levels
Specialist in Legionnaires' disease	Advises on requirements for surveillance of Legionnaires' disease, including environmental sampling

Surveillance case study: activity 2

Background

All urban centres and some surrounding rural areas in Laguna are served by local public water supplies extracted from either surface or groundwater sources. The infrastructure of many public water supplies is ageing and is vulnerable to contamination. The water supply of the capital city is sourced from a large lake that borders two neighbouring countries. An estimated 2 million rural residents are served by either community water supplies or private wells, sourced from groundwater. There are 200 registered industrial cooling towers in Laguna, associated with power plants, food processing and other industrial processes. Most of these are located in and around the capital city.

Existing surveillance infrastructure

Health facilities are required to notify cases of typhoid fever and infectious bloody diarrhoea under the national notifiable-disease surveillance system. Public health laboratories are required under the same system to notify laboratory-confirmed cases of campylobacteriosis, hepatitis A and E, *Salmonella enterica* serovars Typhi and Paratyphi, shigellosis and *Vibrio cholerae*.

The source of infection for these cases is rarely determined unless it is investigated as part of an outbreak investigation, so the burden of WRID is greatly underestimated and there is inadequate capacity for outbreak detection.

Outbreak detection and reporting

Outbreaks usually are detected by district offices of the NPHA, primarily due to reports of clusters of cases by health facilities, and occasionally by direct reports from the public. Outbreaks of AGI associated with public and private water supplies occasionally are reported. In the past five years, several outbreaks of *Cryptosporidium* and *Giardia* have occurred, including a number of outbreaks associated with public water supplies. A cluster of five cases of community-acquired pneumonia was also reported in the previous year. This cluster, subsequently confirmed as Legionnaires' disease, occurred in a suburb of the capital city. The suspected source was an industrial cooling tower, although the source was not definitively identified.

Problem statement

Laguna has inadequate capacity for the surveillance of WRID. New pathogens that are not covered by the existing surveillance system are emerging. The country is vulnerable to outbreaks of WRID due to ageing infrastructure of drinking-water supply systems and inadequate capacity for the timely detection and response to WRID outbreaks.

Recommendations for improvement

Capacity for the surveillance and management of outbreaks of WRID needs to be strengthened. Surveillance needs to be expanded to include emerging pathogens and syndromic and event-based surveillance for the early detection of outbreaks.

Based on the situation analysis, and having gone through a formal process for identifying surveillance priorities, the NPHA identifies the following outcomes for addition to the existing surveillance system:

- *Cryptosporidium* species
- enteropathogenic *E. coli*
- *Giardia* species
- *Legionella* species
- AGI
- outbreaks of WRID.

The NPHA would also like to strengthen event-based surveillance for outbreaks of WRID by ensuring capacity for the receipt of spontaneous reports of clusters of disease, suspected outbreaks and unusual public health events, and by monitoring exceedances of water-quality standards and public complaints relating to the water supply.

- limitations of the available data, especially gaps;
- current sources of data and potential new sources, and existing surveillance capacity at national, regional and local levels;
- main actors and stakeholders and their roles in the surveillance and control of the organisms; and
- international requirements for surveillance.

Ideally, the following should be identified at local level:

- a comprehensive description of the local water-supply system, including the main sources and providers of drinking-water, their geographical distribution and the population served;
- any available data on water quality and the state of the drinking-water supply system (from the WSP, for instance, if one is available for the system), with a particular emphasis on infrastructural weaknesses and including systematic analysis of possible hazardous events that may introduce pathogens into the system or which may fail to remove them;
- an overview of potential sources of *Legionella* (such as the number and geographical distribution of industrial cooling towers); and
- local vulnerable populations and settings.

In identifying surveillance priorities, a number of factors could be considered when deciding where to focus surveillance-system activities. Surveillance systems may be enhanced at certain times of the year to reflect the seasonality of WRID and/or in areas where WRIDs are endemic or where outbreaks are known to occur. This may include:

- areas where the drinking-water is abstracted from surface waters or other vulnerable water sources;
- areas where livestock are farmed in close proximity to the water supply;
- areas subject to droughts, where intermittent supply and/or drops in pressure may allow intrusion of organic

and other contaminated material into the water distribution system;

- areas prone to flooding that could disrupt water-supply systems and contaminate drinking-water;
- areas served by small-scale community water supplies; and
- industrial areas.

Collating and summarizing data on the situation in a country will help to identify the priority surveillance outcomes (pathogens, notifiable diseases and syndromes) the country needs to monitor. It has been recommended that criteria for prioritizing which water-related diseases to include in surveillance should be defined (24). Factors to consider include (25):

- the public health importance of the problem and of individual pathogens;
- the degree to which it is possible to prevent, control and treat the problem; and
- the resources that will be required to undertake surveillance of a particular pathogen, and whether there is capacity to undertake surveillance and control the problem.

A formal process for prioritizing diseases for surveillance can be conducted, involving either strategy grids or Delphi panels (24). Priorities for surveillance can then be translated into surveillance options. Guidance on the prioritization process, including the use of strategy grids and Delphi panels, is given in the WHO practical manual for strengthening surveillance of foodborne diseases (24)

Activity 3. Define the overall purpose, scope and objectives of the WRID surveillance system

The overall purpose and scope of the surveillance system and the surveillance objectives can be defined based on the situational analysis and results of the prioritization exercise.

The purpose is the high-level reason for undertaking WRID surveillance. The scope

Surveillance case study: activity 3

Based on the results of the situational analysis of WRID in Laguna, the advisory group agrees the following. The purpose of surveillance is to collect and analyse public health and environmental data to inform actions to reduce and control WRID. The scope of the WRID surveillance system will include:

- type of disease: waterborne diseases associated with drinking-water contamination and *Legionella*;
- geographic coverage: the entire country;
- population coverage: the entire population; and
- monitoring: all year round.

The objectives are to:

- strengthen capacity to detect outbreaks and changes in disease incidence and sporadic cases;
- enhance capacity for environmental monitoring and risk assessment of water-supply systems;
- monitor trends in water quality and WRID;
- identify high-risk areas to target with control measures; and
- estimate the burden and impact of WRID and publish regular updates to inform policy and improvement measures.

will detail the types of WRID to be included in the system, the geographic coverage, the population to be covered and the time period for surveillance. Surveillance systems can have more than one objective. The elements of the system need to be sufficiently timely, representative, sensitive and specific to address their respective objectives, which in turn influence the methods of data collection, including the frequency. For instance, if the objective is outbreak detection, then ensuring the system is sensitive and can readily identify cases will be a priority, as will the timely collection of data, so that outbreaks can be identified early to enable their rapid management. If the objective is to identify high-risk groups, ensuring the data are representative of the general population will be important.

Activity 4. Identify the outcomes for surveillance, the core surveillance dataset and design the system

Based on the results of the situational analysis, and having agreed the purpose, scope and objectives of the system, the advisory committee could:

- list the priority outcomes (pathogens, notifiable diseases and syndromes) for the country to monitor;
- select (where necessary) additional surrogate outcomes, such as water

complaints, that will enable the earlier detection of potential exposure events and outbreaks;

- link all outcomes under surveillance to specific surveillance objectives;
- identify appropriate sources for the provision of data on each surveillance outcome, such as water providers who can report water-quality data; and
- establish readily available databases that can be accessed to capture data on, for instance, laboratory diagnoses, prescriptions for antidiarrhoeal medications or calls to medical helplines automatically.

These sources of data and the data provided by them will comprise the elements of the surveillance system.

It is good practice to develop a schematic overview of the surveillance system based on the identified types of surveillance (building blocks), surveillance outcomes and sources of data (elements) of the system.

Each type of surveillance will have its own objectives and outputs and may cover different population groups; it can be helpful to define these. Ideally, only as much data as are required are collected, and all data collected have a specific purpose in helping to fulfil a specific surveillance objective.

Define the case definitions for each outcome under surveillance

Surveillance case definitions may differ from clinical case definitions or case definitions used during outbreaks. Countries usually will adopt their own case definitions, or may decide to use publicly available definitions published by other organizations.

The European Union, for example, has published a list of standard case definitions for communicable disease surveillance (38,39). These are used by the ECDC and some national public health agencies in Europe. Box 1 presents an example of the European Union case definition for cryptosporidiosis.

Define the data to be collected and reporting frequency

Typically, data on notifiable-disease cases or laboratory-confirmed cases will be case-based. Syndromic surveillance data may be either case-based or surveillance sites may report aggregated data. Ideally:

- all data collected have a defined purpose and can be used to prevent or control the disease under surveillance: for instance, data on geographic distribution of WRID may help to identify weaknesses in the water distribution system or geographic areas where there is a higher incidence of cases, which is suggestive of an outbreak: if the data do not have an actual purpose, they should not be collected;
- the frequency of data-reporting is defined: this will depend on the purpose of the data:
 - data intended for outbreak detection typically are reported as soon as possible;
 - data used to monitor trends and seasonality usually are collected on an ongoing basis (weekly, for instance); and
 - data used for burden-of-disease estimates or to monitor what pathogens are associated with WRID could be collected less frequently (monthly or annually).

Box 1. European Union surveillance case definition for cryptosporidiosis

Clinical criteria: any person with at least one of the following two:

- diarrhoea
- abdominal pain.

Laboratory criteria: at least one of the following four:

- demonstration of *Cryptosporidium* oocysts in stool
- demonstration of *Cryptosporidium* in intestinal fluid or small-bowel biopsy specimens
- detection of *Cryptosporidium* nucleic acid in stool
- detection of *Cryptosporidium* antigen in stool.

Epidemiological criteria: one of the following five epidemiological links:

- human-to-human transmission
- exposure to a common source
- animal-to-human transmission
- exposure to contaminated food/drinking water
- environmental exposure.

Case classification:

A. Possible case: not applicable

B. Probable case: any person meeting the clinical criteria with an epidemiological link

C. Confirmed case: any person meeting the clinical and the laboratory criteria.

Note: if the national surveillance system is not capturing clinical symptoms, all laboratory-confirmed individuals should be reported as confirmed cases.

Source: European Union (38).

Table 5 outlines typical data that are collected for different outcomes.

Identify other sources of data that can be used to inform surveillance

Other data, such as climatic data, could be used to identify high-risk periods for outbreaks or to identify risk factors for WRID, which may pinpoint areas that could be targeted for control measures.

Consider the strengths and limitations of the surveillance system

Having decided on what data to collect and their sources, it is useful to consider the strengths and limitations of the surveillance system and how the design could be strengthened to address any identified limitations. In particular, consideration could be given to:

- whether any populations, such as users of individual and small private water supplies, will be missed by the surveillance system,

and what impact (if any) this is likely to have on the control of WRID in the country;

- the potential sources of bias associated with the data;
- how likely it is that cases will be missed by the system;
- how likely it is that cases are misclassified as non-cases and non-cases misclassified as cases, and how this could impact the surveillance estimates and conclusions derived from the data;
- whether the system is sufficiently timely to enable early outbreak detection;
- how easy it will be to adapt or modify the system in, for instance, the event of an emergency, and whether the system can be expanded or reduced in response to the public health need;
- whether the system is overly complicated; and
- whether there are any redundancies or duplications in the data collected, and whether all data are being collected for a specific purpose.

Table 5. Data commonly collected for different surveillance outcomes

Surveillance outcome	Type of data	Suggested core data set	Example reporting frequency
Notifiable cases of WRID	Case-based	Name, age, date of birth, sex, address, occupation, work address, date of onset of illness, date and place of hospitalization, case outcome (alive, died), recent travel history	Within 24 hours
Laboratory-confirmed cases of WRID	Case-based	Reporting laboratory, patient name, age, sex, residential postcode, date of onset of illness, specimen type, specimen date, pathogenic organism (full organism name and any typing results), identification methods	Within 24 hours for urgent notifications, otherwise weekly
Syndromic surveillance data (AGI, diarrhoea)	Aggregate	Total weekly cases by age group, sex and place	Weekly
WRID outbreaks	Case-based	Location and date of outbreak, total cases, number hospitalized and died, causative agent, source of outbreak (public or private water supply, cooling tower etc.), water quality, main risks of water-supply system contamination, contributory factors	Quarterly

Surveillance case study: activity 4

Based on the results of the situation analysis, the advisory committee in Laguna agrees that the surveillance system should include both indicator- and event-based surveillance. The types of surveillance, outcomes under surveillance and sources of data to be included in the system are summarized in Table CS2.

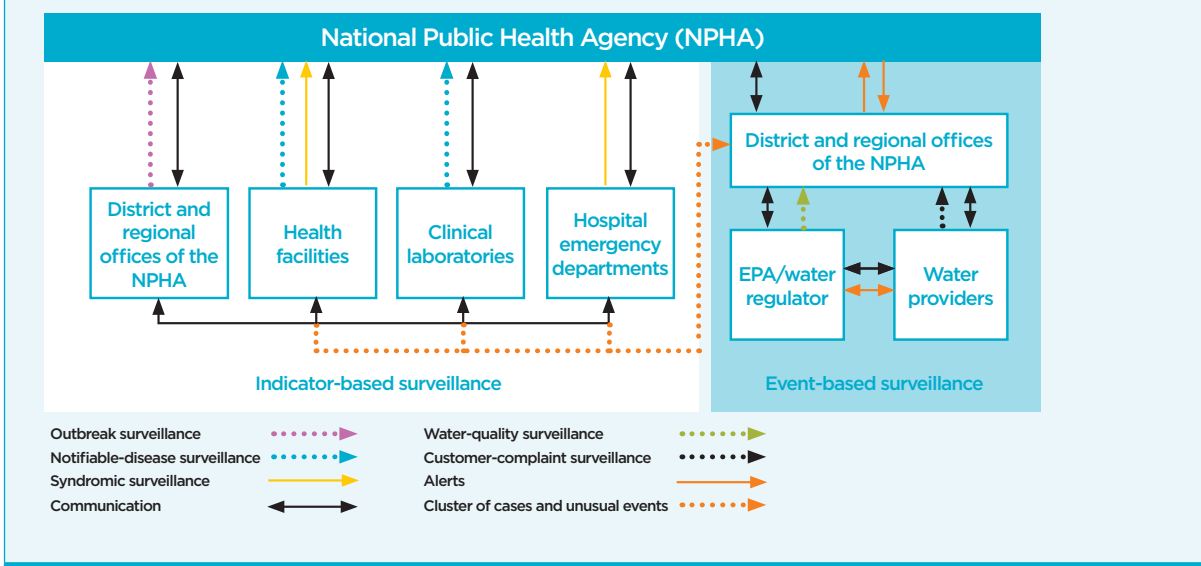
Table CS2. Types of surveillance, outcomes under surveillance, and sources of data to be included in the Laguna surveillance system

Associated WRID surveillance objective	Type of surveillance	Surveillance outcomes	Data sources	Population under surveillance
Indicator-based surveillance				
Detect outbreaks Monitor trends Identify high-risk areas Estimate burden and impact Use surveillance data for policy and control of WRID	Notifiable-disease surveillance	Clinical diagnoses of: <ul style="list-style-type: none"> • typhus • infectious bloody diarrhoea • community-acquired pneumonia 	Health-care facilities	Patient population
		Laboratory diagnoses of: <ul style="list-style-type: none"> • <i>Campylobacter</i> • <i>Cryptosporidium</i> • enteropathogenic <i>E. coli</i> • <i>Giardia</i> • hepatitis A and E • <i>Legionella</i> • <i>Salmonella</i> • <i>Shigella</i> • <i>Vibrio cholera</i> 	Public and private clinical laboratories	Patient population
Detect outbreaks Monitor trends	Syndromic surveillance	AGI	Primary-care facilities and hospital emergency departments	Patient population
Identify high-risk areas Estimate burden and impact of WRID Use surveillance data for policy and control of WRID	Outbreak surveillance (surveillance of investigated outbreaks that have already been attributed to water)	Waterborne outbreaks	District/regional offices of the NPHA	Total population
Event-based surveillance				
Detect outbreaks	Direct notification of clusters of disease and suspected outbreaks	Unusual events and suspected outbreaks	District/regional offices of the NPHA	Total population
Detect outbreaks Identify high-risk areas Use surveillance data for policy and control of WRID	Water-quality surveillance	Exceedance of threshold limits for water quality: <ul style="list-style-type: none"> • <i>E. coli</i> • residual chlorine (for supplies subject to disinfection) 	EPA/water regulator Water provider	Not applicable
Detect outbreaks Identify high-risk areas	Customer-complaint surveillance	Exceedance of threshold limit for customer complaints on water quality and/or water-supply system operation	Water provider	Customers of water supplies

The existing notifiable-disease surveillance system will be expanded to include additional water-related pathogens, and a new syndromic surveillance system for AGI will be developed. The existing outbreak surveillance will also be expanded to include surveillance of water-related outbreaks, as will the existing event-based surveillance system, to include surveillance of water-quality alerts and water-provider customer-complaints surveillance. A schematic diagram of the surveillance system is shown in Fig. CS1.

Surveillance case study: activity 4 contd

Fig. CS1. Schematic diagram of Laguna surveillance system



Activity 5. Develop a methodology for collecting, managing and analysing the surveillance data

The process for conducting surveillance (the methodology) (Fig. 7) needs to be worked out and agreed with all stakeholders, particularly those collecting, reporting and receiving the data.

Ideally, the methodology should describe:

- roles and responsibilities in operating the surveillance system at each level of the system, including the people responsible for collecting, reporting and receiving data;
- the process for identification of cases at health facilities and reporting of data on cases to the public health agency, including data flows from local to subnational to national levels;
- the process for electronic capture of data from other systems, such as laboratory, environmental or prescribing databases;
- the data to be collected from each data source;
- the reporting forms, including case-based reporting forms for notifiable-disease surveillance;
- data management, including how data will be coded and entered into the system, how they will be stored, who will have ownership or guardianship, and how the data will be protected;
- the process for analysing and interpreting data and generating surveillance reports (discussed further in the next chapter);
- alert thresholds for indicator- and event-based surveillance; and
- the process for investigating individual cases of notifiable diseases.

Thresholds can be defined and applied to the surveillance data to facilitate outbreak detection and monitor seasonal epidemics. Thresholds for outbreak detection may be:

- an increase in the number of cases compared to the background rate for a specific disease over the same time period and place; for instance, a two-fold increase in the rate of cryptosporidiosis above the baseline surveillance rate for the previous five years (40) or a doubling of the weekly average number of cases of bloody diarrhoea (24); and
- a defined number of cases that will prompt an outbreak investigation, such as five

cases of suspected shigellosis or bloody diarrhoea (41).

The WHO practical manual for strengthening surveillance of foodborne diseases (24) provides further information on how to set and use thresholds.

It is good practice to communicate the results of surveillance to stakeholders on a regular basis to:

- inform decision-making for public health action; and
- demonstrate the purpose and usefulness of surveillance data to those who are reporting data to motivate and engage them in surveillance.

This is best achieved through the regular generation and publication of a surveillance report or bulletin. Ideally, these bulletins will be:

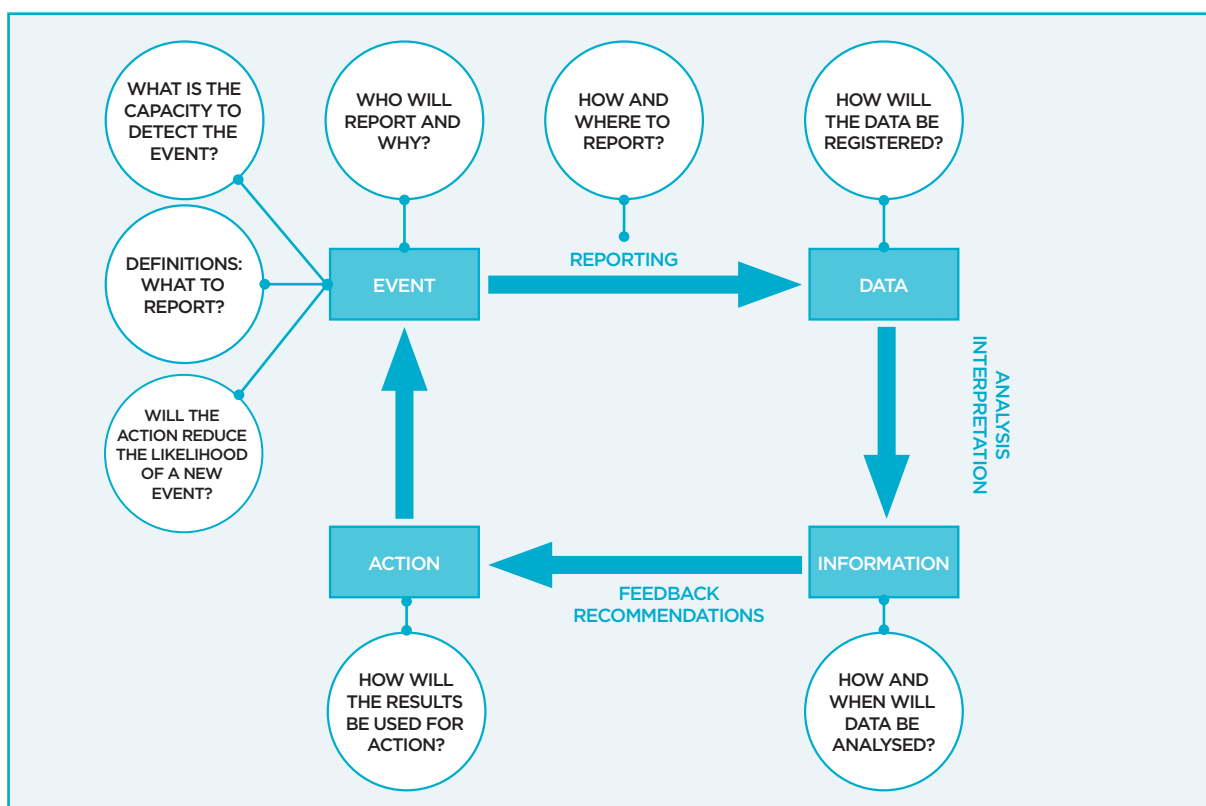
- disseminated to all stakeholders involved in surveillance, including water providers and regulators; and
- made publicly available on, for instance, the website of the public health agency.

Activity 6. Develop processes for monitoring and evaluating the system

Surveillance data may not be of the highest quality. Consequently, some effort is needed to deliver a basic level of quality to ensure the consistency and validity of the surveillance results. This is achieved through monitoring and evaluation (M&E). M&E can include ongoing monitoring of data quality and periodic evaluations of the surveillance system.

For ongoing monitoring, automated data checks can be incorporated into electronic data-management systems by building into the system:

Fig. 7. Overview of the typical process for conducting surveillance



Surveillance case study: activity 5

In developing and agreeing the surveillance methodology, the Laguna advisory committee:

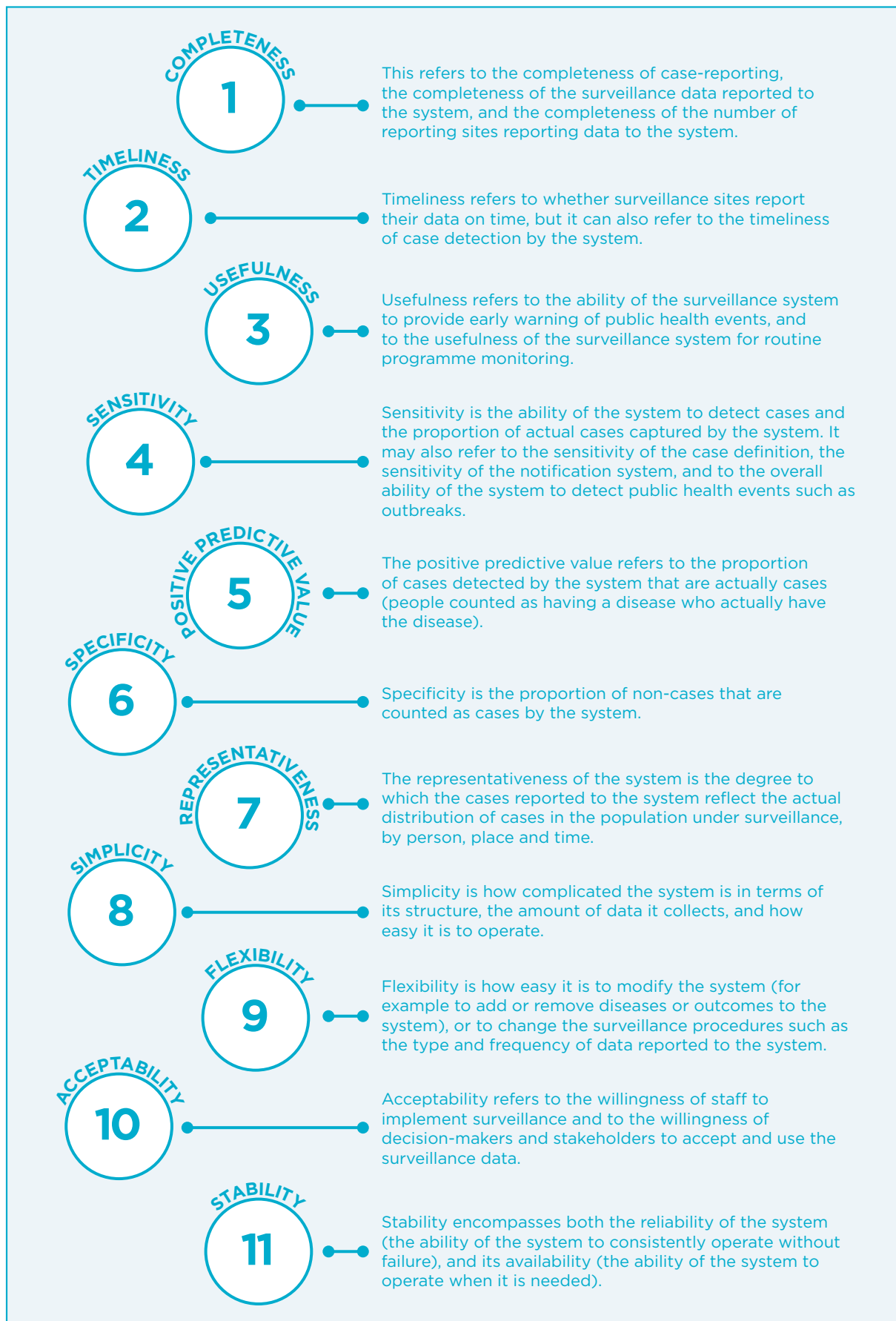
- asks all organizations involved in surveillance, including health facilities, laboratories, water providers, the EPA and offices of the NPHA at national, regional and district levels, to appoint one or more responsible persons for surveillance;
- develops and adopts officially case-based and aggregated data-reporting forms and associated databases;
- develops a web-based reporting system for notifiable disease, syndromic surveillance and outbreak surveillance data-reporting;
- develops procedures for reporting of clusters of cases and suspected outbreaks, exceedances of thresholds for water-quality standards and customer complaints, involving notification by email and phone to either the district or regional offices of the NPHA, depending on the geographical coverage of the water-supply system;
- documents the design of the system, case definitions and surveillance procedures in a surveillance protocol that is adopted officially by all parties;
- develops alert thresholds for the notifiable, syndromic and event-based surveillance elements of surveillance; and
- develops routine data-analyses plans and a template surveillance bulletin, including a plan for its dissemination to key stakeholders.

- data entry checks that control against errors at the time of data entry;
- interdatabase checks that cross-check the consistency of data between different data tables and databases in the data-management system; and
- checks on the completeness and timeliness of data-reporting into the system by, for instance, checking that all reporting sites (such as laboratories) have reported into the system.

Surveillance systems can be evaluated periodically against a set of attributes (27,42) (Fig. 8).

A description of some of the attributes of the different types of surveillance described in this document is provided in Table 4.

Evaluations are conducted to assess the system in relation to these attributes and to assess the degree to which the system is meeting its surveillance objectives. The evaluation can inform recommendations for improvement of the system. Detailed information on how to evaluate a surveillance system is given in the guidance documents (27,43) listed in Annex 2.

Fig. 8. Surveillance systems: periodical evaluation against defined attributes

Source: WHO (27); European Programme for Intervention Epidemiology Training (42).

Enabling factors for strengthening and sustaining WRID surveillance

National authorities, with support from the surveillance advisory group, could undertake a number of supporting actions to enable the conduct of WRID surveillance, including the following.

1. Set targets for the prevention and control of WRID:
 - obtain a situation overview on water and health in the country, and set dedicated targets to reduce or prevent priority WRIDs; and
 - review the existing national surveillance, early-warning and response capacity and set specific target/s towards strengthening the WRID surveillance system.
2. Set legal requirements or formal procedures for surveillance of WRID:
 - review and update national legislation and/or guidelines and establish formal requirements for surveillance of WRID as an integral part of the national disease (public health) surveillance system; and
 - ensure that the surveillance system complies with all national legislation relating to research ethics and data protection.
3. Ensure there are adequate resources and infrastructure for surveillance:
 - develop a budget for setting up and running the system and secure the necessary resources: if WRID surveillance

Surveillance case study: enabling surveillance

The advisory group works together and with national authorities to enable the strengthening of the WRID surveillance system through the following actions:

- memoranda of understanding are agreed and signed by all Parties to govern the sharing of data;
- standard operating procedures governing all surveillance activities are developed and training is given at all levels of the system;
- the surveillance system will be financed using core funding from the Ministry of Health and NPHA;
- as laboratory surveillance is being extended to include a greater number of microorganisms, additional resources for testing of these organisms is directed to the laboratory network and additional training on testing methodologies is provided; and
- legislation governing notifiable-disease surveillance is updated to include the reporting of additional waterborne pathogens.

and control is conducted mostly at local level, target resources there; and

- ensure there is adequate laboratory capacity to support surveillance activities, including capacity to test for the priority pathogens under surveillance.

In addition to actions by national authorities, the advisory group could work to:

- develop a training programme for all staff working on WRID surveillance at all levels of the system;

- develop standard operating procedures and instruction manuals to guide day-to-day surveillance activities; and

- put in place the necessary information technology, transportation and communication infrastructure to operate the system; this could include computers, Internet, an electronic data-management system, transportation for specimen collection, laboratory supplies or a web-based reporting system.

Approaches to WRID surveillance data analyses

WRID surveillance data usually are analysed on a continuous basis by, for instance:

- time: plotting incidence rates or number of cases over time;
- place: tabulating or mapping the distribution of cases by district, municipality or water-supply zone; and
- person: tabulating the frequency of cases or the incidence by age, sex and other potential risk factors for infection.

Ideally, the data analyses will be targeted to address specific surveillance objectives and the surveillance questions associated with those objectives. Table 6 gives examples of how specific surveillance objectives can be addressed by particular types of data analyses.

Suggested approaches to surveillance data analysis are detailed in the following publications:

- WHO's manual on strengthening surveillance of, and response to, foodborne diseases (24); and
- WHO's technical guidance on water-related disease surveillance (4).

Spatial analyses

Spatial analyses map the distribution of cases or disease incidence and other surveillance indicators, such as complaints to water companies, and how these correspond to water-supply zones. To do this, a geographical marker, such as the residential postcode of the

Table 6. Surveillance analyses to address specific surveillance objectives

Surveillance objectives	Analytical outputs that can address these objectives	Typical frequency of analysis
Identify temporal trends and detect possible outbreaks	Line graph of incidence over time	Weekly
Identify groups who are at higher risk of WRID	Table of total number of cases and incidence or prevalence rate by age, sex and geographic area	Weekly
Detect possible outbreaks or clusters of cases; identify areas of the water-supply system associated with higher rates of disease that can be targeted with resources to improve the water-supply system infrastructure	Table or map of the number of cases or the incidence rate by geographical area	Weekly
Estimate disease burden	Table of frequency of cases	Quarterly or annually
Evaluate the impact of control measures, such as implementing a new water-treatment step	Incidence of disease before and after changes in the water treatment	Based on needs

case or the location of the reporting medical facility, will need to be collected as part of surveillance. Spatial analyses can greatly be supported by employing geographic information systems (GIS). Spatial analyses are discussed in further detail in WHO's technical guidance on water-related disease surveillance (4) and an example of their use for WRID surveillance data analysis is shown in Box 2.

Time-series analyses

Time-series analyses can utilize many sources of surveillance data, including syndromic surveillance data on AGI, notifiable-disease surveillance data based on International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10) codes, notifications of laboratory-confirmed cases, prescription data and calls to medical helplines (45), as well as water-quality data

(45–47) and meteorological data (48). Time-series analysis uses regression methods to analyse trends in WRID over time, identify possible outbreaks based on aberrations in these trends and identify seasonality in disease occurrence (46,49) or potential correlation with water-quality data (45–47) and meteorological data (48). Time-series analyses can be used for forecasting the future trajectory of a disease or an outbreak, so can be a useful way to prioritize areas for public health action.

A detailed explanation of the time-series methods is beyond the scope of this document, but they have been described elsewhere (45,49,50). Many time-series models are freely available, and their performance has been evaluated and discussed elsewhere (51). An example of the use of time-series analysis to investigate the association between rainfall and AGI is shown in Box 3.

Box 2. Use of spatial analyses for WRID surveillance data analysis

Public health professionals from the University of Bonn and the Institute for Public Health in North Rhine-Westphalia, Germany, conducted a retrospective study to assess the association between the spatial distribution of diarrhoeal illness caused by enteric pathogens and different drinking-water sources. The study area comprised eight municipalities, 42 subdistricts and 440 square kilometres, and covered a population of 272 000 people. Electronic spatial data on the water-supply structures were recorded in a GIS. These structures included five public waterworks serving 99.6% of the population and private water supplies. Three of the five waterworks produced groundwater and the other two surface water. The groundwater was physically purified and in one waterworks additionally disinfected. The surface water was treated by filtration, flocculation and disinfection. Additional disinfection was conducted, with faecal-indicator bacteria isolated from the distribution network.

The study team had access to 11 years of electronic routine surveillance data on cases of diarrhoea caused by enteric pathogens (hereafter known as cases), including the spatial location of cases. They included all enteric pathogens that could cause diarrhoeal illness, except *Salmonella* and *Shigella*, as these pathogens were known primarily to be foodborne in Germany. The data were integrated into the GIS. The study team calculated age-standardized incidence rates and standardized morbidity ratios and mapped areas with low and high incidence rates to visualize the disease distribution. They used spatial autocorrelation to detect clusters of cases and correlation techniques to assess the association between the water supply and disease incidence. They quantified the number of people served by surface, groundwater and private water supplies.

Box 2 contd

The age-standardized incidence rates for enteric pathogens varied between 60 and 140 cases per 100 000 people for the middle and south of the study area, compared to between 15 and 30 cases per 100 000 for the north (Fig. B2.1). The standardized morbidity ratio in some districts was 70–150% higher than the standard rate for the Rhine-Berg district. Lower standardized morbidity ratios were found in the east and north of the study area (Fig. B2.2). Areas of extremely high incidence rates (beyond what would be expected by chance alone, as determined by a Poisson probability distribution model) were found in the south and middle (Fig. B2.3). Spatial clustering of cases was demonstrated. The study team demonstrated a correlation between consumption of groundwater and the occurrence of cases. The study team attributed this association to the lack of chlorination of the groundwater supply.

Fig. B2.1. Age-standardized incidence rates of gastroenteritis by subdistrict, Rhine-Berg district, 1988–1999

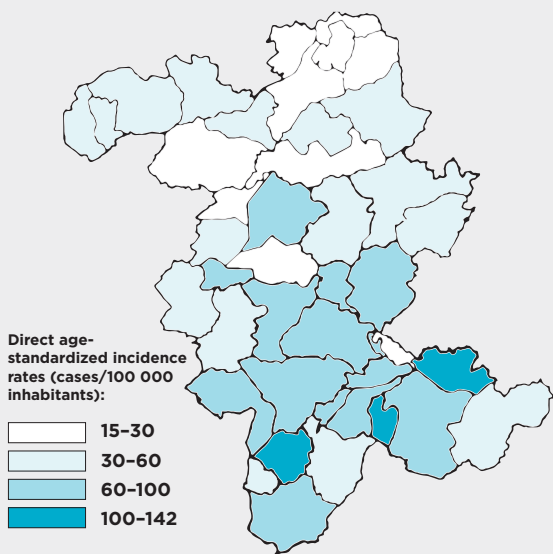


Fig. B2.2. Standardized morbidity ratios by subdistrict, Rhine-Berg district, 1988–1999

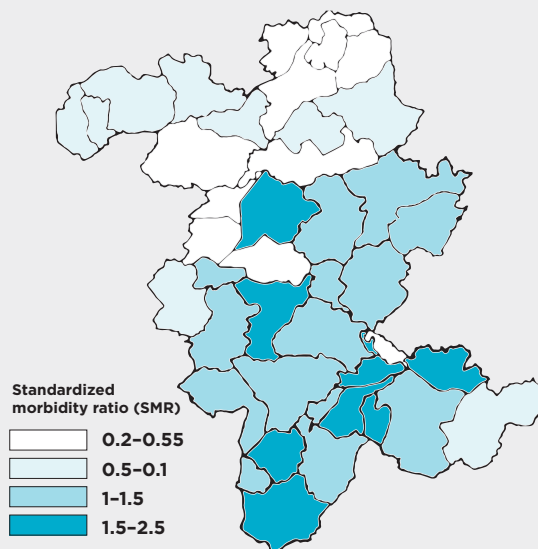
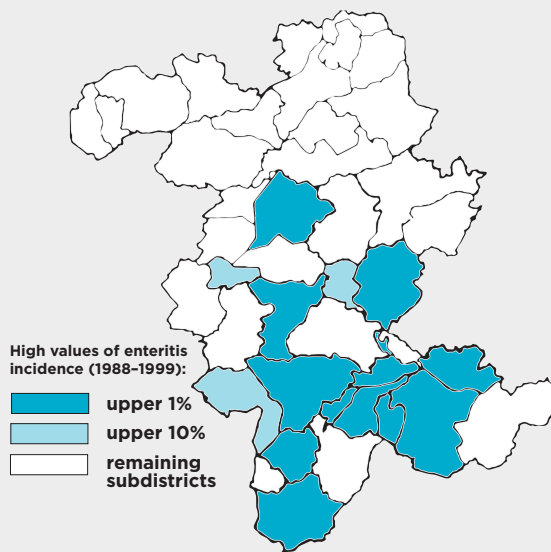


Fig. B2.3. Mean annual gastroenteritis incidence rates by subdistrict, Rhine-Berg district, 1988–1999



Source: Dangendorf et al. (44) (reproduced with permission from Elsevier).

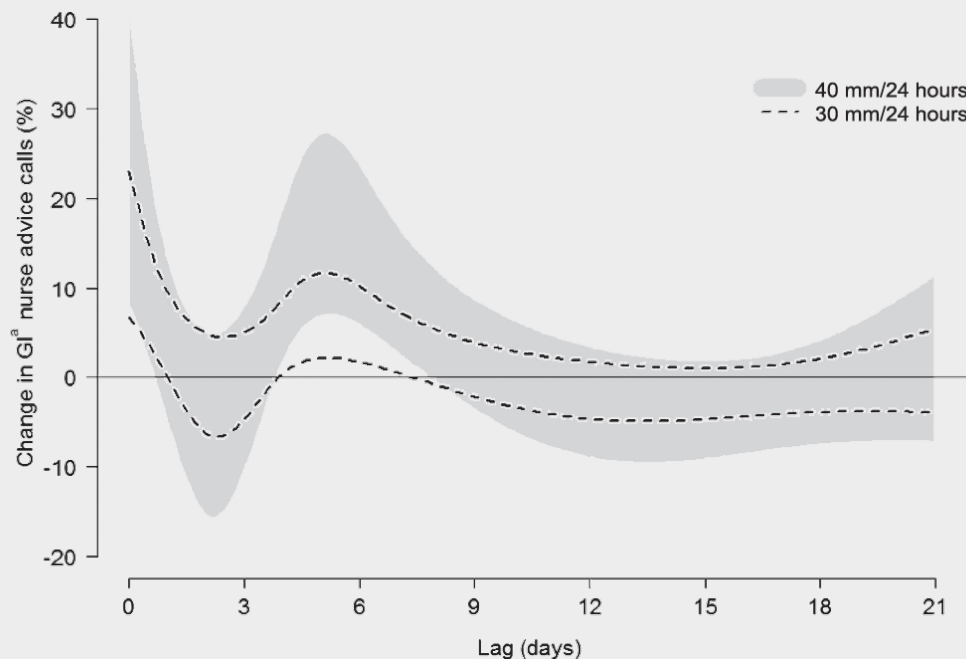
Box 3. Use of time-series analysis to investigate the association between rainfall and AGI

A study from Sweden investigated the association between gastrointestinal illness and rainfall in the city of Gothenburg. Gothenburg, population 500 000, has two drinking-water utilities, one of which uses primarily river water for drinking-water production. The investigators previously demonstrated a peak in water turbidity and indicator bacteria at the river water intake to the drinking-water utility two days after rainfall. They wanted to assess whether sporadic cases of gastroenteritis were related to rainfall and so could indirectly be linked to the quality of river water used for drinking-water production at the utility. Using data on calls to a nurse medical helpline from those living in the area supplied by this water utility between November 2007 and December 2011, the investigators classified the calls according to whether they were associated with AGI (based on the presence of vomiting, stomach pain and diarrhoea). They also used data on precipitation from a weather station located close to the water utility.

The investigators analysed the association between daily precipitation and daily number of AGI calls to the helpline for those living within the water-utility delivery area. Calls were analysed within a 0–21-day lag period for precipitation. They adjusted for potential confounders, including season, time trend, holidays and days around holidays, day of the week and daily mean temperature. They also adjusted for daily number of calls to the nurse advice line for non-AGI symptoms.

During the study period, 25 659 AGI calls were made to the nurse advice line, ranging from 3–47 calls per day. Call volume followed a distinct seasonal pattern and was highest in winter. Precipitation of over 25 mm in 24 hours was associated with an increase in AGI calls on the same day and around 5–6 days later. Precipitation of 30 mm in 24 hours was associated with an increase in AGI calls of 15% at day 0 (95% CI:6–23%), 7% (95% confidence interval (CI):2–12%) at day 5 and 6% (95% CI: 2–11%) at day 6 (Fig. B3.1). Compared to dry days, the number of AGI calls increased by 5% (95% CI: 3–8%) on wet days, and four consecutive wet days were associated with a 13% (95% CI: 5–21%) increase in the number of calls (Fig. B3.2). No association between precipitation and non-AGI calls was demonstrated.

Fig. B3.1. The association between heavy precipitation and calls to a nurse advice line for AGI



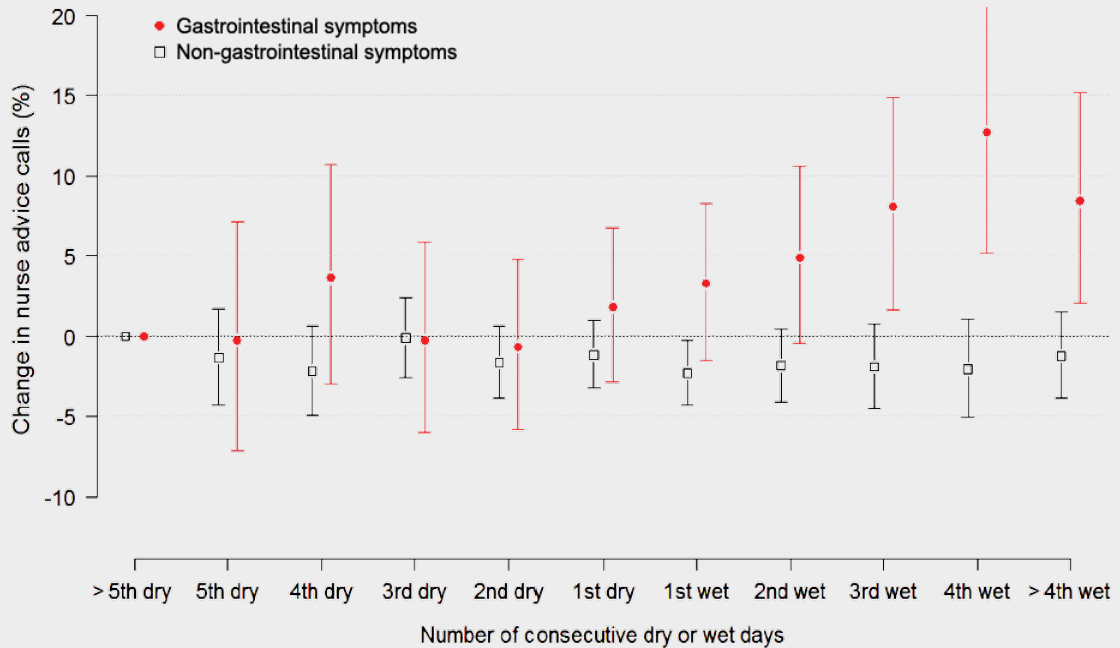
Note: calls made to advice line between 0 and 21 days after a heavy precipitation event. Graph displays 95% CI of the association for heavy precipitation events of 30 mm in 24 hours and 40 mm in 24 hours.

^a GI: gastrointestinal illness

Source: Tornevi et al. (52) (reproduced with permission from PLoS One).

Box 3 contd

Fig. B3.2. Estimated change in daily number of AGI and non-AGI calls to a nurse advice line associated with consecutive days of dry or wet weather



Source: Tornevi et al. (52) (reproduced with permission from PLoS One).

The investigators hypothesized that the increase in AGI calls 5–6 days after a heavy precipitation event was due to viral contamination of drinking-water, as viruses such as *Norovirus* have a short incubation period, are more difficult to remove by filtration (due to their small size) and are more resistant to disinfection. The observed seasonality of the AGI calls would also reflect the seasonality of enteric virus infections. The increase in AGI calls on the same day as heavy precipitation was unlikely to be related to the poor quality of the source water, but could be explained by ingress of sewage into the drinking-water distribution system when storm-water systems were stressed by heavy rainfall, although no such ingress had previously been documented in the study area.

Interlinkage of water-quality surveillance with WRID surveillance

Drinking-water supply systems are subject to routine monitoring for faecal-indicator bacteria (such as *E. coli* and enterococci) and other indicators of contamination (8,9). Monitoring microbiological water-quality indicators will provide information that the water may not have been safe at the time of sampling and may trigger investigative and corrective action to prevent the supply of unsafe water.

Health authorities should always be notified of such events. Ideally, mechanisms will be established as part of event-based surveillance to govern the reporting of such events to the health department. For instance, thresholds can be developed for different indicators or events that will trigger communication between the water provider and the health authority. Similarly, standard operating procedures can be developed and agreed between the health authorities to provide instructions on how to make such reports. Examples of events that could be reported include evidence of faecal contamination of the drinking-water supply (identified by monitoring *E. coli* or coliforms in the water supply) or an increase beyond a certain threshold of customer complaints to the water company. The public health agency

could then investigate whether this breach is correlated with an increase in human cases of gastrointestinal illness or another health-related outcome under surveillance.

In addition, operational monitoring procedures, which are an integral part of a WSP implemented by water suppliers (8), should be established continuously to assess the performance of control measures so that timely corrective action can be taken if needed to prevent the supply of unsafe water. Examples of such operational monitoring parameters include turbidity levels and chlorine residuals.

Water-quality surveillance data can be analysed alongside disease-surveillance data, such as syndromic surveillance data on gastrointestinal illness, using time-series analysis (see the section in the previous chapter on “Time-series analysis”) to determine the degree to which they are correlated (45,50). These types of analyses will be facilitated by the availability of electronic water-quality data that can easily be shared on a periodic basis with national public health agencies to support the conduct of such analyses.

Using surveillance data for advocacy

WRID infections and outbreaks can exert a considerable societal burden due to their impact on health (53,54), health resource utilization (55) and productivity losses (56,57).

The results of surveillance can be used to:

- identify priorities and inform resource allocation for the development and maintenance of water systems to prevent further illness;
- evaluate the impact of control measures applied to the water-supply system; and
- inform the development of policy, regulations and guidelines for WRID control.

This requires the availability of high-quality surveillance data (58). Burden of disease estimates that account for disease severity and economic and societal costs (such as disability-adjusted life-years (DALYs), quality-adjusted life-years and direct and indirect costs) are considered more informative for decision-making than surveillance case numbers alone (59) as the number of cases of a particular illness does not necessarily reflect the impact of that illness on society.

The Ministry of Health in Egypt ranked the 15 diseases most commonly reported to the national communicable-disease surveillance system over an eight-year time period to develop composite risk indexes by geographical area, season and time (58). In doing so, they identified diseases transmitted via food and water as being responsible for the greatest burden of disease, and defined improvements to environmental sanitation as a priority measure for disease control.

Other countries have combined surveillance data on the total number of cases and total number of deaths of common enteric pathogens with data (either national (53) or regional (60)) on the proportion of cases attributable to water to estimate the burden of disease attributable to drinking-water supply systems (53) and calculate DALYs for waterborne disease (61). WRID DALYs could be compared to DALYs for other diseases to identify priorities for health-care resource allocation.

Surveillance data can also be used to demonstrate the impact and value of improvements to water and sanitation systems. For instance, the addition of water filtration to a water supply vulnerable to *Cryptosporidium* outbreaks in the United Kingdom (Scotland) was demonstrated to halve the incidence of *Cryptosporidium* in the target population (62). A cost-benefit analysis of water-supply system improvements undertaken in a rural community in the United States estimated health-care cost savings of almost US\$ 850 000 and the prevention of 155 cases of hepatitis A and 5165 cases of gastrointestinal illness over a 26-year period (63).

In addition to routine surveillance data, post-hoc analyses of data from outbreaks can provide convincing evidence of the need to invest in water-supply system infrastructure, not only to protect public health, but also for economic reasons. An outbreak of *Cryptosporidium* in Ireland with 242 confirmed cases, which required the implementation of a boil water notice lasting five months and affected an estimated 120 432 people, was estimated to cost €19 million, or €120 000 per day (64). The analysis demonstrated the

benefit of investing in the safety of drinking-water supply systems to both public health and the wider economy.

Analysis of outbreak data to estimate the economic burden can include a number of factors (55-57,64), such as:

- direct costs – health-care costs and resource utilization, provision of alternative water supplies and outbreak response costs; and
- indirect costs – loss of income, loss of business, and productivity losses such as work and school absenteeism.

PART B. MANAGEMENT OF OUTBREAKS OF WATER-RELATED INFECTIOUS DISEASE

This part provides an overview of the steps involved in investigating, responding to and managing outbreaks of WRID. The approach to outbreak investigation described here broadly is similar to that described elsewhere (24–26,65,66). It highlights some of the specific considerations related to the management of waterborne outbreaks associated with drinking-water supply systems. Additional information on the investigation of *Legionella* outbreaks associated with environmental exposures is documented in Annex 4. It also contains an illustrative outbreak case study presented over 10 parts, which describes steps taken in Laguna in managing the WRID outbreak.

Part B is targeted towards all those involved in the management of WRID outbreaks, particularly public health and environmental health professionals, water providers and risk communicators.

Summary

Contamination of water supplies can cause massive outbreaks affecting large populations in a short period of time. Outbreaks of WRID can have substantial health, social, economic and political consequences. Out of the investigated outbreaks of infectious diseases that could potentially be water-related in the pan-European region, 18% were attributed to water (14).

Outbreak of waterborne disease is defined as “a situation in which at least two people experience a similar illness after exposure to water and the evidence suggests a probable water source” (67).

Waterborne outbreaks, particularly those associated with large water-supply systems, typically are characterized by:

- their association with specific watershed events, such as defects or failings in the water-treatment process or distribution system, or an exceedance of water-quality parameters;
- a sudden, rapid and widespread occurrence of cases, including medically attended cases;
- the clustering of cases in a particular water-supply zone, with fewer cases in adjacent supply zones; and
- the occurrence of cases relative to the distribution pattern of water.

WRID outbreak management capacity ideally will be developed in advance through a process of contingency planning to facilitate a rapid, coordinated, effective, multisectoral response. Such contingency planning will encompass both a public health response to contain the spread of an outbreak, and an incident management response to secure access to a safe drinking-water supply.

The detection of an outbreak triggers a multifaceted response, involving:

- investigation of the outbreak;
- implementation of control measures; and
- ongoing communication to stakeholders and the public.

This document outlines a 10-step process for outbreak management that broadly is similar to the approach described in international guidelines. As the steps have been described in detail elsewhere, this document provides only a brief overview of the general aspects on each step and instead focuses on the specific factors that are important in the investigation of WRID outbreaks.

An overview of the steps and specific actions related to the management of outbreaks of WRID associated with drinking-water supply systems is illustrated in Table 7 below. These steps usually are conducted simultaneously and in parallel throughout the response. Control measures are implemented as early as possible in the response and as needed throughout the response, and communication is conducted on an ongoing basis.

Effective risk communication to the public is a critical component of outbreak management as it supports those at risk to make informed decisions to protect themselves and others and to take action to minimize the spread of the outbreak.

Risk communication usually needs to be integrated within each stage of the outbreak response and within the decision-making process to maximize opportunities for management and control of the outbreak.

Table 7. Step-by-step specific actions for WRID outbreak management

Outbreak step	Associated WRID specific actions
1 Detect and confirm the existence of the outbreak and confirm the diagnosis	<ul style="list-style-type: none"> • If water is suspected as the source, find out from the water provider about any recent events relating to the water supply (such as a contamination event or increase in customer complaints) and check if other geographical areas are also experiencing an increase in cases. • Once the outbreak is confirmed, report to relevant stakeholders such as environment agencies, water providers and municipal authorities. • Decide on whether water and environmental specimens need to be collected. If so, decide on the sampling locations, number and types of samples to be collected, the indicators to be tested, and the sampling and testing methodology, including the needed equipment and materials. • Take samples from the suspected source of the outbreak: for waterborne disease outbreaks, sample from drinking-water sources, water stored in households or other water sources to which cases were commonly exposed; for <i>Legionella</i> outbreaks, take samples of biofilms from water systems or cooling towers.
2 Form the rapid-response team (RRT)	<ul style="list-style-type: none"> • Include environmental health or sanitation experts in the team and, as indicated, representatives from the water provider, environment agencies and municipal authorities.
3 Define cases	<ul style="list-style-type: none"> • Where standardized case definitions for a specific WRID exists, these can be used in the investigation. Where no standardized case definitions exist, the RRT will need to define its own case definitions. The RRT can specify definitions for suspect/possible, probable and confirmed cases. • Exposure to the suspected source (such as a particular water source) usually is not included in the case definition, otherwise it will not be possible to test whether that source is in fact the source of the outbreak.
4 Identify cases and obtain information	<ul style="list-style-type: none"> • Collect geographical data on possible places of exposure to different water sources, such as place of residence, work or study. • If the causative agent is known, collect information, including on water exposures and risk factors known to be associated with the particular pathogen. If the causative agent is not known, the RRT will need to collect data on the clinical presentation of disease and a wide range of exposures to determine the causative agent.
5 Conduct a descriptive epidemiological investigation (time, place, person)	<ul style="list-style-type: none"> • Analyse by person: calculate attack rates by exposure to particular water sources. • Analyse by place: calculate attack rates by place and map the distribution of cases to assess the geographical extent of the outbreak and identify potential sources. Undertake spatial analyses to visualize and explore the spatial distribution of cases in relation to suspect sources, investigate clusters and model the spatial dispersion of potential contaminants in a water system. • Analyse by time: if the causative agent is known, use the epidemic curve to estimate the likely time period of exposure and focus the environmental investigation on that time period. Assess if the epidemic curve correlates with events in the water-supply system and implementation of control measures.

Table 7 contd

6	Conduct additional studies and collect additional information (environmental, microbiological)	<ul style="list-style-type: none"> • Conduct a sanitary inspection and environmental risk assessment, and assess the WSP. • Collect historical data from water-quality monitoring. • Collect additional samples at different points in the water-supply system and analyse for indicators and suspected pathogens.
7	Interview cases and generate hypotheses	<ul style="list-style-type: none"> • Generate hypotheses on suspected sources of the outbreak and immediately target control measures at these sources. • Review the descriptive epidemiological data, the laboratory and environmental data, and the circumstances surrounding the outbreak, and assess the plausibility of the hypotheses against these facts.
8	Evaluate the hypotheses	<ul style="list-style-type: none"> • If necessary, conduct an analytical study to test the hypotheses and generate stronger evidence on the source of the outbreak. • Try to quantify the level of exposure to water and other sources to enable possible dose-response relationships to be investigated. • Consider the results of the analytical study, in combination with the descriptive data, environmental assessment, microbiological analysis and risk assessment data from the water system, to categorize the strength of the evidence that the water system is the source.
9	Inform risk managers and implement control measures (throughout the response)	<ul style="list-style-type: none"> • Implement control measures targeting, as indicated, the water-supply system, secondary vehicles of transmission (such as food items prepared with contaminated water) and secondary spread through person-to-person transmission. • Target control measures at both the immediate cause of the outbreak and the underlying factors (such as policy, training or inadequate maintenance of the water system) that contributed to the outbreak.
10	Communicate findings (throughout the response), make recommendations and evaluate the response	<ul style="list-style-type: none"> • Communicate immediate control measures relating to the water system in interim reports released frequently throughout the outbreak. • Communicate regularly to the public about the outbreak and preventive measures. • Make recommendations for long-term improvements to the water-supply system in the outbreak report and update the water-safety plan with these recommendations as needed.

Introduction to outbreaks

Outbreaks may be defined in a number of ways (25,26), including:

1. an unexpected increase in the number of cases of disease or another health outcome beyond what is expected in a particular group of people or in a particular place during a specific time;
2. two or more cases of disease linked to the same source; and
3. an exceedance of a predefined alert threshold.

WHO defines an outbreak of waterborne disease as “a situation in which at least two people experience a similar illness after exposure to water and the evidence suggests a probable water source” (67).

Waterborne outbreaks, particularly those associated with large water-supply systems, typically are characterized by:

- their association with specific watershed events, such as defects or failings in the water-treatment process or distribution system or an exceedance of water-quality parameters;
- a sudden, rapid and widespread occurrence of cases, including medically attended cases;
- the clustering of cases in a particular water-supply zone, with fewer cases in adjacent supply zones; and
- the occurrence of cases relative to the distribution pattern of water.

Outbreaks can be investigated in any or all of the following circumstances:

- the outbreak is likely to continue and/or spread without intervention to stop it;
- the source of the outbreak is unknown;
- the cause of the outbreak is unknown;
- the disease is severe and/or unusual; and
- there is a large number of cases.

Outbreaks may also be investigated if:

- there is public or political expectation of a formal response, or a legal requirement to do so; and
- it is perceived as a training opportunity or an opportunity to conduct research.

A full investigation may not be required if the causative agent and source can readily be identified without the need for epidemiological and other supporting investigations and the outbreak has already been brought under control. For WRID outbreaks, the root cause of the outbreak ideally will always be investigated and preventive measures taken to avert future outbreaks. Available resources for outbreak investigation, characteristics of the outbreak and the local context will inform the extent of the investigation.

Typically, the main objectives of outbreak management to prevent further cases and control the spread of the outbreak are to:

- confirm the outbreak;
- identify the source of, and factors contributing to, the outbreak; and
- implement control measures.

Contingency planning

The occurrence of WRID outbreaks can be unpredictable, sudden and of a scale that can overwhelm the capacity of the public health system. The potential health, social, economic and political impact is such that a rapid and coordinated response involving multiple agencies, working together under highly stressful conditions, may be required. Advance contingency planning is critical to enable a rapid, coordinated, effective, multisectoral response. Contingency planning includes preparedness, response and recovery planning. This chapter specifically refers to the preparedness and response parts of contingency planning.

Contingency planning involves ensuring that functioning systems are in place, appropriate people are engaged and trained, and supplies and medicines are available to enable a rapid response in the right place at the right time.

Contingency planning is a key activity under the implementation of the Protocol (Article 8) and of the IHR. Ideally, contingency planning for WRID outbreaks will be conducted within the broader process of national contingency planning for public health emergencies.

This chapter is informed by the following sources:

- WHO's technical guidance on water-related disease surveillance (4);
- the national strategic plan for public health preparedness and response of the CDC (68);
- the report of the Preparedness, Emergency Response, and Recovery Critical Infrastructure Partnership Advisory Council working group on all-hazard consequence management planning for the water sector (68); and
- the emergency response planning guide for public drinking-water systems of the Washington State Department of Health and Environmental Public Health Office of Drinking Water (69).

Within the context of WRID outbreaks, contingency planning ideally would encompass a public health response to contain the spread of an outbreak, and an incident management response to secure access to a safe drinking-water supply.

Considerations in contingency planning

WRID outbreak detection and response primarily occurs at local level. Given this, national authorities are encouraged to support local authorities in developing contingency plans for the management of WRID outbreaks. Local contingency plans could be expanded to include WRID contingency planning. The following factors could be considered when developing contingency plans for WRID outbreaks:

- identify and appoint members of the national and local RRT:
 - maintain an up-to-date list of the names and contact details of the RRT members, including back-up persons for each role if the primary member is unavailable;
 - agree the roles and responsibilities of each member of the RRT and the chain of command; and
- in the event of an outbreak, ensure rapid access to information about the water-supply system, such as:
 - monitoring and maintenance records;
 - water-supply surveillance data;

- plans, descriptions and maps of the entire water-supply system; and
- Global Positioning System locations of key infrastructure that may affect the water-supply system (such as wastewater systems or recreational sites).

Detailed information on the water-supply system usually is available in the WSP, if a WSP has been prepared for that water supply. It is particularly useful to know: the water-supply system flow diagram/layout; the identified system vulnerabilities, including relevant hazards and hazardous events and risks and their associated consequences; and an estimate of the supply needed to meet the average daily demand.

Procedures for reporting and sharing information and data between different agencies and stakeholders involved in the response should formally be agreed, ensuring the procedures are adopted through an appropriate legal framework, such as a memorandum of understanding. Protocols and notification flow charts can be developed to describe these procedures.

Toolkits such as template-outbreak protocols, line listings, case investigation forms, boil water notices or water avoidance notices, and other tools that can rapidly be adapted for use in an outbreak can also be developed to support the response. Template line listings, case investigation forms and other tools for outbreak investigation are available (24,65) and their use is described in the next chapter.

Regular training is important to keep members of the RRT engaged and to maintain strong collaborative relationships among team members and the agencies and organizations involved in outbreak response. It is also essential to ensure that all parties are fully competent in the processes and procedures for outbreak response. It is important to:

- conduct simulation exercises of outbreak scenarios to test emergency procedures

and coordination between the different agencies and parties involved in outbreak response;

- agree an ongoing programme of training with the RRT that should be conducted regularly (perhaps biannually) and ideally includes simulation exercises; and
- review the lessons learned from each training exercise and update contingency plans as needed and in accordance with the lessons learned.

Laboratory capacity can be strengthened by:

- identifying the laboratories at local, national and international level with capacity for testing and risk assessment that will be responsible for testing clinical and environmental specimens and engaging them in the emergency planning process;
- developing template laboratory investigation plans for use in outbreaks, agreeing in advance details such as the number of cases to test to confirm the cause of an outbreak or the number and types of environmental specimens to collect for different types of WRID outbreaks;
- ensuring that the laboratories have all the necessary equipment, reagents and other consumables needed to provide testing in an outbreak, or that they can rapidly access them in the event of an outbreak; and
- ensuring that laboratory personnel are trained on all analytical procedures and procedures specific to outbreak response, such as ID allocation and reporting of results to the RRT.

Contingency and control plans for public water supplies should be prepared, including plans for terminating the supply of tap water and replacing it with another source, and implementing alternative treatment of the water supply.

Critical customers, such as hospitals, that will need a secure supply and the earliest restoration of service, should be identified in advance.

Protocols for the provision of emergency water supplies may include accessing back-up water supplies, mutual aid agreements with neighbouring supplies, bulk supply using water tankers or the provision of bottled water. Available resources to ensure supply of the minimum requirement of water should be available.

A communication plan should cover:

- provision of a list of the key actors (agencies, institutions and stakeholders) with communication focal points for each agency involved in the response, and a communications lead and deputy lead for the RRT;
- processes for internal communication within agencies, such as reporting procedures within the public health agency or health ministry;
- processes for communication among the agencies, institutions and stakeholders involved in the outbreak response;
- procedures for communicating with the media and the public that include:
 - ensuring all communication leads and spokespersons receive media training;
 - developing a template communication plan that can be adapted for different outbreak and emergency scenarios and which includes predeveloped and approved advisories (such as boil water notices) and predefined public health messages (including those advising the public to switch to a safe alternative source of water) tailored to different audiences, with stakeholders such as water providers and municipal authorities engaged in the development of the messages;
 - working to strengthen relationships with stakeholders, the media and the public to promote trust in the event of an outbreak; and
 - pre-testing public health messages extensively in the community, especially in high-risk and hard-to-reach communities.

Boil water notices

Boil water notices should be prepared as an integral part of contingency planning. The WHO guidelines for drinking-water quality (8) recommend that a protocol for the issuance of boil water notices be developed. This could include:

- the criteria and process for issuing and revoking notices (boil water notices may be issued in the event of: considerable deterioration in source-water quality; treatment failures; breaches to the integrity of the distribution system; inadequate disinfection; detection of pathogens or faecal indicators in drinking-water; and evidence of an outbreak associated with the drinking-water supply);
- the information to be provided to the general public and specific groups, including those at high risk of disease or severe outcomes of disease for specific WRIDs, such as *Legionella* – examples include people on immunosuppressive therapy, elderly people and those with underlying comorbidities such as chronic obstructive pulmonary disease; and
- the mechanisms for the communication of boil water notices.

The drinking-water guidelines recommend that the notice should include:

- a description of the problem;
- possible health risks and symptoms;
- activities that are affected, such as consumption, food preparation, bathing and laundry;
- current investigation and control measures;
- the expected timescale to resolve the problem;
- information that the water can be made safe by bringing it to a rolling boil and then allowing it to cool down on its own, without the addition of ice – this procedure is effective at all altitudes and can be used with turbid water; and
- information that unboiled water cannot be used for drinking, preparing cold drinks,

making ice, preparing or washing food or brushing teeth, but usually is safe for bathing and washing clothes unless it is heavily contaminated.

The notice may include specific advice for vulnerable groups, such as pregnant women or people who are immunocompromised, and for health-care facilities (including dental practices, dialysis centres and inpatient and outpatient facilities), childcare facilities, schools, long-term care facilities and nursing homes, the food industry, the pharmaceutical industry and operators of public pools and spas.

Boil water notices can be revoked when:

- the safety of the drinking-water supply has been secured by restoring the quality of the source water;
- failures in the treatment or distribution systems or with disinfection processes have been resolved;
- there is evidence that microbial contamination has been removed or inactivated; and
- the epidemiological data suggest that the outbreak is over.

Information regarding the revocation of boil water notices is usually disseminated through the same channels deployed to issue the notice.

A basic template boil water notice is provided in Annex 3. This can be adapted by countries for use at local level. In addition, the CDC has developed a toolbox to support the issuance of boil water notices (70).

Revising and updating emergency response plans

The response to the outbreak ideally would be evaluated after each outbreak, as discussed in the next chapter. Based on this review, it may be necessary to update the contingency plan to reflect lessons learned from the outbreak, including the possible regulatory consequences and consequences for risk management.

Contingency plans ideally will be reviewed and updated periodically (every five years, for instance).

Steps in outbreak management

The management response to an outbreak will vary from outbreak to outbreak and will reflect the size, complexity and potential public health, social, economic and political impact of the outbreak. Detection of an outbreak triggers a multifaceted response involving:

- investigation of the outbreak;
- implementation of control measures; and
- ongoing communication to stakeholders and the public.

This guidance document uses the 10-step approach for outbreak management (Box 4).

Outbreak management is not a linear process. The steps are conducted simultaneously and in parallel throughout the process (Fig. 9). In particular, control measures are implemented as early as possible in the response and as needed throughout the response, and communication is conducted on an ongoing basis.

The steps of outbreak investigation have been described in detail elsewhere. Consequently, this chapter provides only a brief overview of the general aspects on each step involved in managing an outbreak and highlights specific factors that are important in the investigation of WRID outbreaks. Each step is illustrated with a case study. For a further in-depth explanation of the steps, the following sources can be consulted:

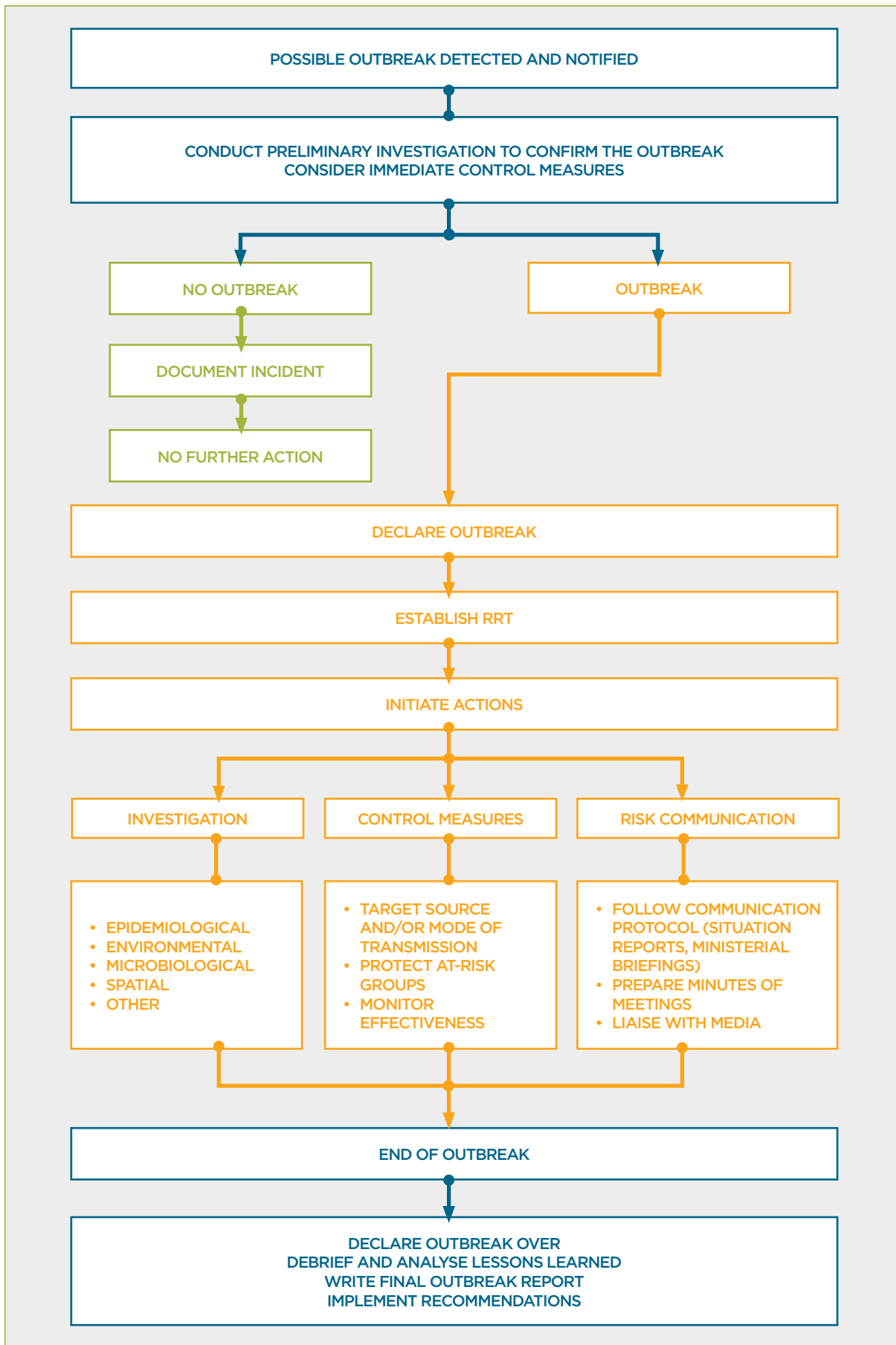
- the WHO guidelines for investigation and control of foodborne disease outbreaks (65);
- the WHO *Strengthening surveillance of and response to foodborne diseases* report (24);

- technical guidance on water-related disease surveillance from the WHO Regional Office for Europe (4);
- European Programme for Intervention Epidemiology Training's field epidemiology manual Wiki, Lecture 03 on outbreak investigations (26);
- the third edition of the CDC's *Principles of epidemiology in public health practice. An introduction to applied epidemiology and biostatistics* (25); and
- Public Health England's operational guidance on communicable disease outbreak management (66).

Box 4. The 10-step approach for outbreak management

1. Detect and confirm the existence of the outbreak and confirm the causative agent
2. Form the RRT
3. Define cases
4. Identify cases and obtain information
5. Conduct a descriptive epidemiological investigation (time, place, person)
6. Conduct additional studies and collect additional information (environmental, risk assessments, laboratory)
7. Interview cases and generate hypotheses
8. Evaluate the hypotheses
9. Inform risk managers and implement control measures
10. Communicate findings, make recommendations and evaluate the outbreak response

Fig. 9. Overall process for the management of outbreaks



Source: adapted from Public Health England (66).

Step 1. Detect and confirm the existence of the outbreak and confirm the causative agent

Outbreaks can be detected in varying ways (Fig. 10). Health authorities will need to verify that the outbreak is real by conducting a preliminary investigation to assess whether cases are linked by person, place and time. They will also need to identify and confirm the pathogen that is causing illness among cases. This is done by characterizing the clinical features of the illness and taking additional specimens to isolate the causative agent in the outbreak.

Identifying the pathogen may help to:

- develop a hypothesis about the source based on previous events and known reservoirs;
- identify the most likely time of exposure based on the incubation period; and
- choose control measures to prevent secondary transmission from the cases.

Once the outbreak is confirmed, it is recommended that a rapid risk assessment

be conducted to assess whether there is an ongoing risk to public health. Detailed guidance on how to conduct a risk assessment is available (71) (Annex 2).

Based on the results of the rapid risk assessment, the relevant authorities may decide to take immediate action and to declare the outbreak.

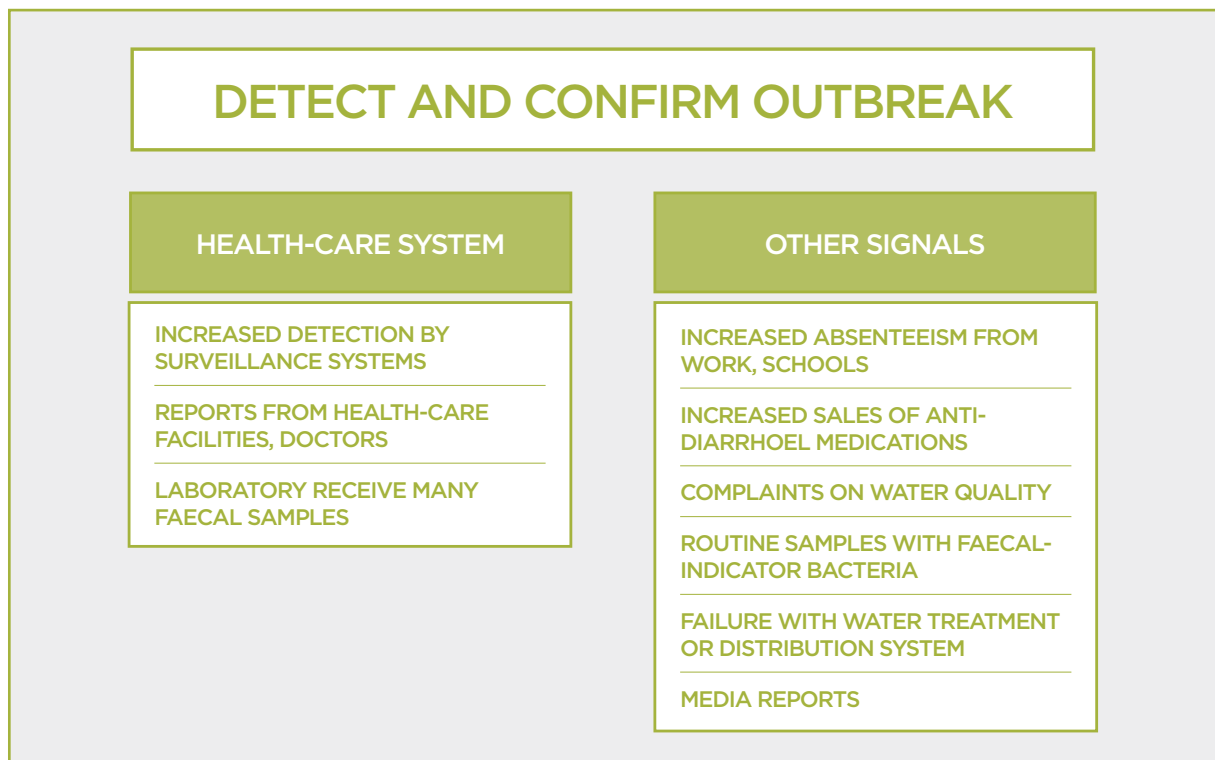
Special considerations for WRID outbreaks

If water is suspected as the source, the drinking-water service provider should be contacted to find out about any recent events relating to the water supply and check if other geographical areas are also experiencing an increase in cases.

Immediate precautionary control measures should be implemented to prevent further cases, even before the outbreak and source is confirmed.

Once the outbreak is confirmed, relevant stakeholders such as public health agencies (if detected at local level, the local public health

Fig. 10. Signals for WRID outbreak detection



agency will report to national level; if detected at national level, the national public health agency will report to local level), environmental health agencies/state sanitary inspectorates, environment agencies, water providers and municipal authorities should be contacted and informed.

A decision on whether water and environmental specimens need to be collected should be made. If so, the sampling locations, number and types of samples to be located, indicators to be tested, and sampling and testing methodology, including the needed equipment and materials, should be defined. For waterborne disease outbreaks, source waters, drinking-water sources, water stored in households or other water sources to which cases were commonly exposed should be sampled.

Consideration should be given to whether additional specialized laboratory analyses would help to strengthen the evidence of

either the diagnosis or the link between cases and possible sources of the outbreak. Confirmatory testing in a reference laboratory, with DNA, chemical or biological fingerprinting, or polymerase chain reaction (PCR), may be considered.

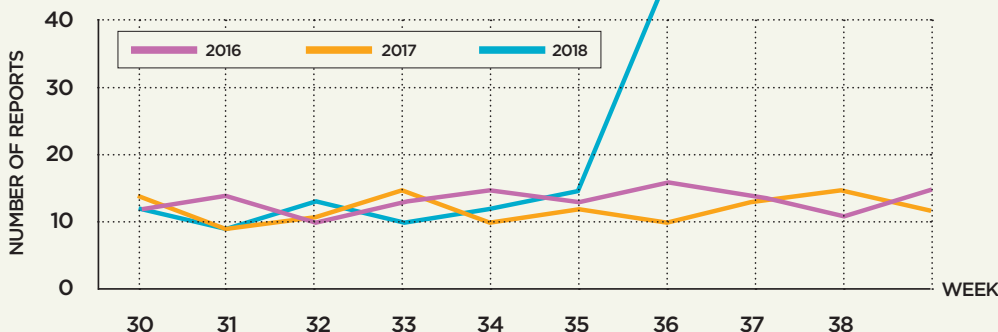
Even if an outbreak is detected, substantial time may have elapsed between the water being contaminated and the outbreak being detected, especially for illnesses such as cryptosporidiosis, giardiasis and hepatitis A, which have lengthy incubation periods. The longer the delay in outbreak detection, the lower the probability of detecting the causative agent in clinical and environmental specimens. Delays in outbreak detection may also reduce the quality of data collected during the epidemiological and environmental investigations due to declining accuracy of recall on the events at the time of exposure and illness. Water and environmental samples from the time period under investigation may no longer be available.

Outbreak case study: step 1

On Wednesday 12 September (week 37), during routine analyses of surveillance data, the principal epidemiologist of the FWD team of the NPHA notices a three-fold increase in the number of reports of AGI from the Mountain district of Laguna for week 36. The number of cases far exceeds that seen in previous years, even accounting for seasonality of infection, and exceeds the outbreak detection threshold for AGI (Fig. CS2).

Preliminary analysis reveals that most cases have been reported from the town of Waterfall. Waterfall, the municipal capital of the Mountain district, has a population of 136 000.

Fig. CS2. Reports of AGI, Mountain district of Laguna, 2016–2018



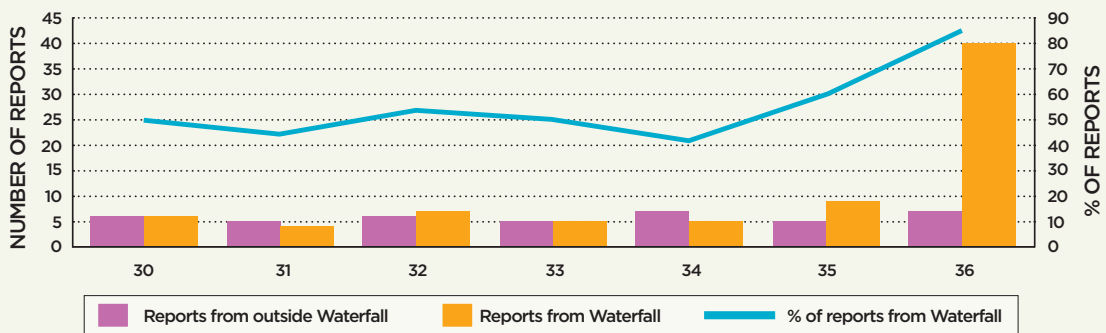
Outbreak case study: step 1 contd

The next day (Thursday 13 September), the epidemiologist interviews five cases, including two severely ill cases admitted to the university hospital. The epidemiologist arranges for stool specimens to be taken from all five cases and for these to be priority screened for a full range of enteric pathogens, including viruses and parasites. There are no obvious common exposures or direct links between the cases, such as eating at a particular restaurant or common place of work. Given the clustering of cases in time and place, and the common presentation of symptoms among cases, the epidemiologist suspects an outbreak of an enteric pathogen with either a food or water source.

There has been recent heavy rains and flooding in Mountain district (week 34). Given this and the absence of a direct link between cases, the epidemiologist contacts the municipal water authority to ask if there have been any recent issues with the water-supply system. They report an exceedance of acceptable turbidity levels in two samples taken from the distribution system of the municipal water supply in the western zone of the city on 21 and 23 August. Given their correlation with the increase in reported cases of AGI, both in time and place, the epidemiologist suspects that the municipal water supply could be a potential source of the outbreak.

Forty cases of AGI are reported from Waterfall in week 36 (Fig. CS3), compared to nine in the previous week. Normally, reports from Waterfall account for about half of all reports of AGI from the Mountain district, but in week 36, they account for almost 90% of cases. There was also a slight increase in the number and percentage of reports from Waterfall in the previous week which may have coincided with the start of the outbreak. Syndromic surveillance data for week 37 are not yet available.

Fig. CS3. Number and percentage of AGI reports from Waterfall compared to the rest of the Mountain district, weeks 30–36



Of the 12 cases for whom data are available, most report profuse watery diarrhoea and abdominal cramping, with symptom onset from 27 August onwards.

The district epidemiologist conducts a rapid risk assessment to assess the likelihood of further transmission and the potential consequences to public health. The epidemiologist considers the risk to be high, declares the outbreak and notifies the district Director of Public Health, the FWD team lead at the NPHA and the municipal water authority.

Step 2. Form the RRT

Ideally, a multidisciplinary RRT will be formed to provide the necessary expertise and human resources to investigate the outbreak and provide a coordinated response.

Special considerations for WRID outbreaks

The management of WRID outbreaks requires a multisectoral and interdisciplinary response involving public and environmental

health agencies, water providers and municipal authorities, and clinical, laboratory, epidemiological, hygiene, environmental, engineering and communication experts, among others.

The RRT will include stakeholders who play distinct and active roles in the investigation, response and management of the outbreak.

- Local or regional public health agencies will lead the overall coordination of the investigation and response to the outbreak. The national level may provide technical support if needed, especially for complex analyses such as analytical epidemiological studies or spatial analyses.
- Food and water authorities or local public health or environment agencies will usually lead and coordinate the environmental investigation and control activities.
- Water suppliers will play an active role in implementing control measures targeting the water-supply system proposed by the public health agency.
- Health-care providers are responsible for identifying and reporting cases and will lead on case management and the implementation of health-related interventions, such as vaccination (for

outbreaks of hepatitis A or typhoid, for instance).

- Laboratories test clinical and environmental samples collected during the outbreak and report cases. National reference laboratories may undertake testing if testing capacity for a particular pathogen is not available at local level, or may be enlisted to confirm local laboratories' findings. They may also equip and train local health protection authorities on the collection of specimens. Laboratory capacity for testing environmental waterborne pathogens such as *Cryptosporidium*, *Giardia* or *Norovirus* are needed. The capacity needed to test such pathogens may differ to that needed to identify them in clinical specimens.

Coordinating activities across agencies and stakeholders can be complicated. It usually necessitates clearly defining roles and responsibilities and procedures for engagement, and developing processes for clear communication and reporting. To support this, it is advisable to develop terms of reference to guide the actions of the RRT, an outbreak plan to guide the conduct of the investigation, a laboratory plan to guide human and environmental specimen collection and testing, and a communications plan.

Outbreak case study: step 2

On Friday 14 September, the District Director of Public Health convenes an RRT. The team meets and agrees the objectives of the investigation and the roles and responsibilities of team members. The RRT develops a plan for investigating the outbreak. The RRT agrees the following immediate actions:

1. implement immediate control measures;
2. start active case finding (step 4) by:
 - enhancing surveillance for AGI by notifying all health facilities in the town and requesting that they report syndromic surveillance data daily until further notice;
 - maintaining a list of data (otherwise known as a line list) on all cases of AGI reported from Waterfall in weeks 35 and 36 and until the outbreak is declared over;
 - collecting additional epidemiological data on a subset of these cases to generate hypotheses on the cause and source of the outbreak; and
3. undertake an environmental risk assessment and microbiological investigation of the town water supply (step 6: additional studies).

In accordance with contingency plans, the Director of Public Health and the water authority jointly issue a precautionary boil water notice that is disseminated via mainstream and social media (step 9: implement control measures).

Step 3. Define cases

To identify people who are part of the outbreak, it is helpful to define criteria (person, place, time and clinical diagnosis) by which those who are part of the outbreak can be classified as a case. Cases can be defined as suspect/possible, probable and confirmed.

Outbreak case study: step 3

The causative agent of the outbreak is unknown and there is no clearly identifiable index case for the outbreak. There is insufficient information to define the exposure period. Consequently, at this early stage of the investigation, the RRT decides to include a long potential exposure period to maximize case ascertainment.

The RRT agrees the following preliminary possible case definition:

“A person who lives in the town of Waterfall, with diarrhoea (≥ 3 loose stools in 24 hours) and any one of the following symptoms – abdominal pain, nausea and vomiting – and date of onset of symptoms from 1 August 2018.”

Special consideration for WRID outbreaks

It is common to develop a number of case definitions with varying sensitivity and specificity, including definitions for suspect/possible, probable and confirmed cases, to allow for uncertainty in the clinical diagnosis and provide flexibility, particularly if there is likely to be a delay in obtaining laboratory confirmation of the disease or if laboratory testing of all cases is not warranted. Case definitions can be revised during the outbreak as more data become available.

Step 4. Identify cases and obtain information

This step involves identifying as many cases affected by the outbreak as possible to:

- implement control measures to prevent cases (especially asymptomatic) from further spreading the infection and further propagating the outbreak;
- facilitate the treatment of cases, especially for outbreaks of organisms that are difficult to diagnose but which have severe clinical sequelae; and
- assess the size of the outbreak so that adequate resources can be deployed to control it and the cost and impact of the outbreak can be estimated.

Active case-finding may involve searching for symptomatic people who meet the case definitions for the outbreak, or contact-tracing (searching for) contacts of known cases for testing or ongoing follow up to see if they develop the disease.

Special considerations for WRID outbreaks

A questionnaire can be used to collect data on cases, including clinical and risk-factor data and data on their demographic characteristics. For waterborne outbreaks, it is especially important to collect geographical data on possible places of exposure to different water sources, such as place of residence, work or study, which may be risk factors for infection.

If the causative agent is known, the questionnaire can include (but not be limited to) exposures and risk factors known to be associated with the particular pathogen.

The known incubation period for a particular pathogen will enable a likely period of exposure to be calculated. The questionnaire can focus on this exposure period.

If the causative agent is unknown but the clinical presentation indicates a short incubation period, the questionnaire can focus on exposures during the 72 hours prior to onset of illness.

A phone survey of a random sample of the population in different water-supply areas can be a quick way to identify cases and estimate attack rates by water-supply area

Some waterborne pathogens, such as *Noravirus*, are also easily spread by person-to-person transmission. Consequently, secondary

cases who have been infected by contact with a primary case rather than the contaminated water source are common. These secondary cases can complicate the containment of the outbreak and the epidemiological investigation. Control measures needed for secondary cases and sources of transmission may differ to those for the primary outbreak.

Outbreak case study: step 4

On Saturday 15 September, the district epidemiologist visits all the health facilities in Waterfall that reported cases of AGI in weeks 35 and 36 to collect line-list data on the outstanding reported cases. The earliest identified possible case dates from 27 August.

On Sunday 16 September, the regional laboratory confirms that two of the five initially tested cases have tested positive for *Cryptosporidium parvum*. The other three specimens are inconclusive.

Cryptosporidium is a parasitic infection that causes profuse watery diarrhoea. Diarrhoea is associated with cramping and abdominal pain. Transmission is by faecal-oral spread and may include person-to-person transmission, as well as water and foodborne transmission. *Cryptosporidium* has been associated with a number of large outbreaks in public water supplies. The exact incubation period is unknown but is considered to average seven days, with a range of 1-12 twelve days. Oocysts can be shed in stools for several weeks after symptoms resolve and may remain infective in water for 2-6 months.

The RRT requests that the laboratory characterises the specimens to assess if they are genetically identical (step 6: additional studies).

In light of the laboratory data, the RRT considers that *Cryptosporidium* is likely to be the cause of the outbreak. The RRT enhances *Cryptosporidium* laboratory surveillance by requesting that all specimens routinely collected from AGI cases in Waterfall be tested for *Cryptosporidium* until further notice, and that the laboratory starts daily reporting of *Cryptosporidium* cases (step 4: active case-finding).

The RRT requests that samples taken as part of the microbiological investigation of the water system be tested for *Cryptosporidium*. The investigators will also endeavour to take specimens such as bottled water and ice samples for microbiological investigation from the homes of those interviewed during the epidemiological investigation.

The RRT updates the case definitions for the outbreak (step 3: define cases):

“Probable case: a person who lives in the town of Waterfall, with diarrhoea (≥ 3 loose stools in 24 hours) and any one of the following symptoms – abdominal pain, nausea, vomiting, anorexia – and date of onset of symptoms from 15 August 2018.

Confirmed case: a person who lives in the town of Waterfall, with laboratory-confirmed cryptosporidiosis and onset of symptoms from 15 August 2018.”

Step 5. Conduct a descriptive epidemiological investigation (time, place, person)

Data collected during the outbreak usually are analysed by time, place and person as soon as possible after the outbreak is reported, and on an ongoing basis throughout the investigation as more data become available. Data are analysed to:

- describe the outbreak in relation to the affected population (person), the geographic distribution of the outbreak (place) and the duration and temporal characteristics of the outbreak (time);
- identify the population at risk of infection;
- estimate when the initial exposure to the causative pathogen occurred;
- generate and verify hypotheses on the possible source, aetiology and modes of transmission of the outbreak (by examining differences in exposures); and
- identify opportunities for control of the outbreak.

Special considerations for WRID outbreaks

The distribution of cases should be mapped to assess the geographical extent of the outbreak and identify potential sources. A cluster of cases might suggest exposure to a particular local source, such as a well, while widely dispersed cases might suggest a disseminated source, such as a public water supply. Attack rates should be calculated by exposure to particular water sources and by place.

If possible, geographical information systems and computer-modelling should be used to visualize and explore the spatial distribution of cases in relation to suspect sources, investigate clusters and model the spatial dispersion of potential contaminants in a water-supply system.

The shape of the epidemic curve can indicate the type of source (single, continuous or intermittent common-point source) or the mode of transmission (person-to-person), the time period of exposure to the causative agent and the minimum, maximum and mean incubation periods for the disease. Common source outbreaks (with point, continuous or intermittent exposure), such as those associated with a single water supply (or cooling tower for *Legionella* outbreaks), are most common for water-related outbreaks associated with water-supply systems. Further information on types of outbreaks and the interpretation of epidemic curves is available from the WHO guidelines for investigation and control of foodborne disease outbreaks (65).

The epidemic curve can indicate when the outbreak started and if it already has ended or is still ongoing. If the causative agent is known, the epidemic curve can be used to estimate the likely time period of exposure and focus the environmental investigation (step 6) on that time period. Assessment should be made to determine if the epidemic curve correlates with events in the water-supply system and implementation of control measures.

It should be established if any cases secondary to the primary outbreak have occurred, as secondary infection can arise through person-to-person transmission or transmission in food.

Outbreak case study: step 5

By the end of week 37, a further 118 cases of AGI have been reported from Waterfall under the routine syndromic surveillance system (Fig. CS4). Of these, 96 meet the probable case definition, and two are confirmed cases (Fig. CS5). Due to media attention, there has been a surge in people accessing health services with symptoms of AGI.

Fig. CS4. Number and percentage of AGI reports from Waterfall, weeks 30–37

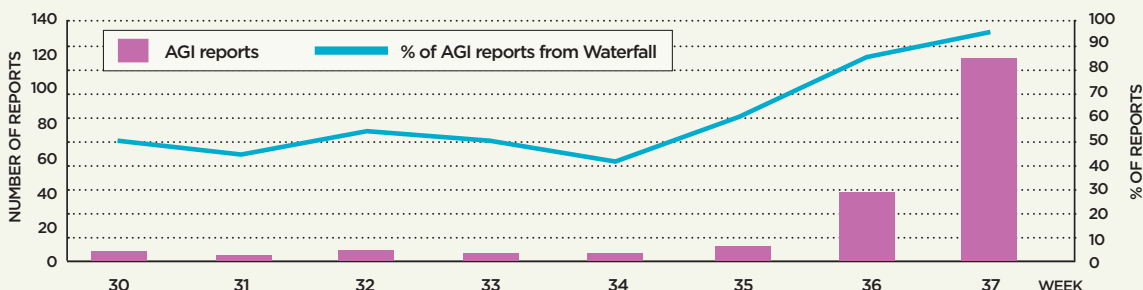
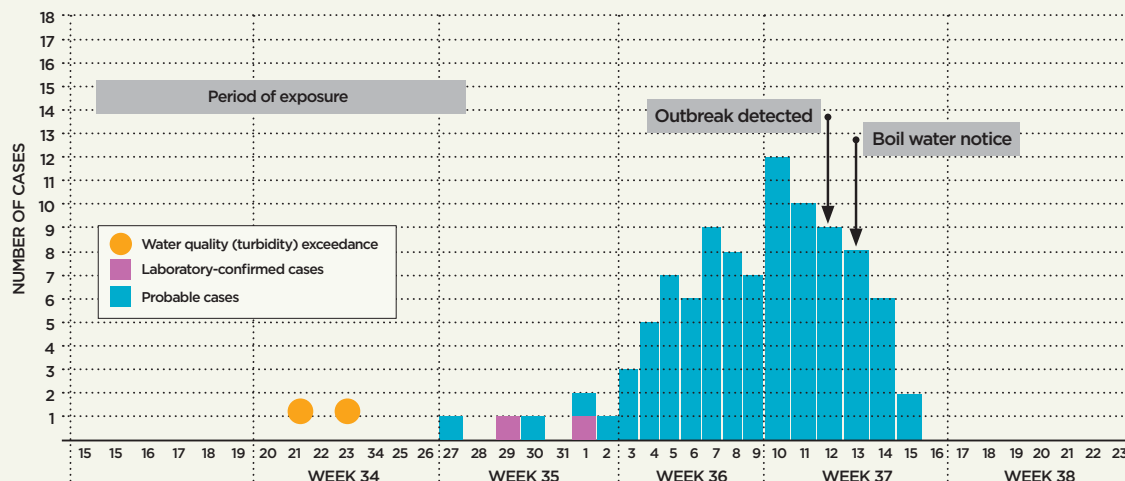


Fig. CS5. Probable and confirmed cases of *Cryptosporidium*, Waterfall, by date of onset of symptoms, weeks 35–37



The first identified case dates from 27 August, so the likely period of exposure is from 15–26 August. The epidemic curve (Fig. CS5) is characteristic of a continuous common source outbreak.

The percentage of cases is slightly higher in women and is highest in those aged 25–44 years, followed by those aged 15–25 years (Table CS3). All cases have diarrhoea (as per the case definition) and 80% of cases report abdominal pain. Nine per cent of cases have been hospitalized.

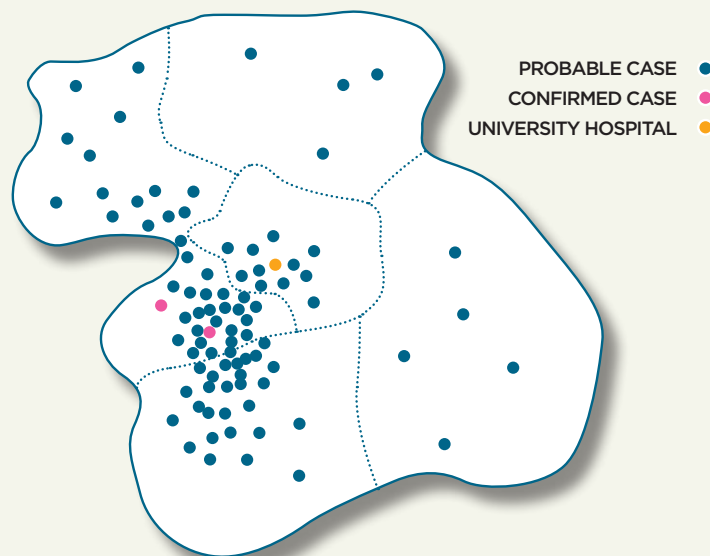
Waterfall is divided into five geographic zones: the city centre and a northern, southern, eastern and western zone. A dot map of cases (Fig. CS6) reveals considerable clustering of cases in the western and southern zones of the city.

Outbreak case study: step 5 contd

Table CS3. Characteristics of cases in an outbreak of *Cryptosporidium*, Waterfall, weeks 35–37

Characteristic		Number (% of all cases)	
Case classification	Confirmed	2	(2)
	Probable	96	(98)
Sex	Female	52	(53)
	Male	46	(47)
Age group	0–4	11	(11)
	5–14	10	(10)
	15–24	21	(22)
	25–44	28	(29)
	45–64	17	(17)
	≥ 65	11	(11)
Symptoms	Diarrhoea	98	(100)
	Abdominal pain	78	(80)
	Nausea	47	(48)
	Vomiting	36	(37)
	Anorexia	43	(44)
	Hospitalized	14	(9)

Fig. CS6. Map of probable and confirmed cases of cryptosporidiosis, Waterfall, weeks 35–37



Over 50% of all cases are resident in the western zone, followed by almost 30% in the southern zone and 11% in the city centre. Few cases have been reported from the northern and eastern zones of the city. The attack rate in the western zone is 1.6 times higher than in the southern, twice that in the city centre, eight times that in the eastern zone and 16 times that in the northern. The western and southern zones are the most heavily affected by the outbreak (Table CS4).

Table CS4. Case distribution and attack rate by residential zone

Residential zone	Number of cases	Percentage of cases	Total population	Attack rate (number of cases per 10 000 residents)
City centre	11	11	13 750	8
Western zone	50	51	32 125	16
Southern zone	28	29	28 540	10
Eastern zone	5	5	24 672	2
Northern zone	4	4	36 913	1

Step 6. Conduct additional studies and collect additional information (environmental, laboratory)

Environmental and laboratory (microbiological) investigations should be conducted in parallel with the epidemiological investigation. These investigations generate further information on the suspected sources of the outbreak or related vehicles of transmission and support results from the epidemiological investigation. The RRT will try to identify circumstances that may have led to a suspected source causing the outbreak and isolate the causative agent from the suspected source or vehicle. The characteristics and geographical distribution of cases, the timing of the outbreak and evidence relating to the causative agent may help to narrow the focus of the investigation to specific potential sources and vehicles of transmission.

Special considerations for WRID outbreaks

If the pathogen is known, the investigation can focus on known sources and conditions that allow the pathogen to survive and reproduce. If the outbreak is caused by a pathogen that may be waterborne, the RRT may start to investigate possible failures in the drinking-water supply system that could be the source of the outbreak.

Spatial investigations can help with the identification of potential sources if the preliminary evidence does not point to a particular source.

For the environmental investigation of outbreaks suspected to be associated with drinking-water supply systems, the RRT, in close cooperation with the water service provider, will launch an investigation of the water-supply system to identify and assess any possible incident that may have caused faecal contamination of drinking-water. Depending on the circumstances, this may

require a qualified environmental specialist, engineer, environmental health specialist or microbiologist to support the investigation.

The objective of the environmental risk assessment is to identify the cause of contamination of the water-supply system. This includes an evaluation of the appropriateness and effectiveness of existing control measures along the drinking-water supply chain (in source-water protection, water treatment, disinfection, storage and distribution), including possible failures and incidents that may have compromised system safety.

In settings where the water service provider has established a functional WSP, the environmental risk assessment ideally will capitalize on its findings. In accordance with the WSP principles (72), the assessment of the water-supply system entails the following aspects.

1. If not already available, a schematic flow diagram of the water-supply system should be developed. Basic information can be obtained on the water source, abstraction points, treatment processes (if applied), storage tanks and distribution network. An important element of the system description is a characterization of the source of the water, including runoff and recharge processes, and details of land use in the catchment, such as location of sewage treatment plants, septic tanks, industry and other potential contamination sources. The flow diagram and the system description support the search for system deficiencies and contamination events.
2. A rapid system assessment should be carried out. Any possible hazardous event that might introduce contamination (see Table 2 for examples of such events) should be identified for each step in the water-supply system, and an assessment made of whether appropriate control

measures are in place. In doing so, the following steps should be considered:

- interview water-supply system personnel about any possible deficiencies and events in the period before the outbreak of which they may be aware;
- in non-piped systems, investigate water collection, transport, storage and handling practices by community household members, including hygiene aspects;
- review the outcomes of sanitary surveys conducted by regulatory agencies and water-service providers; if they do not exist, undertake rapid on-site sanitary surveys of key system components to investigate the condition of the system and identify deficiencies that may compromise the integrity of infrastructure and therefore provide contamination pathways;
- collate and assess water-quality information to track unexpected changes to water quality preceding the outbreak; this step enables the identification of hazardous events at different points in the water-supply system, and includes checking data from regulatory compliance monitoring (such as on the presence of faecal indicators like *E. coli*) and operational parameters (turbidity, disinfectant levels and pH, for instance) that may indicate spikes or rapid changes in source-water and/or drinking-water quality, which may signal possible contamination events or suboptimal treatment performance;
- obtain weather records of events (such as torrential rain, snow thaw and drought) that could have triggered ingress of faecal matter into the system;
- analyse operational records to identify possible problems in operations that may have compromised the functioning and effectiveness of control measures – treatment failures may also be documented in incident reports and operational logs maintained by the water provider;
- review customer complaint reports that may provide information on the geographic location and nature of problems;
- use maps to detail the location of potential exposures of interest, such as the water-supply system, in relation to the location of cases:
 - spatial analyses can be used to measure the distance between cases and suspected sources or risk factors for infection, and the data can be integrated with additional data such as those on flooding to generate or strengthen the evidence implicating a suspected source (a particular reservoir or water source, for instance);
 - attack rates can be calculated by increasing distance from one or several suspected sources to generate evidence on any possible dose-response effect associated with increasing proximity to the source (73);
 - cluster and regression analyses can be used to formally test hypotheses related to the spatial distribution of cases and their association with particular sources;
- use, where indicated and if possible, additional tools such as environmental risk mapping to investigate the relationship between specific variables (exposures) and risk of disease;
- use computer modelling to model the diffusion of a pathogen through the water-supply system to identify areas that are likely to have been exposed to a particular contaminant introduced from a particular common source, or to identify the common source; these techniques can inform where to target control measures and may also help to identify areas at risk of future outbreaks; and
- verify whether any staff working with the suspected water source became ill and, if so, did they have direct contact with the source.

Laboratory investigation of the water-supply system can:

- provide convincing evidence on the link between the source of the outbreak and cases;
- help to identify the cause of the outbreak where this otherwise is unknown; and
- identify the failure in the water-supply system that led to the outbreak.

It is still possible to demonstrate that water is the source of an outbreak even if the causative agent is not isolated from the water-supply system. If resources allow, and if a laboratory investigation can be launched quickly, an attempt should be made to isolate the causative agent from the system.

The scope of the laboratory investigation will depend to a large degree on the availability of qualified personnel and laboratory resources and is likely to require the support of national or regional reference laboratories with expertise in the detection of water-related microorganisms. Guidance on sampling and analysis for microbiological investigations is given in the WHO guidelines on drinking-water quality (8) and in the WHO/Organisation for Economic Development and Co-operation document *Assessing microbial safety of drinking water* (9).

If a water supply is suspected as the source of an outbreak, sampling of the supply may be enhanced to identify the system failure that led to the outbreak and to try to isolate the causative agent from the water supply. Isolating the causative agent from the water supply and demonstrating that it is the same organism that caused disease in cases provides some of the strongest evidence that the water system is the source of the outbreak, especially if the two isolates genetically are identical.

Enhanced sampling may include:

- increasing the frequency of sampling from the normal sampling sites to detect

temporary changes in water quality; this may especially be useful for small supply systems that are sampled less frequently than larger supplies; and

- increasing the number of sampling sites in the system to detect localized problems within the system, and to increase the chance of detecting temporary changes in water quality; the results of the rapid risk assessment can indicate where additional sampling should be targeted.

Sampling can be extended to include:

- suspected sources of pollution within the catchment area, such as livestock, septic tanks or leaking sewers;
- source-water sampling, including sediment from storage reservoirs and decommissioned wells;
- critical points in the treatment plant, such as backwash from filter beds;
- water and sediment from different points in the distribution system, such as service reservoirs, pipelines and consumer taps; and
- stored water, such as water stored in household containers, bottles in customers' fridges, ice or filters.

Extending microbiological analyses beyond the routinely conducted monitoring of faecal indicators for water-quality assessment may target evaluation of different parts of the water-supply system. Testing for more persistent bacteria such as *Clostridium perfringens* or aerobic spore-forming bacteria could be conducted to assess the effectiveness of disinfection.

The recovery of microorganisms from water-supply systems is often unsuccessful, even when there is strong epidemiological evidence implicating the water supply as the source of the outbreak. Microorganisms may not be detected in the water-supply system for a number of reasons, including:

- a substantial amount of time may have elapsed between the contamination event,

exposure of cases to the contaminant and the time when samples are actually taken; if the contamination of the system is transient, the likelihood of detecting the causative agent is very low;

- once the water supply is suspected as the source of the outbreak, a superdisinfection of the system may rapidly be performed as a preliminary measure to contain the outbreak; any microorganisms still circulating in the system will be destroyed, unless they are resistant to the disinfectant;
- the persistence of the causative agent in the water environment will influence the likelihood of its detection, as will the detection methods used; and
- very large sample volumes of up to 1000 L may be needed, particularly if trying to isolate enteric viruses or protozoa; special sampling equipment may be needed.

Sampling of the water system should therefore be done as soon as possible and samples should be analysed for a broad spectrum of organisms. In the event of contamination of water-supply systems with wastewater or sewage, the system may be contaminated with multiple pathogens; it

may be that the pathogens detected will therefore not correspond with the causative agent identified in the outbreak. In this case, there will be evidence of water contamination but no direct link between the contamination and the disease under investigation.

In addition to trying to isolate the suspected causative agent, additional monitoring of faecal indicators may be conducted to assess whether faecal contamination of the supply may be ongoing.

Molecular techniques, such as PCR, cell culture pulse field gel electrophoresis and multilocus sequence testing, can greatly increase the possibility of detecting pathogens, especially viruses, from water. PCR enables rapid detection, while cell culture is more sensitive for the detection of viruses when the levels of virus particles in sampled water are low. Ideally, these two techniques should be combined. In situ hybridization and species-specific probes enable the rapid detection and identification of bacteria during field investigations. Microarrays enable the screening of water samples for multiple pathogens so may be particularly useful when the causative agent of an outbreak is unknown.

Outbreak case study: step 6

The district environmental health officer, sanitary engineer from the municipal water authority and the water-quality and safety officer from the EPA undertake an onsite sanitary inspection, an environmental risk assessment and a microbiological investigation of the water-supply system.

The team describes the entire water-supply system, including the local hydrogeology, the water source, water treatment plants and water-distribution system using data provided by the municipal water authority and the EPA and data obtained from site visits, physical investigations and review of the WSP for the system. They identify potential hazardous events and associated microbial hazards and investigate possible sources of contamination in the catchment area, including sewage contamination and contamination from grazing livestock. They review water-quality data on turbidity, residual chlorine and *E. coli* counts, as well as maintenance records for the system since 15 August. The EPA provided information on rainfall statistics and the municipal authority supplied data on flood warnings during the same time period.

Waterfall is served by two separate water supplies. The northern and eastern zones of the city are served by water from a groundwater source to the north of the city (water supply 1, WS1). The western and southern zones are served by water from Moon Lake to the west of the city (water supply 2, WS2). The city centre is served by both. The land surrounding both water sources is primarily used for livestock grazing, although there are also some residential developments.

Outbreak case study: step 6 contd

For WS1, water is extracted from an aquifer and piped to a reservoir. The water is chlorinated before entering the distribution system. For WS2, water is extracted from Moon Lake at a depth of 20 meters and is filtered and chlorinated before entering the distribution system. The water distribution system for WS1 has recently been upgraded and the inspection of the system did not identify any hazards. The water distribution system for WS2 is quite old, with some parts dating from the 1930s. Some of the pipes are corroded and ingress into the distribution system was identified as a risk at several points in the system. Unusually heavy rains had fallen in Waterfall between 16 and 19 August and there had been flood warnings in the city. A sewage overflow was documented by the municipal authorities on 19 August in the western district of the city.

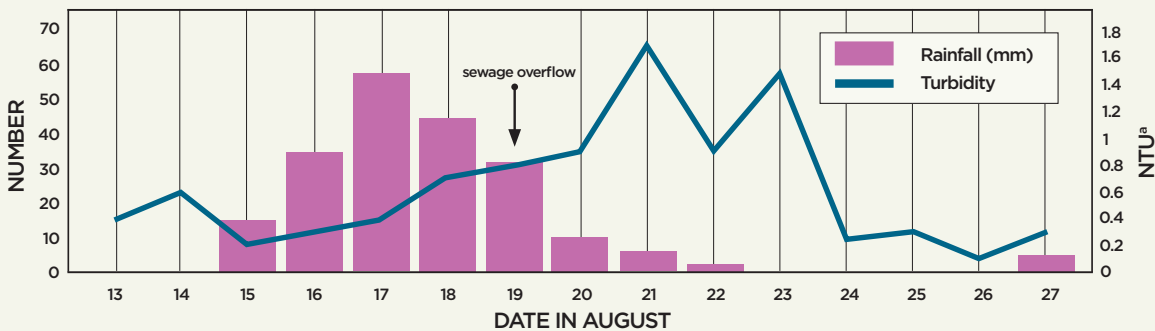
An inspection of the water supply system revealed a number of likely factors that contributed to the outbreak:

1. the heavy rains led to likely contamination of Moon Lake with animal waste runoff from surrounding pasture lands;
2. the filtration system at the water treatment plant for WS2 temporarily was breached, which likely led to contamination of the treated water with raw water; and
3. the sewage overflow may have caused an ingress of contaminated water into the WS2 water distribution system in the western district.

As part of water-quality surveillance, there is weekly testing for *E. coli* and daily monitoring for turbidity in the water-distribution system. *E. coli* were isolated from the distribution system in a sample taken on 19 August. Turbidity measurements taken on 21 and 23 August exceeded the acceptable limit of 1 nephelometric turbidity unit (Fig. CS7).

The RRT took large water samples (2000 L) from the source water, water-treatment plants, reservoirs and pumping stations, and a series of 10 L grab samples from the distribution system and fire hydrants (during flushing of the system) from locations with the highest number of cases. They also took samples from the homes of a random sample of the probable and confirmed cases. Samples were taken on Saturday 15 September, prior to flushing of the water-supply system.

Fig. CS7. Rainfall (mm) and nephelometric turbidity unit measurements taken from WS2 during the likely exposure period (15–26 August), Waterfall



^a NTU: nephelometric turbidity unit.

Cryptosporidium oocysts were isolated from Moon Lake (25 oocysts/1000 L) and from a pumping station in WS2 (65 oocysts/1000 L), as well as from a fire hydrant in the western zone (5 oocysts/10 L). All other samples, including those taken from the homes of cases, were negative. Genotyping revealed that the isolated oocysts were genotype 1.

Step 7. Interview cases and generate hypotheses

Results of the different investigations and analyses should be collated, reviewed and

interpreted to develop hypotheses. Hypothesis generation can enable the identification of potential sources of the outbreak, or high-risk groups for infection or severe disease that can immediately be targeted with control measures

to limit the spread and impact of the outbreak. Depending on the outbreak, hypotheses may address some or all of the following:

- the cause of the outbreak;
- the source of the outbreak;
- the mode (or vehicle) of transmission; and
- risk factors or exposures associated with disease.

Special considerations for WRID outbreaks

The descriptive epidemiological data, laboratory and environmental data and the circumstances surrounding the outbreak should be reviewed and the plausibility of the hypotheses assessed against these facts. If water is suspected to be the source, it should be considered the target for immediate control measures.

Outbreak case study: step 7

Based on the results of the epidemiological and environmental investigations, the RRT hypothesize that heavy rains led to contamination of WS2 and that this was the source of the outbreak. Accordingly, the RRT hypothesize that being a case was associated with:

1. residing in a residential area supplied by WS2
2. consumption of water from WS2.

Step 8. Evaluate the hypotheses

This step involves evaluating all hypotheses on the cause, source, vehicle of transmission and risk factors for infection against the available evidence to assess their plausibility and how likely they are to be true.

It is important to provide strong evidence to support any claims about the source of an outbreak, so any doubts about the source of the outbreak can be countered and targeting control measures at the source justified. Providing strong evidence is especially

important if implicating a particular source that will have economic or legal implications for the water service provider.

This step involves reviewing the descriptive epidemiological data, the laboratory and environmental data and the circumstances surrounding the outbreak and assessing the hypotheses against these facts. An RRT may choose to undertake an analytical study if the descriptive epidemiological, laboratory, environmental and other available data do not enable the identification of the source. Such a study can be conducted to generate even stronger evidence to support the hypothesis under investigation and to quantify the size and strength of the association between an exposure (such as a water source) and an outcome. The analytical studies usually used in outbreak investigations are cohort studies, case-control studies and ecological studies. Guidance on how to conduct such studies is discussed in detail in the documents detailed in the first chapter in this part (“Introduction to outbreaks”).

In cohort studies, the risk or rate of disease over a defined time period is compared among those exposed to a certain factor, such as a particular water source, versus those not exposed to the factor. If those exposed to the factor have a higher rate of disease, this provides evidence that the factor is the cause of the disease. This assumes that both groups are the same, except in terms of their exposure to the factor.

Case-control studies are observational studies in which cases (those with the health outcome of interest) are compared to non-cases (those who do not have the health outcome) to find out if there is a difference in their exposures (the factor that may be the source of the outbreak). The control group must represent the population at risk of disease and must not have the disease under investigation at the time of their recruitment. Controls represent the background level of exposure in the population. If the level of exposure is much greater among

cases than controls, this provides evidence that the exposure is associated with disease.

In ecological studies, rates of disease and their association with particular exposures are compared among defined populations or communities. They are particularly useful for outbreaks associated with environmental exposures, as environmental exposures can be difficult to characterize at individual level, and for investigating outbreaks associated with public water supplies where defined population groups are exposed to a single water supply and where it is possible to compare attack rates between those exposed to the supply with those not exposed to the supply. Associations in ecological studies relate to population level, not individual level, as the association does not reflect variations in the level of exposure between individuals. Ecological studies include time-series analyses and spatial analyses.

Special considerations for WRID outbreaks

The main exposure investigated during a suspected WRID outbreak is exposure to a particular water source. Collecting reliable data on water usage during an outbreak period can be challenging, especially if a lot of time has elapsed between the exposure period and the time of the investigation, and particularly if respondents changed their water use in response to publicity surrounding the outbreak or as part of control measures for the outbreak (in response to boil water notices, for instance). People often are exposed to more than one source of water – the source that supplies their home, and the source that supplies their place of work, for example. Within a household, children may be exposed to different water sources to adults.

When collecting data on water usage during the outbreak period, the RRT could consider variations in water use at home and outside the home, treatment of water within the home, the use of bottled and filtered water, and both the consumption of water and exposure to water from bathing and recreational activities.

If everyone in the study population is exposed to the suspected water source, it may not be possible to demonstrate an epidemiological association between exposure to a particular water source and getting ill.

In WRID outbreaks, the analysis could investigate whether the risk of illness increases with consumption of increasing amounts of water. This would require the collection of data on the volume of water consumed daily. The demonstration of a linear dose–response relationship provides even stronger evidence that water is the source of the outbreak than simply demonstrating an overall increased risk.

Sometimes a primary outbreak can cause a secondary outbreak. For instance, contamination of a municipal water supply may lead to a primary outbreak of *Salmonella Typhi* among customers. One of the cases from the outbreak may prepare food which subsequently is served at a party in an area not served by the supply. This may lead to a secondary outbreak of *Salmonella Typhi* at the party that is not associated with the water supply, but which rather is associated with the infected food handler.

These secondary cases should be analysed separately to the primary cases, as they have not been exposed to the original source of the outbreak. Including them in an investigation of a particular water supply as the source of the outbreak will reduce the power of the study. The cases therefore should be analysed separately to determine the source (or, in this case, the vehicle) of their infection, which is in fact the food item. Secondary outbreaks of gastrointestinal illness can usually be identified from the epidemic curve, as normally they occur at least one incubation period later than the primary outbreak.

An assessment of the evidence implicating a water source must consider all evidence from all steps of the investigation, including:

- the circumstances surrounding the outbreak: for instance, to determine if there was an increase in cases of *Campylobacter* following flooding or after a cluster of customer complaints to the water provider;
- descriptive epidemiological data linking cases to a potential source by person, place or time, such as clustering of cases close to a particular water source or a temporal association between an increase in cases and a known exceedance of water-quality indicators monitored through routine water-quality surveillance;
- environmental data, such as the results of the risk assessment demonstrating a failure in integrity of the distribution system that corresponds to the time of the outbreak;
- a temporal association between the introduction of a control measure and a decline in the number of cases;
- laboratory data, such as the isolation of a genetically identical organism from the water supply and cases; and
- data from the analytical epidemiological study on the statistical probability of an association between illness and the source.

laboratory confirmation from either cases or the source, clinical and epidemiological data can be used, although the strength of the evidence will be less.

It is not always possible to isolate the causative agent in an outbreak from the suspected source of the outbreak (74). Failure to isolate the causative agent from the suspected water source does not rule out the possibility that it is a WRID outbreak.

Tillett et al. (75) have proposed a classification system for assessing the strength of the evidence that an outbreak is associated with water (Table 8). The system ranks epidemiological data higher than water-quality or engineering data when assessing the strength of the evidence. An epidemiological association, paired with microbiological and environmental evidence, provides the strongest evidence that the outbreak is water-related; however, outbreaks can be classified as water-related based on epidemiological evidence alone, or based on isolation from the environment alone.

In WRID outbreaks, some of the strongest evidence on the source of an outbreak is gained by securing laboratory confirmation of the pathogen isolated from cases (supported by clinical and epidemiological data), and by linking this pathogen to an identical laboratory-confirmed agent isolated from the suspected source of the outbreak. In the absence of

Such a system can help to systematize the way in which outbreaks are classified as water-related, which can be particularly useful when trying to combine evidence from many different sources to demonstrate an association, especially given the challenges in demonstrating water definitively as the source in many outbreaks.

Table 8. Classification system for assessing the strength of the evidence linking an outbreak to water

A. Pathogen identified in clinical cases also found in water	B. Water quality failure and/or water-treatment problem of relevance, but outbreak pathogen is not detected in water
C. Evidence from an analytical (case-control or cohort) study demonstrates an association between water and illness	D. Descriptive epidemiology suggests that the outbreak is water-related and excludes obvious alternative explanations

Strongly associated if (A+C) or (A+D) or (B+C); probably associated if (B+D) or C only or A only; possibly associated if B only or D only.

Source: Tillett et al. (75) (reproduced with permission from Cambridge University Press).

Outbreak case study: step 8

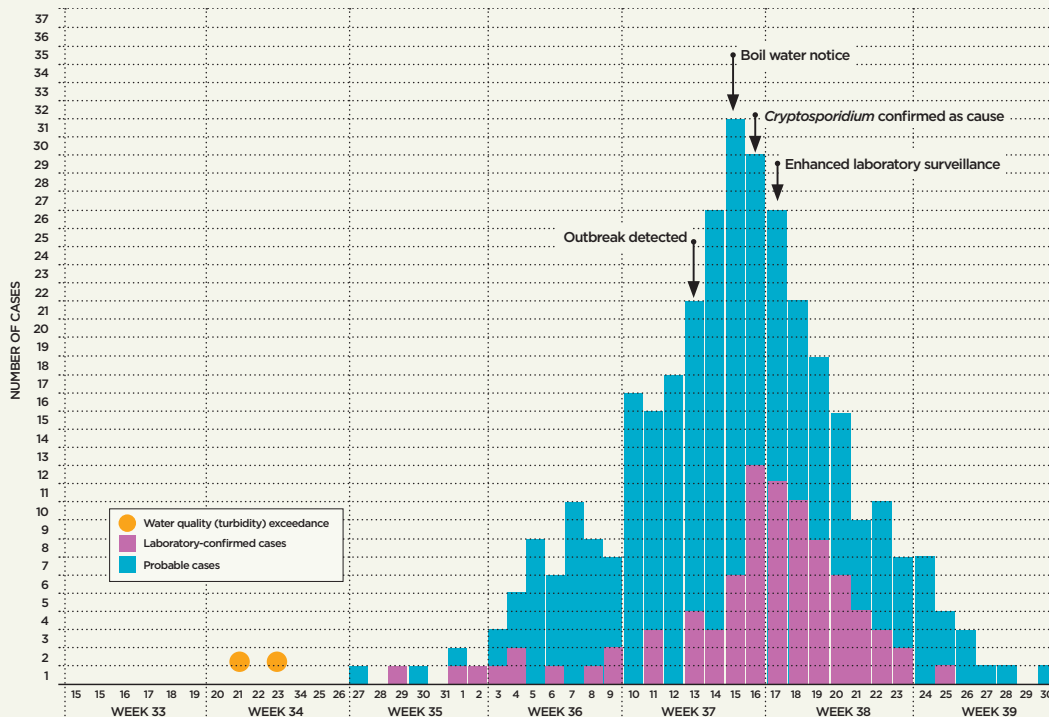
By the end of week 39, 330 cases have been identified as part of the outbreak (Fig. CS8). No further cases associated with the outbreak are reported after week 39. Usually, there is an approximately one-month turnaround on receipt of reports from laboratory surveillance, but daily reporting was introduced at the start of week 38. By the end of week 41, all laboratory results have been received.

Of the 330 cases identified during the outbreak, 83 are laboratory confirmed as *Cryptosporidium*. A subset of these have been genotyped and confirmed to be genetically identical to the *Cryptosporidium* isolated from the water-supply system.

The RRT decides to conduct a case-control study to test the hypothesis that exposure to WS2 was associated with getting sick with *Cryptosporidium* and to identify factors associated with *Cryptosporidium* infection. For the purposes of the case-control study, cases are those who meet the confirmed case definition for the outbreak investigation:

“Confirmed case: a person who lives in the town of Waterfall, with laboratory-confirmed cryptosporidiosis and onset of symptoms from 15 August 2018.”

Fig. CS8. Probable and confirmed cases of *Cryptosporidium* by date of onset, Waterfall



Possible secondary cases (those who became ill between one and 14 days after another case in the same household) are excluded.

Controls are selected randomly from the population register for Waterfall and are matched by sex, age and water-supply system. Two controls are interviewed for each case.

The RRT administers a standardized telephone questionnaire to 80 confirmed cases and 160 controls. The questionnaire collects data on water consumption and other risk factors for *Cryptosporidium* infection, such as diet, contact with farm animals and pets, and use of a swimming pool. Data are collected on exposures from 15 August, when the outbreak was announced and the boil water notice was issued, until the outbreak is declared over.

The results of the case-control study indicate that residing in the western or southern zones and consumption of water from WS2 are associated with being a case (Table CS4). A dose-response relationship is also found between the volume of water consumed daily and illness. No other factors are associated with illness.

Outbreak case study: step 8 contd**Table CS4. Factors associated with *Cryptosporidium* infection**

Variable	Adjusted odds ratio	95% CI
Residential zone:		
<i>northern</i>	reference	-
<i>eastern</i>	1.24	0.52–1.95
<i>central</i>	3.13	2.12–4.85
<i>southern</i>	7.58	4.93–9.7
<i>western</i>	10.44	7.84–13.58
Consumption of water from WS2		
<i>No</i>	reference	-
<i>Yes</i>	6.53	4.95–8.16
Daily water consumption		
<i>< 1 glass</i>	reference	-
<i>1–2 glasses</i>	2.11	0.67–9.2
<i>3–4 glasses</i>	4.34	0.96–18.10
<i>≥ 5 glasses</i>	8.42	1.95–27.34

In addition to the case-control study, the RRT calculate population-based risk ratios for cryptosporidiosis by water-supply zone (Table CS5).

Table CS5. Population-based risk ratios for cryptosporidiosis by water-supply zone

Variable	Risk ratio	95% CI
Water supply zone		
<i>WS1</i>	reference	-
<i>WS1+2</i>	6.31	3.28–11.01
<i>WS2</i>	24.25	17.31–28.52

There is robust evidence that residing in the western and southern zones is strongly associated with *Cryptosporidium* infection. Those in the western zone are over 10 times more likely, and those in the southern zone almost eight times more likely, to be infected than those in the northern zone. Consumption of water from WS2 is associated with an almost seven-fold increased risk of infection. Those who consume a higher volume of water daily are more likely to get sick. Finally, those living in areas supplied solely by WS2 have an almost 24-fold increased risk of infection than those living in areas supplied by WS1 only.

There is strong evidence to support the hypothesis that the outbreak of cryptosporidiosis that occurred in Waterfall during weeks 35–39 was associated with contamination of WS2 in the town, and that WS2 was the source of the outbreak. The causative agent has been isolated from cases and the water source. The environmental investigation has revealed weaknesses in the integrity of the water and sewage systems that coincided with heavy rainfall and flooding. There is evidence of poor water quality in the days prior to the onset of symptoms in the earliest cases. The implementation of control measures is followed by a decline in cases.

Step 9. Implement control measures

Control measures, such as boil water notices (see the section above on “Boil water notices” and Annex 3), usually are implemented immediately at the start of the outbreak to stop the spread of the outbreak and prevent further cases. Ideally, control measures will

be evaluated continuously throughout the outbreak and adjusted as needed. These measures typically will target different steps on the chain of transmission (Table 9), such as the causative agent, source of the outbreak, mode of transmission, portal of entry or the host.

Special considerations for WRID outbreaks

In most WRID outbreaks, water serves as a vehicle for the transmission of the infectious agent between a human or animal reservoir and the population. For certain organisms, such as *Legionella* or species of *Vibrio cholerae*, water itself serves as the reservoir.

Control measures during WRID outbreaks typically will target:

- the water-supply system (catchment, treatment, storage, distribution and end user) to remove the source of contamination by securing the system or by sanitizing the environment to prevent the growth of pathogens or by limiting access to the water;
- secondary vehicles of transmission, such as food items prepared with the contaminated water; and
- secondary spread via person-to-person transmission.

Control measures may target more than one mode of transmission. For instance, an outbreak of hepatitis A suspected to be associated with a contaminated water supply

ideally should prompt control measures targeting the water supply and vaccination of the contacts of cases. An explanation of the different steps in the chain as they relate to WRID and examples of control measures targeting these steps is given in Table 9.

Control measures should not only target the immediate cause of the outbreak (such as contamination of the water supply or hazardous events leading to the outbreak), but also the underlying causes of the outbreak (such as insufficient policy or tools, or inadequate training of waterworks personnel or maintenance of the water distribution system).

The outbreak may highlight issues that will need to be addressed in the WSP, such as measures to protect source waters or extension of treatment processes to include treatments targeting protozoa such as *Cryptosporidium*.

Similarly, the findings of an outbreak may prompt policy changes, such as changes to the location of industrial cooling towers or extension of surveillance to include pathogens that are newly emerging in the country, including *Giardia*, *Legionella* and *Cryptosporidium*.

Outbreak case study: step 9

In addition to the boil water notice issued on 15 September, a number of additional control measures are implemented:

1. advice on hand hygiene and infection control measures are issued to the public to prevent secondary transmission within households; cases are also provided with this information individually;
2. the entire water-supply system, including the pumping station, is flushed to eliminate oocysts from the distribution system and consecutive disinfection of the system after flushing is conducted;
3. the filtration system is repaired and flushed to eliminate oocysts;
4. leaking and corroded pipes in the water-distribution system are repaired or replaced as needed;
5. sewage system pipes repaired and improved to enhance their capacity to cope with increased volumes during flooding events; and
6. an order is issued to remove livestock from the pasture lands surrounding Moon Lake to minimize the presence of faecal matter in areas that may generate runoff into the lake (mid-term).

Table 9. Overview of the components of the chain of transmission and examples of associated target control measures for WRID

Component	Description	Example of targeted control measures
Portal of exit	The way by which the infectious agent leaves the reservoir: for example, cracks in distribution pipes enabling infiltration of raw sewage, and pigeons breaching water storage tanks and defecating into the treated water supply	Securing the water source against contamination by animal waste Repairing distribution systems Securing water storage tanks against invasion by rodents or birds
Mode of transmission	The mechanism by which the infectious agent is transmitted to people: for example, indirect spread through consumption of contaminated drinking-water or inhalation of aerosolized <i>Legionella</i>	Super-chlorination of the water distribution system Temporary closure of a suspected industrial cooling tower or spa facility
Portal of entry	How the infectious agent gets into the human body: for example, consumption of contaminated water or inhalation of <i>Legionella</i>	Water avoidance notices and provision of alternative water supply
Susceptible host	A person who is not immune to the disease as they have never had the disease, or they have not been vaccinated	Vaccination to stop a hepatitis A outbreak
Causative agent	The microorganism that causes the illness	Increase treatment and disinfection of source water, following treatment or during distribution Boil water notices
Reservoir	Where the causative agent is able to grow and multiply: for example, biofilms for <i>Legionella</i>	Disinfection of distribution systems Optimization of temperature control in hot- or cold-water distribution system in buildings to prevent <i>Legionella</i> growth (keep the water temperature outside the range of 20–50 °C, if possible)

Step 10. Communicate findings, make recommendations and evaluate the outbreak response

It is good practice to communicate with stakeholders, including the public, at regular intervals throughout the outbreak, and also at the end of the outbreak. This will keep stakeholders informed on what is happening during the outbreak, the progress and findings of the investigation and recommendations for control measures. It is also important to evaluate the outbreak response to document lessons learned and identify needed improvements to outbreak response capacity, and to inform the updating of emergency response plans. A number of guidance

documents for after-action reviews of public health events explain how to conduct an evaluation (76,77) (Annex 2).

Interim and final reporting is best informed by a communications strategy that can be agreed at the start of the outbreak. A variety of methods can be used to communicate with the public, including radio, text-messaging and social media. Risk-communication principles and tools are discussed in the next chapter. A final written outbreak report is important to ensure the investigation, its findings, lessons learned and recommendations for control and other public health measures are documented. Recipients for the final report will vary

depending on the outbreak, and usually are decided by the RRT.

Special considerations for WRID outbreaks

Communication should begin early. It is not prudent to wait until the conclusions are clear. Communications should set out what is known currently and what is being done to investigate and control the situation, and provide general advice about preventing disease.

Immediate control measures relating to the water system should be communicated to relevant stakeholders, including the public, municipal authorities and relevant government ministries, through interim reports released frequently throughout the outbreak.

The public should receive regular updates about the development of the outbreak, findings from the investigation and preventive measures (see the next chapter).

The frequency of interim reporting should vary as needed throughout the outbreak in

response to need. If weekly situation reports are published throughout the outbreak, for instance, additional ad hoc reports may be released as new information becomes available, or if there are urgent recommendations on community control strategies during the outbreak.

Recommendations for long-term improvements to the water-supply system should be made in the final outbreak report, with the WSP being updated with the recommendations as needed.

If serious problems with the water-supply system are identified during the outbreak, it may be necessary to recommend in the final report that the water provider undertakes a full systematic water-supply system risk assessment in accordance with WSP principles to identify potential additional long-term improvements to the system.

With a view to identifying lessons to be learned from the outbreak, after-action reviews of the outbreak response ideally would include an assessment of:

Outbreak case study: step 10

Throughout the course of the outbreak, daily interim reports were sent to the municipal authorities, Ministry of Health, Director of the NPHA and Director of the Water Provider to update them on the status of the investigation. Daily updates were posted on the NPHA website and announced (with links) on social media. The RRT published an outbreak report within one month of declaring the outbreak over, in which it made a number of recommendations, including:

1. introducing ozonation of raw water to deactivate *Cryptosporidium* in the source water prior to treatment;
2. upgrading parts of the distribution system by replacing piping;
3. undertaking work to protect the water filtration system from future flooding;
4. introducing a protection zone around Moon Lake within which livestock grazing will be prohibited, to minimize faecal pollution runoff into the source water; increasing the frequency of inspection of the water-supply system, including the filtration system, after extreme weather events; and
5. increasing the frequency of water-testing at all stages of the system during and after extreme weather events.

The RRT conduct an after-action review of the outbreak and decide to reduce the threshold for reporting water-quality exceedances under event-based surveillance.

- the process of outbreak detection and alert;
- the conduct of the investigation;
- the suitability and speed of implementation of control measures;
- the process of outbreak reporting and communication; and
- what worked well in the outbreak and what could be improved in future outbreak investigations.

Risk communication

Outbreaks are emergencies requiring rapid action to care for cases, prevent spread and control the outbreak. This requires rapid decision-making and action, often with cooperation from the public.

Risk communication is a key component of risk management (78,79). It is used in WRID outbreak management to guide public participation to support the rapid control of the outbreak, alleviate public concern and mitigate the social and economic consequences of the outbreak. Risk communication during an outbreak investigation should be guided by risk-communication planning. Risk-communication planning is a key component of contingency planning and is discussed in further detail in the chapter above on “Contingency planning” in this part. Risk communication opportunities exist at different steps throughout an outbreak investigation and skilled communication is critical, especially if using the media to engage the public in outbreak containment measures.

Article 8 of the Protocol stipulates that Parties give prompt and clear notification about outbreaks, incidents or threats. In the event of any imminent threat to public health from water-related disease, Parties shall “disseminate to members of the public who may be affected all information that is held by a public authority and that could help the public to prevent or mitigate harm” (7). Emergency risk communications capacity is also a core requirement for countries within the framework of the IHR.

WRID outbreaks, particularly those associated with public water supplies, potentially can cause considerable social and economic disruption and are likely to attract considerable political and media attention.

Human behaviour often contributes to the spread of outbreaks, so communications to the public can and should form a key component of outbreak control measures. The ultimate purpose of effective risk communication is to enable people at risk to take informed decisions to protect themselves and those around them. Consideration should be given to what risk communication opportunities exist at different steps of an outbreak investigation. Risk communication is not limited to notification in the investigation process and needs to be integrated throughout the decision-making processes, offering an opportunity for control of the outbreak and its response.

Effective risk communication and planning can mitigate complications during outbreaks that may be caused by a number of factors, including the following.

- Outbreaks often are characterized by uncertainty, confusion and a sense of urgency. They can be unpredictable and alarming to the general public, with a potential to cause social disruption and economic losses beyond their direct health-care costs and disproportionate to the severity of the risk.
- Outbreaks may have a high political profile, beyond ministries of health. This can mobilize political commitment to outbreak management, but if political authorities are motivated by economic rather than public health concerns, it can impede outbreak management.
- Outbreaks are often newsworthy and RRTs frequently have to communicate through the media. Engagement with the media also puts the RRT under public scrutiny and creates pressure for them to act rapidly and decisively. Exaggerated media coverage can exacerbate public anxiety, a

scenario that is more likely to occur in the absence of trustworthy official information. The flow of official information from the RRT may need to be rapid to meet the increasingly rapid media cycle, especially since rumours may be used to stem any void in official information.

- Communication failures during outbreaks can impede outbreak control measures, undermine public trust and engagement and exacerbate and prolong social, economic and political turmoil.

Given these factors, communication expertise is as essential to WRID outbreak management as epidemiological, environmental and laboratory expertise. In-depth guidelines for outbreak communication are listed in Annex 2. In particular, the WHO Regional Office for Europe has launched a five-step capacity-building emergency risk communication package (80). Fig. 11 presents an overall framework for risk communication.

Key elements of risk communication

Best practices for risk communication during an outbreak include the following.

Trust

Those responsible for risk communication should seek to:

- communicate in ways that build, maintain or restore trust: lack of trust leads to fear and reduced engagement with outbreak control measures;
- keep to the facts while acknowledging uncertainty and avoiding excessive reassurance;
- trust that the public will not automatically panic if given incomplete and sometimes worrying information;
- work to build trust between those leading on communication, policy-makers and other members of the RRT who may see communication with the public as

a diversion from the task of outbreak response;

- build consensus among members of multisectoral RRTs and key stakeholders, especially when these include different ministries, agencies and perhaps even private commercial organizations, and especially if partners have conflicting interests;
- work to ensure accountability and transparency by, for instance, allowing high-profile critics to observe and possibly even participate in decision-making; and
- listen to and be aware of public concerns.

Announce the outbreak early

Early announcement of an outbreak helps to build public trust that the authorities are not withholding information and sets expectations that information will not be concealed. The first person or agency to announce an outbreak is often remembered by people, and they will turn to that person/agency for further information.

The size of the outbreak, or a lack of information, are not always justifications for delaying the announcement of an outbreak. For some outbreaks, such as cholera, even one case can justify an early announcement.

To prevent rumours and misinformation spreading, especially on social media, the outbreak should be announced early. Those responsible for risk communication should seek to:

- avoid withholding information to “protect” the public: this may make the information seem more frightening, especially if it is revealed by an outside source;
- always announce early if:
 - containment of the outbreak is dependent on public behaviour change;
 - a risk group, such as residents served by a particular water supply, has been defined: alert them to the risk and explain ways to reduce it;

- neighbouring countries are at risk and need advice to be alert to imported cases;
- if the country can benefit from international support and experience;
- publicly acknowledge that the announcement is based on preliminary information that may be incomplete or incorrect, so the situation may change as further information emerges;
- ensure there are clear communication channels between key stakeholders so they are aware in advance of the announcement, especially if they disagree with the initial assessment; test these communication channels as part of contingency planning; and
- take particular care with the first communication about an outbreak, as it is likely to be newsworthy, to come as a surprise, and to capture the attention of the media and the public, and therefore potentially could cause alarm; how this initial announcement is handled may impact on the reception to all subsequent communication.

Late detection of the outbreak will lead to late reporting. This is a particular issue for WRID outbreaks, as the outbreak may not come to the attention of the authorities until it is suddenly conspicuous.

Outbreaks should not be announced based on rumours alone; rather they should only be announced following verification of at least some of the facts and, most typically, following verification of the outbreak itself.

Transparency

Greater transparency leads to greater trust. Communication should be frank, easily understood, complete and factually accurate. Transparency allows the public to see that the RRT systematically is investigating and responding to the outbreak, and it promotes deliberate and accountable decision-making.

The decision on what information to reveal to the public and what to withhold should be

based on an assessment of what will help the public and what is likely to cause harm within the limits of transparency.

Those responsible for risk communication should seek to:

- keep the public informed about the activities of the investigation, including the information-gathering, risk assessment and decision-making process of outbreak management;
- focus on what is being done and the next steps, rather than what is not being done; and
- be aware that pride, embarrassment, fear of revealing weaknesses and fear of being blamed can lead to a lack of candour, so develop strategies to address these issues as part of contingency planning to promote transparency.

Note that protecting public health is a higher priority than economic concerns, and that economic recovery is usually faster when governments are transparent and effectively manage the outbreak.

Unverified rumours, information that has no public health benefits, confidential data on patients and information that could lead to discrimination against patients, their families or particular minority groups should not be revealed.

Understand the public

The public is entitled to information relating to their health. Knowing who the public is, and what they think, is essential in developing effective public health messages. Crisis communication is a dialogue.

Those responsible for risk communication should seek to:

- make sure they understand the public's beliefs, opinions and knowledge about specific risks;
- involve representatives of the public in the decision-making process, if possible; if not

possible, the communication lead should understand and represent the public's views in the decision-making process;

- respect the public's concern, regardless of its validity, and address the concern in any policies developed in response to the outbreaks;
- publicly acknowledge and correct mistaken concerns;
- include information in risk-communication messages on how the public can protect themselves, as this enables the public to take control over their own well-being which, in turn, will encourage a more reasoned public response to the risk; and
- share information on the symptoms of infection, who is at risk and how and when to seek medical care if necessary.

Contingency planning

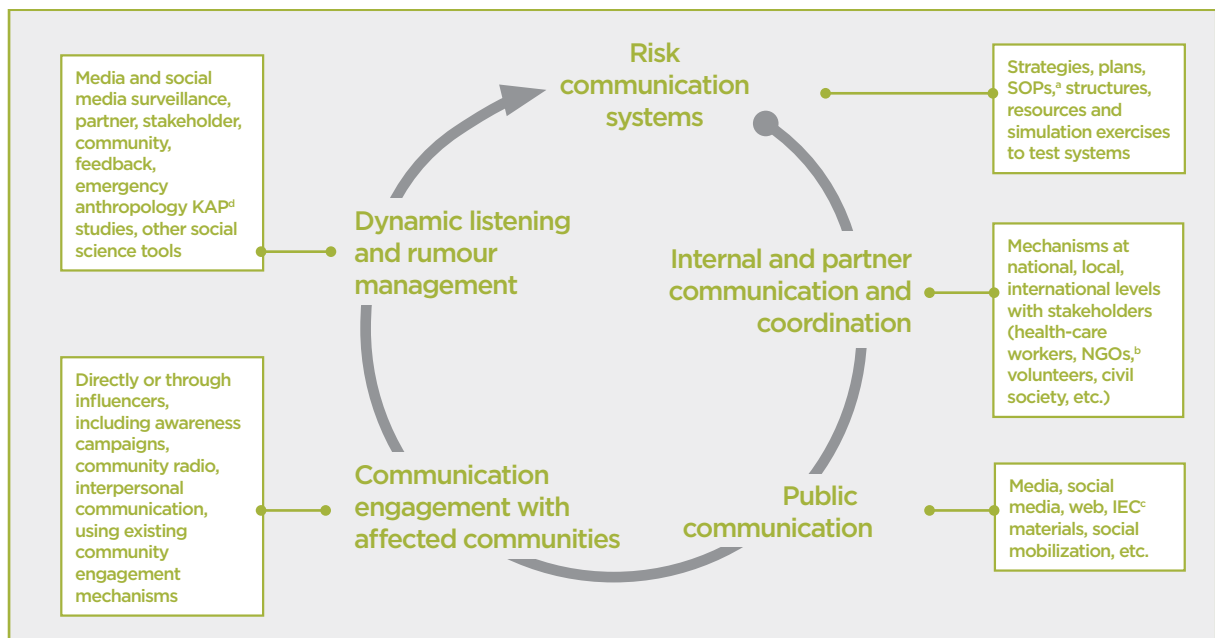
Public trust and risk perception are more influenced by the decisions and actions of public health officials than by communication. Ideally, risk communication should be integrated with risk analysis and risk management and

incorporated into contingency planning for major events and outbreak response.

Those responsible for risk communication should seek to:

- ensure that the relevant members of the RRT have received media training as part of contingency planning and have practised delivering bad news and discussing uncertainty;
- consider having a daily press conference rather than answering multiple media enquiries throughout the day;
- prepare in advance pre-approved public health messages that can be adapted for the outbreak, as part of contingency planning;
- develop the risk-communication plan as part of the outbreak-management plan from the start of the outbreak: this can be an adapted version of the template plan developed as part of contingency planning;
- brief senior management from the outset of the need to acknowledge uncertainty

Fig. 11. Integrated model for risk communication



^a SOPs: standard operating procedures.
^b NGOs: nongovernmental organizations.
^c IEC: information, education and communication.
^d KAP: knowledge, attitudes and practice.

Source: WHO Regional Office for Europe (80).

and to empathize with the public's beliefs and fears, as these principles may be counter to their approach to dealing with the public; and

- agree the first announcements, limits of transparency and other communication factors with senior management, key stakeholders, and if necessary, political leaders early on – specifically the aim should be to agree the following:
 - What needs to be done?
 - Who needs to know?
 - Who is the communications lead (agency and individual)?
 - Who needs to act?

These steps should be linked to the activities of other ministries and agencies as needed.

Generally, technical staff must understand the need for clear, jargon-free communication; communicators must understand the need for scientific and medical accuracy, and for framing scientific knowledge within the local political context; and decision-makers must accept the need to inform the public so that communicators are not left to face an expectant audience without a response.

Preparing public health messages

It is important to provide clear information and advice to the public during the outbreak. This is best done through prepared communication messages containing clear public health advice. When writing these messages, those responsible for risk communication should consider the following.

- Who is the target audience for the message?
- What is their relationship to the event?
- What is their level of education and the nature of their interest in the event?

Action messages should be kept short, simple and memorable, and should describe clearly what needs to be done, by whom, when it needs to be done, how it needs to be done

and for how long. These messages should be capable of being understood by, and be accessible to, different groups, such as people with disabilities, those with different languages and literacy skills and people with various access to media.

The target audience can absorb only a limited amount of information and may not understand the data, so the single overarching communication outcome and the key message that needs to be understood by the audience should be determined. When developing the key message, considerations should be given to what is important to the target audience, and what the target audience needs to know. The key message should be simple, accurate, credible, relevant, consistent and timely, and should not contain technical language. It should be supported by a small number of facts that the audience can remember. Input from medical experts will ensure that the public health messages and medical guidance are complementary.

Partnership with stakeholders

As with all aspects of outbreak management, coordination and collaboration with partners and stakeholders is key to ensuring effective risk communication. Relationships with stakeholders should be developed and the processes for communication agreed upon when developing the communication plan as part of contingency planning.

Engaging with social media and the community

Social media can be an important tool for directly and immediately communicating with the public. It enables peer-to-peer communication, can raise awareness about the outbreak and can be used to communicate about and support control and response measures in the community. Social media gives the public a voice and enables those who use it to become involved in the response to the outbreak through commentary and the provision of information on the outbreak.

It is also useful for monitoring response and public concerns about the outbreak, including community resistance, and can be used to monitor and counter rumours about the outbreak.

Use of social media should be integrated within the overall communications strategy for the outbreak. It is important to apply the same criteria regarding transparency, accuracy and timing, as explained above, in developing social media messaging. For larger outbreaks or those causing much public concern, it may be

prudent to appoint a dedicated social media officer to manage the social media response.

Community engagement can be crucial in outbreak response. In addition to use of social media, or in areas of poor social media uptake or connectivity, public meetings can be used to establish dialogue and build trust with the affected community.

Guidance documents (87) on using social media for outbreak communications are listed in Annex 2.

International frameworks for managing transboundary events and outbreaks

Outbreaks associated with transboundary waters that are likely to affect multiple countries may require close coordination and cooperation between countries to manage the outbreak and protect public health.

Several international agreements and regulations aim to strengthen collaboration on cross-border health threats, including threats linked to shared water resources. These include:

- the Protocol: Article 13 of the Protocol requires Parties that border common transboundary waters to work together to prevent and control water-related disease outbreaks by sharing information on risks and establishing coordinated surveillance, early-warning systems and contingency plans so they can respond to outbreaks, especially those due to water pollution and extreme weather events;
- the European Union decision on cross-border health threats (82): this provides a framework for crisis management and coordination of cross-border health threats that is implemented with assistance from ECDC and the European Food Safety Authority;
- the ECDC early-warning and response system: this is a web-based platform that allows public health agencies in the European Union and European Economic Area, ECDC and the European Commission to exchange information and report outbreaks and potential cross-border health threats with a view to improving coordination for their control; and
- the IHR: the regulations require all WHO Member States to report and collaborate to detect and respond to health threats with potential for international spread; countries may also request technical assistance from WHO.

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Annex 1. Glossary of terms

This glossary has been adapted from the WHO foodborne outbreak investigation guidelines (1), the WHO International Health Regulations (IHR) checklist and indicators for monitoring progress in the development of IHR core capacities in States Parties (2) and the International Epidemiological Association dictionary of epidemiology (3).

Attack rate: proportion of people becoming ill after a specified exposure.

Case: an occurrence of illness as defined by investigators.

Case definition: a set of diagnostic criteria for use during surveillance and outbreak investigations that must be fulfilled to be regarded as a case of a particular disease. Case definitions can be based on clinical criteria, laboratory criteria or a combination of the two, along with the elements of time, place and person.

Case classification: gradations in the likelihood of being a case (such as possible, probable and confirmed). This is particularly useful where early reporting of cases is important and where there are difficulties in making definite diagnoses (such as when specialized laboratory tests are required).

Case-control study: observational study in which subjects are enrolled on the basis of presence (cases) or absence (controls) of the disease of interest. Information is collected about earlier exposures and compared between cases and controls.

Cohort study: observational study in which subjects are enrolled on the basis of presence (exposed) or absence (unexposed) of risk

factors. Subjects are followed over time for the development of a disease outcome of interest.

Common source outbreak: an outbreak that results from a group of people being exposed to a common agent. If the group is exposed over a relatively brief period of time (that is, all cases occur within one incubation period), the common source outbreak is further classified as a point-source outbreak.

Control: in a case-control study, comparison group of persons without the disease under investigation.

Descriptive epidemiology: the aspect of epidemiology concerned with organizing and summarizing health-related data according to time, place and person characteristics.

Dose-response effect: the increasing magnitude and/or frequency of an outcome with increasing magnitude of exposure.

Early-warning system: in disease surveillance, a specific procedure to detect as early as possible any abnormal occurrence or any departure from usual or normally observed frequency of phenomena (such as one case of Ebola fever). An early-warning system is only useful if linked to mechanisms for early response (3).

Endemic: the constant presence of a disease within a given geographical area or population group.

Epidemic: the occurrence of cases of an illness clearly in excess of expected rates; often referred to as an outbreak.

Event: a manifestation of disease or an occurrence that creates a potential for disease

as a result of events including, but not limited to, those that are of infectious, zoonotic, food-safety, chemical, radiological or nuclear origin or source.

Event-based surveillance: the organized and rapid capture of information about events that are a potential risk to public health, including events related to the occurrence of disease in humans and events related to potential risk exposures in humans. This information can be rumours or other ad hoc reports transmitted through formal channels (such as established routine reporting systems) or informal channels (like the media, health workers and nongovernmental organizations' reports).

Exposure: contact with an agent in a manner that may cause disease.

Geographic information system: an organized collection of computer hardware, software, geographical data and personnel designed efficiently to capture, store, update, manipulate, analyse and display all forms of geographically referenced information. It is first and foremost an information system with a geographical variable, which enables users easily to process, visualize and analyse data or information spatially. It can be used to prepare models showing trends in time and space. Satellite imaging and remote sensing have expanded its scope to, for example, identify regions prone to malaria.

Hazard: a biological, chemical, physical or radiological agent in, or condition of, water, with the potential to cause an adverse health effect.

Host: a person or animal that can be infected by an infectious agent under natural (as opposed to experimental) conditions.

Incidence: number of new cases in a specified population in a defined period of time, divided by the population at risk.

Incubation period: the time interval between the initial contact with an infectious agent and

the first appearance of symptoms associated with the infection.

Indicator-based surveillance: the routine reporting of cases of disease, including through notifiable diseases surveillance systems, sentinel surveillance and laboratory-based surveillance. This routine reporting originates typically from a health-care facility where reports are submitted at weekly or monthly intervals.

Notifiable disease: a disease that must, by law or ministerial decree, be reported to a government authority.

Odds ratio: measure of association that quantifies the relationship between an exposure and an outcome from an analytical study (most often, a case-control study). Strictly speaking, the odds ratio describes the likelihood of exposure to the risk factor under investigation in both diseased and non-diseased groups.

Prevalence: the number or proportion of cases in a defined population.

Rate: an expression of the frequency with which an event occurs in a defined population.

Reservoir (of infection): ecological niche in which a pathogen lives and multiplies and upon which it depends for its survival. Reservoirs include human reservoirs, animal reservoirs and environmental reservoirs.

Risk: the likelihood of identified hazards causing harm in exposed populations in a specified timeframe, including the magnitude of that harm and/or the consequences.

Risk assessment: evaluation of known or potential adverse health effects resulting from human exposure to waterborne hazards. The risk assessment process involves four steps: hazard identification, hazard characterization, exposure assessment and risk characterization.

Risk communication: the range of communication capacities required through the preparedness, response and recovery phases of a serious public health event to encourage informed decision-making, positive behaviour change and the maintenance of trust.

Standardized morbidity ratio: the ratio of the incident number of cases of a specified condition in the study population to the incident number that would be expected if the study population had the same incidence rate as a standard or other population for which the incidence rate is known.

Source of infection: the water source or substance from which an infectious agent passes to a host. The source of infection may or may not be part of the reservoir of infection.

Surveillance: the systematic collection, analysis, interpretation and dissemination of health data on an ongoing basis, to gain knowledge of the pattern of disease occurrence and potential in a community, to control and prevent disease in the community.

Vector: an animate intermediary in the indirect transmission of an agent that carries the agent from a reservoir to a susceptible host.

Vehicle: an inanimate intermediary (such as food) in the indirect transmission of an agent that carries the agent from a reservoir to a susceptible host.

Waterborne disease: any disease of an infectious or toxic nature caused by the consumption of water

Zoonosis: an infectious disease that is transmissible under natural conditions from animals to humans.

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Annex 3. Template boil water notice



Important Information for all Households in the [XYZ] District

Boil Water Advice

The [INSERT RELEVANT AUTHORITY] advises:

The water from your tap may be contaminated with microorganisms. It needs to be made safe before you use it for drinking, brushing teeth, cleaning wounds and food preparation.

In case you use local water sources (such as domestic or community wells or springs) of uncertain microbial quality, the water also needs to be made safe before use.

Boiling is a highly efficacious method to make your water safe. Boiling reliably kills bacteria, viruses and parasites in water that may make you sick.

How to boil your water effectively?

For boiling water you can use a pot on a gas or electric cooker or wood-burning stove. You can also use an electric kettle or water boiler.

Bring the water to a rolling boil. This is when you observe the water boiling vigorously and clearly forming lots of bubbles.

After the water has reached a rolling boil, remove the pot or kettle from the heat and allow cooling naturally. Do not add ice.

Keep the hot water away from children to avoid scalding.

Cool and store all boiled water in a clean and covered container. This protects the water from re-contamination during storage.

In case the water is murky or cloudy and you want to clarify it for aesthetic reasons, do this before boiling.

You can use the tap water for other domestic purposes (e.g. cleaning, laundry) and personal hygiene (e.g. hand washing, bathing, showering).

Vigorous handwashing with soap is important, especially before and during handling food and after going to the toilet. To be effective, you SHOULD wash your hands for 40-60 seconds with (unboiled) tap water and soap.

Please also inform your family members, cohabiters and neighbors.

You will be informed when this advice is being lifted.

Annex 4. *Legionella* resources

Legionellosis is an acute bacterial infection caused by bacteria of the genus *Legionella*, including most frequently *Legionella pneumophila*. The clinical and epidemiological characteristics of legionellosis have been described in detail elsewhere (1,2) and are summarized here.

Briefly, legionellosis varies in severity from a mild non-pneumonic febrile illness known as Pontiac fever to a more severe form of pneumonia known as Legionnaires' disease. The incubation period for Pontiac fever is a few hours to up to two days. Pontiac fever causes influenza-like symptoms, such as fever, chills, headache, malaise and myalgia, and lasts 2–5 days.

Risk factors for Legionnaires' disease include increasing age, smoking and underlying comorbidities, including cancer, chronic lung disease, diabetes, renal disease and being immunocompromised. Males are more than twice as likely to develop Legionnaires' disease as women. Legionnaires' disease has an incubation period of 2–10 days, although incubation periods of up to 19 days have been recorded in some outbreaks. It usually manifests as pneumonia and is characterized by anorexia, malaise, myalgia, headache, chills and fever, commonly of 39.0–40.5 °C. Other common symptoms are non-productive cough, diarrhoea and abdominal pain. It frequently requires hospitalization and has a fatality rate of 10–15%. Case fatality rates of up to 39% have been reported in hospitalized patients. Mortality is highest in people who are immunocompromised. Most cases and outbreaks of legionellosis occur in summer and autumn. Attack rates of 0.1–5% in the at-risk population have been reported.

Legionella bacteria live and grow in water systems at temperatures of between 20 °C

and 50 °C, most optimally at 35 °C. *Legionella* can grow and form biofilms in the pipes of distribution systems, as well as on outlets, mixing valves and on washers (3,4). Once biofilms have developed in a water-supply system, they are extremely difficult to remove and are resistant to disinfection. Preventing their growth is an important measure to control *Legionella* infection. Biofilms are more likely to form when there are nutrients present in the source water and in the system, when there is corrosion or scale in the system, when the temperature of the water is warm, and when the flow rates are low or the water is stagnant, for instance in dead ends of the system or storage tanks. Biofilms in water distribution systems can inoculate building water-supply systems where they are associated with *Legionella* outbreaks (3–5). Hot- and cold-water supply systems, air conditioning cooling towers, evaporative condensers, humidifiers, whirlpool spas, fountains and respiratory therapy devices have all been associated with outbreaks. Airborne transmission via small aerosolized water droplets carrying the bacteria is the most common route of infection. Person-to-person transmission may occur under rare circumstances (6).

When a case of *Legionella* is detected, the case will be investigated to determine the exposure history in the time period corresponding to the incubation period (for instance, in the two weeks prior to onset of illness). Diaries and street maps may be used to help to aid the collection of these data. Based on the exposure history, the case may be classified as community-acquired, domestically-acquired, occupational, nosocomial or travel-associated. Cases usually are reported to the national surveillance system after data on the exposure history has been collected. Single cases may be investigated for possible links to other cases by

time and place. Potential sources of infection for these cases may be identified and a risk assessment of these sources may be launched, even just for a single case. For instance, the identification of a nosocomial or domestically-acquired infection is likely to instigate the launch of an environmental investigation of the water-supply system in the health-care facility or building associated with infection, with a view to implementing control measures to secure the water-supply system. Such environmental investigations usually involve the sampling of biofilms from water-supply systems, cooling towers or other potential sources. Clusters of community-acquired cases would usually prompt an investigation of potential sources in the neighbourhoods in the vicinity of cases. Maps can be used to detail the location of potential exposures of interest, such as cooling towers, in relation to the location of cases. Spatial analyses can be used to measure the distance between cases and suspected sources or risk factors for infection. These data can be integrated with additional data such as data on wind direction to generate or strengthen the evidence implicating a suspected source (for instance, a particular cooling tower in an outbreak of Legionnaire's disease (7)).

European technical guidelines exist to support the investigation and control of infections caused by *Legionella* species (8). Travel-associated cases in the European Union/European Economic Area may be reported through the European Legionnaires' Disease Surveillance Network (ELDSNet) to a specific surveillance scheme which has the objective of identifying clusters or outbreaks related to accommodation sites anywhere worldwide (9).

Legionella outbreak investigation case study

Step 1. Receipt of initial report and confirmation of the outbreak

On 6 June the district epidemiologist in the Mountain district of Laguna received a report of a single case of Legionnaires' disease in an elderly man admitted to the university hospital.

Additional notifications occurred on 11 and 15 June, by which time there were five cases.

The epidemiologist completed a case investigation form for all cases in accordance with standard operating procedures. Cases were clustered in the northern zone of the city. One case died. All cases had onset of symptoms after 1 June. Four of the five were male and all were aged over 60 years. Four lived in the northern zone and the remaining case lived outside the city but worked in the northern zone. All cases had underlying comorbidities or were smokers. All cases had laboratory confirmation of *Legionella pneumophila* based on either culture from respiratory specimens or urinary antigen testing. None were considered to be travel- or health-care-associated. The epidemiologist started a line list to document key information on the cases.

Rapid public health risk assessment

The epidemiologist conducted a rapid public health risk assessment.

The epidemiologist noted that cases had occurred over a 10-day period, indicating that transmission in the community was ongoing. Legionnaires' disease can have severe outcomes, including death, and one case had already died. If action was not taken to contain the outbreak, it was likely that more cases would occur and the consequences to public health could be severe. Given this, the epidemiologist classified the outbreak as high-risk.

Report to stakeholders

The epidemiologist declared the outbreak and notified the district director of public health.

Form rapid response team (RRT) and prepare for investigation

The district director of public health convened an RRT on 16 June to investigate and control the outbreak. The RRT consisted of:

- the district epidemiologist;
- the district environmental health officer;
- a microbiologist with expertise in *Legionella* from the regional public health laboratory;
- a risk manager from the municipal authority;
- a *Legionella* expert from the Environmental Protection Agency (EPA);
- a specialist in geographic information systems (GIS) from the National Public Health Agency (NPHA); and
- a communications expert.

The RRT met to agree the objectives of the outbreak investigation, to agree on roles and responsibilities and to develop a plan to investigate the outbreak. Having reviewed the data, the RRT agreed that this was an outbreak of Legionnaires' disease with a likely source in the community.

Step 2. Confirm the cause

All cases had laboratory confirmation of *Legionella pneumophila* based on either culture from respiratory specimens or urinary antigen testing. None of the cases were considered to be travel- or health-care-associated.

Step 3. Define cases

The RRT agreed the following case definitions for the outbreak.

Confirmed case: a person with community-acquired pneumonia, with laboratory confirmation of *Legionella pneumophila*, with date of onset of illness from 15 May, who lived in or visited the northern zone of Waterfall in the two weeks prior to onset of illness.

Probable case: a person with community-acquired pneumonia, with date of onset of illness from 15 May, who lived in or visited the northern zone of Waterfall in the two weeks prior to onset of illness, without laboratory confirmation of *Legionella pneumophila*.

Step 4. Active case-finding

The RRT alerted local primary-care doctors and hospitals about the outbreak and asked them to consider *Legionella* as a possible cause of community-acquired pneumonia and to submit urinary specimens from probable cases for testing. The public health laboratory was asked to notify the RRT on a daily basis about any new laboratory confirmed cases of *Legionella*. The NPHA alerted all districts in the country about the outbreak and asked them to forward the details of any cases that met the case definitions to the RRT and arrange for testing of these cases.

The RRT interviewed all cases about their movements in the two weeks before onset of illness using a standardized questionnaire, taking detailed information on the location of the places they visited and the timing of their visits. The questionnaire also collected data on where they worked, where they shopped, any recent travel or overnight stays in hotels, and exposure to potential sources such as spa pools or fountains. Lower respiratory tract specimens were taken from all confirmed cases for reference culture and typing at the national reference laboratory.

Step 5. Descriptive epidemiological investigation

Time

By 30 June, a total of 50 cases had been notified, all with data of onset between 4 and 28 June (Fig. A4.1).

The shape of the curve was consistent with a continuous point source. The index case had onset of symptoms on 4 June, and the last reported case had a date of onset of 28 June, suggesting a potential exposure period of between 21 May and 13 June.

Place

Thirty-nine cases (78%) were resident in the northern zone (Fig. A4.2), which corresponded

to an attack rate of 16 per 10 000 residents of the northern zone. There were a further 11 cases who resided outside the northern zone but who either worked there or were regular visitors to that part of the city. No cases were reported from outside the Mountain District.

Person

Table A4.1 summarizes the characteristics of cases. All cases had a positive urinary antigen test for *Legionella pneumophila* serogroup 1 (LPI). Five case were culture-positive.

Forty-five (90%) were admitted to hospital; the remaining cases were treated at home. Cases were aged between 56 and 91 years (median = 63) and 75% (38) were male. Five cases (10%) died. Fifteen cases (30%) had underlying comorbidities, including asthma (three cases), chronic obstructive pulmonary disease (COPD) (seven), diabetes (three) and immunosuppression (two). Thirty-two cases (64%) smoked and an additional four were ex-smokers. None of the cases had travelled abroad or been admitted to hospital in the two weeks prior to illness onset.

Fig. A4.1. Cases of Legionnaires’ disease by date of onset, Waterfall, 3-28 June

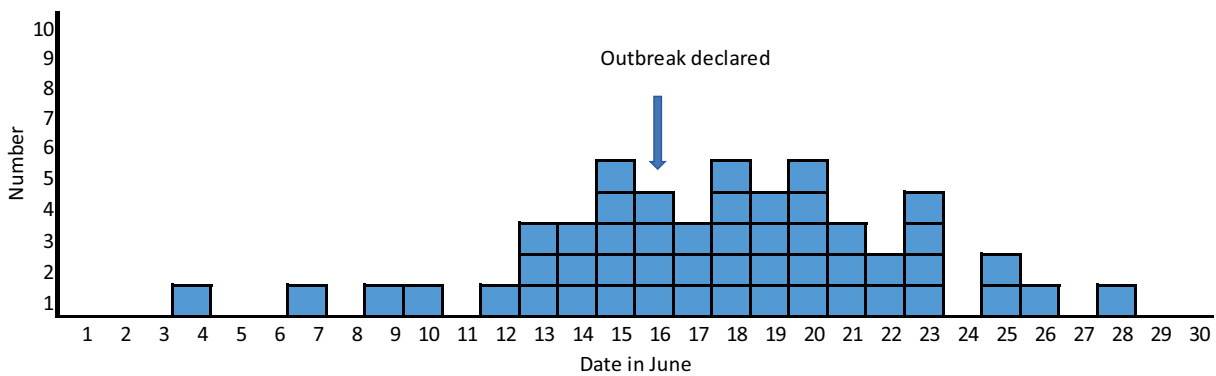


Fig. A4.2. Distribution of cases of Legionella pneumophila, Waterfall, June 2018

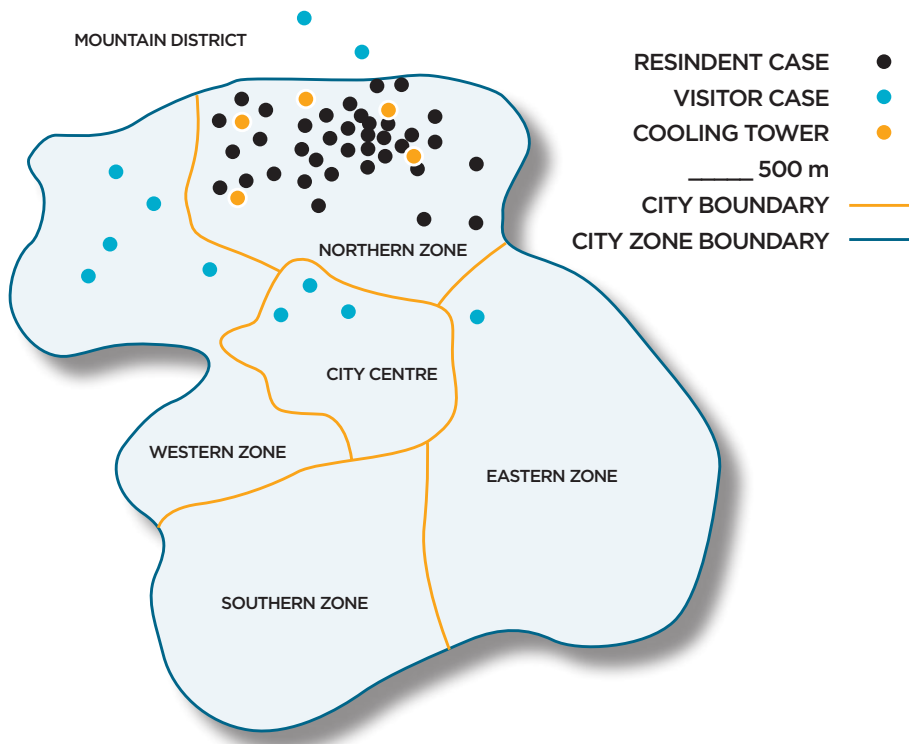


Table A4.1. Characteristics of cases of *Legionella pneumophila*, Waterfall, June 2018

Characteristic	Number (% of cases)
Confirmed cases	50 (100)
Status	
Hospitalized	45 (90)
Died	5 (10)
Age group	
40–49	2 (4)
50–59	5 (10)
60–69	14 (28)
70–79	18 (36)
≥ 80	11 (22)
Sex	
Male	36 (72)
Female	14 (28)
Underlying comorbidities	
Any	15 (30)
Asthma	3 (6)
COPD	7 (14)
Diabetes	3 (6)
Immunosuppression	2 (4)
Smoking status	
Current smoker	32 (64)
Former smoker	4 (8)

Table A4.2 summarizes the attack rates for the 39 cases resident in the northern zone. Among residents in the zone, the attack rate was highest for those aged 70–79 years and 80 years and over, as well as for males.

Table A4.2. Attack rate for *Legionella pneumophila* among residents of the northern zone

Characteristic	Number	Attack rate/10 000 people
Overall	39	16
Age group		
40–49	0	0
50–59	2	4
60–69	10	23
70–79	16	43
≥ 80	11	45
Sex		
Male	30	26
Female	9	7

Step 6. Additional studies

Environmental investigation

The district environmental health officer, the risk manager from the municipal authority and the representative from the EPA led the environmental investigation. The geographical distribution of cases indicated that the epicentre of the outbreak was in a neighbourhood to the north-east of the northern zone. They listed all potential sources within a 500-meter radius of the epicentre and prioritized them for investigation. They also:

- consulted the municipal register of industrial cooling towers to identify cooling towers;
- identified additional potential sources in the area, such as whirlpool spas, car washes, fountains and supermarket food display units with humidifiers;
- visited each site and conducted a risk assessment of the potential source;
- reviewed the operation and maintenance procedures and cleaning and disinfection records for the potential source;
- asked the operators about unusual events relating to the potential sources during the previous two months, including periods when the source was not operating and any breakdowns in equipment; and
- took water samples and swabs from areas where *Legionella* species were likely to grow, from areas where there was a lot of biofilm growth and from close to the heat source, and sent samples to the local EPA laboratory for culture and typing.

When all sources within a 500-meter radius were identified and inspected, they repeated the exercise at increasing 500-meter radii to a maximum of two kilometres. This enabled a more efficient use of resources for the investigation as the RRT were able initially to concentrate the investigation within a small geographic area (radius) of the epicentre, where the source was most likely to be located. The

RRT only expanded the investigation to a wider geographic area when they had investigated and eliminated all potential sources closer to the epicentre of the outbreak. The greater the area to be covered by the investigation, the more time-consuming and resource-intensive the investigation.

Spatial analyses

The daily movements of cases in the two weeks prior to illness onset and their place of residence and work were entered into a GIS database, along with details on the location of possible sources of the outbreak and data on meteorological data (specifically, data on the prevailing wind direction and speed each day from 15 May).

Given the geographic distribution of cases, information on the prevailing wind directions during the period of exposure and findings from the environmental risk assessments, three cooling towers to the north-east of the northern zone were identified as the most likely sources of the outbreak. The RRT also modelled the atmospheric dispersion of plumes from these sources during the exposure period to assess the degree to which the likely geographic spread of emissions from these sources matched the spatial distribution of cases.

Step 7. Generate hypotheses

Considering the results of the epidemiological and environmental investigation, the RRT

hypothesized that one of the three cooling towers located in the north-east of the city was the most likely source of the outbreak.

Step 8. Evaluate hypotheses

Ecological study

The RRT conducted an ecological study to quantify the risk of infection for those living at various distances from each of the suspected sources. The RRT calculated attack rates for those living at distances of 500 m, 1000 m, 1500 m and 2000 m from each of the suspected sources. They then calculated rate ratios for each zone compared to those living outside the zone.

Table A4.3 shows attack rates per 10 000 persons and risk ratios for *Legionella pneumophila* infection by proximity to the suspected cooling towers.

Assessing the strength of the evidence

The ecological study demonstrated that the risk of *Legionella* infection increased with increasing residential proximity to cooling tower B. This association was not observed for cooling towers A and C, suggesting that cooling tower B was the source of the outbreak.

This finding was supported by data from the environmental and microbiological investigations and from atmospheric modelling.

Table A4.3. Attack rates per 10 000 persons and risk ratios for *Legionella pneumophila* infection by proximity to suspected cooling towers, Waterfall, June 2018

Distance (m)	Cooling tower A		Cooling tower B		Cooling tower C	
	AR ^a	RR ^b	AR ^a	RR ^b	AR ^a	RR ^b
500	27	3.1	95	19.1	56	7.2
1 000	20	2.5	72	12.3	39	5.1
1 500	32	3.9	23	2.9	18	3.4
2 000	36	4.1	8	1.5	6	1.2

^a AR: attack rates.
^b RR: risk ratios.

The environmental risk assessment revealed that those operating cooling tower B were not complying with regulations for cleaning and maintenance of the water-supply system in the tower. The water-supply system was found to be heavily contaminated with biofilm. A sample taken from the biofilm tested positive for *Legionella pneumophila* and was found to be genetically identical to the organism isolated from cases.

Step 9. Implement control measures

All sources were shut down and subjected to a precautionary decontamination before being permitted to operate again. This was done after the environmental risk assessment and collection of environmental samples.

The owners of cooling tower B were instructed to:

- comply with regulations for the cleaning and maintenance of the water-supply system;
- increase the frequency of disinfecting the system; and
- maintain cold-water temperatures at $\leq 25^{\circ}\text{C}$ and hot-water temperatures at $\geq 55^{\circ}\text{C}$.

Step 10. Communicate findings

Throughout the outbreak, the RRT sent daily updates on the progress of the investigation to the NPHA and municipal authorities. The outbreak attracted substantial local media attention, so regular reports were also issued to the public and the media and were disseminated through social media. The final report recommended that further resources be allocated to the enforcement of regulations for the maintenance of cooling towers and other potential sources of *Legionella* infection.

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Legionella guidelines and tools⁴

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Water-related infectious diseases (WRID) pose a public health threat in the pan-European region. In particular, drinking-water supply systems – from the water source to the point of consumption – are the most important source of WRID. Due to suboptimal capacity for WRID surveillance and outbreak investigation, the true burden of WRID is unknown.

The Protocol on Water and Health to the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes is the key policy instrument for promoting better health through effective water management and water-related disease surveillance. The Protocol calls on parties to strengthen their capacity for surveillance and outbreak management to reduce outbreaks and the incidence of WRID.

This document supports implementation of the Protocol by addressing how WRID surveillance systems can be strengthened and WRID outbreaks can be managed. It focuses on WRID associated with drinking-water supply systems. The technical information on specific features, activities and methodologies related to WRID surveillance and outbreak management will enable countries to strengthen the capacity of existing surveillance and management systems.

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