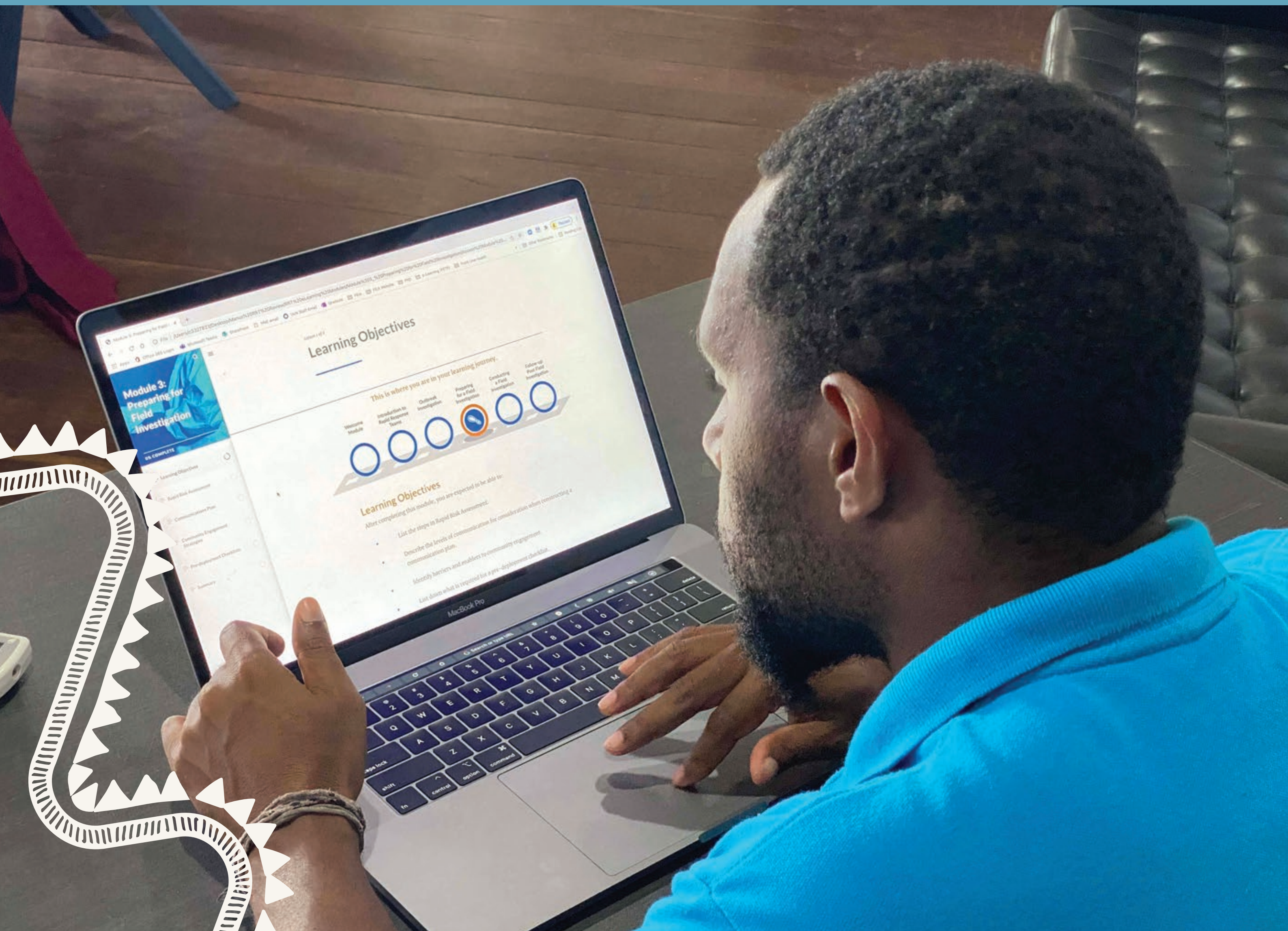
Field Epidemiology
IN ACTION

Case Study

Epidemiological Concepts



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Note: If this case study includes any technical terms which you may not understand, refer to the Field Epidemiology in Action reference guide which provides general epidemiology definitions. The Field Epidemiology Reference Guide document is available at: https://www.fieldepiinaction.com/reference-guide

All people, places and scenarios contained in this case study are fictional.

1 Background

The Constellation Islands is a tropical, mountainous island country located in Oceania. The country is comprised of several island provinces, each one named after constellations historically used for seafaring and navigation by the Melanesian peoples who call the islands home.

Like many small Pacific Island nations, the Constellation Islands is located in a region prone to natural disasters including cyclones, earthquakes, volcanic eruptions, tsunamis, and landslides. As a small, geographically isolated country with limited financial, logistical and human resources, the Constellation Islands is highly vulnerable to these natural hazards, with limited means to prepare and respond to such events (1).

Figure 1: A depiction of the rugged coastline of Aries Island, in the Republic of the Constellation Islands.

You are a senior epidemiologist employed by the Communicable Diseases Branch of the National Ministry of Health. It's early morning on Monday, 28 March 2022.

The previous week, the country unfortunately suffered a direct hit by Cyclone Ranu, resulting in an unprecedented natural disaster. Large areas across several islands have suffered significant damage to infrastructure caused by powerful winds, tidal surges, flooding and landslides. Initial estimates indicate that at least 58 people have lost their lives, with many more missing or unaccounted for. Large areas on several islands have been left without power.

Countless buildings were severely damaged or destroyed, and both surface and ground water sources have been contaminated by floodwater or sewage. Several islands' major access roads, ports, and airstrips are severely damaged or entirely destroyed.

The President of the Republic declared a National State of Emergency, and has appealed for international assistance. The country's National Disaster Management Office has been activated. The Office Headquarters (HQ) is responsible for coordinating the emergency response at national, provincial, and district level under emergency response legislation, the Natural Disaster Management Act (2015).

As an experienced Field Epidemiologist, you've been seconded to the emergency response in the role of **Specialist Technical Adviser: Epidemiologist**. It is your responsibility to provide expert epidemiological advice to the Public Health Response Team. This is a challenging and complex task, which includes identifying and responding to the most urgent public health priorities arising in the aftermath of the disaster. You will be reporting directly to Doctor Mary Tukana, who is leading the Public Health Response Team, and is also the country's Chief Medical Officer.

The National Incident Controller is Major-General Thompson of the National Armed Forces, who reports directly to the President. The Major-General invites you and Dr Mary into his office to provide a briefing about his expectations for your role within the Public Health Response Team.

Figure 2: Coastal devastation caused by a tropical cyclone in the Pacific. Photo credit: Australian Government, Dept of Foreign Affairs and Trade.

Major-General Thompson says:

Thank you for your service to our country in this time of need.

We anticipate this will be a complex and challenging humanitarian emergency response lasting several months. Our country may face several urgent health challenges due to the widespread damage to critical infrastructure, displacement of communities, disruption of health care systems and routine services, as well as logistical, transport and supply chain problems. I expect you both to provide specialist health advice at national, provincial and district level. Your expertise in communicable disease control will be very important. We'll rely on you to identify the most critical, time-sensitive health risks, take steps to control these risks, and effectively communicate the response teams on the front line.

I'll ask Dr Mary to explain the details of the task ahead.

Good luck! We're counting on you.

The Chief Medical Officer, Dr Mary, nods in agreement with Major-General Thompson, and provides additional information and instructions.

Dr Mary says:

Welcome to the Public Health Response Team, here at HQ!

We need a Field Epidemiologist who understands and can clearly explain complex epidemiological concepts of communicable disease control to our public health response staff on the various islands. Some of these responders have only basic health training, or are community volunteers. It will be very important to help our response teams identify and understand the most urgent priorities to manage public health risks in different contexts, and institute timely interventions and control measures, even if the exact cause of the problem may not yet be known.

We also need you to provide advice and training to officers managing the national syndromic surveillance system, and help identify and address public health risks that may develop due to disruption of basic service delivery. Longer-term, we should also anticipate public health problems due to disruption of routine health care services like childhood immunisation programs, gender-based violence and sexually transmissible infections (STIs), increased prevalence of chronic lifestyle diseases due to a lack of access to medications, and mental health problems like post-traumatic stress disorder (PTSD) in cyclone-affected communities.

Our response teams may face varied, complex public health problems all over the country, which may last for several months, or even years. For many infectious diseases especially, you have a limited window of opportunity to act to prevent many more cases of illness or death, and therefore, time is of the essence! So, you will need to think on your feet, and respond with practical advice and interventions quickly, even when faced with incomplete or very limited information about exact circumstances or specific diseases.

As a well-trained field epidemiologist, I'm confident you're up for the challenge. Good luck!

You realise it is a great honour and responsibility to have been selected to perform this important advisory role during a time of national crisis.

You immediately start preparing for the task ahead by consulting the country's National Disaster Management Plan (2), as well as the Pacific Outbreak Manual (3) for response guidelines to core syndromic surveillance conditions. You know that you will need to be fully aware of the principles of communicable disease control, including:

- Stages of infectious disease;
- Chains of infection, and modes of transmission;
- Zoonotic, vector-borne and water-borne diseases;
- Intervention points and control options to interrupt disease transmission;
- The epidemiological triangle of agent-host-environment (and vectors, where relevant); and
- Common communicable disease risks associated with sudden natural disaster or complex humanitarian situations.

2

Syndromic surveillance

Dr Mary explains that one of the Public Health Response Team's first tasks is to support staff working at provincial and district level in the Ministry of Health's national syndromic surveillance system and local public health response teams with technical expertise. This will help ensure the syndromic surveillance system functions optimally and continues to generate adequate high-quality data needed to inform operational decision making as part of the broader emergency response. Another important task is coordination with Logistics and Operations teams to ensure the provision of necessary financial and human resources, medical stockpiles and equipment in the immediate aftermath of the cyclone.

This support is important because many local Ministry staff, especially on smaller provincial islands, may initially experience great difficulty performing their public health surveillance work after the cyclone struck. Damage or loss of Government property, prolonged power outages, loss of telecommunications infrastructure and work absenteeism all complicate the task of collecting and reporting syndromic surveillance data.

Some staff have suffered damage or loss of their homes or personal property, like vehicles. Some have also experienced physical injury or suffered tragic personal loss of family members or friends.

There is also a need for providing guidance to inexperienced volunteers working in evacuation centres, and other organisations providing public or environmental health support functions e.g. NGOs, faith-based health providers, district or village councils, and local municipalities.

You recall that under normal circumstances, the Ministry of Health conducts routine, weekly surveillance for six major disease syndromes:

1. Acute fever and rash (AFR)
2. Acute watery diarrhoea (AWD)
3. Acute flaccid paralysis (AFP)
4. Influenza-like illness (ILI)
5. Prolonged fever (PF) and
6. Unusual/unexplained health events (UE)

Several of your colleagues from the National Ministry of Health have also been seconded to the Public Health Response Team at HQ, and are responsible for analysis and reporting of the Health Ministry's national syndromic surveillance data to help inform the response.

You will be working closely with these Surveillance Officers to monitor national syndromic surveillance data for signals that may indicate unusual epidemiological patterns, which could provide early warning of infectious disease outbreaks or other acute public health problems.

3

Aries Island: Gastrointestinal illness

3.1 Public Health Risk

It's late March, 2022.

It's been one week since the country was struck by Cyclone Ranu. The Public Health Response Team at HQ has received the following email:

==

Date: Wed, 30 March 2022

From: Public Health Response: Aries Island Province

To: Public Health Response: HQ

Subject: Seeking urgent advice for AWD outbreak

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Dear Colleagues,

We have suffered significant flood damage here on Aries Island due to extensive rainfall caused by the cyclone. Many surface and ground water sources have been contaminated by floodwater, and there has been overflow of sewage into waterways and streets of the provincial capital. The local sewerage works is not currently operational, due to ongoing urgent repairs. There is very limited electricity supply, and frequent blackouts.

We've received several unconfirmed reports of outbreaks of acute watery diarrhoea (AWD) involving mostly infants and children, but also older people, living in temporary shelters and informal settlements. Many of these displaced and affected communities are not easily reachable, due to the flood-damaged roads.

We're very concerned, and seeking your urgent epidemiological advice to help us understand what may be causing this, and what can be done to slow or stop these outbreaks?

Unfortunately, we have very limited capacity to collect samples or do any kind of laboratory testing, at this time.

Many thanks, Aries PH team

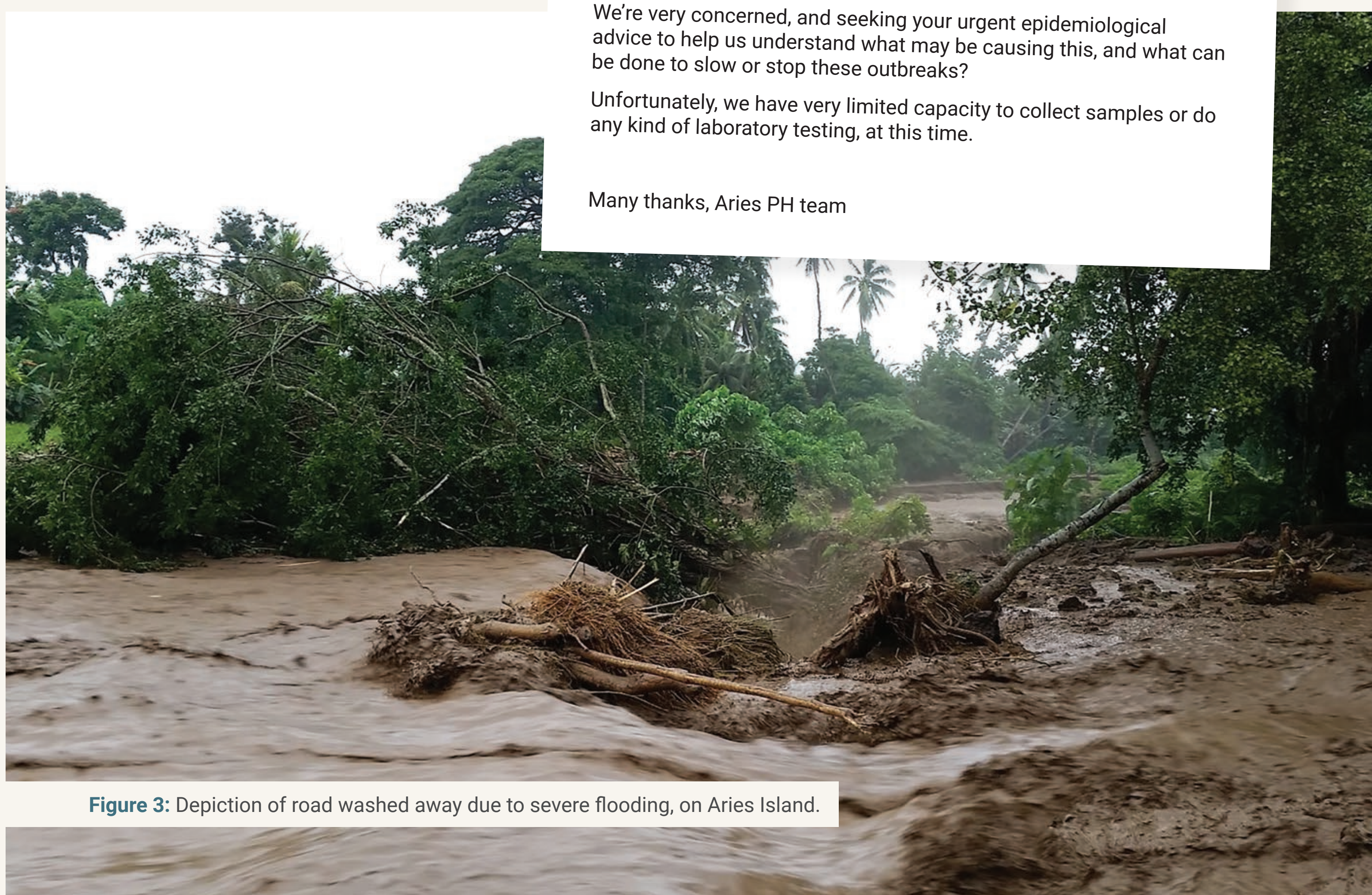


Figure 3: Depiction of road washed away due to severe flooding, on Aries Island.

You know that insanitary conditions and a lack of access to fresh, clean and safe (potable) water for drinking, cooking and washing is a common cause of gastrointestinal illnesses in humanitarian emergency settings (4).

You decide to work with the Public Health Response Team at HQ to develop some ideas to share with provincial colleagues about common gastrointestinal illnesses associated with contaminated water, food and inadequate sanitary conditions, including **chains of infection**, and known **transmission routes**. You'll also provide advice on practical public health interventions which can be quickly implemented.

Having a good understanding of chains of infection and transmission pathways of common infectious gastrointestinal diseases means that effective public health interventions can be made, even without knowing a definitive cause of the illness.

3.2 Epi Concepts

Acute watery diarrhoea (AWD) and other gastrointestinal syndromes are oftentimes caused by **infectious diseases**, which include several **pathogens** like viral, bacterial, protozoal or parasitic organisms that exits in various **sources/reservoirs** (e.g. infected humans, contaminated water or soil, other animals, etc.). Following **exposure** to a pathogen, these organisms can infect a **susceptible host** (e.g. human, animal), then multiply, cause illness (infectious disease) and can spread onwards to other susceptible hosts – this pathway is called the **chain of infection**. Examples of gastrointestinal diseases include: norovirus, hepatitis A and E, hookworm, cholera and typhoid.

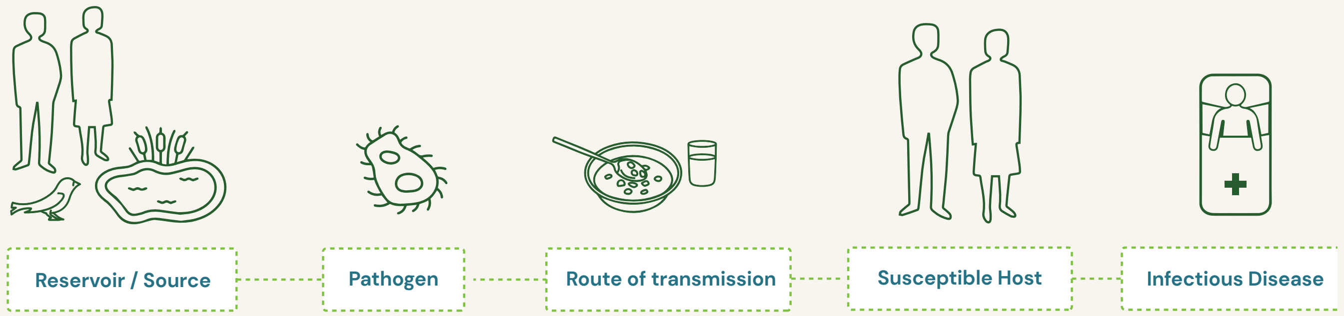


Figure 4: The Chain of Infection.

A pathogen may be passed from its natural reservoir to a susceptible host via several possible **routes of transmission** - these are called **transmission pathways**. **NB:** Many pathogens can have several possible transmission pathways.

The diagram below depicts several possible transmission pathways associated with gastrointestinal illnesses in environments with inadequate water, sanitation and hygiene (WASH).

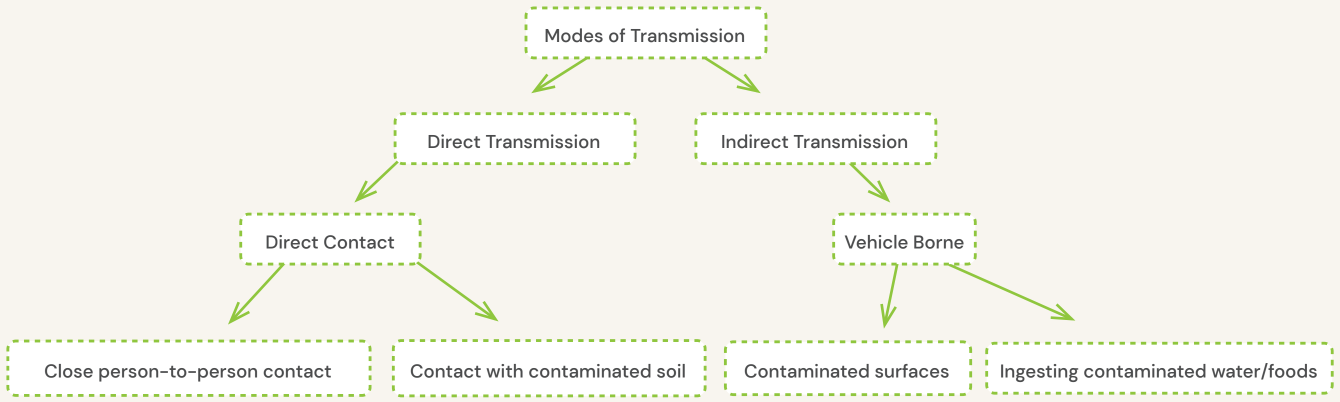


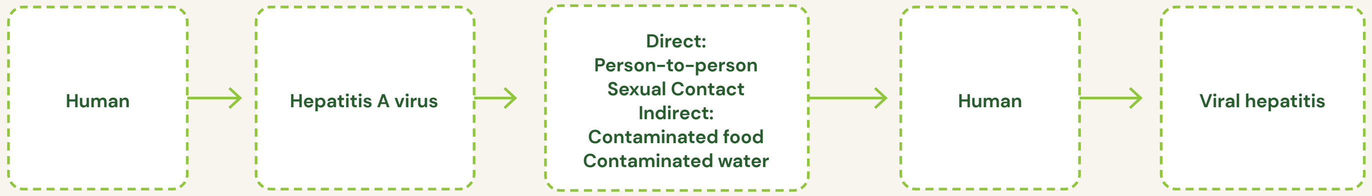
Figure 5: Selected transmission pathways for gastrointestinal illnesses associated with inadequate WASH.

Inadequate access to WASH is a leading cause of gastrointestinal infectious diseases in emergency settings.

Diarrhoeal diseases are common in emergency settings where there are insanitary conditions and/or a lack of access to fresh, clean and safe (potable) water for drinking, cooking and washing, and/or inadequate sanitary facilities for using the bathroom. Some examples of gastrointestinal pathogens and their chain of infection are described below.

Viral gastrointestinal infections, e.g. norovirus, may be transmitted by direct contact with vomit or stool of an infected person, or person-to-person contact, e.g. shaking hands with someone who has been sick and has the virus on their hands, or indirect transmission via contaminated objects, or airborne particles when people vomit (5).

Hepatitis A (HAV) is a viral illness causing inflammation of the liver. It can be a foodborne illness, e.g. transmitted by eating contaminated fruits or vegetables. HAV can also be passed from person-to-person by the by direct or indirect contact with faeces, or sexual transmission (6).



Hepatitis E (HEV) is a viral illness causing inflammation of the liver. It can be a foodborne illness, e.g. transmitted by eating undercooked meat like pork liver, deer and wild boar. HEV can also be passed from person-to-person by direct or indirect contact with faeces, or vertical transmission (from a pregnant woman to her baby, across the placenta) (7).

Parasitic **soil-transmitted helminth** infections, e.g. hookworm (ancylostomiasis) may occur when free-living parasitic larvae penetrate the skin, e.g when walking bare foot on contaminated soil. Hookworm infections often occur in areas where human faeces are used as fertilizer, or where open defecation onto soil happens (8).

Human → *Ancylostoma duodenale* → Direct: Exposure to contaminated soil Indirect: Larvae passed in stool → Human → Ancylostomiasis intestinal hookworm

Waterborne bacterial illnesses, e.g. cholera is spread most commonly through contaminated water either by drinking, washing with or brushing teeth with unsafe water that has been contaminated with sewage (9).

Human → *Vibrio cholerae* → Indirect: Contaminated food Contaminated water → Human → Cholera

Foodborne illnesses may result from eating food items that have become spoilt due to a lack of refrigeration, have been undercooked, or cross-contaminated during preparation. Food may also contain toxins (e.g. fungal or bacterial enterotoxins, botulinum nerve toxin), or become contaminated by infectious organisms e.g. due to incorrect preparation or storage, or exposure to contaminated flood waters during planting, growing, harvesting, packaging, storage or preparation. The bacterial illness typhoid fever may be contracted by ingesting food contaminated by infectious food handlers who have poor hand hygiene practices (10).

Human → *Salmonella enterica*, serotype Typhi → Direct: Person-to-person (rare) Indirect: Contaminated Food Contaminated water → Human → Typhoid Fever

Next, your team will utilise existing scientific knowledge and epidemiological evidence about the chains of infection and transmission pathways for gastrointestinal diseases associated with inadequate WASH to formulate advice on timely public health intervention strategies.

Aries Island: Gastrointestinal illness

3.3 Public Health Interventions

You work with the environmental health officers in the Public Health Response Team to identify and quickly adapt suitable resources for sharing with provincial health response teams on the various islands. The focus is on practical intervention strategies that may interrupt transmission of communicable gastrointestinal illnesses by raising awareness and optimising implementation of sound water, sanitation and hygiene **(WASH)** systems and processes in the wake of the cyclone.

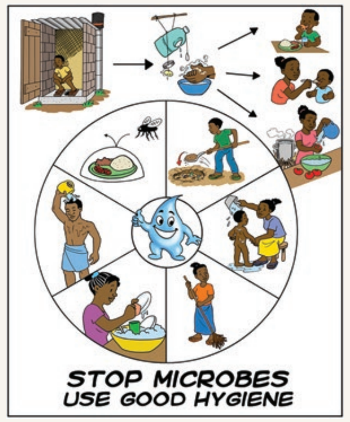
These may include:

Issuing an urgent **Public Health Alert,** including a Boil Water Notice or Advisory.

Developing and implementing a **risk communication strategy,** which may include using various materials and media (SMS, posters, public service announcements, church services) to emphasise the importance of good sanitary habits, including hand hygiene before and after preparing food or using the bathroom, and use only clean, safe or treated water sources, as well as sound principles of food safety, e.g.:

- The Four Steps to Food Safety: Clean, Separate, Cook and Chill;
- Wash your hands thoroughly using soap for at least 10 seconds and dry them with a clean towel after using the toilet, after caring for someone with diarrhoea and/or vomiting, and before preparing food;
- Use dedicated ablution facilities (e.g. constructed pit latrines) and avoid defecating out in the open;
- Use only bottled or boiled water (for drinking and for brushing your teeth); and
- Do not consume untreated water.

Some examples of WASH-related risk communications materials are provided below:



Source: Centre for Affordable Water and Sanitation Technology

When feasible, attempt to collect faecal specimens from AWD case clusters for **laboratory testing** and confirmatory diagnosis.

Collaborate with environmental health officers to **monitor water quality** to ensure public water sources meet minimum public health standards.

> In the longer term, internally displaced persons (IDPs) living in temporary shelters or camps will require access to appropriately designed and constructed **WASH facilities**. The Sphere Handbook (Humanitarian Charter and Minimum Standards in Humanitarian Response) (11) provides appropriate guidance on the essential components to ensure:
>
> - Hygiene promotion;
> - Water supply;
> - Excreta removal;
> - Vector control;
> - Solid waste management; and
> - WASH in disease outbreaks and healthcare settings.

Remember to consider **gender, disability,** and the needs of other **vulnerable groups** like the elderly, expectant mothers and children in the design and construction of WASH facilities to help limit **gender-based violence (GBV)** and other forms of human rights abuses (4, 12). Such principles may include:

- Ensure an adequate number and quality of WASH facilities, within a reasonable walking distance of temporary accommodation or shelters;
- WASH facilities should provide an adequate supply of soap and water to service the population in need, and supplies frequently replenished;
- Provide separate facilities for men, and women and children;
- Ensure female facilities provide menstrual products, and a convenient and private way to dispose of menstrual waste;
- Ensure appropriate ventilation, and that pathways and facilities have adequate lighting at night;
- Ensure sufficient privacy screens for bathing and changing clothing; and
- Ensure doors are lockable.

KEY MESSAGE

When implemented early, simple but coordinated public health interventions can prove highly effective to limit the spread of gastrointestinal diseases that are caused by various infectious organisms (viral, bacterial, protozoal, parasitic, or toxic exposures). Provision of adequate water, sanitation and hygiene **(WASH),** and implementing basic but effective **water and food safety** strategies, supported by **risk communication,** can help interrupt the various pathways through which these gastrointestinal diseases are transmitted.

Understanding the **chain of infection** and **transmission pathways** of the various possible causes of a disease syndrome can help identify simple, cost-effective intervention strategies, even without knowing the exact cause(s) of the illness in every particular circumstance.

4

Gemini Island: Measles

4.1 Public Health Risk

It's early April, 2022. It's been nearly three weeks since the country was struck by Cyclone Ranu. The Public Health Response Team at HQ has received the following email:

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Date: Fri, 08 April 2022

From: Public Health Response: Gemini Island Province

To: Public Health Response: HQ

Subject: URGENT: AFR alert - suspected measles

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Dear Colleagues,

I'm writing from the Gemini Island Cyclone Evacuation Coordination Centre.

In the past 2 weeks, we've provided temporary shelter to several hundred internally displaced persons. These people are mainly from the western district of the island, which was heavily damaged by destructive winds. Many people have lost their homes, crops, livestock and all their belongings. Initially, we set up several temporary shelters here in the provincial capital city, including at the Municipal Community Centre, and the main City Central Church. We've also constructed a temporary tented camp inside the city's main football stadium, where we anticipate, many people will need to live for several months.

Yesterday, we received a SMS from a Surveillance Officer who is part of an evacuation team sent to the Anas Archipelago. This is a remote chain of islands which form part of a region inhabited by the seafaring Anas tribe.

The Anas are an ethnic minority group who primarily live a nomadic, seafaring lifestyle. Historically, the Anas have been a marginalised group who permanently live on ocean faring boats. The Anas have no formal documentation, education or fixed land address. As a result, they have almost no access to public services, including primary health care. The evacuation team was sent by boat to perform a rapid health assessment, and provide medical and evacuation assistance to any Anas families in need. It was unclear how badly these nomadic seafaring communities were affected by the impact of the cyclone.

Unfortunately, the news we have received is not good. The Surveillance Officer reported that there is great humanitarian need, and the evacuation team is travelling in a flotilla, escorting several large boats full of Anas refugees towards Gemini Island. These people are all in urgent need of medical attention, food and shelter. The Cyclone Evacuation Coordination Centre is currently urgently planning for their arrival.

Most concerningly, the Surveillance Officer reported that during the rapid health assessment, the team identified several young children on two boats who are suffering from acute fever and rash (AFR), and respiratory signs. The nurse who conducted the assessment suspects measles, and recommends response arrangements to be made in advance of their arrival to Gemini Island. These boats contain two large extended families, who reported that they were travelling together, but separately from any other boats before joining the evacuation flotilla. So, we're hoping the illness may be contained to these two boats, but we're unsure.

The Anas have cultural objections to childhood immunisation, so we're assuming all the children in the flotilla are unvaccinated. There's concern about inadvertently introducing measles into people sheltering in the island's evacuation centres or tented camp, which could result in a large measles outbreak in these vulnerable people!

The Governor of Gemini Island has agreed to provide refuge to the evacuated Anas people, but wants guarantees that the public health response team can prevent the spread of measles on Gemini Island. So, there is also a lot of political pressure to manage the public health risks faced under these difficult circumstances.

We are urgently seeking your advice on the following:

-Case and contact management, e.g. risk assessment, screening, quarantine and isolation procedures. E.g., can we isolate children with symptoms only? We've heard measles is very contagious, but unsure what that means, exactly, and how best to manage the situation.

-We've been informed that a quantity of measles vaccine has been shipped to Gemini Island for immunisation of people in temporary shelters and other at-risk groups, as part of the national cyclone response. What sort of immunisation coverage is needed to successfully prevent the transmission of measles virus, and prevent large outbreaks in IDPs in the tented camp?

Many thanks, Gemini PH team

You know that measles is a highly contagious disease caused by the measles virus, starting with a high fever, cough, red eyes and runny nose. Measles can be a serious and fatal disease, especially in undernourished children with weakened immune systems, pregnant women, and young adults that have no immunity (13, 14).

It is very important to:

- Ensure appropriate measles case and contact management, and
- Attain adequate vaccination coverage in at-risk populations, to achieve herd immunity.

This could prevent the rapid spread of measles in people sheltering in temporary accommodation, which could otherwise lead to a serious outbreak.

You decide to work with the Public Health Response Team (HQ) to develop some principles to share with provincial colleagues on the various **stages of infectious disease**, clarify concepts around contagiousness, **herd immunity and immunisation coverage.** You'll also provide guidance on **case and contact management** to limit transmission of highly contagious airborne or droplet spread viruses.

Figure 6: Refugees travelling on the open sea by boat. Photo credit: EPA-EFE/ANSA

4.2 Epi Concepts

4.2.1 Transmission pathways, stages of diseases

Measles virus is spread through several direct and indirect transmission pathways, as demonstrated in the diagram below. Droplet transmission is the most common mode of transmission.

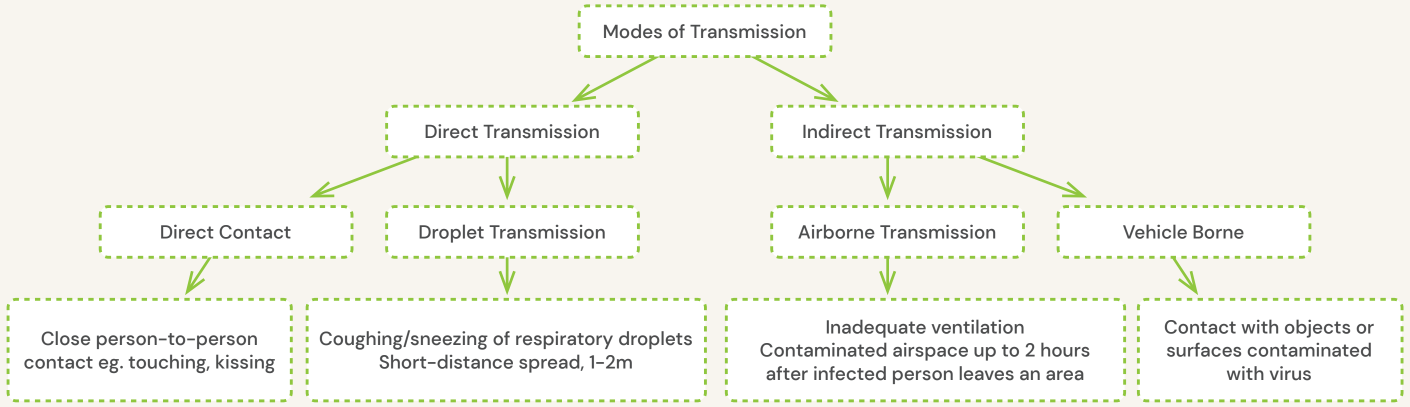


Figure 7: Transmission pathways for measles virus.

By understanding the **stages of disease**, we can predict when a case is likely to be **infectious** (i.e., able to transmit the disease to others). This is very important for appropriate **case and contact management.**

This is especially important for measles, because a case can become infectious one day before any symptoms appear, and up to four days before a rash appears. The infectious period can last up to four days after a rash first appears.

The following terms are important to understanding the stages of disease:

Incubation period: The time between a host being infected by a pathogen, and the onset of symptoms of disease. For measles, the incubation period is usually 10 days (range: 7-18 days).

Clinical disease: The time period of the disease process where there are signs and symptoms. It begins with the onset of symptoms, and ends with recovery, disability or death.

Infectious period: The time period from when an infected person is capable of transmitting a pathogen to other susceptible individuals, until they are no longer able to pass the infection on. For measles, the infectious period starts 24 hours before symptom onset, and lasts up to four days after a rash first appears.

Latent period: Also called the pre-infectious period, this is the time between a host being infected by a pathogen, and when becoming infectious. For measles, the latent period is one day shorter than the incubation period.

These concepts are demonstrated in the example diagram below, where case A has transmitted measles to case B.

Case A

Infected on 03 April;

Becomes symptomatic on 14 April;

Develops a rash on 17 April;

Infectious period starts on 13 April (one days before symptom onset) and lasts until 21 April (four days after the onset of rash);

Clinical symptoms resolve by 24 April; and

Fully recovered by 26 April.

Case B:

Infected by case A on 13 April;

Becomes infectious on 23 April;

Becomes symptomatic on 24 April;

Develops a rash on 27 April;

Infectious period starts on 23 April (one day before symptom onset) and lasts until 01 May (four days after the onset of rash);

Clinical symptoms resolve by 03 May; and

Fully recovered by 06 May.

Note: Case B was infected by Case A, on 13 April. The disease transmission event occurred on the first day of Case A's infectious period, which was one day before Case A was showing any symptoms of illness.

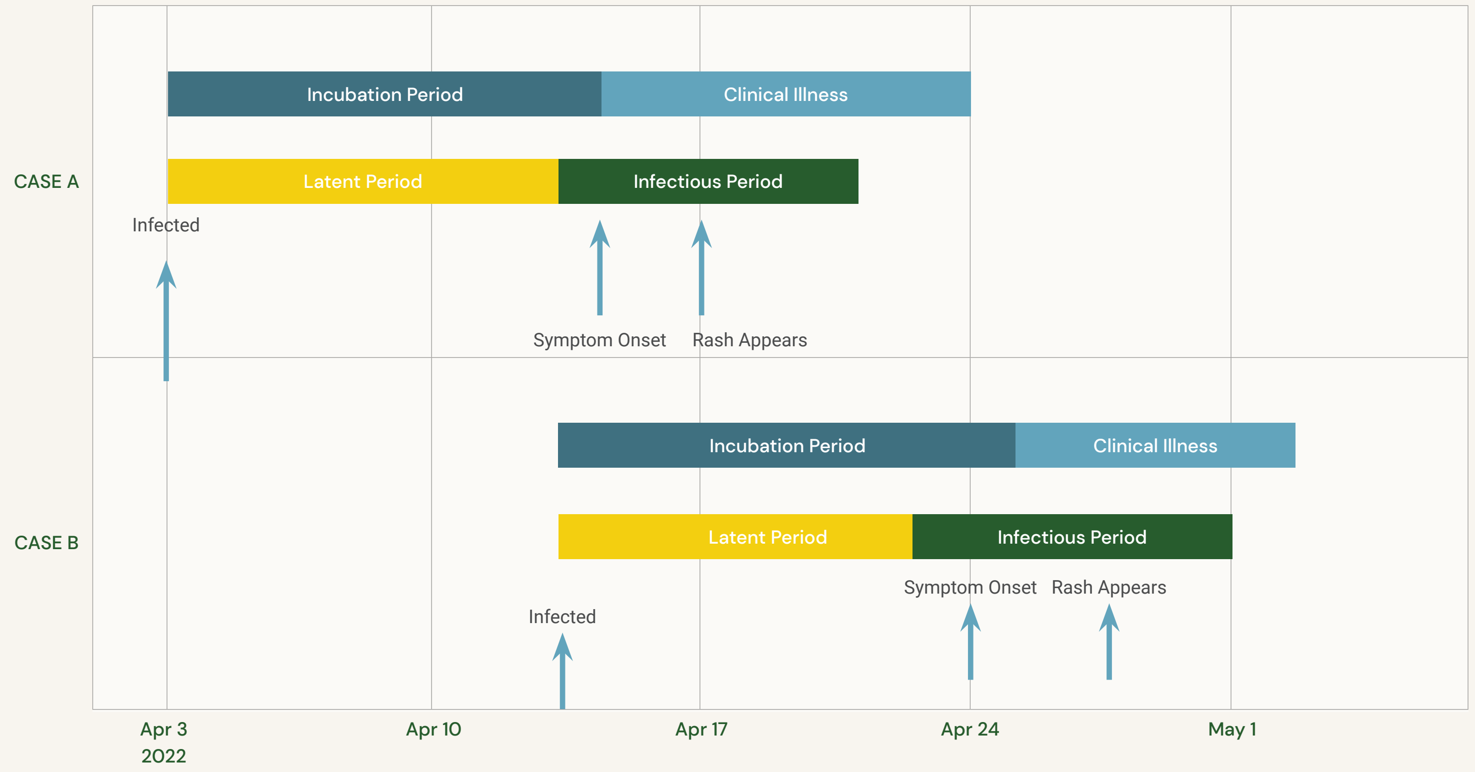


Figure 8: Measles stages of disease: Case A infects case B.

Gemini Island: Measles

Measles transmission events and stages of disease are rarely as clear as the example above, but it does demonstrate an important concept, namely that:

- Urgent identification, tracing and quarantine of persons who were in contact with infectious, but asymptomatic measles cases is critical to help stop an outbreak.
- Early quarantine of a contact exposed and potentially infected by a measles case before the contact themselves become infectious will break the cycle of transmission, because the measles virus is then unable to find other susceptible hosts to spread to.

4.2.2 Contagiousness and R0

Measles is a **highly contagious** virus, meaning it spreads readily between infectious and susceptible individuals. One epidemiological measure of a disease's contagiousness (ability to spread) is the **basic reproductive number** (R0) - *pronounced "R nought"* (15).

Basic Reproductive Number (RO)

- R0 is defined as the *"average number of secondary cases that result if a single infectious case is introduced into a **fully susceptible** population".*
- If R0 is greater than 1, an infectious disease will continue to spread in a population; if R0 is less than 1, a disease will stop spreading.
- During an infectious disease outbreak, epidemiologists may recommend a range of preventive and control measures (e.g. physical distancing, segregation, hand hygiene, mask wearing, isolation of cases and quarantine of contacts, vaccination of at-risk populations, treatment of sick cases, etc.) - collectively, these measures are aimed at getting R0 less than 1, thereby bringing the outbreak under control.
- **Note:** R0 is difficult to estimate under real-world conditions. It assumes that an infectious case is introduced to a fully susceptible population - however this is rarely true, because most populations will have some degree of underlying immunity to an infectious disease, unless it is a completely new (novel) emerging disease.
- Immunity to an infectious disease is usually acquired, e.g. through previous infection, vaccination, or from maternal antibodies in breast milk.
- Under real-world conditions, a more commonly used measure is the **effective reproductive number (Rt).**
- Rt is defined as the average number of secondary cases that result if a single infectious case is introduced into a population where not all individuals are susceptible.
- As soon as some individuals in a population are no longer susceptible (e.g. when an outbreak occurs, and some people recover and become immune or are vaccinated), Rt becomes more relevant than R0.

For measles, the theoretical R0 is typically 12-18 (16).

The diagram below demonstrates a scenario where one infectious, primary measles case is introduced to a fully susceptible population. With a R0 of 12-18, this means that a single measles case, if introduced to a fully susceptible population, is capable of transmitting the illness to 12-18 other people. In turn, each of these 12 to 18 secondary cases, will be capable of spreading the illness to another 12-18 people (tertiary cases). You can see how a measles outbreak can spread very quickly to become an uncontrollable epidemic!

Figure 9: Measles transmission at R0=12, in a fully susceptible population.

4.2.3 Immunity

Immunity refers to protection against disease. Immunity is indicated by the presence of antibodies in the blood and can usually be determined with a laboratory test (17).

Active immunity refers to the production of antibodies against a specific disease by a person's immune system. Active immunity can be acquired in two ways:

- By contracting a disease (natural immunity); or
- Through vaccination (vaccine-derived immunity).

Passive immunity is acquired when a person is administered antibodies, rather than producing them through their own immune system.

- Maternally-derived antibodies are transferred from a mother to her unborn baby through the placenta.
- Certain infectious disease treatments may involve administration of blood-derived antibodies from another person or animal to the patient - this is termed immunoglobulin therapy.
  E.g. post-exposure prophylaxis (PEP) against rabies virus exposure may involve administration of immunoglobulins (antibodies).

Herd immunity, or community immunity refers to a situation in which a sufficient proportion (%) of a population is immune to an infectious disease (through vaccination and/or prior illness) to prevent ongoing person-to-person spread. Even individuals not vaccinated (e.g. newborns, or immunocompromised persons) are offered some protection because the disease has little opportunity to spread (18).

Vaccination coverage refers to the proportion (%) of persons vaccinated in a population against a particular vaccine-preventable disease (e.g. measles, influenza, or COVID-19).

Herd immunity threshold (HIT)

The basic reproductive number (R0) of an infectious disease is important, as it relates to the herd immunity threshold (HIT).

The herd immunity threshold refers to the proportion (%) of a population that needs to be immune in order to interrupt disease transmission, and bring R0 < 1 to prevent or stop or an outbreak.

HIT = R0 - 1 / R0

Returning to measles, we know R0 = 12-18, in a situation where one infectious case is introduced into a fully susceptible population. So, to calculate the HIT required to interrupt measles transmission such a population, assuming a measles R0 = 18:

HIT = (18-1) / 18
= 17 / 18
= 0.94, or 94%

This result means, due to the very high contagiousness of measles virus (R0 = 12-18), between 92-94% of a population will need to have immunity to interrupt measles transmission through adequate herd immunity.

Therefore, a very high **vaccination coverage** will be required to protect against a measles outbreak in a vulnerable population, if there is very little underlying population immunity against measles.

Next, your team will utilise existing scientific knowledge and understanding of measles transmission, stages of disease, contagiousness and immunity to formulate advice on timely public health interventions to protect vulnerable communities displaced by Cyclone Ranu on Gemini Island.

4.3 Public Health Interventions

Let's recap the current public health risk facing Gemini Island, and consider timely public health interventions.

Summary of public health risk posed by measles on Gemini Island:

A flotilla of refugee boats is scheduled to arrive on Gemini Island soon. These vulnerable refugees are in need of medical attention, food and shelter. The refugees will be assisted by the Gemini Provincial Government and external partner organisations, in accordance with national and international humanitarian laws.

This nomadic community, the seafaring Anas tribe do not routinely access primary health care services. The provisional public health risk assessment suggests it's highly likely that very few, or no children in the flotilla have received routine childhood vaccinations.

At least two boats in the flotilla have been assessed as likely containing symptomatic, infectious measles cases. The measles status of persons travelling on other boats in the flotilla is unclear, at this time.

Simultaneously, there is a large population of vulnerable internally displaced persons living in temporary evacuation centres or a large tented camp community inside Gemini Island's main football stadium. Should measles become established in this larger vulnerable population, that could result in a very large measles outbreak on Gemini Island.

You identify two key strategies to prevent, or minimise the risk of introduction and establishment of a measles outbreak on Gemini Island.

1. Interrupting the routes of transmission

Transmission of measles can be interrupted through:

- **Risk assessment and screening of at-risk groups:** Identifying those groups or locations at high risk of measles transmission.
- **Case and contact management:** Including isolation of infectious cases, and quarantine of contacts.
- **Isolation:** Refers to the separation and restriction of movement of cases who are ill;
- **Quarantine:** Refers to the separation and restriction of movement of a group of potentially infectious people;
- **Infection control:** Using appropriate personal protective equipment (PPE) and barrier nursing techniques;
- **Post-exposure prophylaxis (PEP):** Susceptible contacts of infectious cases could be given the Measles, Mumps and Rubella (MMR) vaccine, ideally within 72 hours (3 days) of exposure to prevent infection.

To assist the public health response team on Gemini Island, you develop the below diagram to demonstrate a **risk-based** approach to measles management, including: screening, case and contact management (including isolation, quarantine), PEP and supportive treatment.

This process is a **public health risk mitigation measure**, before allowing a sub-population with a different risk profile to join other IDP communities sheltering in evacuation centres or living in the large, temporary tented camp community on Gemini Island.

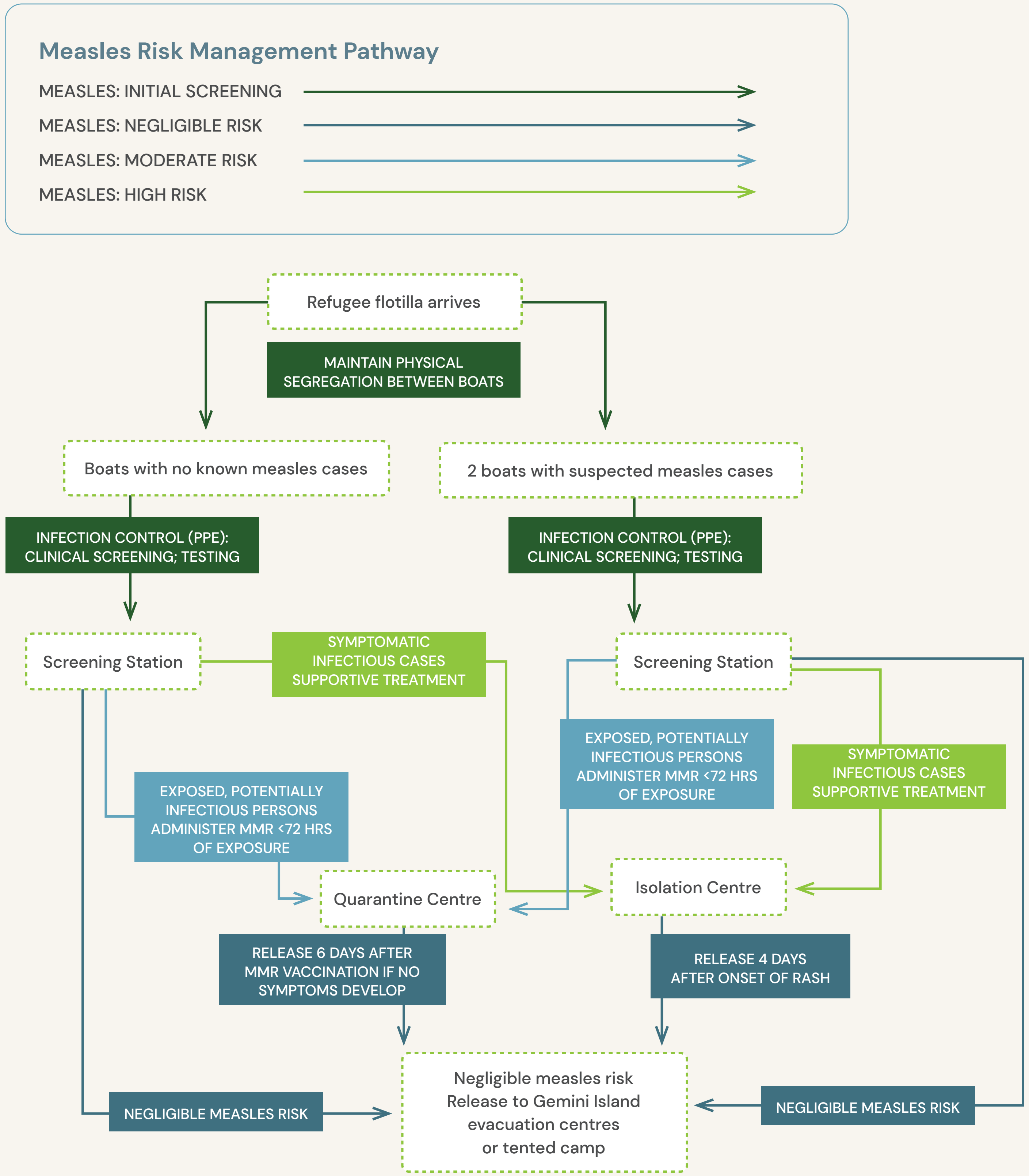


Figure 10: Flow diagram for measles risk assessment, screening, case and contact management for Gemini Island refugee arrivals.

2. Identifying and reducing (or eliminating) the susceptibility of vulnerable groups

Susceptibility to measles can be reduced through:

- **Vaccination** (vaccine-derived immunity);
- **Strengthening host resistance:** Provision of good nutrition, adequate shelter and primary health care; and
- **Education:** Including risk communication, and community engagement.

Measles is a vaccine-preventable disease. Measles can be prevented with several vaccines, including the combination Measles, Mumps and Rubella (MMR) vaccine. The MMR vaccine is generally recommended as part of routine childhood immunisation programmes, and is very safe and effective. MMR vaccine effectiveness is estimated at 93% for a single dose; 97% effective for two doses (19).

Noting the high contagiousness of measles, you recommend that the public health response team aims to achieve a **vaccination coverage of 94% or higher** in the **target population eligible for vaccination** (e.g., all children between 6 months and under 10 years of age).

You recommend that the provincial logistics and operations teams assist the public health response team with vaccination, including coordination, supply and distribution, cold chain management, vaccine delivery, record keeping, data collection, as well as vaccine coverage, resources permitting.

Figure 11: A child receives a dose of measles and rubella vaccine during an immunisation campaign.
Photo credit: © UNICEF/UN0567019/Wilander.

KEY MESSAGE

Understanding the epidemiological concepts of **transmission pathways, stages of disease, contagiousness and herd immunity** allows identification of key strategies to prevent, or minimise the risk of introduction and establishment of an infectious disease outbreak.

Two key strategies for preventing highly contagious airborne infectious disease outbreaks include:

1. Interrupting the routes of transmission (e.g. case and contact management); and
2. Reducing (or eliminating) the susceptibility of vulnerable groups (e.g. vaccination, and providing adequate nutrition).

5

Capricorn Island: Leptospirosis

5.1 Public Health Risk

It's late April, 2022. It's been one month since the country was struck by Cyclone Ranu. The Public Health Response Team at HQ has received the following email:

===

Date: Tue, 26 April 2022

From: Public Health Response: Capricorn Island Province

To: Public Health Response: HQ

Subject: Fever illness outbreak, Lepto suspected

===

Dear Colleagues,

Capricorn Island suffered significant flooding due to persistent rainfall in the weeks following the cyclone. Large areas on the outskirts of the provincial capital city remain inundated by flood waters. These flood waters flowing down from the Highlands pass through subsistence farming areas on the hillsides above the city. Many of these hillside villages farm livestock, especially pigs, but also goats, some cattle and chickens.

Two weeks ago, we received the first reports of some sick farmers on the hillsides. Several were complaining of fever, chills, muscle pain, and vomiting. The local health post reported two deaths in pig farmers by SMS. The exact cause remains unknown.

Since then, we've received similar reports of several cases of unexplained fever-like illness in communities living in informal settlements in low-lying areas downstream from the hillside villages. These are communities living in and around swamplands with inadequate drainage, and lacking proper sewage and sanitation services. There is also a build-up of refuse and waste, plus lots of scavenging dogs, rodents and other pests like crows. It's all been made worse by the stagnant water pooling everywhere.

We've sought further information from the provincial hospital here in the capital city. They reported treating several prolonged fever (PF) patients in the past month, some of who showed signs of kidney and liver damage. Three patients, including one child, have died. Thankfully, several of the patients have responded to antibiotic therapy and have since recovered. The Hospital Director suspects leptospirosis, because this is a well-known historical disease problem in the area, especially during the wet season.

The hospital has limited antibiotics and equipment for treating severely ill patients. Noting the diagnosis has not been laboratory-confirmed but is strongly suspected, and given how serious this illness is, we are seeking your urgent advice on practical measures to help slow or stop this suspected outbreak?

Many thanks, Capricorn PH team

You know that leptospirosis is a bacterial illness of humans and animals (a **zoonotic disease**), and commonly associated with close contact with animals or in people who are exposed to water, mud, soil, or vegetation that has been contaminated with animal urine.

Figure 12: Depiction of large areas of the provincial capital inundated by stagnant floodwaters, Capricorn Island.

You decide to work with the Public Health Response Team (HQ) to develop some concepts to share with provincial colleagues, to help simplify and explain the complicated epidemiology of leptospirosis. This should assist development of locally relevant risk communication materials.

Understanding leptospirosis in the context of the epidemiological triangle of agent-host-environment will allow the team to quickly identify and prioritise practical intervention points and control options to interrupt disease transmission and slow the outbreak (20).

5.2 Epi Concepts

The **epidemiological triangle** of infectious disease refers to the interactions between three elements:

- an **infectious agent** (also called a pathogen);
- one or more **susceptible host** species; and
- the **environment** within which both the agent and host(s) and their interactions occur.

The interactions between these three elements may result in **disease** causation.

The **source** or **reservoir** is a term used to describe the environment where an infectious agent persists and survives in its natural cycle - usually this may be one or more different host species, but can also involve vectors (e.g. mosquitoes) and the environment.

Importantly, the epidemiological triangle concept also allows consideration and identification of various possible **intervention points.**

- Interventions (preventive or control measures) can be implemented on the **pathways** between the three elements to prevent, slow or interrupt the interactions which result in disease transmission, as demonstrated in the diagram below.
- In addition, interventions (preventive or control measures) can also be applied directly on one or more of the elements (agent, host, environment) to prevent, slow or interrupt the interactions which result in disease transmission, as demonstrated in the diagram below.

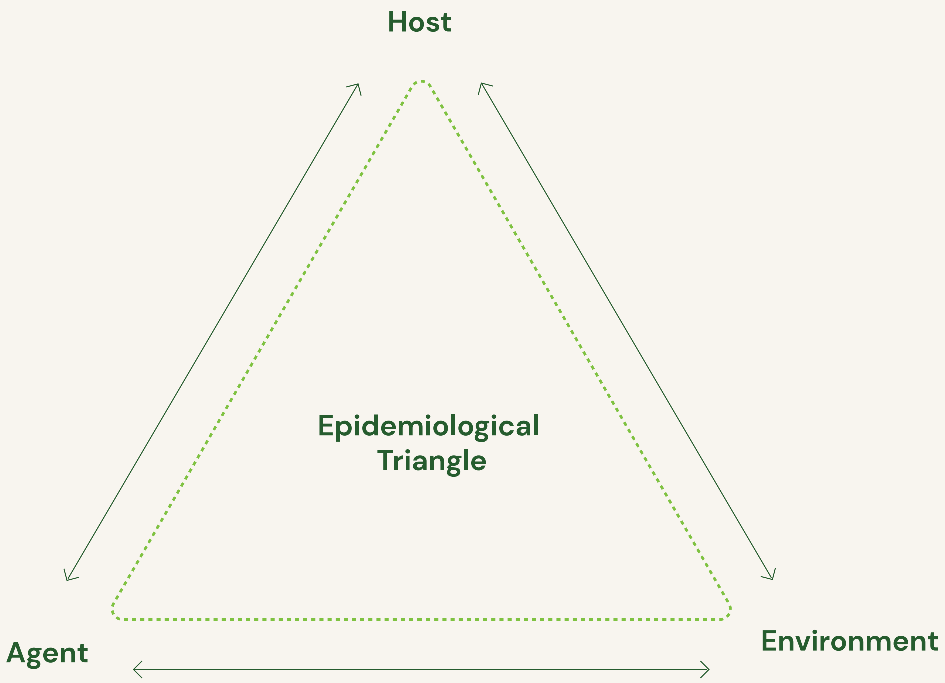


Figure 13: The epidemiological triangle of infectious disease causation.

Next, your team will utilise existing scientific knowledge and evidence about the epidemiology of leptospirosis to help identify control points and effective health intervention strategies to prevent or slow disease transmission, and halt the suspected outbreak.

5.3 Public Health Interventions

Agent: Leptospirosis is a zoonotic infectious disease, caused by various **serovars** (types) of *Leptospira spp*. bacteria, belonging to a class of organisms called spirochaetes (21).

Host: The **source (reservoir)**, or natural hosts of these bacteria include various species of vertebrate animals. Some *Leptospira serovars* are more commonly associated with certain species of animals, but most serovars can also infect other species of animals. For example:

- *Leptospira arborea* and *Leptospira interrogans* usually infects rodents;
- *Leptospira pomona* usually infects domestic and feral pigs;
- *Leptospira hardjo* usually infects cattle;
- Other serovars, e.g. *Leptospira kirschneri* have also been found in fruit bats in the Pacific region (22, 23).

Leptospirosis is a **zoonotic** disease, meaning humans can also become infected and serve as hosts to these bacteria. The **routes of transmission** that lead to human infection with leptospirosis include:

- Contact of broken skin or mucous membranes (such as the eyes, nose or mouth) with contaminated soil or water, or ingesting water contaminated with the urine of infected animals;
- Direct contact with the urine or tissues of infected animals, e.g. during slaughter or when assisting birthing animals.
- Human-to-human transmission or inhalation of bacterial aerosols is possible, but occurs only very rarely.

Environment: Outbreaks are usually related to exposure to contaminated water sources (e.g. flood water runoff), or environments contaminated with the tissues or secretions (e.g. urine) of infected animals, e.g. soil or contaminated surfaces in animal pens.

You develop a detailed diagram depicting the epidemiological triangle and pathways between the elements that lead to leptospirosis. These pathways are then evaluated as possible **intervention points** to apply preventive or control measures, as shown below.

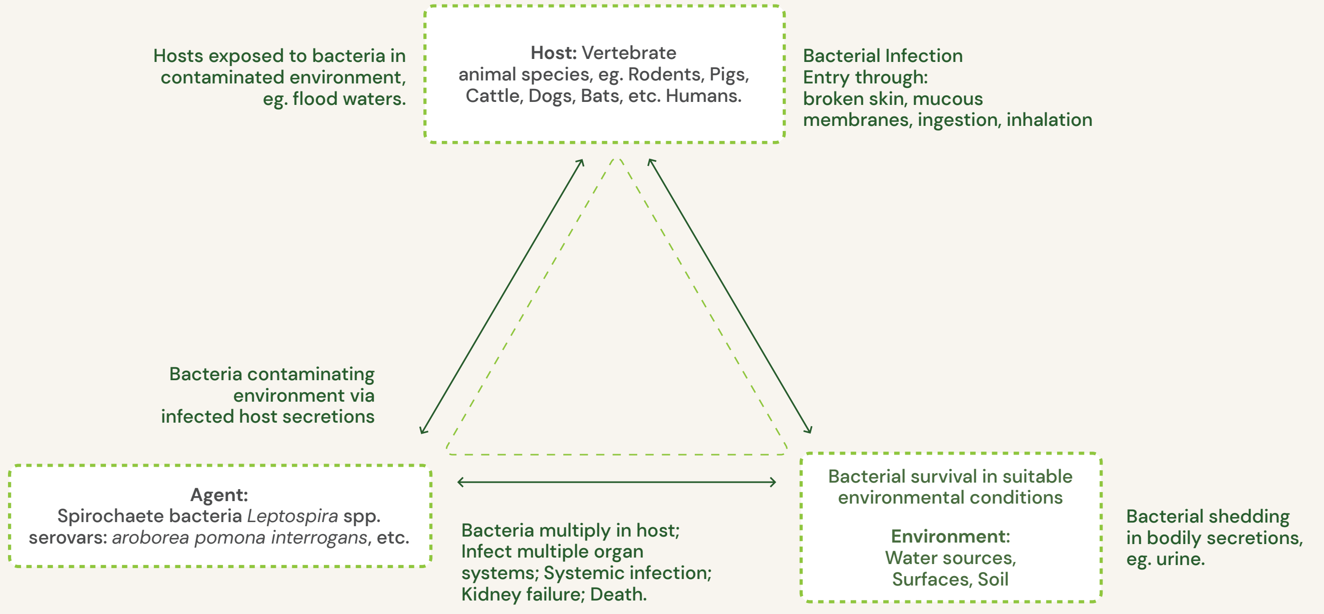


Figure 14: The pathways between agent, host and environment in the epidemiological triangle of leptospirosis.

Now that these epidemiological elements and pathways have been mapped, you use this information to identify and document the possible control points and intervention strategies available to help halt the outbreak, as shown below.

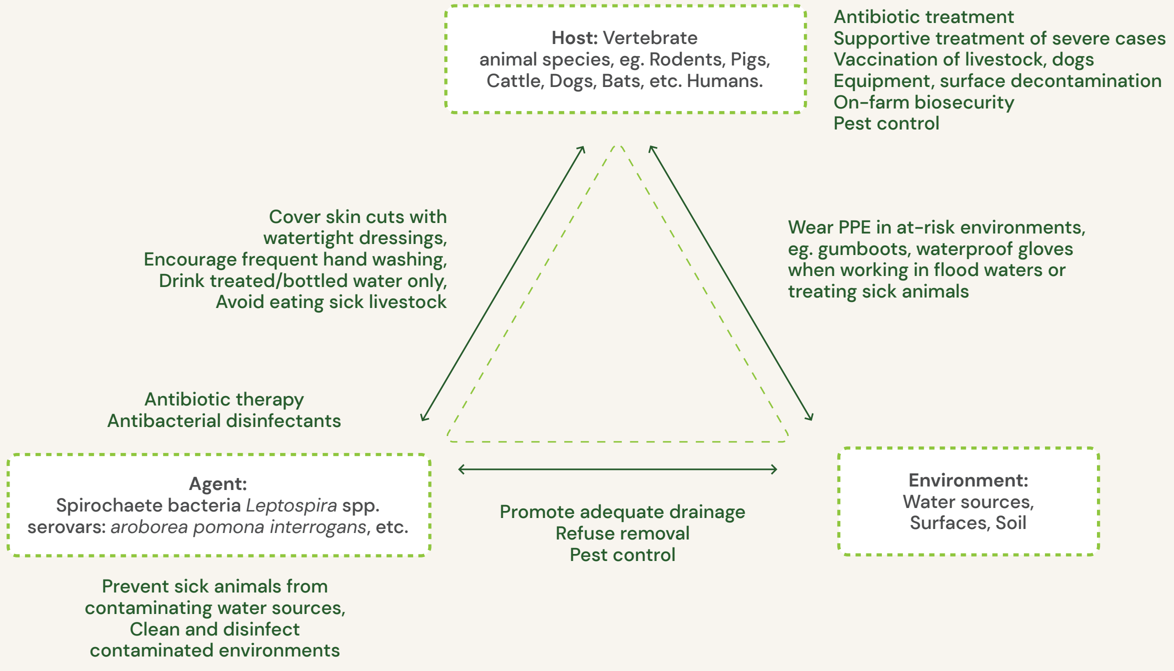


Figure 15: Preventive and control options for leptospirosis targeting the agent, host or environment, and the pathways between these elements.

A summary list of leptospirosis prevention and control options is shared with the provincial public health response team on Capricorn Island.

Routine preventive and control strategies using a One Health approach include:

Public health:

- Provide antibiotic and supportive therapy for symptomatic cases.
- Wear personal protective clothing (PPE) in at-risk environments, e.g. waterproof gumboots, coveralls and gloves when working in flood waters or treating sick animals.
- Avoid close direct contact with sick livestock (e.g. slaughtering or providing birthing assistance), unless wearing appropriate PPE.
- Cover skin cuts or abrasions with waterproof dressings; especially when active in at-risk areas, e.g. flooded farm fields.
- Encourage frequent hand hygiene - hand washing or use antibacterial hand sanitiser.
- Only consume treated or bottled water in flood-affected areas.
- Avoid consuming the meat or tissues of sick or dead animals.

Animal health:

- Provide antibiotic and supportive therapy for unwell animals.
- Vaccinate livestock and dogs against circulating *Leptospira* serovars, where possible.
- Thoroughly decontaminate (clean and disinfect) equipment and facilities that were soiled by sick animals' secretions.
- Maintain good on-farm biosecurity, e.g. separating any newly purchased or sick animals from the rest of the group.
- Maintain general farm hygiene, keep facilities clean, and equipment in good working order.
- Prevent livestock from having close contact or co-feeding with wild or feral animals.
- Implement feral animal and rodent control, especially where animal feed is stored.
- Avoid placing animal enclosures under fruiting trees or near bat roosting areas.
- Prevent livestock from wandering into or feeding in flood waters.

Environmental health:

- Use engineering controls to promote adequate drainage of flood-affected areas, where possible (e.g. pump floodwater from streets).
- Thoroughly decontaminate (clean and disinfect) any contaminated areas, e.g. flood-affected animal pens or houses.
- Prevent sick animals from wandering in, drinking from or otherwise contaminating water sources.
- Ensure appropriate integrated pest management, especially rodent control.
- Prevent an accumulation of refuse or other waste which attracted pests.

KEY MESSAGE

The epidemiological triangle of an infectious disease refers to three key elements: an infectious agent, one or more susceptible host species, and the environment within which interactions between these elements occur to result in disease causation.

Understanding the epidemiological triangle of disease causation, including the pathways between these elements allows identification of possible intervention points to apply preventive or control measures to slow disease transmission and stop an outbreak.

6

Aquarius Island: Dengue fever

6.1 Public Health Risk

It's mid-June, 2022. It's been nearly three months since the country was struck by Cyclone Ranu. The Public Health Response Team at HQ has received the following email:

===

Date: Wed, 15 June 2022

From: Public Health Response: Aquarius Island Province

To: Public Health Response: HQ

Subject: AFR - new dengue virus outbreak, vaccine enquiry

===

Dear Colleagues,

Following the widespread flooding and destruction first caused by Cyclone Ranu back in March this year, we've seen continued above-average rainfall during the wet season here on Aquarius Island. Since then, our provincial public health response team has been working very hard to address several public health challenges.

In recent weeks, we've experienced an explosion in mosquito numbers associated with the persistent rainfall, which has left large areas of the island with extensive flooding, particularly in low lying coastal districts. These long-standing stagnant water bodies and inundated areas, including in built-up urban areas create an abundant environment for mosquito breeding.

In recent days, we've received notification of at least two cases of dengue virus infection (DENV) here in the provincial capital, in a semi-urban area on the outskirts of the city. Both these cases were in young adults treated for a haemorrhagic illness. Both tested positive for DENV on a rapid diagnostic test and were diagnosed with severe dengue fever; one of these cases has sadly died. Confirmation of the virus serotype from the national diagnostic laboratory is still pending.

Although dengue virus has long been present on Aquarius Island, we are concerned since the national diagnostic laboratory warned us that the cases of severe dengue might indicate the presence of a new, exotic dengue virus serotype not previously known to occur in the country.

We have several questions, including if there are any differences between the various dengue viruses in terms of transmission pathways, host or reservoir species, mosquito vector species, incubation periods, and disease?

We understand the basic principles of dengue outbreak management, including mosquito bite prevention and vector control measures, but are struggling to understand how the arrival of a new virus serotype may change the epidemiological situation of dengue on the island, and what that means for any pre-existing community immunity?

A foreign donor organisation has offered to ship a large quantity of a new dengue virus vaccine to the island, but we've read some media reports saying there are health risks associated with vaccination against dengue. So, we're unsure whether to accept the donation and if so, the best strategy to administer the vaccine safely? We already face significant vaccine hesitancy in our communities.

To complicate matters further, we've already received enquiries from the media asking if the rumours about a new virus on Aquarius Island is true, and one newspaper is pressuring us to provide clear information, because they plan to publish a story with an alarming headline: "New mosquito-borne killer virus threatens outbreak on Aquarius Island"

So, we're under pressure to devise an effective strategy to explain the changing epidemiology and public health risks posed by a new dengue virus serotype through risk communication and community engagement.

Any expert advice or recommendations would be much appreciated!

Many thanks, Aquarius PH team

You know that dengue is a mosquito-borne infectious disease caused by a virus.

Although many dengue virus infections can be asymptomatic or mild, typical symptoms include an acute fever, rash, aches and pains, severe headache, nausea and vomiting. Most cases of dengue fever recover uneventfully; however, subsequent infections can also occasionally result in severe complications, leading to a life-threatening illness called severe dengue (sometimes referred to as 'dengue haemorrhagic fever') (24).

You decide to work with the Public Health Response Team (HQ) to develop some concepts to share with provincial colleagues on the epidemiology of dengue, including: **host (reservoir), transmission pathways, vector ecology, stages of disease, concepts of immunity, risk factors** and how these various elements may affect **disease severity.** You'll also provide advice on a **pre-vaccination screening strategy** prior to using a recently-approved **dengue vaccine** as a public health intervention in the face of dengue fever outbreaks (25-27).

6.2 Epi Concepts

Dengue is caused by infection with four distinct, but closely related serotypes (family groups) of dengue virus (DENV), namely: DENV-1, DENV-2, DENV-3, and DENV-4 (24).

The four types of dengue viruses are all part of the Flavivirus family, which also includes other viruses like Zika virus (ZIKV) and Japanese Encephalitis virus (JEV).

1. Transmission pathways

The diagram below depicts several possible transmission pathways associated with DENV transmission.

- Dengue viruses are primarily transmitted through the bites of infectious *Aedes* species mosquitoes.
- Direct person-to-person transmission also occurs; however, these modes of transmission are very rare (e.g. through blood transfusion, receiving infected organs through donation and vertical transmission - i.e. from a pregnant woman to her baby, across the placenta).

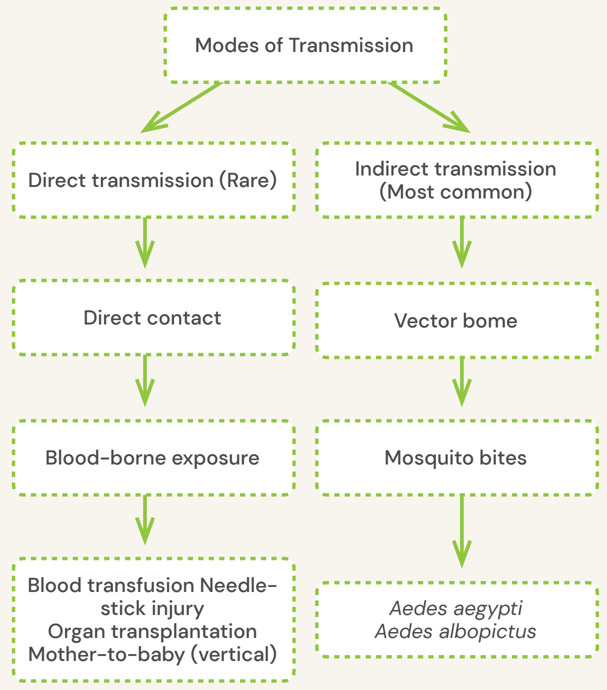


Figure 16: Transmission pathways for dengue virus (DENV) infection.

2. Vector ecology

Dengue virus is principally transmitted by biting females of two mosquito species: *Aedes aegypti*; and *Aedes albopictus*.
These mosquito species are also implicated in the transmission of other vector-borne viral illnesses, including **Zika virus (ZIKV), Japanese encephalitis virus (JEV)**, and several others.

- *Aedes aegypti* is the primary vector species of DENV. It is well adapted to urban habitats, and breeds readily in human-made objects and infrastructure containing standing water. This mosquito species is a day-time feeder; its peak biting periods are early morning and early evening before sunset.
- *Aedes albopictus* is a secondary vector species of DENV. This mosquito is highly adaptive, and has spread widely around the world due to international trade in containerised goods, e.g. used tyres that provide a breeding habitat. This mosquito is a cold-tolerant species and is also a day biter.

3. Stages of disease (extrinsic and intrinsic)

In infectious diseases epidemiology, the incubation period is defined as: the time between a host being infected by a pathogen, and the onset of symptoms of disease.

For vector-borne infectious diseases, additional concepts in the stages of disease also apply:

- The extrinsic (vector) incubation period;
- The period of infectivity; and
- The intrinsic (host) incubation period.

Dengue virus transmission occurs in a human - mosquito - human - mosquito cycle.

Mosquito-to-human transmission

After feeding on an DENV-infected person, the virus replicates in the mosquito's midgut, before spreading to the salivary glands.

The time period between the mosquito ingesting the virus when taking a blood meal from a viraemic (viruses present in blood) person, to actual transmission of the virus to a new human host is termed the **extrinsic incubation period (EIP)** of a vector-borne disease.

For DENV, the EIP takes about 8-12 days when the ambient temperature is between 25-28°C. The EIP may vary depending on fluctuations in daily temperature, virus genotype, the amount of virus ingested by the mosquito, and other factors.

Once infectious, the mosquito is capable of transmitting DENV for the rest of its life.

Human-to-mosquito transmission

Mosquitoes can become infected from people who are viraemic (i.e., have dengue virus circulating in their blood).

Viraemic human cases can transmit DENV to mosquitoes that bite them during their **period of infectivity** (approximately 7 days).

A viraemic human case can be symptomatic, pre-symptomatic (i.e., still incubating the disease, and not showing symptoms yet), or asymptomatic (not showing symptoms).

Human-to-mosquito transmission can occur up to 2 days before a case becomes symptomatic, and up to 2 days after the fever has resolved.

The time between an DENV-infected mosquito biting a susceptible person, and that person becoming symptomatic with dengue fever is the **intrinsic incubation period** (3-14 days) (28).

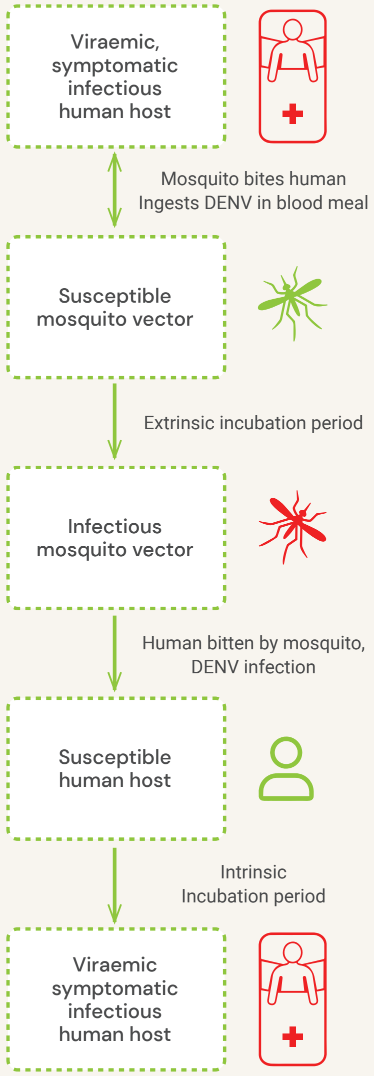


Figure 17: Human-mosquito-human transmission pathway of dengue virus (DENV) infection.

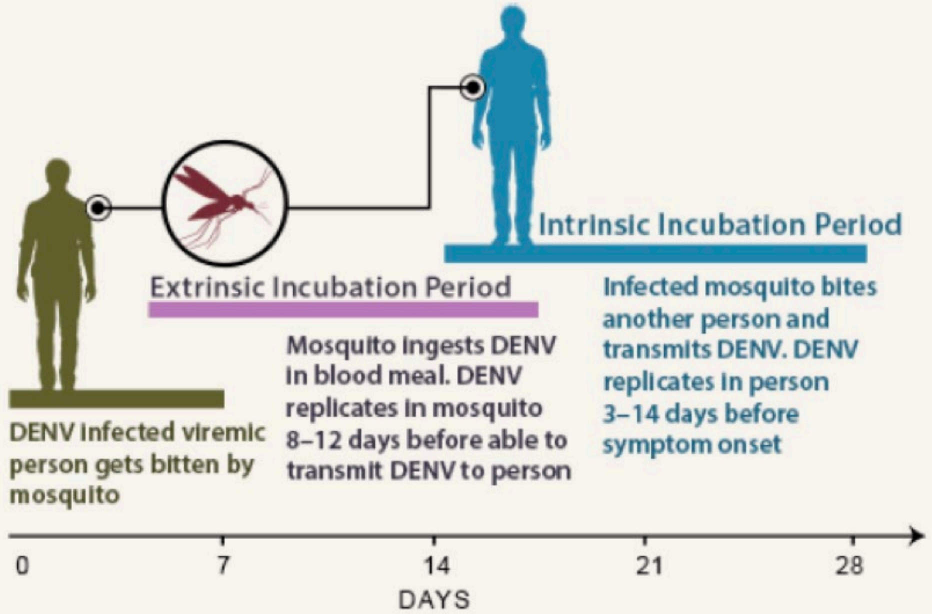


Figure 18: Extrinsic (mosquito) and intrinsic (human) incubation periods of dengue virus infection. Image credit: US-CDC online training module: Dengue Clinical Case Management (DCCM)

4. Dengue virus immunity and disease severity

Serotypes are separate groups within a species of a bacteria or virus that all share a similar characteristic, such as antigens or other molecules found on their surfaces. This means, a human can be infected with dengue virus up to four times in their life.

The World Health Organization (WHO) classifies dengue into 2 major categories:

- Dengue (with / without warning signs); and
- Severe dengue.

Risk factors for developing severe dengue include:

- Previous infection with DENV: infection with a **second** DENV of another serotype is most likely to cause hospitalization or severe disease.
- Unplanned urbanisation is associated with dengue transmission through multiple social and environmental factors, including: population density, human mobility, access to reliable water source, water storage practices, etc.
- Community knowledge, attitudes and practice towards dengue, as well as the implementation of routine sustainable vector control activities in the community.

After an infection with a DENV serotype, the case will have:

- Lifelong type-specific immunity. (e.g., a case infected with DENV-1 cannot become ill as a result of DENV-1 infection again).
- Short-term cross-immunity against other DENV serotypes for about 2 to 6 months.

A live, attenuated (weakened virus) vaccine against dengue first became available on the world market in 2015. Clinical trials have shown this vaccine to be efficacious and safe in persons who have had a previous dengue virus infection (seropositive individuals) (29).

However, persons who are seronegative (i.e. not previously infected by DENV) at time of first vaccination had a higher risk of more severe dengue and hospitalizations from dengue compared, to unvaccinated participants.

Next, your team will utilise existing scientific knowledge and understanding of dengue virus transmission, stages of disease, and immunity to formulate advice on timely public health interventions to protect communities on Aquarius Island against incursion of a new DENV serotype (30).

6.3 Public Health Interventions

International trade is known to spread new DENV serotypes to other regions of the world through the inadvertent transport of infected mosquitoes in goods which provide suitable breeding habitat.

Dengue risks may also change in tropical and subtropical regions due favourable environmental conditions caused by climate change. Mosquito vectors may also adapt to new environments.

In the case of Aquarius Island, the suspected introduction of a new, exotic DENV serotype means that persons previously infected by the endemic serotype may be at risk of developing severe dengue, if infected by the new virus serotype.

Vaccination against dengue fever

Considering that an endemic DENV serotype has long been present on Aquarius Island, this suggests that a proportion of the population would be immune to this serotype. However, the introduction of a new, exotic DENV serotype may place previously infected persons at risk of more severe disease, if they were infected a second time with the new serotype.

Therefore, vaccination of at-risk populations against severe dengue could be implemented; however there are additional risk management factors to consider. WHO recommends that a live, attenuated vaccine could be recommended for persons between 9-45 years of age, who have had at least one episode of dengue virus infection in the past, and who live in DENV endemic areas.

Pre-vaccination screening

Decisions about implementing a pre-vaccination screening strategy requires consideration of local DENV epidemiology, the diagnostic accuracy of available tests, and available human, financial and laboratory resources (31). With pre-vaccination screening, only persons with evidence of a past dengue infection would be vaccinated (based on an antibody test, or on a documented laboratory confirmed dengue infection in the past).

If a person who has never previously been infected with DENV is vaccinated, and then infected by DENV, this may result in an infection that is similar to the second dengue virus infection, which poses the highest risk for severe disease. If you vaccinate a person who has been previously infected with dengue virus, the person skips the second dengue virus infection. If then infected with another DENV after vaccination, the case will experience an infection that is similar to the third or fourth DENV infection, which are the lowest risk for severe disease.

Dengue prevention and control strategy

Aquarius Island should aim to implement an integrated dengue prevention and control strategy. This should comprise of several components, including:

- **Vector control:** Integrated mosquito management (IMM) aims to control mosquitoes, by focusing on the various stages of the mosquito life cycle, namely: removing places where mosquitoes lay eggs, controlling larvae and pupae, and killing adult mosquitoes.
- **Surveillance:** Active mosquito and virological surveillance to determine the species composition and abundance of vector species, as well as circulating DENV serotypes. In addition, ensuring appropriate diagnostic testing capacity, e.g. antigen and antibody detection tests.

Preventive measures:

- Prevent mosquito bites: use bed nets, mosquito repellent, protective clothing and household protection measures, e.g. window screens, and draining standing water around the house.
- Risk communication and community engagement to raise public awareness and to provide key information to communities at risk on dengue prevention and control.
- Encouraging persons experiencing symptoms, whether vaccinated or not, to come forward for early testing and treatment.

KEY MESSAGE

Understanding the epidemiology of a vector-borne infectious disease means considering various elements including: the host (reservoir), transmission pathways, vector ecology, stages of disease (including period of infectivity, intrinsic and extrinsic incubation periods), concepts of immunity, risk factors and how these various elements may affect disease severity.

7

Orion Island: Acute flaccid paralysis

7.1 Public Health Risk

It's late September, 2022.

It's been six months since the country was struck by Cyclone Ranu.
The Public Health Response Team at HQ has received the following email:

==

Date: Thu, 29 Sep 2022

From: Public Health Response: Orion Island Province

To: Public Health Response: HQ

Subject: AFP alert: Seeking advice on surveillance.

==

Dear Colleagues,

It's been a challenging six months for the Orion Island Provincial Public Health Response team since Cyclone Ranu struck. Unfortunately, just as we thought things are finally quietening down, there's been a concerning new development.

In the past month, we've received three notifications of acute flaccid paralysis (AFP) in children under 15 years of age as part of our weekly provincial syndromic surveillance reports. These three cases are from different districts in the east of Orion Island.

As you know, the Republic of the Constellation Islands has long implemented a routine childhood vaccination program which includes administration of oral polio vaccine (OPV) to all children under five years of age. However, due to the COVID-19 pandemic in 2020-21, followed by the damage to infrastructure, and disruption to the local health and logistics systems following Cyclone Ranu, the routine childhood immunisation program in the country has fallen behind schedule. As a result, several cohorts (age groups) of young children have not received their routine vaccinations for several years, including MMR, OPV, diphtheria and other vaccines.

Some months ago, we noticed an international alert describing an outbreak of a vaccine-related polio in our neighbouring country, the Alphabet Islands. Considering there is a lot of movement of people and goods between our countries, we're wondering if these reports of AFP cases here on Orion Island may be a cause for concern, and possibly even linked to what's occurred in the Alphabet Islands?

Some of our colleagues have dismissed these reports of polio in the Alphabet Islands as simply rumours or fake news, saying polio has almost been eradicated worldwide. In addition, they're saying it's also not possible for a vaccine to cause an illness that it's supposed to prevent!

We've sought permission for additional funding and personnel from the provincial Incident Management Team (IMT) to conduct further AFP case finding and stool testing, but that request for funding has been denied. The IMT has questioned how only three cases of AFP in different districts on the island could constitute an outbreak? Some colleagues feel there's no need for alarm, and suspect sporadic invasive meningococcal disease (IMD).

We would greatly appreciate your assistance in helping us understand and communicate some of the concepts around AFP/polio epidemiology.

We suspect the problem is more extensive than it seems, but we're unsure how best to explain that to the provincial policymakers?

Many thanks, Orion PH team

You know that in the event of syndromic surveillance reporting of **acute flaccid paralysis (AFP)**, it is of utmost priority to rule out **poliomyelitis**.

Polio is an ancient disease with a complex epidemiology which can be difficult to understand, and even harder to explain to at-risk communities through risk communication and community engagement.

You decide to work with the Public Health Response Team (HQ) to develop some concepts to share with provincial colleagues on the epidemiology of polio, including: **outcomes following exposure**, use of **live, attenuated (weakened) vaccines** e.g. the oral poliovirus vaccine (OPV), and the challenges associated with genetic **reversion to virulence** and the emergence of **circulating vaccine-derived polioviruses (cVDPVs)** (32, 33).

7.2 Epi Concepts

Poliomyelitis is caused by an enterovirus called **poliovirus**. Poliovirus is spread mostly by the **faecal-oral route.**

Poliovirus enters through the mouth and multiplies in the intestine. Infected individuals shed poliovirus in their stool. The virus can spread rapidly through a community, especially in areas with suboptimal water, sanitation and hygiene (WASH).

Types of polioviruses

Historically, there were three wild (natural) polioviruses circulating around the world: **wild-type polioviruses 1, 2, and 3 (WPV1-3). WPV-2 and WPV-3** were officially declared eradicated from the world in 2015 and 2019, respectively.

Today, only WPV-1 remains, and still persists in a few remaining conflict-affected countries with poor sanitation, weak health systems, and limited resources. The success of the near-worldwide eradication of wild polioviruses is due in large part to the widespread use of the **oral poliovirus vaccine (OPV)**, which consists of live, attenuated (weakened) strains of poliovirus.

The OPV virus provides stronger immunity in the gut, which is where the poliovirus replicates. The OPV virus is also excreted in the stool, and in communities with suboptimal WASH, this means that person-to-person spread can occur and actually help provide **herd immunity** by immunising those individuals who have not received the OPV.

However, in communities with low immunisation coverage rates, as the vaccine virus spreads from one unvaccinated child to another, it can mutate and take on a virulent form that can cause paralysis just like WPV. This process is called genetic **reversion to virulence**, and usually happens over a long period of time (about 12-18 months).

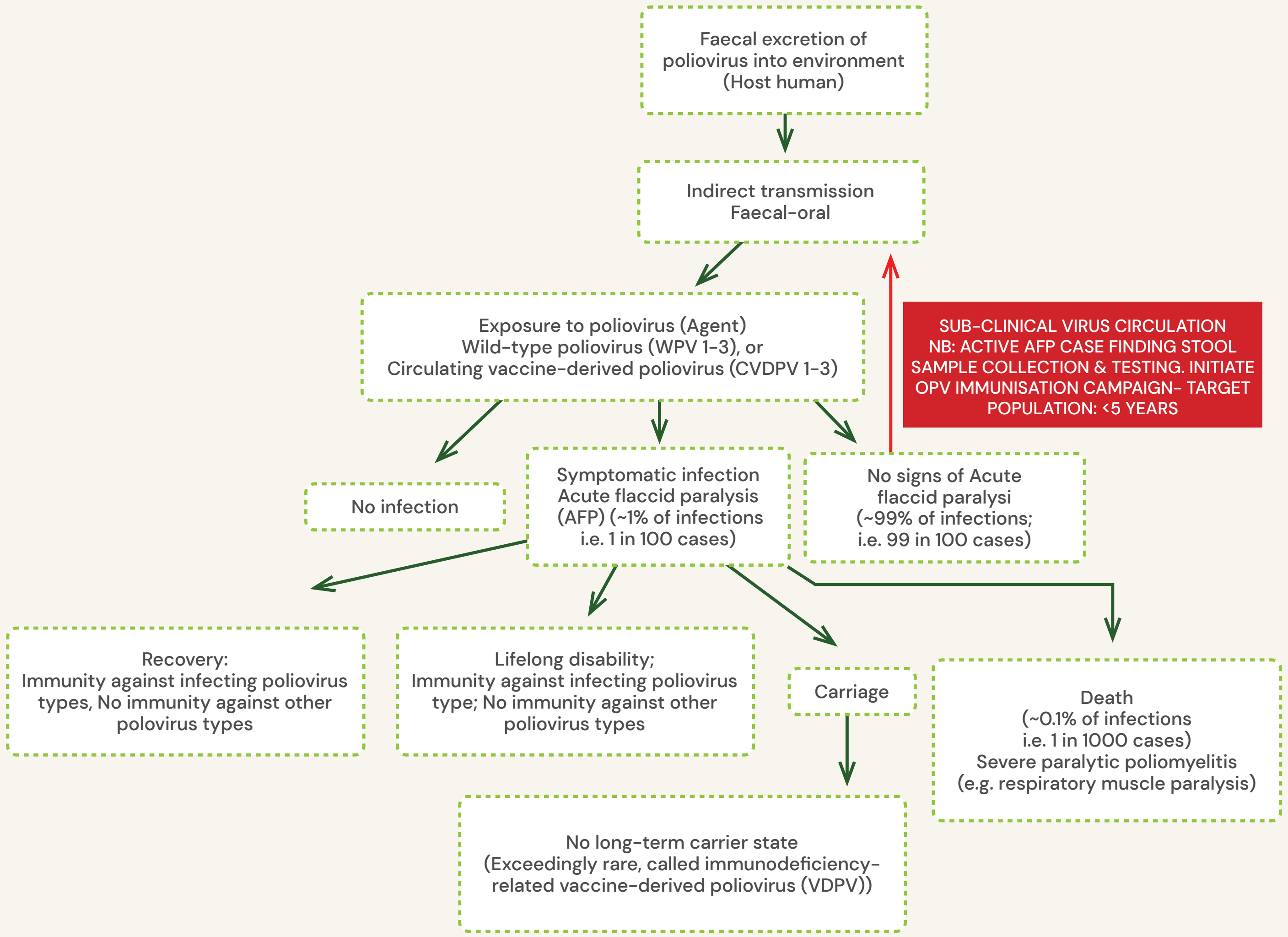
This mutated vaccine virus can then spread in communities, causing outbreaks of **circulating vaccine-derived poliovirus (cVDPVs).**

Refer to Figure 19 to examine the various possible outcomes following exposure to poliovirus. Note the red arrow, which highlights the critical epidemiological link where the majority (99%) of silent poliovirus circulation and spread may be occurring within communities.

There are various possible outcomes following exposure to poliovirus:

- Exposure, not followed by infection;
- Infection not involving the central nervous system (CNS), which results in minor illness with mild, or no symptoms (~ 99% of all poliovirus infections); or
- Infection involving the central nervous system (CNS), which results in paralytic **poliomyelitis**, which may cause paralysis, lifelong physical disability or death (~1% of cases).

Figure 19: Possible outcomes following exposure to wild or vaccine-derived poliovirus.



The silent spread of polioviruses

Based on Figure 19, it's clear that for every 1 case of AFP caused by poliovirus, there is likely to be at least 99 with no signs of Acute flaccid paralysi cases, who may be shedding poliovirus into the environment for several weeks.

If you are aware of 3 cases of AFP due to poliovirus across different districts on Orion Island, that means there are likely to be at least 297 other asymptomatic cases of poliovirus infection, who may continue to spread the virus.

If AFP cases have already been detected in different districts, that also suggests that an outbreak of poliovirus may be far more widespread than first meets the eye.

Understanding these concepts is critical to be able to effectively communicate with policymakers.

Next, your team will utilise existing scientific knowledge and understanding of polio epidemiology, including outcomes following exposure, and concepts of immunity to conduct a risk assessment and formulate advice on timely public health interventions to verify and contain a possible poliovirus outbreak on Orion Island (34).

7.3 Public Health Interventions

Your team provides the following information to the Orion Island Incident Management Team (IMT):

> Due to health system disruptions over the past several years, Orion Island, like other provinces in the country has not achieved optimal childhood immunisation coverage rates in recent years, including against polio using OPV.
>
> Current epidemiological evidence suggests there are at least 3 AFP cases of unknown cause, located in separate districts in the east of Orion Island.
>
> If poliovirus is confirmed as the cause of AFP in these three cases, this would point to the existence of a significant outbreak of poliovirus likely involving hundreds of asymptomatic cases over several districts. Additional cases of AFP may be expected.
>
> Based on the limited available information, the national public health risk assessment concludes that the risk of polio in this instance is medium to high.
>
> It is therefore strongly recommended for the Orion Public Health Response Team to be appropriately resourced to initiate an urgent investigation in accordance with response procedures outlined in the Pacific Outbreak Manual (3).

These response procedures include:

- Report the findings to national public health authorities;
- Conduct urgent active case finding: conduct a thorough, extensive search for other AFP cases;
- Collect stool specimens from AFP cases and their close contacts (where possible) for laboratory testing;
- Collect epidemiological information, by completing detailed case investigations (interview next-of-kin);
- Management of contacts, including immunisation using OPV; and
- Initiate risk communication and community engagement to raise awareness of AFP symptoms and reporting.

Remember that if poliovirus is laboratory-confirmed, it is important to comply with international reporting obligations of notifiable disease events by notifying the World Health Organization (WHO) under the International Health Regulations (IHR 2005).(35)

Depending on the results of the initial investigation, particularly if poliovirus is laboratory-confirmed, the National Ministry of Health will assist the Orion Provincial Government with planning and implementation of an Expanded Program on Immunisation (EPI) to achieve optimal OPV immunisation coverage rates in the target population for vaccination, e.g. all children under 15 years of age.

KEY MESSAGE

For infectious diseases with a complex epidemiology like polio, understanding the various possible outcomes following exposure, and concepts related to immunity, including the properties of different vaccine types is critical to communicate preventive and control strategies to policymakers and develop effective strategies for risk communication and community engagement.

8

Conclusion

It's late December, 2022.

It has been a challenging year for the Republic of the Constellation Islands.

Thankfully, the National State of Emergency has been declared over, and the Public Health Response Team (HQ) is finally standing down. All the response staff are exhausted and looking forward to enjoying a restful holiday period surrounded by family and friends after a difficult, challenging year.

Rebuilding has started, and there have been many lessons learnt.

On your last day on duty in the National Disaster Management Office, you receive an email from Dr Mary Tukana, Chief Medical Officer and National Public Health Response Team Leader. This ends an eventful year in your position of Specialist Technical Adviser: Epidemiologist. You look forward to the break and feel ready to face the new year and its challenges with renewed energy and enthusiasm.

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Date: Fri, 23 Dec 2022

From: Chief Medical Officer

To: Public Health Response: HQ

Subject: Message of gratitude

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Dear Team,

On behalf of the People and Government of the Constellation Islands, I just wish to extend my sincere thanks for your tireless efforts in assisting our provincial islands with the various public health challenges faced over the course of this challenging year.

Your expert epidemiological insights, and practical advice to implement timely interventions has helped saved countless lives, and improved the quality of life of the many peoples that call our beautiful country home.

I am extremely proud of the excellent, tireless work you have performed under difficult conditions in a time-pressured environment. I wish you a well-deserved break, and a blessed New Year surrounded by your family and loved ones.

Best wishes,

Dr Mary Tukana (Chief Medical Officer)

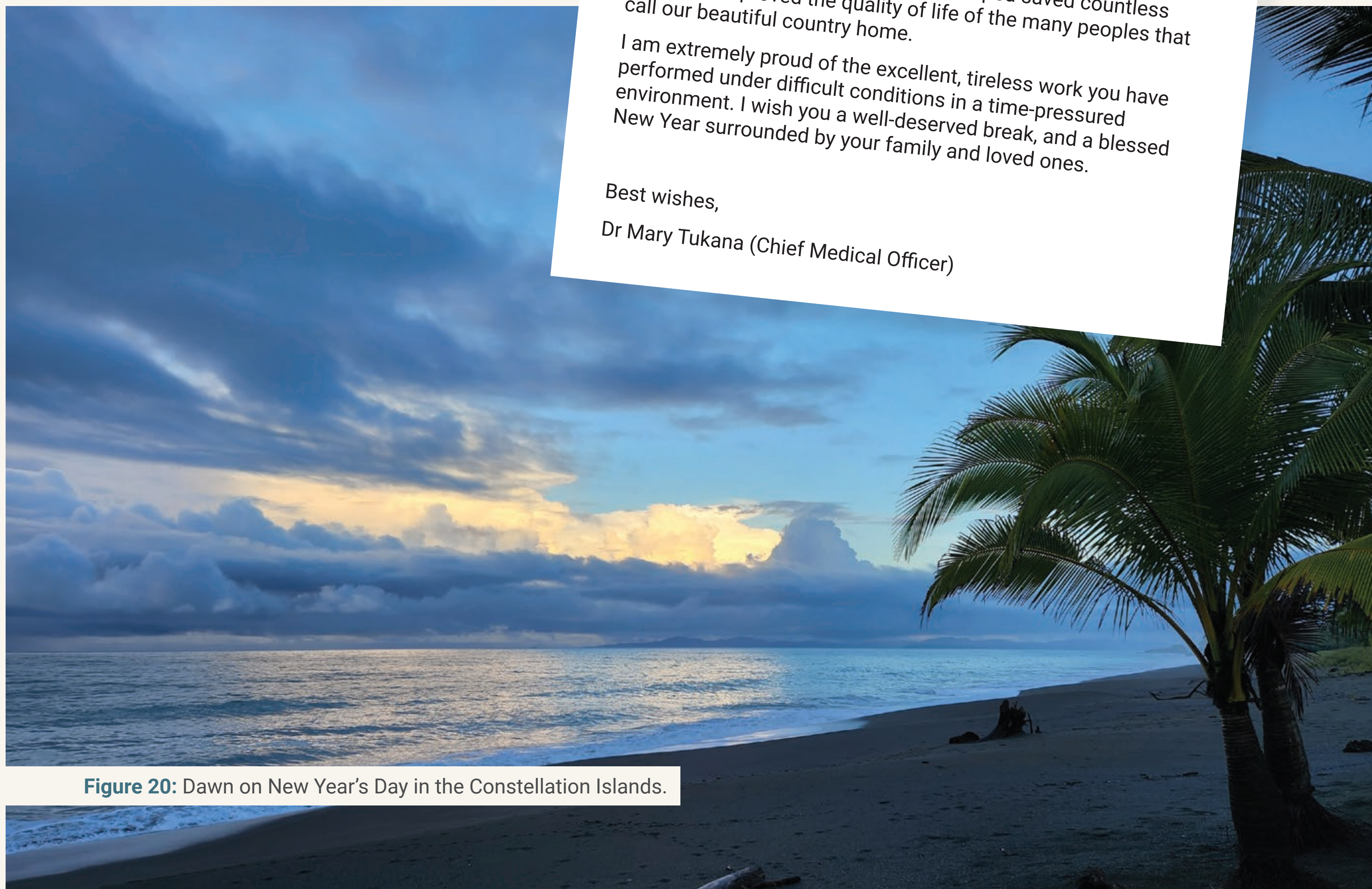

Figure 20: Dawn on New Year's Day in the Constellation Islands.

9 References and additional resources

This evidence-based case study was developed through a review of the scientific literature and publications produced by global public health agencies including the World Health Organization (WHO) and the United States Centers for Disease Control and Prevention (US-CDC).

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Case Study: Epidemiological Concepts

CASE STUDY

EPIDEMIOLOGICAL CONCEPTS

Field Epidemiology
IN ACTION