Investigating the transmission of faecal pathogens in urban informal settlements in and around Port Vila, Vanuatu, recognising biophysical and demographic diversity

International WaterCentre
Griffith UNIVERSITY Queensland, Australia

Faecal pathogen transmission exposure typologies

RESEARCH BRIEF

This Master of Integrated Water Management research project uses national census data, household survey data and integrated spatial data to investigate whether there are:

> *locally derived, water-related, faecal pathogen transmission routes in urban informal settlements in and around Port Vila, and are there biophysical and demographic characteristics that increase residents exposure*?

With our local partners, we sought to identify and characterise urban informal settlements in Port Vila, and explore the diversity of these settlements using GIS and remote sensing research methods. The research outcomes highlight that when it comes to reducing the burden of faecal pathogen transmission in such communities, one size rarely fits all.

Research Background

a. Urban informal settlements

Globally, between 863 million and 1 billion inhabitants live in urban informal settlements [1]. Urbanisation is increasing in many regions because of economic migration from rural areas, population growth and in response to weather-related disasters or conflict [2, 3]. Also called slums, squatter settlements or shanty-towns, informal settlments are residential areas defined by the United Nations (UN) [2] as:

1. lacking secure tenure of land or housing,
2. generally non-compliant with planning and land-use regulations,
3. often on marginal or hazardous land, and
4. lacking services (particularly water and sanitation) and access to infrastructure.

This final point is poorly addressed in informal settlements worldwide. Contributing factors include complex socio-political settings and heterogeneity between and within informal settlements that preclude uniform solutions. However, as made explicitly clear from the recent global spread of infectious, hygiene-associated SARS-CoV-2, ignoring vulnerable sections of society can increase the risk of communicable diseases for all society. The most significant public health breakthroughs in history were complex collective ones, notably clean water and sanitation. Water is a shared resource, with shared consequences for its degradation.

A challenged faced by countries and cities when addressing the needs of informal settlement residents is a lack of accurate, relevant and timely data to describe demographics and living conditions within the settlements [2, 4]. Several global organisations are actively expanding data and quantification of informal settlements. However, this data is often at too high a resolution (i.e. country or city-level) to sufficiently describe the particular experiences of informal settlements residents.

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Informal settlements are less likely to have access to Water, Sanitation and Hygiene (WASH) services, and more likely to be exposed to risk from the spread of communicable diseases from faecal pathogens, than other urban residents [7]. A predominant cause of inadequate services in informal settlements is insecure land and housing tenure, which can constrain residents from accessing public services, receiving assistance from state and non-state actors, or investing in more suitable infrastructure [5, 6].

b. Faecal pathogens – what, how and where?

Faecal pathogens which originate in human faeces include viruses, bacteria, protozoa and helminths, and all have human or ecosystem health significance when transmitted from person with ill-health. The UN Environment Program (UNEP) concluded one-third of rivers in Asia, Africa and Latin America are affected by severe faecal pathogen pollution [15].

In Vanuatu, Global Health Data Exchange data indicate that approximately 2,000 Disability-Adjusted Life Years (DALYs) and 35 deaths per year are attributable to diarrhoeal disease [16]. Encouraging, the observed rate of both DALYs and deaths per population has consistently decreased since 1990. However, diarrhoeal diseases still account for 6% of deaths for children under four in Vanuatu [17]. Other chronic health impacts, such as stunting in children, have been related to faecal pathogens [18].

Faecal pathogens have been found in water sources, waterways and coastal waters around Port Vila. Water quality testing of the Tagabe River reported faecal coliform bacteria levels of greater than 200 cfu/100ml in multiple samples (WHO defines 0-10 cfu/100ml as low risk, and 100-1000 cfu/100ml as high risk) [19]. Monitoring of Mele Bay found elevated nutrients levels, particularly in near-shore locations, attributed by the researchers to pollution from untreated sewage and stormwater [20]. String, Singleton [21] found in a Vanuatu-based study that 52% of water collection point samples and 65% of stored water samples had risky levels of *E. coli* colonies.

There are many routes that faecal pathogens can take from an infected person to a susceptible host (faecal-oral routes), and many of them are related to water. Water-borne (ingested) and water washed (spread by inadequate hygiene practices) diseases typically require multiple barriers to prevent them from causing ill-health [22]. The 'F'-Diagram (Error! Reference source not found.) illustrates the main routes for pathogen spread through fluids, food, flies, fields/floors, fomite, fingers and floods [23, 24]. It can be used as a diagnostic tool to examine local contexts and identify the routes to which particular communities are most exposed.

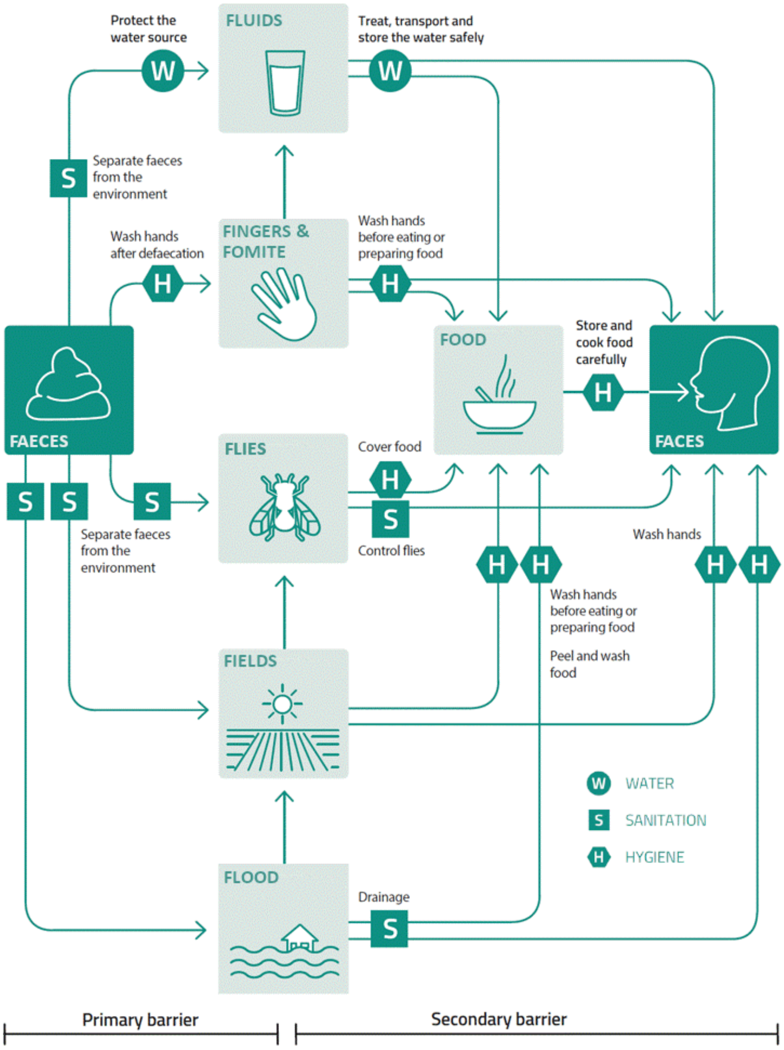

Figure 1: 'F'-Diagram of faecal-oral disease transmission, adapted from Sphere [25]

The diagram clearly confirms sanitation, water and hygiene practices as important transmission barriers.

Research Methods

c. Data sources and analyses

Locating and characterising urban informal settlements, and comparison of WASH infrastructure and behaviour characteristics in informal settlements to Port Vila's peri-urban villages and national statistics, is an important investigative step in understanding faecal pathogen transmission pathways and addressing WASH equity across the country. Using remote sensing and Geographical Information Systems (GIS) methods, combined with national Census data and household survey data (referred to here as the Live and Learn Environmental Education Rapid Household Survey, LLEERHHS), the International WaterCentre and its research partners located and characterised the WASH situation across informal settlements in and around Port Vila. This is reported separately in the two related publications named at the end of this brief.

This research was a desktop project based on secondary data, including Vanuatu national census data, household survey data, and a compiled spatial database as noted in Error! Reference source not found.. Data analyses included statistical summaries and averages, and GIS processing like as intersections of vector layers and the build-up of raster layers using multiple spatial variables.

Source	Biophysical data component	Use
Geosciences Australia	Digital Elevation Model, aerial imagery	Licenced
The Pacific Community (SPC)	Population density Enumeration area boundary 2016 Vanuatu census spatial layers (VNSO)	Public / licenced by VNSO
JBPacific (raster layers)	Q100 alluvial and pluvial flood maps Coastal storm surge dataset	Licenced
Open Street Map (vector layers)	Roads, waterways, buildings, boundaries	Public
PCRafi	Streams and waterways, administrative areas	Public
SPREP	Community garden locations	Public
Institut de Recherche pour le Developpment	Soil types	Public

d. Indicator framework and exposure typologies

For each 'F'-Diagram faecal pathogen transmission route, a detailed list of WASH, biophysical and demographic characteristics, or indicators, that increase the likelihood of that pathway, was developed based on the literature review. This list of indicators was then refined according to the data available and the status of indicators in informal settlements then analysed. For a complete list of indicators refer to the full research report available by request from author. By combining this analysis with the spatial datasets, six faecal pathogen transmission typologies were developed; these describe the most probable transmission pathways and charactertistics active in informal settlements of Port Vila.

Characteristics were converted into spatial indicators that could result in a yes/no binary response, and the indicators relevant to each typology were assigned. Each typology comprised up to two primary indicators and up to six exacerbating indicators. Spatial indicator layers were overlaid in QGIS to create a spectrum of exposure reflecting the number of indicators present in a particular location . All indicators were assumed to have equal weighting to simplify the analysis, though the primary indicator(s) had to be present to register that typology

e. Study limitations

The following limitations were identified concerning this research:

- The use of secondary sources precludes the ability to design data collection methods to suit the research question; for instance, there were limited data available to assess faecal sludge management. Nonetheless, the datasets used were judged to be appropriate in scope and methods, particularly when used in combination.
- Without ground-truthing settlement locations, all remote analysis is approximate only.
- It was not possible to investigate if each settlement accorded with local planning and land use regulations as part of this research, as no gazetted city plan exists.
- Agreement between the 2016 census and LLEERHHS toilet type terminology was not exact. However, both generally followed SDG 6/JMP definitions.

Research Outcomes

a. Identifying Port Vila's informal settlements

In Port Vila and it's peri-urban surrounds, 28 urban and peri-urban settlements identified and spatially located (**Figure 2**), including:

- 18 informal settlements in the Port Vila council area (thus categorised as 'urban');
- 5 informal settlements within the greater MPVR (categorised as 'peri-urban'); and
- 5 peri-urban village settlements – Ifira, Mele, Mele Maat, Pango and Erakor Village.

An estimated 38,200 people were found to be living in these settlements based on 2016 census data. Excluding the peri-urban villages (approximately 9,100 people), 39% of the total Metropolitan Port Vila Region (MPVR) population of around 74,520 could be described as living in informal settlements.

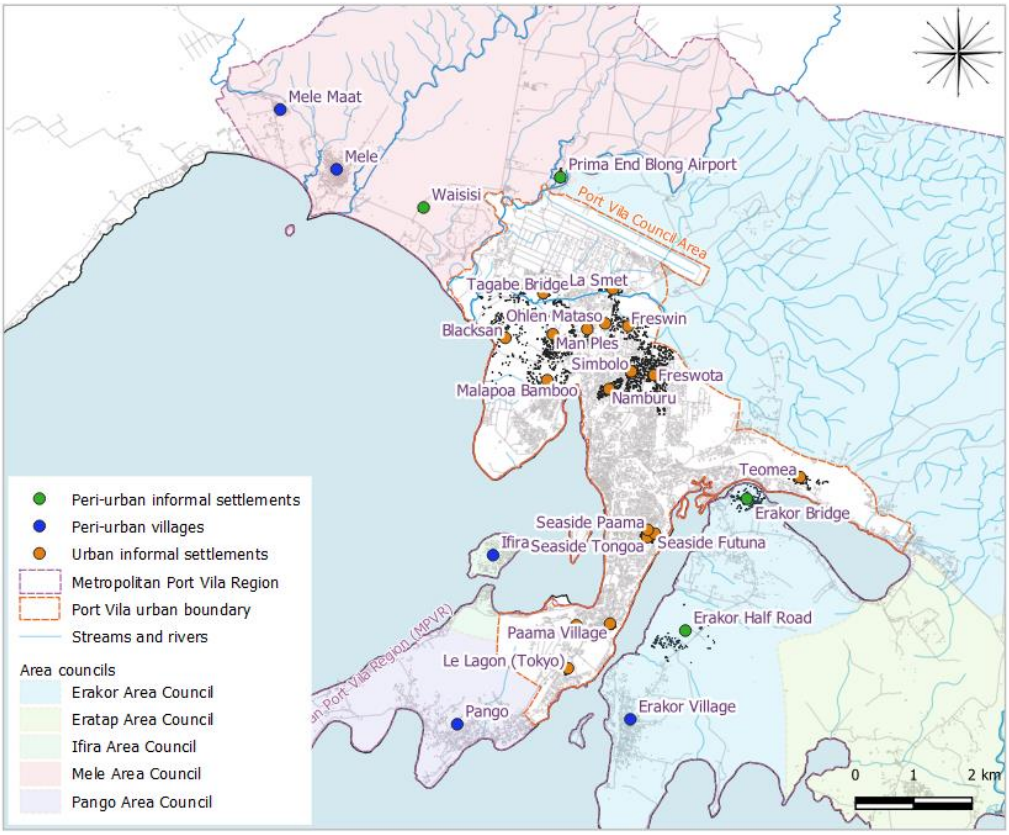

FIGURE 2: SETTLEMENTS IDENTIFIED IN AND AROUND PORT VILA

b. Sanitation, water and hygiene characterisation

Residents in informal settlements in and around Port Vila were found to be, on average, 15% less likely than other urban residents in Vanuatu to have access to *at least basic* sanitation in accordance with SDG 6 / Joint Monitoring Program (JMP) defintions, and 30% more likely than all Vanuatu residents to have *limited* (that is, shared) sanitation access. Urban and peri-urban informal settlements were found to have less adequate sanitation access in general than peri-urban villages around Port Vila. It was observed across settlements that the likelihood of access to *at least basic* sanitation was greater when residents owned their own home, or when the land was held under customary tenure.

Vanuatu demonstrated notable improvement in universal access to improved water in the last two decades, and this was reflected in this research. Almost 80% of settlement residents reported access to piped water and 93% access to *at least basic* water access in accordance with SDG6/JMP definitions. Peri-urban villages had, on average, 4% more households with *at least basic* water access. Overall, more shared piped connections were reported than on-premises sources. More than 10% of households in Prima End Blong Airport, Etas and La Smet reported using rivers as a primary drinking water source, while more than 10% of households in Blacksan, Tagabe Bridge and Teomea reported using groundwater as a primary drinking water source.

Data from the LLEERHS demonstrated that 50% or more of households across the surveyed communities had access to a handwashing facility. However, to achieve adequate hand hygiene that can act as a secondary barrier to break faecal pathogen transmission routes, behaviour and knowledge regarding handwashing are equally as important [26]. When combined with behavioural survey questions, the derived proportion of households with adequate hand hygiene reduced across all settlements.

c. Biophysical and demographic characterisation

Using the available data, seven key biophysical and demographic data were spatially analysed, including proximity to streams and rivers, flooding (river and localized), coastal storm surge inundation, soil type, road access, population density and proportion of population under 5 (children). Importantly, spatial diversity in these characteristics was observed across and within the identified informal settlements.

d. Faecal pathogen transmission exposure typologies

A diversity of WASH, biophysical and demographic characteristics was found to influence the types of likely water-related faecal pathogen transmission routes present in informal settlement. From this characterisation, six exposure typologies were resolved that describe situations in which key faecal pathogen transmission routes and elements of the 'F'-Diagram are more likely to eventuate.

a) *High groundwater reliance typology* – residents access and use groundwater, and maintain sub-surface sanitation types in permeable soil conditions. Faecal pathogen transmission may occur from uncontained subsurface faecal matter in pits and septic tanks, via soil to groundwater, which is then extracted and consumed from a borehole or well.
b) *Waterway users typology* – residents access and use surface water (waterways) and use *unimproved* sanitation that do not contain faecal wastes. Pathogen transmission may occur when wastes enter waterways via contaminated drainage, through subsurface, or directly. Residents, particularly children, drink, recreate or wash in the waterway.
c) *Flood-prone areas typology* – residents inhabit flood-prone areas where floodwaters can enter and overfill pits and tanks, causing faecal matter to flow through communities. *Unimproved* sanitation types may increase exposure, but improved types can also be affected. Floodwaters may enter homes, or residents may walk or play in floodwaters.
d) *Storm surge typology* – residents inhabit coastal areas subjected to storm surge during extreme weather. Tidal inundation can spread faecal matter through communities, in a similar manner to the flood-prone typology.

e) *Shared toilet typology* Error! Reference source not found.– residents who share sanitation access amongst household or community. Inadequate handwashing, *unimproved* sanitation types and overcrowding were proposed as exacerbating factors for the potential transmission of faecal matter from shared toilets, via fingers, fomite and flies, to other residents.

f) *Shared waterpoints typology* – residents who share water access amongst household or community. Shared water access is likely to be off-premises, requiring the carrying and storing of water within the home. These actions are known to increase the risk of faecal pathogen contamination.

The exposure typologies provide an evidence-based, systems-thinking method of categorising and comparing potential faecal pathogen transmission between areas while highlighting the diversity within and amongst settlements. Some settlements in and around Port Vila align with multiple typologies and the residents of these areas are likely exposed to multiple transmission routes.

Stakeholders seeking to address faecal pathogen transmission in communities, including governements, residents and others, need to be able to communicate the existing situation and challenges present in those communities. Visual presentation of pathogen transmission is useful to communicate complex concepts particularly those with their own terminology.The exposure typologies and their associated local pathogen transmission routes were translated into visual conceptual diagrams (**Figure 4** to **Figure 8)**. The diagrams include symbolism described in Figure 3 and present:

- the pathogen source(s), either an unimproved toilet or open defecation;
- the exposure pathways, such as floods or soil transmission; and
- the receptors within the communities.

These diagrams could be used to build a collective understanding of faecal pathogen transmission, which is required for effective stakeholder participation.

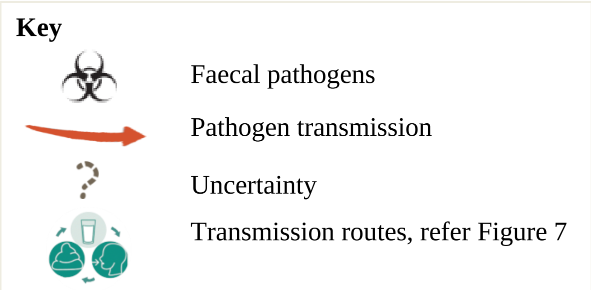

FIGURE 3: CONCEPTUAL DIAGRAM KEY

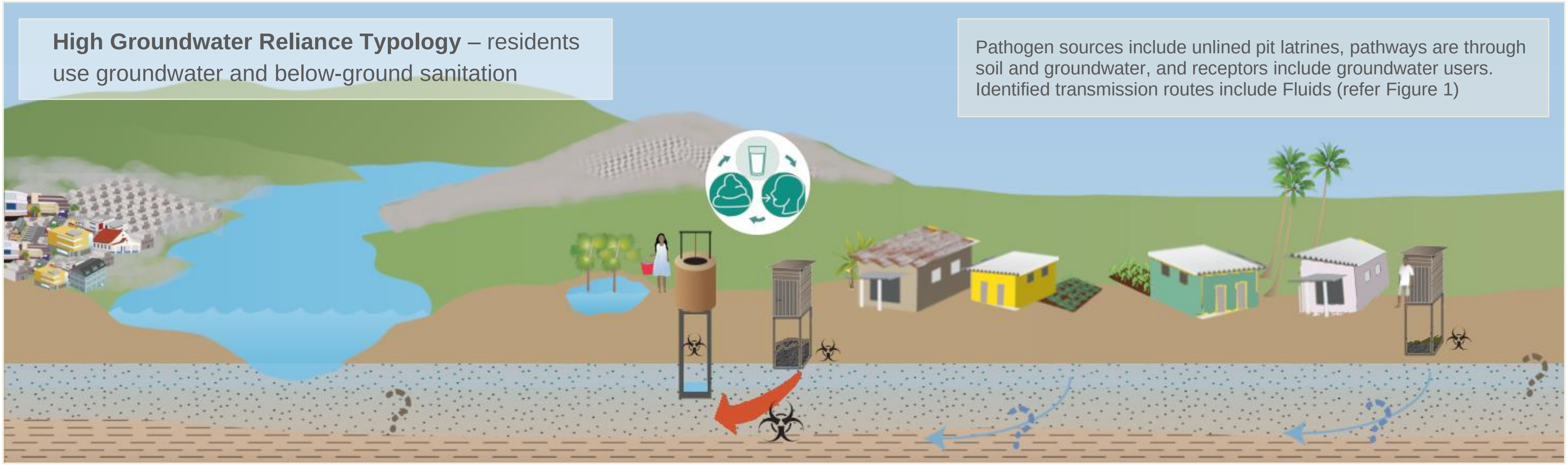

Figure 4: Conceptual diagram of Typology A

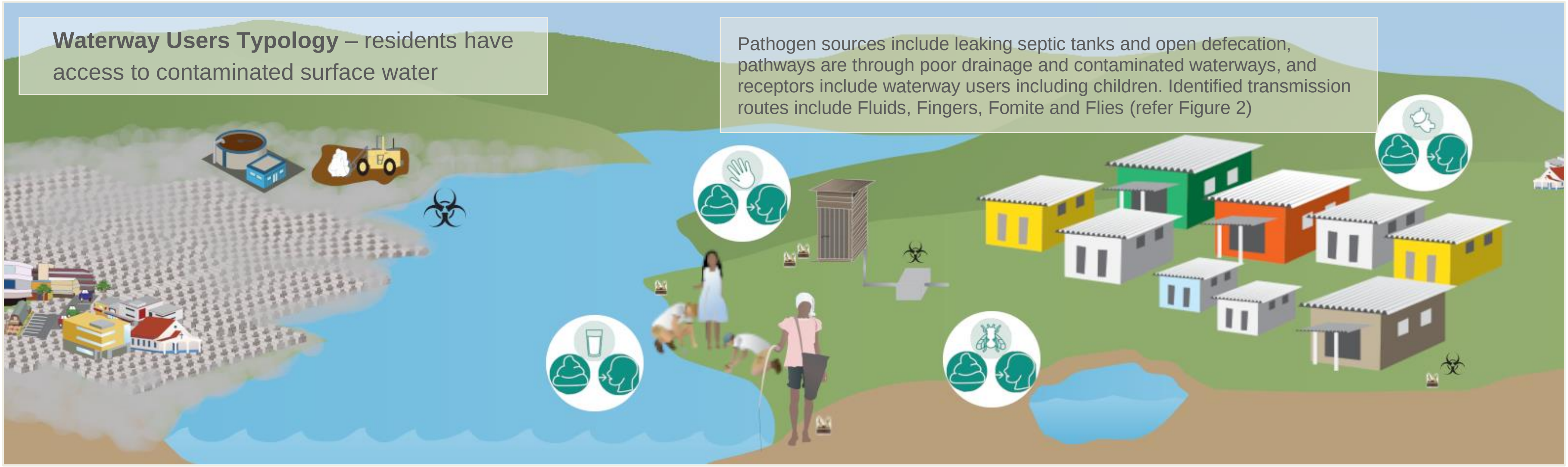

Figure 5: Conceptual diagram of Typology B

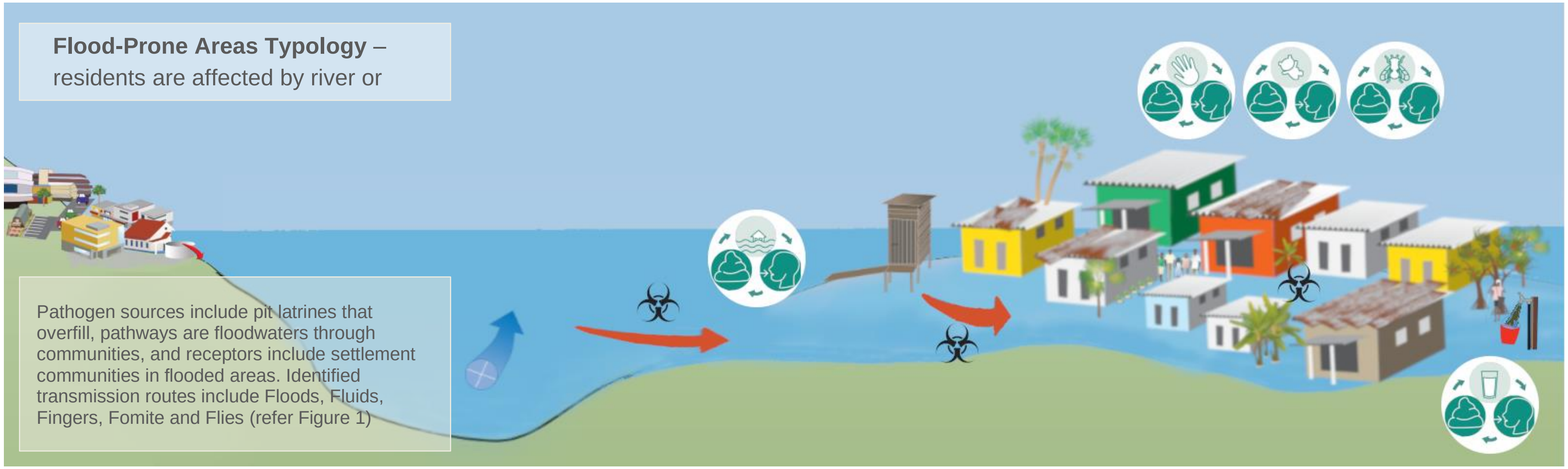

Figure 6: Conceptual diagram of Typology C

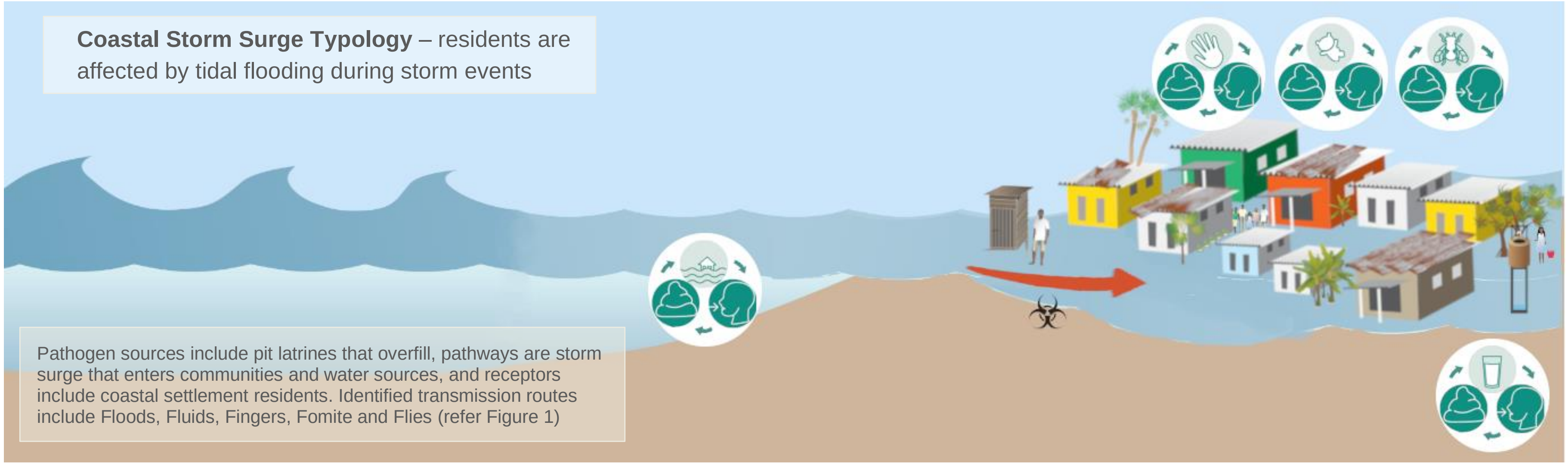

Figure 7: Conceptual diagram of Typology D

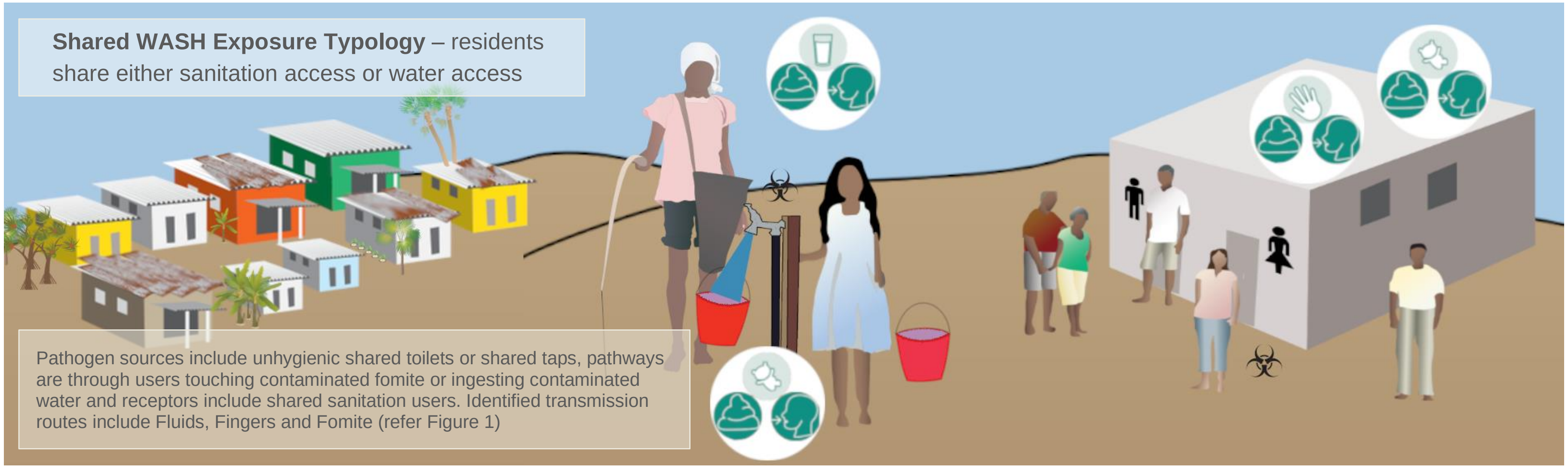

Figure 8: Combined conceptual diagram of both the shared toilet and shared water source typologies of exposure.

Reducing the burden of faecal-oral disease transmission

The typologies described in this research demonstrate that characterisation of biophysical and demographic characteristics in a locale can likely reveal faecal pathogen transmission routes, and hence can be used to inform the types of interventions that may reduce transmission. For all typologies described, holistic consideration of WASH and faecal pathogen transmission is recommended.

For example, improving handwashing access and behaviour is considered crucial and relevant to all typologies. Importantly, the research does not indicate each typology requires one specific intervention approach, particularly because any one locale might have multiple transmission typologies representing multiple transmission routes acting simultaneously. As such, the typologies can guide project design and provide insight to potential combinations of responses and best practice (**Table 1)**.

WASH project design must recognise the full scope of potential faecal pathogen transmission for any chance of success in reducing associated disease. Research shows projects simultaneously addressing toilets, faecal sludge management, water source protection, handwashing and other hygiene factors to have better health impacts than more traditional siloed sanitation approaches [18].

TABLE 1: EXAMPLE INTERVENTIONS THAT ADDRESS TYPOLOGIES

Typology	Example Interventions
A – groundwater reliance	- Hydrogeological investigation for MPVR to better characterise subsurface. - Siting guidelines for toilets and groundwater bores that account for subsurface. - Design criteria and regulated practice for groundwater drilling, i.e. casing protection around wells/bores, concrete aprons around standpipes, appropriate borehole drilling techniques
B – waterways access	- Septic tanks that leak to surface and waterways need appropriate design, operation and maintenance, including desludging. - Where groundwater is not used, improved pit latrines (VIPs) may be a better interim option than leaking septic tanks. - Nature-based solutions to intercept sewage, greywater and contaminated stormwater (evapotranspiration beds, bio-filtration, improved septic tanks, rainwater harvesting)
C – flood-prone	- All toilets with pits and septic tanks should be raised above flood level to avoid overfilling of the system. - Where possible pits should be emptied and septic tanks desludged prior to predicted extreme weather to reduce the likelihood of pathogen transmission.
D – coastal storm surge	- Typology C example interventions also apply. - Locate all WASH infrastructure away from coastal areas where possible. - Integrate climate change adaptation with WASH projects, including nature-based solutions such as mangroves to protect WASH infrastructure.
E – shared toilet	- The development of new, shared toilet facilities by funding organisations should be stringently reviewed for appropriateness and user preference. - Water and hygiene practice intervention to accompany building of shared facilities.
F – shared waterpoints	- Government/UNELCO to better understand shared water connectivity, and whether shared connections allow appropriate access levels for users. - WASH interventions to address how water is conveyed and stored, particularly the types of containers and how they are cleaned and maintained to reduce faecal pathogen transmission.

Positively, it appears efforts are underway to expand Vanuatu's approach to addressing faecal pathogen transmission. The MOH's Draft Rural Sanitation Guidelines includes a Decision-Making Tool (DMT) with two selection trees for sanitation – Site Conditions and User Preference – which elucidate critical biophysical, social and financial considerations. They allow users to contextualise the selection of appropriate toilet types for rural conditions (Marshall & de Greslan, 2019). This tool aligns with the outcomes of this research, in that WASH projects should be cognisant of specific local conditions. Such a DMT could be developed, drawing upon this research, for informal settlements and peri-urban villages around Port Vila, as a practical way to address the diversity of conditions and recognise that one size does not fit all with regards to sanitation. Importantly, the inclusion of centralised service options, including septic pump-out services, where appropriate, should be included for urban contexts.

Many elements of this research are tightly interwoven with climate change considerations. Researchers agree sanitation access will be affected with a resultant increase in diarrhoeal disease and associated ill-health [27]. The biophysical and demographic characteristics identified are all likely to be affected as the climate continues to change. Flooding impacts may change and increase, groundwater availability may decrease and overcrowding may increase if Vanuatu experiences more urban migration in response to increased extreme weather.

Conclusions and Recommendations

This desktop research project synthesised data from multiple sources to ask whether there are locally derived, water-related, faecal pathogen transmission routes in informal settlements in and around Port Vila, and what characteristics increase exposure.

The main findings of the research were:

- 28 urban and peri-urban settlements were identified in and around Port Vila, of which 23 were considered informal according to UN definitions. They potentially include 51% of the Port Vila region's population. Informal settlements have less adequate access to WASH than other urban residents, and on average less adequate than residents in peri-urban villages.
- Sources of faecal pathogens in informal settlements likely consist of sanitation types that fail to contain faeces, rather than extensive open defecation. Septic tanks and pit latrines are common, though not necessarily unimproved options – more information about faecal sludge management is required. SDG 6/JMP classifications are useful for benchmarking, but more nuanced understanding of WASH access is needed to better address faecal pathogen flows.
- Pathways that faecal pathogens take in informal settlements are influenced by the biophysical and demographic characteristics of each location, so for instance proximity to waterways increases residents' exposure to ingesting contaminated fluids through accessing that waterway.
- Conceptual diagrams can visually communicate the likely faecal pathogen transmission routes present in each typology. They may be a useful way to build collective understanding of transmission pathways and situations and enable constructive stakeholder participation.
- The faecal pathogen transmission typologies are intended to give insight into the diversity of conditions experienced by informal settlement residents. Interventions to address pathogen transmission may be guided by those typologies, but do not constitute 'one-size-fits-all' models.

Based on the research presented herein, the following recommendations for stakeholders are presented:

- Consider spatial heterogeneity when considering WASH interventions, including the diversity represented in this research as well as important other forms of diversity not assessed here, such as economic, social, and cultural factors.

- Include behavioural (i.e. where people go to defecate as opposed to what toilet type the household accesses) and infrastructure (how is faecal sludge managed) questions into national census surveys, as this would provide additional information to assist government and service providers to address WASH access across the region.
- Ensure that climate change conditions are incorporated into any and all WASH planning, project design and execution, particularly in areas demonstrated by this research affected by flooding or coastal storm surge transmission typologies.
- Connect the WASH department of the MOH, the NGO WASH Cluster and the National Water Resources Advisory Committee to prioritise a holistic view of WASH service delivery, that seeks to address overall faecal hygiene in preference to sectoral provision of toilets and taps.

This research has demonstrated there are several likely water-related, local faecal pathogen transmission routes, and the biophysical and demographic diversity of the settlements affects the prevelance and nature of those routes. WASH access in the settlements was quantified to understand the existing faecal pathogen sources and pathways and relatedly, the existing barriers to pathogen transmission. Importantly, improved sanitation facilities alone do not guarantee interruption to transmission routes, particularly when facilities are not well maintained, unhygienic, or not used correctly. Nonetheless, as described by the 'F'-Diagram, sanitation that separates faeces from the environment; a protected water source; and handwashing are all important barriers for households and communities to adopt.

With a population that equates to almost 14% of all Vanuatu, faecal pathogen transmission in urban and peri-urban settlements in and around Port Vila must be addressed through holistic WASH approaches that aim to provide suitable, sustainable, inclusive and user-appropriate WASH services to improve health and wellbeing

Related publications

1. Sanderson, R. and Souter, R., 2020, *Shit flows matter – understanding faecal pathogen transmission in urban informal settlements in Port Vila, Vanuatu* (full report), International WaterCentre & Griffith University
2. Sanderson, R. and Souter, R., 2020 *Investigating the transmission of faecal pathogens in urban informal settlements in and around Port Vila, Vanuatu, recognising biophysical and demographic diversity - Water, Sanitation and Hygiene informal settlement characterisation* (Research brief), International WaterCentre, Griffith University

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Contact

For more information including access to the full report and recommendations, please contact Rosie Sanderson at rosie.sanderson@griffithuni.edu.au, or Dr Regina Souter at r.souter@watercentre.org.

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