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Environmental and Socio-Economic Vulnerability to Water-borne Diseases in Peri-urban Zanzibar, Tanzania

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M-IES

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Declaration

I, Elizabeth MacAfee, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature………………………………..

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Abstract

Cities around the world are growing rapidly, giving rise to sprawling peri-urban areas in their surroundings. In coastal East Africa, residents of peri-urban areas find themselves frequently exposed to water-borne infectious diseases when untreated wastewater contaminates drinking water supplies. These areas often lack infrastructure for water, sanitation, and waste management, and due to their position outside municipal boundaries it can be unclear whose responsibility it is to provide services to their residents.

Zanzibar, Tanzania has experienced this problem, and it will likely grow, as between sixty and seventy percent of residents of Zanzibar Town are currently living in unplanned or unauthorised settlements where the population is expected to double in less than twenty years (Revolutionary Government of Zanzibar, 2013; National Bureau of Statistics, 2014). This thesis aimed to examine differences in vulnerability between members of the population of peri-urban Zanzibar Town and the factors that put them at risk of exposure to hazardous bacteria and pathogens. It asks the question, in a densely populated settlement that may appear close to homogeneous at first glance, what makes some people more likely to suffer from water-borne diseases than others?

A combined approach including both water quality testing and qualitative interviews was used to analyse contributions of social, economic, institutional, and environmental factors in determining vulnerability of individuals and groups. Root causes of vulnerability were theorised using a combination of field data and a review of pertinent literature, and this was considered in tandem with observed variations in likely exposure to hazards. Selected study sites were the areas surrounding two wells in the neighbourhoods of Tomondo Mshelishelini and Kijito Upele. The quantity of faecal coliform and E. coli in some of the drinking water wells was quite high, indicating elevated exposure risk for many households. However, within a small spatial area, strategies used by households to prevent disease and clean water, and level of dependence on individual resources, varied greatly. These differences stem from a combination of environmental and socio-economic characteristics and also perception and awareness of impacts of using well water for household needs.

In terms of preventing illness and mitigating exposure to pathogens, from the perspectives of interview subjects (both households and institutions) the responsibility seemed to lie mainly with individuals and households, rather than the government. Personal strategies such as handwashing and treatment of drinking-water were highly emphasized. This perception places the burden of adapting to hazardous conditions on vulnerable members of the community, rather than on government and institutional actors with far greater access to resources. To sustainably reduce disastrous impacts of diarrhoeal disease in peri-urban areas, the government of Zanzibar will need to accept a greater portion of the responsibility for providing safe and sufficient drinking water to all of its citizens.

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Acronyms

cfu	Colony forming unit
E. coli	Escherichia coli
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IMS	Institute of Marine Sciences
JICA	Japan International Cooperation Association
NGO	Non-governmental organization
PAR	Pressure and release framework (Wisner et al., 2003)
ppm	Parts per million
ppt	Parts per thousand
RGoZ	Revolutionary Government of Zanzibar
SUZA	State University of Zanzibar
UNDP	United Nations Development Program
Well KA	Kijito Upele Well A
Well KB	Kijito Upele Well B
Well TA	Tomondo Mshelishelini Well A
Well TB	Tomondo Mshelishelini Well B
WHO	World Health Organization
ZAWA	Zanzibar Water Authority
ZMC	Zanzibar Municipal Council

1. Introduction

1.1 Background to Research Problem

Urbanization and the associated spread of informal settlements without necessary environmental and health safeguards can place heavy pressure on finite water resources (Corvalán, Kjellstrom, & Smith, 1999). Coastal areas in East Africa in particular are seeing rapid urban growth without sufficient simultaneous expansion in the necessary infrastructure to manage waste and provide safe and sufficient drinking water for their growing populations (Mohammed, 2002). The limited water available in surface or groundwater resources in these areas can easily become contaminated, constraining the ability of inhabitants to meet their basic needs and avoid water-borne illness.

Peri-urban communities with many informal housing areas may not be connected to piped water or have adequate sanitation infrastructure (UN-Habitat, 2010). The challenge posed by “supplying water and sanitation services to the city and its peri-urban fringe is characterised by uncertain dynamics - interlocking social, technological and ecological/ hydrological dimensions” (Marshall, Waldman, MacGregor, Mehta & Randhawa, 2009, p. 15). Inability to adequately address this challenge can lead to contamination of groundwater through leaching of waste from inadequate sanitation and waste management facilities, making this water unsafe for human consumption (Simon, 2008). This can and often does lead to greater incidence of disease, because if the only easily accessible and affordable sources of water in a community are contaminated, residents may be forced to turn to more expensive or distant water sources, or to continue using water known to be unsafe (Simon, 2008; Mehta, 2014).

Water-borne infectious disease is responsible for 90% of infectious disease deaths in developing countries around the world and about 94% of this can be attributed to environmental conditions (Baer & Singer, 2009). The World Health Organization states that there are almost 1.7 billion cases of diarrhoeal disease every year worldwide (WHO, 2013), and 58% of these are due to inadequate water, sanitation and hygiene (UNWater, 2008). In low-income countries only 8% of wastewater is treated, as compared to nearly 70% in high-income countries and between 28 and 38% in middle-income countries (Sato, Qadir, Yamamoto, Endo & Zahoor, 2013). In many places, the safest source of water is piped drinking water, but that is not always available or sufficient. Where this is the case, people typically depend on wells or surface water (Adetunji & Odetokun, 2011).

Vulnerability to hazards caused by inadequate or unsafe water supplies is not homogeneous or consistent among all segments of a population. Differential exposure and sensitivity mean that even within a small spatial area different members of a community will experience varying levels of risk (Adger, 2006; Turner et al., 2003; Wisner, Blaikie, Cannon & Davis, 2004). It is important to analyse and understand the root causes of this vulnerability in order to effectively help communities and individuals lead healthy and productive lives free from disease. Identifying the most vulnerable groups in a community and what leads them to be vulnerable can also have important implications for governments and other actors priorities for reducing vulnerability (Wisner & Adams, 2002). As such, this study will examine both the socio-economic and institutional contributors to vulnerability in two peri-urban communities in Zanzibar alongside the dynamic environmental pressures that may cause pathogenic contamination to occur.

1.1.1 Aim of Study

This study analysed the contributions of social, economic, institutional and environmental factors to vulnerability to exposure to contaminated water in a peri-urban community of Zanzibar. By using both water quality testing and qualitative interviews examining perceptions of risk, both direct and perceived vulnerability are considered. Qualitative interviews with individuals, households and institutions in the study area also provided insight into differential distribution of vulnerability. The overall aim of the study was to examine these variations in exposure to hazards and how they can interact with root causes of vulnerability to create potentially disastrous outcomes. This study also provides useful information for local governments and development professionals aiming to more effectively target interventions for reduction of the burden of diarrhoeal disease.

1.1.2 Research Questions and Objectives

What factors constrain or enable access to safe and sufficient water for drinking and household use in peri-urban communities in Zanzibar?

Objective: Examine vulnerability of individuals to water-borne infectious disease.

1. Observe and measure water quality in several wells used for drinking and household activities.

2. Compare and contrast perceptions of water quality obtained from interviews with water quality data and reviewed literature.

    a. How do community perceptions of water quality coincide with measured levels of phosphorous, salinity and faecal coliform?

    b. What are the community perceptions of risks of consumption and use of contaminated water?

    c. What are possible or probable causes of contamination?

3. Examine contextual factors that cause some members of the community to be more or less vulnerable to negative health impacts of exposure to contaminated water sources.

    a. What social, economic, political or demographic factors contribute to vulnerability to exposure to contaminated water?

    b. In the case of contamination of wells, how sensitive are individuals to exclusion from use of this resource?

1.2 Zanzibar Background Information

Zanzibar is a part of the United Republic of Tanzania and consists of multiple islands located between latitude 4°50' and 6°30' South, and longitude 39°10' and 39°50' East off the coast of East Africa in the Indian Ocean. The majority of the population live on the largest island, Unguja, where Zanzibar Municipality and Zanzibar Town are located (Revolutionary Government of Zanzibar [RGoZ], 2004b). Zanzibar Town is growing rapidly, particularly near the coast and "...almost exclusively outside formal land control and urban planning systems" (Myers, 2010, p. 10). Though urban growth has been a steady process since Zanzibar gained independence and united with Tanganyika in 1964, the intensity and impact of expansion has accelerated to unprecedented rates in the last three decades (Myers, 2010).

Almost half of the population of Zanzibar live in urban areas, and while the overall rate of population growth is 2.8% annually, in urban areas it is even faster: 4.8% growth per year (National Bureau of Statistics & Office of Chief Government Statistician, 2014). Assessments by the Ministry of Environment have shown that between sixty and seventy percent of these urban residents live in unplanned or unauthorized settlements (RGoZ, 2013). In the Mjini Magharibi Region, where Zanzibar Town is located, the population is expected to double in less than twenty years, with much of this growth occurring around the peri-urban fringe of Zanzibar Town (National Bureau of Statistics & Office of Chief Government Statistician, 2014; Myers, 2008).

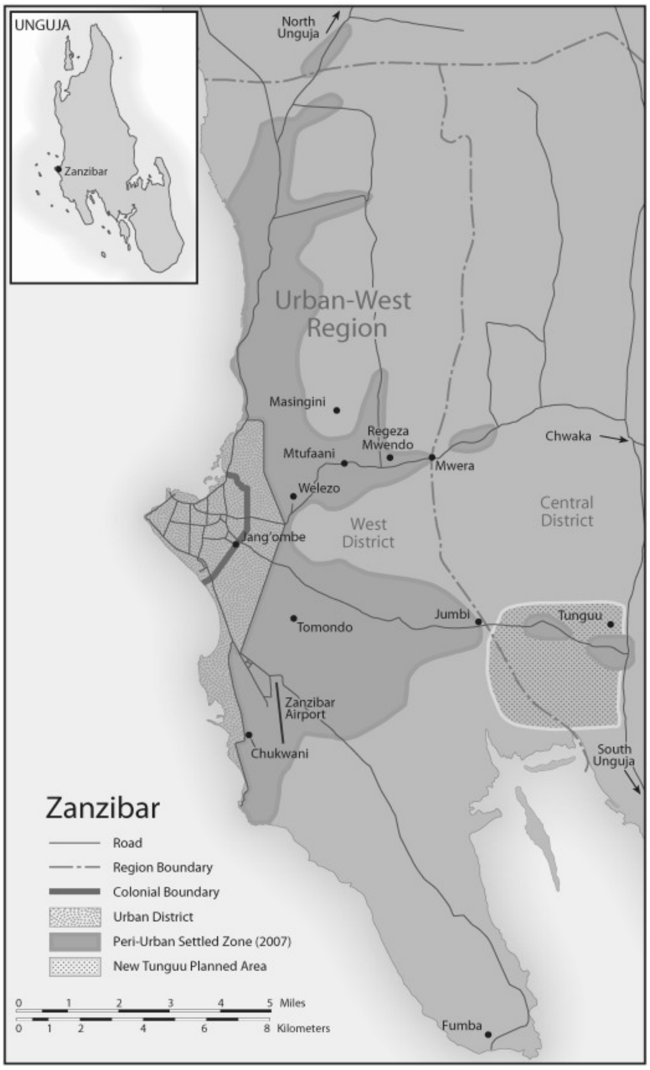

Figure 1. Map of urban expansion in Zanzibar's peri-urban West District (Myers, 2008, p. 265)

Population growth has not been accompanied by equitable economic growth. According to the United Nations Development Programme (UNDP) multidimensional poverty index, which takes into account a combination of education, health, and standard of living statistics, 43.3% of the population of Zanzibar is living in poverty, with 16.6% of those living in extreme poverty (UNDP, 2014).

1.2.1 Water Situation on Unguja, Zanzibar

There are no major rivers or lakes on Unguja Island, so the sole source of drinking water in Zanzibar Town is groundwater. As is the case across much of East Africa, extension of government services is unable to keep up with the pace of urban expansion, and thus many residents of unplanned settlements around Zanzibar Town lack access to basic services such as water and sanitation infrastructure (UN-Habitat, 2010). In these settlements, there is a notable lack of development of sufficient infrastructure and enforcement of regulations. This has led to unmitigated pressure on water resources (Myers, 2008; Myers, 2010). Further, the growth of tourism and its associated large demand for water increases pressure on limited water resources. Overzealous extraction of water from the aquifer may lead to intrusion of seawater into the groundwater supply if the natural recharge capability is exceeded (Gossling, 2001).

On Unguja Island, the majority of aquifer recharge under normal conditions comes from rapid infiltration by surface run off during the rainy seasons of *Masika* [March to May] and *Vuli* [October to December] (United Nations, 1989). Approximately 62% of demand for water is met by boreholes maintained by the Zanzibar Water Authority (ZAWA), and the remainder comes from unregulated and unmonitored private boreholes, shallow wells, caves and springs (RGoZ, 2004b).

Unguja Island is geologically formed from tectonically raised fossilised coral reefs, which are made up of highly permeable porous rock. This means that both saline seawater and possibly contaminated wastewater can move freely through groundwater resources, placing drinking water reserves at risk. On Unguja, a lens of fresh groundwater floats on top of the deeper saline water. Sustainable use of groundwater resources must therefore take into account the potential for shifting water flows, which may allow the saline water from the ocean to infiltrate the aquifer (RGoZ, 2004). A recent study of boreholes (both public and private) in Zanzibar Municipality found that 97% of boreholes analysed were increasing over time in salinity, indicating likely overuse of the aquifer leading to saltwater intrusion

(Mato, 2014, p. 736). A comprehensive study of current use rates relative to the natural recharge potential of the aquifer has not yet been done. Salinisation of the aquifer is a particularly frightening prospect; were it to occur, residents would be forced to seek out alternative sources of water that have not yet been identified. This would, however, be a gradual process, allowing ample time for communities to respond.

In addition to concerns over salinity in the water supply, studies of water quality in Zanzibar municipality have cited "Sewage pollution … as being principally responsible for increased cases of waterborne diseases on the islands. These include diarrhoea, gastroenteritis, cholera and dysentery" (Mohammed, 2002, p. 618). Recent public health data estimate that over half of disease cases affecting the population of Zanzibar are water and sanitation related (RGoZ, 2013).

1.2.2 Access to Water and Sanitation

Only 19% of Zanzibar's population is currently connected to the sewer network, which means that much of the 8,673,000 m^3 liquid waste produced annually is either directly discharged without treatment into coastal waters or seeps into the groundwater from pit latrines and septic tanks (Mohammed, 2002b, p. 304). For much of the population, hazardous sewage and other household wastewater is discharged directly into neighbouring drinking water supplies. In the last census, 19.3% of households reported having no access to any form of toilet facility and using a field, bush or beach instead (Corcoran, et al., 2010; National Bureau of Statistics & Office of Chief Government Statistician, 2014). It is also common in urban and peri-urban areas for pit latrines, septic tanks and soak pits to be constructed in close proximity to water resources, placing them at risk of contamination (RGoZ, 2013). The seriousness of this issue is evidenced by the fact that in the 2015 Demographic and Health Survey in Tanzania respondents reported that 12% of children under 5 years old had suffered from diarrhoea in the prior two weeks (Ministry of Health, 2016). Zanzibar has also been hit by repeated outbreaks of cholera in recent years.

It is estimated that 20.4% of the population of Zanzibar obtain their drinking water from non-improved sources, the majority of these being unprotected dug wells (National Bureau of Statistics & ICF Macro, 2011). These wells are considered much more likely to contain disease-causing agents than piped water, protected wells or protected springs, so users of these wells are more frequently exposed to pathogens (National Bureau of Statistics & ICF Macro, 2011).

1.2.3 Institutional Context

Provision and protection of water resources are discussed in many of the major policy frameworks in Zanzibar, indicating the high level of importance attributed to these issues. Some of these documents include: the 2004 Zanzibar Water Policy, the 2006 Zanzibar Water Act, the 2013 Zanzibar Environmental Policy, and the 2015 Bill for Environmental Management of Zanzibar. Issues of water and public health are also addressed in the 2007 Zanzibar Strategy for Growth and Reduction of Poverty and the Zanzibar Vision 2020. In addition, there "are a number of legislations (sic) and regulations related to environmental and natural resources management and conservation in the areas of [...] water resources that are inadequately enforced" (RGoZ, 2013).

The main institutions responsible for provision and protection of water in Zanzibar are ZAWA, the Ministry of Agriculture, Livestock and Environment, the Ministry of Health, the Ministry of Lands, Water, Energy, and Environment, and the Department of Urban and Rural Planning. ZAWA was created in 2006 by the Zanzibar Water Act in order to improve the quality of water distribution services to all inhabitants of Zanzibar. Because they are both the primary user and also regulator of water, they are overseen by an autonomous resource management board. Management of wastewater is the responsibility of municipalities, the largest of which is the Zanzibar Municipal Council (ZMC) and their Division of Sewerage, Drainage, and Solid Waste (ZAWA, 2013). As of the creation of the 2013-2018 Strategic Business Plan for ZAWA, they have not yet adequately fulfilled their mandate. The public water supply service hopes that with comprehensive changes to their policies and practices in the coming years they will be able to reduce dependence on donor aid and government funding and become an independent income generating water utility (RGoZ, 2013).

Several non-governmental organizations (NGOs) and international development projects have aimed to support Zanzibar in protecting their citizens from water-borne diseases and ensuring safe and sufficient water is available. Some examples of these are: the Zanzibar Urban Water and Sanitation Project supported by the African Development Bank; the project for Enhancement of Water Supply Management of Zanzibar Water Authority supported by Japan International Cooperation Association (JICA); and a partnership with the German development organization Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) to introduce small-scale desalination plants for potable water.

2. Conceptual Framework and Theoretical Approach

The framework used to categorize differential risks in the target community will draw on current literature regarding vulnerability to environmental hazards.

2.1 Vulnerability

For the purpose of this study, vulnerability will be defined both as "...the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor" (Turner et al., 2003, p. 8074), and "... the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard..." (Wisner et al., 2004, p. 11).[1]

It is common to think of a disaster as a sudden perturbation or spike in pressure in a system such as an acute outbreak of cholera or a devastating flood, however pervasive stress and continuously present and slowly increasing pressure on a system can have equally disastrous impacts (Blaikie, Cannon, Davis & Wisner, 1994; Turner et al., 2003; Wisner et al., 2004). Thus, in a community with frequent exposure to the hazards of untreated wastewater and associated bacteria and parasites, any diarrhoeal disease in that community constitutes a disaster. The presence of the hazard itself is not the disaster, as natural events cannot be considered disasters until negative consequences are experienced. One is further not vulnerable to a flood, earthquake, or other natural disaster; they are vulnerable to the loss of life, livelihood, assets, or income, that may be caused by these hazards (Vatsa, 2004).

One conceptual tool available for the analysis of vulnerability is the Pressure and Release (PAR) Model (Blaikie et al., 1994; Wisner et al., 2004). In this model, root causes of vulnerability are present, and are translated by dynamic pressures in the system into unsafe conditions. The presence of these unsafe conditions means that when a hazard event occurs, individuals and communities are susceptible to damage and disruption (Wisner, et al., 2004). Increases at any of the stages along the progression of vulnerability lead to a build-up of

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1 The concept of vulnerability was originally put forth by Blaikie et al. (1994) in the first edition of the book *At Risk: Natural hazards, people's vulnerability and disasters.* , and then further developed and elaborated upon in the second edition in 2004, where Ben Wisner is listed as the first author for his significant contributions to the process.

'pressure' which is released when the vulnerable parties are exposed to a hazard and the 'release' occurs in the form of a disaster. The value of the PAR framework is that it "directs attention to the conditions that make exposure unsafe, leading to vulnerability and to the causes creating these conditions" (Turner et al., 2003, p. 8074). PAR can be used in conjunction with the Access Model (Wisner et al., 2004), which takes into account capabilities, assets and livelihoods available for reducing vulnerability.

For the purposes of this study, the presence of coliform bacteria and phosphorous (as indicators of sewage contamination) in drinking water wells will be considered as a hazard. When this hazard intersects with unsafe conditions, it leads to negative health impacts. Thus, according to the PAR model, the outbreak of any water-borne infectious disease is a disaster to affected communities.

Birkmann and Wisner (2006) define four thematic areas within root causes of vulnerability as: social, economic, environmental and institutional. Social contributors to vulnerability include aspects of their identity such as gender, age, race, ethnicity and religion, alongside "Social relations and the historically rooted patterns of discrimination, inequity in access to resources, and power..." (Birkmann & Wisner, 2006, p.16). The economic area includes source of livelihood, educational status, and income level. Environmental vulnerability encompasses the likelihood of a hazard occurring in the immediate environment of an individual. Lastly, institutions like governments, businesses, markets and health systems play an influential role in the ability of individuals and communities to respond to extreme events when they do occur (Birkmann & Wisner, 2006).

The dynamic pressures that mediate the creation of unsafe conditions, and therefore the influence of these hazards, are multidimensional. Rapid urbanization and population growth, for example, represent changing conditions that create new and exacerbate old stresses on communities' abilities to provide clean water and handle waste appropriately. Salinisation of aquifers and lack of widespread access to piped water and adequate sanitation can both lead to transient water insecurity. The inability to access safe and sufficient water for drinking and household use creates an unsafe condition which increases risk of exposure to disease causing pathogens, as those who are water insecure may be driven to depend on sub-par water resources. Further unsafe conditions may stem from lack

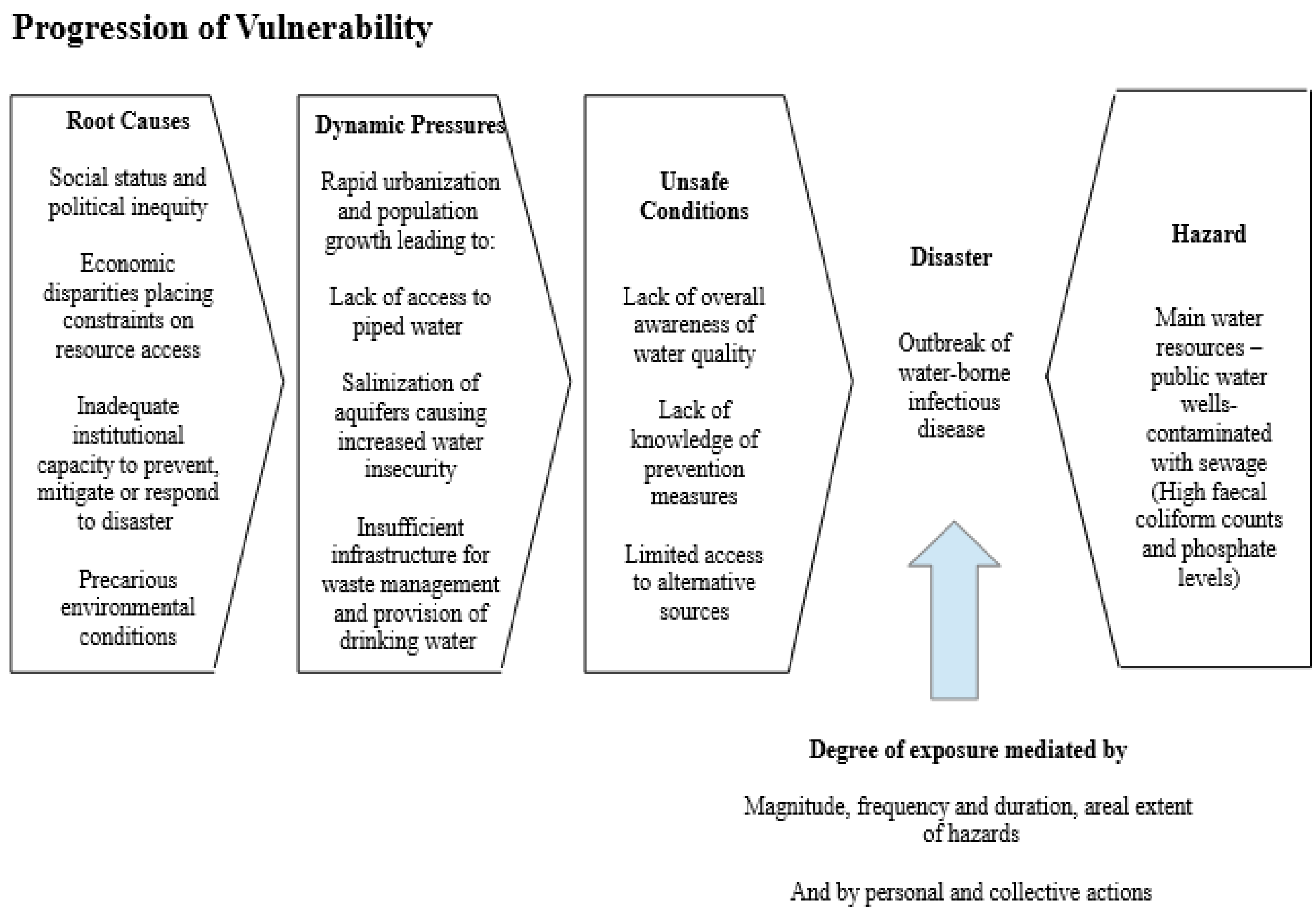

Figure 2. Pressure and release model (PAR): Progression of vulnerability (Adapted from Wisner et al., 2004)

of community awareness of best practices for preventing water contamination and protecting public health. It is possible to represent this progression of vulnerability by adapting a well known figure from Wisner et al.'s (2004) book *At risk: Natural hazards, people's vulnerability and disasters* (Figure 2). Another way of understanding this is that the risk, or likelihood of negative impacts in a coupled human-environment system, is a function of the sensitivity and exposure of that system and its component parts, combined with its capacity to adapt (Adger, 2006). Risk is defined by Wisner et al. (2004) as an objective hazard mediated by social processes, determined by a micro-environment including educational and nutritional status, access to water and sanitation, and livelihood. Thus, to decrease pressure -thereby reducing risk- one must first understand the root causes of vulnerability, and how it can be possible to address them through reducing sensitivity and exposure, improving the micro-environment, or increasing adaptive capacity.

2.2 Sensitivity and Exposure

As mentioned in the previous section, vulnerability is considered to be a function of sensitivity and exposure to perturbations and stresses (Adger, 2006). Sensitivity has to do with level of dependence on a resource, and how exclusion or perceived exclusion from use of that resource could impacts lives and livelihoods (Crona, et al., 2009). In the context of this study, sensitivity is highest when there is limited access to clean and safe water resources. This is because if access is restricted or a water source is shown to contain unsafe levels of contamination, individuals might have no choice but to continue to use it in the event that there is no available alternative. Sensitivity can therefore be decreased by promotion of alternative water sources like rainwater harvesting and desalination.

Exposure represents a high level of physical risk of contamination (Crona et al., 2009) and also the "nature and degree to which a system experiences environmental or socio-political stress" (Adger, 2006). It is tied to the fixed physical attributes of a system and the proximity of the unit of assessment to the hazard event, and also to the livelihoods, economies and cultures that rely on a specific resource (Birkmann, 2013). For a hazard to impact human health, there must be both a spatial and temporal overlap between the presence of people and the presence of the hazard (Corvalan, 1999). Exposure to water-borne infectious diseases can be minimized by improving infrastructure for provision of water and protection of resources from contamination, or by personal and collective actions taken to improve environmental cleanliness, sanitation, and hygiene.

The duration and severity of a disaster are mediated by adaptive capacity, or " the ability of a system to evolve in order to accommodate environmental hazards or policy change and to expand the range of variability with which it can cope" (Adger, 2006, p. 270). This is tied to the complementary concepts of social and ecological resilience. Vulnerability is a dynamic and relative measure. To some extent everyone is vulnerable, but their ability to respond to and recover from changes in response to variables along the progression of vulnerability. In addition, if a system is less resilient, at each incidence of a repeated shock will experience a higher level of vulnerability (Vatsa, 2004).

2.3 Perception

Exploration of direct vulnerability, as discussed in the previous section, can be complemented by the idea of perceived vulnerability. Robert Chambers (1997) argues for putting the experiences, understandings, and perceptions of the poor at the centre of any development intervention. The reality experienced by all individuals, and particularly the poor, is key to understanding why interventions succeed or fail, and is often overlooked by those in power. Furthermore, objective risk -as defined by technical experts- may not encompass subjective understandings of changed self-esteem, livelihood, and community. Different understandings of risk may lead to different courses of action and disagreements about appropriate responses between technical experts and the general public (Vatsa, 2004).

Personal experience and cultural context both play a role in defining perception of risk (Crona et al., 2009), and so "Alongside the socio-natural co-production of hazard and the social qualities of vulnerability [...] the ways in which different stakeholders perceive hazard, vulnerability and risk also need to be considered..." (Birkmann et al., 2013, p. 195). These perceptions are important because they can give insights into the realities of spatial and temporal distribution of risks, and also because differential understandings and expectations regarding risk may alter the behaviours of individuals. Ignorance of the presence of risk can limit ability to avoid or mitigate that risk, whereas awareness of a hazard provides an opportunity to proactively take measures to protect oneself from harm (Wisner et al., 2004). Health and illness are therefore "grounded in people's embodied experience, partly enacted and partly verbalised, reflected upon and recreated in social interactions with other persons, yet at the same time constrained by larger structures of social, political and economic conditions which manifest themselves in particular localities...." (Obrist, 2003, p.276). Vulnerability increases when people are either unaware of the presence of a hazard, such as contaminated water, or unable to access alternative water resources despite their awareness.

2.4 Scarcity

Scarcity is a term used to refer to a condition in which a resource is not available for all people in sufficient quantities to satisfy their needs. Water scarcity increases vulnerability to water-borne diseases, because in conditions where there is insufficient safe water for human use it may become necessary to turn to resources of sub-par quality (Mehta, 2014). Much like risk, perceptions of scarcity vary based on an individual's background, understandings, and expectations. The discourses and definitions used to describe the experience of scarcity and its causes may have direct impacts on the type of solutions that are proposed.

Politicians and development professionals tend to prefer what are considered to be objective measurements of absolute scarcity, such as Litres of water available per person, per day. For example, 1700 cubic meters of water per person is seen as the national threshold for meeting all individual needs, and if a country or region falls below 1000 cubic meters of water per person, they are considered to be experiencing water scarcity (UNDP, 2006). On the other hand, there are those who have argued that scarcity should instead be considered as a social construct, viewed in terms of its lived and experienced impacts (Mehta, 2006). These theorists build on the work of Amartya Sen and see scarcity as a result of entitlement failure and unequal distribution of resources. Thus, when resources are not distributed equitably use of per capita availability of a resource can be misleading.

Biophysical perspectives on absolute scarcity obscure the role of the elite in creating the overuse that leads to scarcity and favour technocratic solutions that do not address existing inequalities and injustices (Mehta, 2006; Ohlsson & Turton, 1999). This approach to what has been called 'first order scarcity' may not make adequate distinctions between "the scarcity or limitedness of water in the hydrological cycle and scarcity of access for the poor for their drinking-water and survival needs (due to the lack of water, its poor quality, or their exclusion due to the prevailing social and power relations)" (Mehta, 2014, p. 61).

The 'second order' of scarcity moves to address this analytical gap by prioritising socio-economic conditions over physical ones. This encompasses the idea that an inability to adapt to physical conditions of scarcity when they do exist is a problem in its own right, independent from absolute quantity (Ohlsson & Turton, 1999). Even when first order scarcity does not exist, second order scarcity can be possible where resources are not allocated equitably (Wolfe & Brooks, 2003). Therefore, it is important to disaggregate users because across social classes, genders, age groups, the level of scarcity can vary dramatically (Mehta, 2014). A political economy perspective can be of use, as its analysis will provide insight into the power relations at play in creating conditions of scarcity for some and not others. For example, certain sectors of the economy -tourism, or industry to name a few- may be be causal factors in the construction of scarcity, "...the result of powerful actors getting away with resource appropriation and thus enhancing degradation" (Mehta, 2006, p. 655). These sectors can flourish in water stressed or scarce areas, while the general population is simultaneously unable to obtain sufficient water for their needs.

As one might imagine, adapting to second order scarcity requires a different suite of potential solutions than first. Rather than attempting to increase supply and overall availability of a resource, policies and projects to address second order scarcity facilitate and promote changes in usage patterns, minimizing the amount of water that is required wherever possible (Ohlsson & Turton, 1999). Increased prices for water during dry periods or tax refunds to households that install water saving appliances are examples of this type of adaptation.

Wolfe and Brooks (2003) further subdivide the original idea of second order scarcity as put forth by Ohlsson and Turton (1999) into a third order of scarcity which is more focused on social, cultural, and political changes rather than technical solutions. Where second order solutions to scarcity might aim to decrease use of a resource through manipulation of prices or subsidies for decreased use, in the third order, changes in lifestyles, education, and population distribution cause a fundamental shift in the overall demand for resources (Wolfe & Brooks, 2003). Wolfe and Brooks hypothesise that third order solutions are therefore less likely to reinforce existing political inequalities with similar winners and losers (2003). They are, however, more challenging to implement rapidly in many contexts.

In this thesis, I build on the ideas of these scholars (Lyla Mehta, Wolfe & Brooks, Ohlsson & Turton, and others) and argue that in the case of vulnerability to water contamination it is important to focus more on second and third order scarcity because measuring absolute quantities of water may not include analysis of the quality of that water. Furthermore, differences between the socio-culturally produced and experienced scarcity of groups within a heterogeneous population may be overlooked.

There is, however, a constructivist dilemma inherent in this debate. It is a concern that considering all aspects of scarcity to be socially constructed will lead researchers to overlook the fact that in some cases in ecological terms, resources may be declining or endangered. A materialist basis should be maintained, through awareness of and reflection on measurable quantitative research, to provide a solid foundation for qualitative research. Space is then provided for consideration of absolute scarcity and the technical solutions that could address it, which can then be built upon while still keeping the focus on the fact that "shortages and degradation are primarily a result of the uneven social measures that manufacture scarcity all over the world for the economic and political gain of powerful interests" (Mehta, 2006, p. 662). Interdisciplinary research is therefore well suited to the study of scarcity, as it allows for the incorporation of both constructivism and materialism-first, second, and third order understandings of conditions of scarcity.

2.5 Relevance of Concept of Vulnerability

Batterman et. al (2009) have reviewed much of the literature describing sustainable control of infectious diseases and come to the conclusion that too much attention is given to the individual-based and behavioural causes of illness and too little on the more systemic causes of disease. This outcome-focused perception of vulnerability places too much of the responsibility for adaptation on those who are vulnerable by emphasizing personal hygiene and sanitation measures at the core of prevention strategies, rather than holistic and systemic policy and infrastructure changes that could protect entire communities (O'Brien, Eriksen, Nygaard & Schjolden, 2007). Batterman et al. note an increase in the number of cross-disciplinary studies, but express concern that there is still a fundamental disconnect between epidemiological studies in public health research and anthropological and social science studies that include political, economic and social contributors to disease exposure (2009).

This study will aim to explore both the personal and institutional characteristics that increase vulnerability to diarrhoeal disease in conjunction with the environmental characteristics particular to Zanzibar that increase likelihood of exposure to contaminated water, both now and in the near future.

3. Literature Review

This section will situate current research on aspects of vulnerability and water, sanitation, and health in the peri-urban context. Environmental, institutional, and social conditions common to many peri-urban communities in developing countries will be considered in relation to their potential influence on exposure to water-borne infectious disease. Literature regarding the likelihood of outbreaks of diarrhoeal disease caused by contaminated groundwater will then be presented, including modes of contamination, methods of prevention, and socio-economic contributors to vulnerability. Wherever possible, this information will be related to the conditions of Unguja Island, Zanzibar.

3.1 Peri-urban context

Peri-urban communities are growing rapidly in line with global trends in urbanization around the world. They are dynamic communities that are not yet well understood, "...often disregarded and characterised by increasing marginalisation and environmental degradation" (Marshall et al., 2009, p. 1). Peri-urban areas exist at the geographical and economic fringe of cities, exhibiting features of both the urban and rural context (Allen, 2003). Scholars are still working to define exactly what qualifies an area as 'peri-urban', as this can be both linked to ideas of place, proximity to cities, or ideas of the complex patterns of settlements and flows of resources (Allen, 2003; Dupont, 2005; Marshall et al., 2009). Where these areas were once viewed as a stepping stone on the road to more 'modern' urbanity, they are now seen as an independent category independent from either traditional rural or urban institutions (Mehta & Karpouzoglou, 2015).

Because of their unique characteristics, peri-urban communities find themselves situated in the centre of what is known as the "health risk transition" (Birley & Lock, 1998). Both 'traditional' diseases, which are associated with a rural lifestyle and frequently communicable and immediately localized, and 'modern' urban diseases which are often non-communicable and can be brought on by injury, psychological problems, or over-nutrition, impact peri-urban residents at disproportionately high rates (Birley & Lock, 1998). Their position on the outer edges of urban society means that not only are they at risk of contracting modern diseases, but they are also still frequently exposed to the traditional communicable diseases which are common in rural areas without the protection and infrastructure offered by a more fully urbanized location.

Furthermore, the growing and highly dense populations of peri-urban areas frequently depend on locally available sources of water, as there is often a lack of water-providing infrastructure by governmental or private sector actors (Marshall et al., 2009). Unprotected dug groundwater wells, which are considered highly susceptible to contamination with pathogenic organisms, are often the water source of choice in peri-urban communities because they are inexpensive and easy to construct (National Bureau of Statistics & IGF Macro, 2011). Contamination of these wells can occur from above by flooding, introduction of pathogens on dirty buckets, or accidental dropping of waste or other items into the water. It can also occur from below through contamination of the aquifer itself, for example through leaching of wastewater from landfills, on-site wastewater treatment, or rivers contaminated with waste nearby. Contamination from above may be caused by unhygienic usage of wells without covers or lids, along with "...poor sanitary practices (for instance, disposal of human excreta in open spaces) in these slum areas [which] lead[s] to contamination of water and consequently water-borne diseases" (Opisa, Odiere, Jura, Karanja & Mwinzi, 2012, p. 2675).

Lack of sufficient regulatory oversight in peri-urban communities contributes to concerns about how to equitably and sustainably manage resources in these areas (Marshall et al., 2009). This can be attributed to a condition of "institutional fragmentation", whereby public, private, rural, and urban organizations and regulations share an unclear and poorly defined level of responsibility for providing services (Allen, 2003, p. 138). In addition, there is a struggle in many peri-urban areas between the need for housing for the poor, and a greater societal desire to protect the environment (Dupont, 2005).

Peri-urban areas often have disproportionately high numbers of poor people, driven into these informal settings by demolishing of slums and migration from impoverished rural areas (Dupont, 2005). Chaterjee (2004) has theorized that in the modern state, there is a distinction between those who bear rights and others, usually the poor, who cross lines of legality in their struggle to survive. This second group, because of their position outside the traditional boundaries of society and citizenship are thus the targets of government laws, policies, and interventions, and often access services in an informal way. In the case of water, this applies to peri-urban residents who must seek out alternative strategies for obtaining water, and for determining and maintaining the quality of that water independent of traditional government support.

3.2 Groundwater quality

Groundwater is a crucial source of drinking-water in peri-urban areas. As populations grow and distribution of settlements change, the risk of contamination increases. Increasing amounts of waste above ground in peri-urban areas is one factor at play. It is common for informal settlements to be located in close proximity to polluting infrastructure, such as factories, dumps, and waste treatment plants. This can introduce disease vectors into their surroundings (Simon, 2008). For areas already without the necessary infrastructure to manage household solid waste and sewage, the additional burden of external waste only serves to heighten the existing distributional inequalities putting pressure on their health and well-being (Simon, 2008). The physical characteristics of many peri-urban communities make removal of both solid and liquid waste a daunting prospect. Winding streets, for example, have insufficient space to drive a truck, and limit the ability to remove garbage or drain septic tanks.

Speed and quantity of movement of contaminants from outside sources into groundwater is impacted by the type of soil, depth of water table, and proximity of the sources. One of the “Commonest cause[s] of pollution is attributed to close proximity of septic tanks to wells...” (Adetunji & Odetokun, p.159). Because of this, in areas where water is obtained from underground sources, use of pit latrines is not recommended unless the groundwater table is very deep or specific known characteristics of the soil prevent migration of contaminants (Opisa et al., 2012). The problem can be mitigated by increasing distances between wells and on-site sanitation systems; however, this may not be feasible in the case of informal settlements, as space is at a premium, and there is rarely adequate or effective regulation of development. Additionally, on-site sanitation and use of unprotected dug wells are often the most affordable option available (Opisa et al., 2012).

Seasonal variations in streamflow, standing water, and distribution of pathogens by surface runoff and flood waters can have dramatic and immediate impacts on levels of pathogens in water resources. Temperature plays a role on these variations, as it may alter growth rates for many bacteria, protozoa, viruses and helminths, increasing the spread of contamination in water resources in warm climates (Bandyopadhyay, 2012). For example, Moynihan, Baker & Mmochi (2012) studied variations in water quality around Stone Town in Zanzibar and found that there was a strong relationship between levels of precipitation and levels of contamination in coastal waters caused by flooding of streets that carried rubbish, agricultural runoff, and sewage into the bay. Similar variations in contamination levels could be expected in groundwater, as the same flooding that carries sewage into the bay may also contaminate surface waters with the potential to leach into subsurface aquifers. The impact of this variation on human health is visible in the Tanzania Demographic and Health Survey in 2010, which found that the prevalence of diarrhoea in Tanzania varies regionally and by season, with the highest rates usually occurring around the rainy season (National Bureau of Statistics & ICF Macro, 2011).

3.3 Prevention of diarrhoeal disease

A significant outcome of inadequate access to safe and sufficient drinking water is the onset of diarrhoeal disease in a community, brought on by exposure to pathogens. There are several pathways by which diarrhoea causing pathogens (bacteria, worms, viruses or protozoa) can infect their hosts. These are: human-to-human via the environment, human-to-human multiplying in the environment, and human-to-animal-to-human via the environment (Curtis, Caincross & Yonli, 2000). In each of these pathways, points of control of the pathogens can be either at the individual or household level, including improved sanitation and hygiene, or at the infrastructural/institutional level, including improved management and treatment of water and wastewater.

The World Health Organization names hand washing with soap and use of improved sanitation as primary interventions for reducing risk of diarrhoeal disease (WHO, 2013). Cleanliness and hygiene in public spaces is also considered a priority area, as the presence of rubbish, excrement, and grey water in hospitals, schools, and other public areas can be a significant contributor to the contamination of shared water resources. This has been reinforced by many individual studies; frequently interventions such as improved water storage, treatment of drinking water, and community education about hand washing are introduced and the baseline prevalence of diarrhoea is compared to the prevalence following the intervention. Interventions of this type are preferred by governments and aid organizations because they are inexpensive and can show rapid results (Curtis et al., 2000). However, despite initially encouraging outcomes, these actions have not been shown to be sustainable independently.

Providing access to improved water sources or improved household sanitation can complement hygienic behaviours (Bartram & Caincross, 2010). The Tanzania Demographic and Health Survey in 2010 unexpectedly found that "there is no notable difference in diarrhoea prevalence among children by source of household drinking water or toilet facility (National Bureau of Statistics & IGF Macro, 2011, p.151)". This contradicts many other studies, including one done in 2014 in Ethiopia that found that type of toilet facility and whether a household had access to improved water sources had a significant relationship to rates of childhood diarrhoea (Mihrete et al., 2014). In the study by Mihrete, children from households with no toilet facility were six times more likely to have diarrhoea than those with an improved toilet facility. Those with non-improved water sources were twice as likely to have diarrhoea than those with improved water sources (Mihrete et al., 2014). It is widely accepted that improved sanitation and access to drinking water are worthwhile interventions for the prevention of diarrhoeal disease. Improving access to these resources should decrease risk of exposure to hazardous pathogens, as "water-related infrastructure, including distribution systems (e.g., reservoirs, wells, treatment systems, pipelines) and drainage facilities (e.g., bridges, dams, channels, culverts, levees, storm sewers) is designed to provide a sufficient supply of healthy water and to remove physical, chemical, and biological (pathogen) contaminants" (Batterman et al., 2009, p.1025).

In terms of protection of groundwater resources, the Tanzania National Environmental Standards describe several factors that should be taken into account. Distances from sources of pollution are very important in predicting likelihood of contamination, but were not measured in this study. A potable water source must be: "50 meters from pit latrines, septic tanks and sewers; 150 meters from borehole latrines, seeping pits, trenches, and subsurface sewage disposal fields; and 150 meters from cesspools, sanitary land field areas and graves" (Tanzania Bureau of Standards, 2003, p. 28). Livestock and other animals, open defecation sites, and drainage waters should also not be allowed within the vicinity of the water source. Furthermore, water sources must be protected from inundation by floods. These guidelines are well-intentioned, but may not be feasible or enforceable in the peri-urban context.

3.4 Socio-economic determinants of vulnerability

As described in the conceptual framework chapter, vulnerability is defined by the likelihood of exposure to a hazard and the ability of an individual or community to avoid, mitigate, or cope with that hazard. Social and economic characteristics of communities and individuals can play a significant role in each of these in turn. Poverty, gender, and education level have each been found to have compelling impacts on vulnerability at multiple levels (Bates et al., 2004; Manderson, Aagaard-Hansen, Allotey, Gyapong, & Sommerfeld, 2009). It has been shown, for example, that richer households are generally more able to cope with the challenges posed by diminished water quality from their primary sources (Mehta & Karpouzoglou, 2015).

The idea of poverty is multifaceted, and can include neglected dimensions lack of access to infrastructure and services, political isolation, and weak institutional support, in addition to the more traditional concept of lack of income leading to impoverishment (Chambers, 2007). Insufficient access to financial resources, at the most basic and fundamental level, makes one more vulnerable to negative health outcomes, because a person or household may not be able to pay for the healthcare and other services needed to treat or prevent disease. Lack of other tangible and intangible resources constrains individual ability to prevent and respond to disease as well (Halvorsen et al., 2003). Tangible resources of note include income, productive assets, safe housing, soap, water filters and storage containers, and sanitation services. Intangible resources include time, social capital and status, and maternal capital (including education, skills and knowledge). A study done by Halvorsen et al. (2003) in Northern Pakistan found that households with the lowest frequency of disease were found to have more substantial access to both tangible and intangible resources.

Poverty and disease can be viewed as a mutually interrelated cycle (Bates, et al., 2004). For many poor people, their body is a crucial asset in the sense that they are largely dependent on their physical capability to perform labour for income (Chambers, 1989). Illness and disability interfere with this ability, turning the body from an asset into a liability as those who are unable to work or attend school because of disease will later be unable to pay for the costs of healthcare or afford an education (Chambers, 1989). Additionally, food poverty may impact the ability of an individual to cope with illness due to compromised immune responses due to low nutritional status. The abstract concept of 'time poverty' is also a factor, whereby individuals are constrained in their ability to satisfy their needs because of a lack of time (Chambers, 2007). When water resources become further away or more time consuming to obtain in any sense, time poverty becomes a factor in the ability to maintain health and a good standard of living. People in these conditions may resort to consumption of unsafe water and lowering of good hygiene practices, because they have no alternative (Bandyopadhyay, Kanji, & Wang, 2012; Mehta, 2014).

On a larger scale, the relationship between poverty and vulnerability to disease is apparent across households, communities, and countries. In poor communities and countries there is a chronic inability "to provide the infrastructure, human resources, and services that reduce the toll of such infections" (Manderson, et al. 2009, p. 4). Furthermore, the creation and proliferation of peri-urban settlements is itself a side-effect of poverty. As these crowded settlements spread without sufficient infrastructure for provision of water or management of waste, residents become more vulnerable to water-borne infectious diseases and other impacts on their health. Residents of peri-urban areas also often pay more for water of lower quality than residents of areas with connections to piped water networks (UN-Habitat, 2010). Thus, poor residents of peri-urban settlements may be particularly vulnerable in times of water shortage or scarcity, because they may not have access to resources -financial or otherwise- for obtaining clean drinking water.

Another individual characteristic that influences vulnerability is gender, and in the case of water scarcity and diarrhoeal disease women are typically considered more vulnerable. One reason for this is that the responsibility often falls on women to care for members of the household who are sick, which can lead to higher rates of exposure (Bates et al., 2004). Inequality in power relations is also relevant because power defines the way women are able to make decisions regarding their own health and the health of their children. Therefore, if women lack access to or control over financial resources, they may be limited in their ability to purchase clean water or the materials necessary to bring improved sanitation and hygiene into their households, or to care for their dependants when they become sick (Halvorsen, 2003, p. 123). In addition, women are frequently responsible for obtaining water for their households. This means that if water resources are interrupted or become scarce, they may have to dedicate significant time and resources to obtaining safe and sufficient water (Mehta, 2014). This exacerbates the already significant gender gap in time poverty caused by the unpaid care burden on women. It also means that the onus is on women to determine whether water is safe for consumption and to decide whether further treatment is necessary.

Because of these responsibilities, the behaviour and understanding of women and mothers in particular are crucial to determining the vulnerability of their entire household, particularly children who are dependent on them. As such, maternal education level has been studied extensively in relation to childhood vulnerability to diarrhoeal disease. One example of this is a study done by Mihrete, Alemie and Teferra (2014) in North Western Ethiopia, which found in a sample of children under five years old, those with mothers with no education were twice as likely to suffer from diarrhoeal disease than those with mothers who had completed primary education or above. Education level is also linked to perception of risks, as education and access to information can change the way that individuals understand how diarrhoeal disease is transmitted and can be avoided (Crona et al., 2000).

Public health interventions often focus on “biologically vulnerable” groups with reduced immunity and ability to recover from disease such as children under five years of age, pregnant women, and the elderly. Many interventions also emphasize personal agency in disease prevention, suggesting that with proper individual hygiene and sanitation practices all diarrhoeal disease can be averted. This approach is valuable, however because it places "...responsibility for change on individuals; it has been criticised because it ignores the social and economic factors that constrain the ability of an individual to change" (Bates et al., 2004, p. 268). A combined approach that holistically considers and addresses multiple contributors to vulnerability will be the most effective in addressing its root causes and sustainably improving health for peri-urban communities.

4. Method

4.1 Research Design

This study was carried out using a combination of quantitative and qualitative research methods with the goal of integrating both social and natural contributors to vulnerability. Mixed methods research was chosen because it allows for a more holistic and thorough understanding of context rather than focusing exclusively on either the natural or social science perspective (Bryman, 2008). The research took place with the support of the larger Noragric/NORHED partnership project: Vulnerability, Resilience, Rights and Responsibilities: Capacity Building on Climate Change in Relation to Coastal Resources, Gender and Governance in Coastal Tanzania and Zanzibar.

4.2 Data Collection

Research was conducted between 15 October 2016 and 12 December 2016. The first two weeks were spent in the planning phase, contacting relevant academics and actors in order to select study sites, identifying research assistants, and obtaining relevant permissions for carrying out research in Zanzibar. The State University of Zanzibar (SUZA) and the Institute of Marine Sciences (IMS) provided extensive support for this process. This was followed by approximately five weeks of water sampling and interviews.

4.3 Study Sites

Sites for fieldwork were selected based on their dependence on potentially contaminated wells and location in peri-urban communities surrounding Zanzibar Town. Input as to the most suitable sites was provided by members of the staff of SUZA and IMS. In each community, or *shehia*[2], two wells were selected for sampling. All wells are located in informal settlements in peri-urban areas, which means they have limited access to government services and there is little or no enforced regulation regarding the way homes and their sanitation infrastructure are built.

Coordinates of each sampling site were recorded using GPS in order to create maps of the study areas and potentially explore any spatial aspects of vulnerability. I originally

2 Shehia is a Swahili term for an administrative district.

intended to take coordinates of each household as well, but because most of the interviews occurred for convenience purposes right next to the wells rather than in the households, this was not possible. In addition, I decided that recording coordinates of interview participants' homes qualified as personally identifiable information that should not be included in the study for the sake of privacy and anonymity of participants.

Tomondo and Kijito Upele are the two *shehias* that were selected for the study. As sampling was carried out in two locations in each of these administrative areas, the wells and their surroundings will be referred to as Well KA and Well KB in Kijito Upele and Well TA and Well TB in Tomondo.

4.3.1 Kijito Upele

Kijito Upele is a *shehia* within with a population of 19,374 people as of the 2012 census (National Bureau of Statistics & Ministry of Finance, 2013, p. 235). Houses are made of concrete bricks and have roofs made of sheet metal. Many of the houses have septic tanks outside of their houses with concrete slabs over them and vent pipes up to roof level to release gases. The well-trafficked walkways between houses are sandy and generally clean. The areas behind the houses are where inhabitants toss out their grey water and trash, and that is where puddles of liquid and solid waste accumulate. Mixed in with the homes is some small-scale agriculture such as banana trees and vegetable plots protected by old mosquito nets. On the larger unpaved roads there are a few small shops, and small-scale commerce occurs near water sources and on the front steps of homes. There is some piped water available in these areas from a borehole maintained by ZAWA, but the 'maji safi' (clean water) trucks are refilled here and this can occasionally lead to shortages for local users.

Figure 3. Sampling sites in Kijito Upele, Well KA and Well KB (Google Earth, 2016)

4.3.1a Well KA (S 06.19033, E 039.24122)

The first well sampled (Well KA) was constructed approximately two months before the study took place. Water is pumped from the well into a 3000 litre tank where it is stored and then distributed from six taps at the base of the tower. Once the water tank at Well KA is full it is treated with sodium hypo-chlorite (brand name: Water Guard), which is available in shops in the area or from ZAWA. Water Guard is available in liquid or in tablet form; one tablet (67 mg) of water guard is recommended to treat 20 litres of tap water for drinking, and two tablets are recommended for water from lakes or wells.

Members of the community were responsible for planning and paying for construction of the well, and will share responsibility for future maintenance. Users pay 500

Tanzanian Shillings[3] for unlimited access to the well for one day. This covers the cost of electricity, and allows them to fill as many containers of water for storage in their homes as possible. The water from Well KA is used for cooking, drinking, and other household purposes.

4.3.1b Well KB (S 06.19113, E 039.24212)

At Well KB, water is drawn by hand using a bucket attached to a rope. The well is covered with a sturdy metal lid, and is approximately 20 meters deep. This water is not regularly used for drinking, but is rather used for cleaning, agriculture, and sanitation purposes. Less than ten families regularly use water from Well KB.

4.3.2 Tomondo Mshelishelini

The population of Tomondo as of the 2012 census was 23,254 people (National Bureau of Statistics & Ministry of Finance, 2013, p. 235). ZAWA employees reported that the area of Tomondo has struggled with water shortages for many years. Because this area is so large, it is subdivided into several smaller neighbourhoods, one of which is Tomondo Mshelishelini, where sampling was carried out. The neighbourhood has both an upper and lower area, distinguished by their different elevations. The water runoff from both areas flows downhill and accumulates in a swamp -visible in the centre of the satellite image in Figure 4. The households in the upper area are generally well spaced out, with clear and straight pathways between the large rectangular concrete houses. The lower area appears much less planned, and houses are haphazardly arranged. Some clear paths are available, but often to move between houses one must walk across wood plank bridges that cover pits and ditches to avoid large puddles and wild vegetation.

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3 At the time of research, 2200 Tanzanian Shillings were equal to approximately 1 US Dollar.

Figure 4. Sampling sites in Tomondo, Well TA and TB (Google Earth, 2016).

4.3.2a Well TA (S 06.19236, E 039.23115)

Well TA is a fully covered well that dispenses water using a hand pump system. The well was constructed in the past two years using money from a local Quranic school, and teachers from the school are responsible for regularly cleaning and treating the well for the community. Users do not pay for use of the water.

The well is located near the edge of the swamp where runoff water from all of Tomondo Mshelishelini accumulates. This neighbourhood is referred to as the 'lower side' because water and waste from uphill flow in this direction toward the swamp during heavy rain.

4.3.2b Well TB (S 06.19387, E 039.22673)

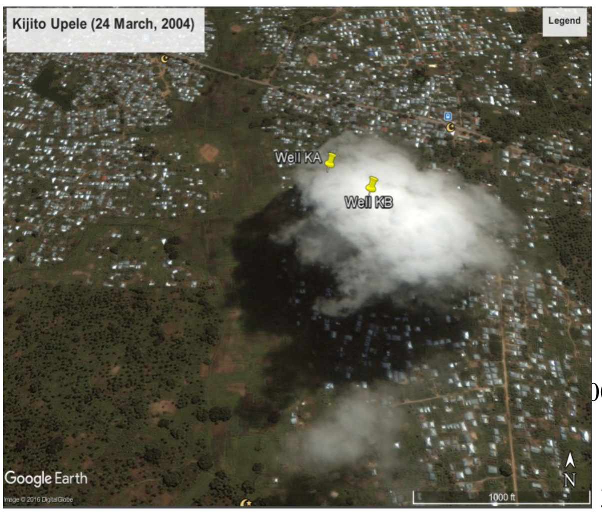
Well TB is a fully covered well attached to a pump system. Households that contributed to the construction of this well about three years ago are connected to the system and when the pump is turned on they are able to receive water from taps in their houses. Users do not pay based on quantity of water used, but rather for the cost of electricity. Samples from this well were taken in the hours following a heavy rain.

4.3.3 Comparison

My original plan was to compare between the two *shehias* as I expected that within the neighbourhoods water access would be somewhat homogeneous, but following the interviews it became clear that the strategies and conditions within each area are highly diverse and heterogeneous. It thus became more practical to look at each of the four well sites as an individual case study, and to compare from that perspective.

4.3.4 Rapid rate of change

When considering the results of this study, and any study done in peri-urban areas, it is important to remember that conditions are highly dynamic. The images and measurements described in this study are a snapshot of the conditions in November and December or 2016. Populations are growing at unprecedented rates, with new land and resources rapidly absorbed into communities. This is visible the satellite imagery available from Google Earth. Figure 5 shows the striking difference between Kijito Upele in 2004 and 2016[4]. In just 12 years much of the green space has been absorbed by houses, and the spaces between many of the homes have been filled in with new structures.



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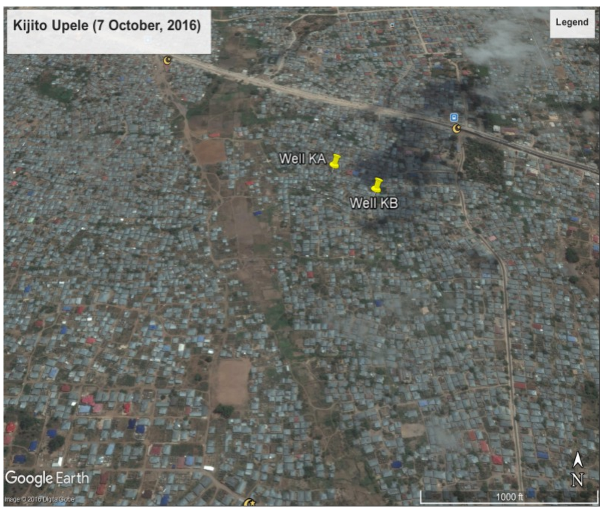

Similarly dramatic development can be seen in the Tomondo Mshelishelini area. Notable in this area is the encroachment of houses into what appears to have once been agricultural land, and is now more of a fluorescent green swamp (Figure 6).

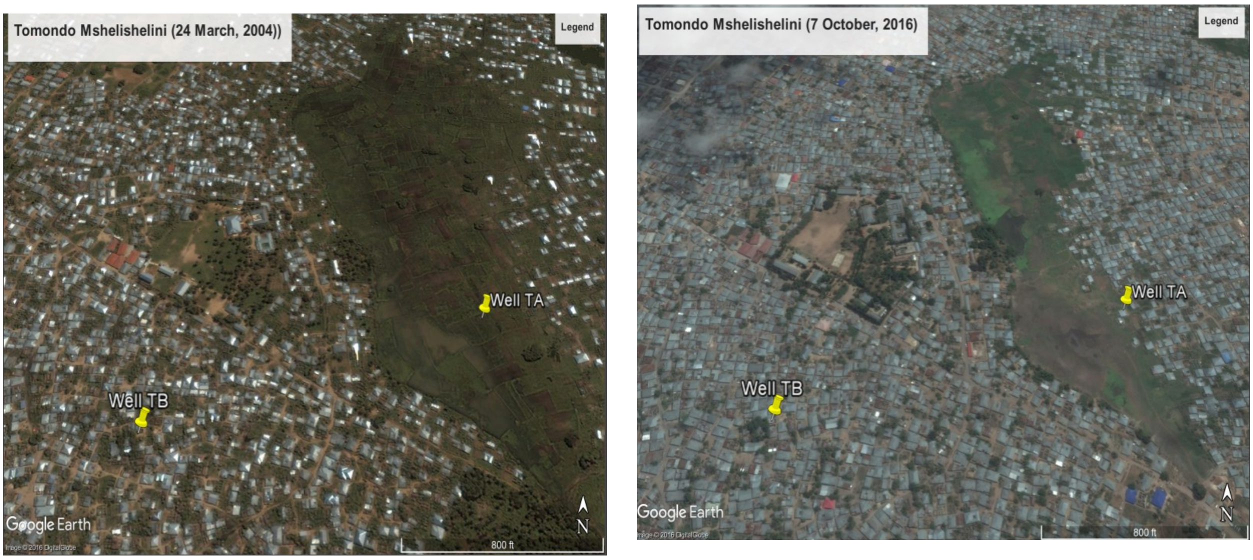

Figure 6. Satellite imagery of Tomondo Mshelishelini in March 2004 and October 2016 (Google Earth Pro, 2017).

In both study areas, it is clear that settlements are growing and changing rapidly. It is likely that they will continue to do so, and as such the dynamics and conditions of vulnerability will continue to develop and change.

4.4 Interviews

4.4.1 Qualitative sampling (household and other stakeholder)

Non-probability sampling was used to select households for qualitative interviews. In addition, due to the short duration of the field work, it was more feasible to proceed with a combination of purposive convenience sampling facilitated by the community leader, or *sheha*[5], and other residents of the community. Purposive sampling is used to target interview subjects with particular characteristics that are relevant to the study, and convenience sampling allows the researcher to accept those subjects that are most easily accessible under the constraints of their situation (Berg & Lune, 2012). In this case, subjects

5 Sheha is a Swahili term for the leader of an administrative district (shehia).

were selected based on their proximity to a particular public well. Snowball sampling, wherein study participants refer other potential subjects following their participation in an interview, was also used to identify possible households for inclusion.

During the day in all study sites a large number of men leave the area to go to work in town or one of the market areas. As such, the majority of respondents were women. I did not find this to be a problem, as my intention had been to sample mostly women because they are typically the ones responsible for collecting water and caring for the health of family members.

Key stakeholder interviews were based on a convenience sample, as some organizations had time and were willing to be interviewed and share records while others did not. Representatives of ZAWA, the organization responsible for provision of water, were extremely helpful in providing interviews from the Departments of Monitoring and Evaluation; Research, Innovation and Development; Public Relations; Planning and Project Engineering; and Credit Control.

Initial contact with study communities was established via the *sheha* of the study area. This occurred prior to commencing research and was facilitated by members of the SUZA staff. For the interviews with ZAWA, assistance was provided by the Department of Research, Innovation, and Development for the scheduling of interviews.

4.4.2 Qualitative interview technique

Interviews were carried out using semi-structured interview techniques. Questions aimed to answer questions about: root causes of vulnerability; perceptions of environmental risk and hazards; sensitivity to exclusion from wells as a water resource; and adaptation and coping strategies (including household sanitation and hygiene routines). Informed consent was obtained verbally from all participants after they had received a brief overview of the project and an explanation of their voluntary and confidential status as participants.

Semi-structured interviewing is an informal technique that uses prepared interview questions to allow for comparison between respondents, while also allowing and encouraging participants to elaborate and expand on ideas wherever they feel it is necessary (Berg & Lune, 2012). Interview guides are provided in Appendix 1.

4.5 Water sampling

Measurements of phosphorus concentration, percent salinity and faecal coliform counts (total and *Escherichia coli*) were taken at two wells in each of the two study locations. The purpose of this testing was to examine the level of agreement between resource users' perceptions of water quality and quantitative measurements of sewage pollution in water sources, and also to understand the current conditions of water resources in peri-urban Zanzibar in order to supplement theoretical discussions of vulnerability. Salinity was included as an indicator because, in the context of this study, saltwater intrusion into an aquifer is a risk factor for impending water scarcity, thus placing pressure on communities to seek out alternative and potentially low quality water resources.

Because the isolation of specific pathogens in water requires specialized equipment and expertise, measurement of faecal coliform bacteria is often used as a proxy indicator for possible sewage contamination (Fawell & Nieuwenhuijsen, 2003). The presence of faecal bacteria is correlated with presence of viruses that are also hazards to health and may be far more difficult to identify in the field (Schmoll, Howard, Chilton & Chorus, 2006). Although they do not provide perfect knowledge regarding quantity of all types of bacteria, protozoa, and viruses, faecal indicator bacteria density in a 1 mL sample can provide insight into the probability that pathogens are present (Schmoll et al., 2006).

Phosphorus levels can also be used as indirect indicators of the presence of sewage at sampling sites; therefore, in this study, phosphate measurements were taken in order to further corroborate measurements of coliform and *E. coli*.

All samples were taken in Kijito Upele (KA and KB) on 1 November, 2016. Samples at Well TA were taken on 6 November, 2016 and samples at Well TB were taken on 8 November, 2016. Six 10 mL vials and six 5 mL vials were collected using a fresh syringe at each well. Between samples the syringes were flushed repeatedly with sample liquid from the bucket where water was stored. All samples were then transported back to my residence, where the salinity and coliform tests were carried out within two hours of initial sample collection. Phosphate tests were delayed due to technical issues.

Phosphate level was tested using a Hanna Instruments 713 Checker HC Handheld Photometer for Phosphate, which automatically provides the phosphate concentration of a sample in parts per millions. Samples were taken using a 10 mL syringe and stored in 10 mL glass vials. Plastic vials were more readily available, but would not have been suitable as it is possible for phosphorus to leach out of plastic into the sample, or for the reagent to react with chemicals in the plastic and distort results.

Salinity was measured using a general salinity hand-held refractometer. The refractometer was calibrated using distilled water. Using a syringe, two to three drops of water from the well was placed on the glass surface of the refractometer to determine the salinity of each sample in parts per thousand.

3M Petrifilm *E. coli*/ Coliform count plates were used to measure the presence of *E. coli* and coliform in samples (Figure 7). 1 mL of sample was directly inoculated onto the centre of the petrifilm plate using a syringe. Syringe samples were transported to the location where petrifilms were safely stored in order to avoid unnecessary jostling during transport after inoculation. They were processed within two hours of initial sampling. This rapid processing of samples is important, as it prevents colonies from continuing to grow in the vial during storage, or dying due to overexposure to sunlight. Once the samples had been inoculated onto the plates, they were stored at room temperature, approximately thirty to thirty-two degrees Celsius. This allowed optimum bacterial growth during the approximately forty-eight hour period before counting of the bacterial colonies on each petrifilm plate.

Pink circles associated with bubbles on the petrifilm represent colonies of coliform bacteria, and blue circles represent the presence of *E. coli*. Each petrifilm was counted three times and an average was calculated in order to ensure the most accurate result possible, and then the plates were individually photographed. For samples with more than one hundred and fifty colonies, three representative squares were counted. The average of those three was then multiplied by twenty to estimate the number of colony forming units per mL as recommended by the 3M Food Safety Interpretation Guide for the petrifilm plates.

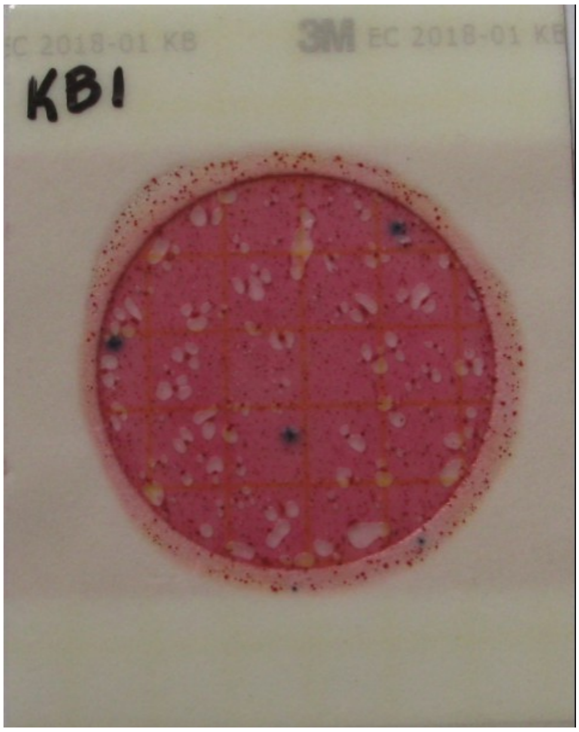

Figure 7. 3M faecal coliform and E. coli plate 48 hours after inoculation with sample liquid

The benefits of using this method rather than a laboratory based test for measurement of *E. coli* and total coliform are: increased flexibility and ability to carry out tests in the field; lower overall costs; and higher levels of consistency between samples relative to individually-plated agar.

4.5.1 Water quality criteria

The World Health Organization (WHO) Guidelines for Drinking Water Quality state that the presence of *E. coli* and total coliform bacteria should not be detectable in any 100 mL sample in water that is used for drinking (WHO, 2011). This is repeated in the Tanzania National Environmental Standards Compendium (year) which states that “Drinking water should not contain any organisms of faecal origin” and “The presence of *Escherichia coli* (faecal coliform) indicates recent faecal pollution, and hence dangerous condition if found in consecutive sample of water tested” (Tanzania Bureau of Standards, 2003, p. 25). Further, they state that any water for drinking should be 'pleasant and safe to drink', meaning that it should not have any unpalatable odour, colour, taste, or turbidity. These factors were addressed in the qualitative interview portion, as they are subjective and personally defined conditions that cannot be measured with instruments.

4.6 Limitations of study

4.6.1 Language

One major limitation to the qualitative interview portion of this study was my inability to communicate in the native tongue of study subjects, Kiswahili. Use of a translator allowed me to more or less understand what respondents were saying, but I expect that some nuances were lost in translation.

Furthermore, after the first fourteen interviews carried out in Kijito Upele I decided to switch to a different translator, as limited linguistic understanding and translation experience were proving to restrict my capacity to communicate effectively and elaborate on points of interest. This may have led to some decrease in the validity of the overall results, as the responses I received were filtered differently at each site, but it was necessary to the overall quality and depth of understanding of the comments provided by participants.

4.6.2 Lack of resources and time

Due to the short duration of the study, I was unable to examine or control for seasonal variations in water availability or quality. Because the study took place over a period of only two months, during the short rains, seasonal variations are acknowledged, but cannot be fully incorporated into the analysis. I expect that were I to do the study during the long rainy season that the responses would have been different for several of the questions, particularly those dealing with prevalence of diarrhoeal disease in households and communities.

Receiving input about current conditions, opportunities, and challenges in peri-urban areas from local hospital staff would have been extremely beneficial, but I found that when I visited the health centre in Fuoni that they were extremely busy and unable to take time to participate in an interview.

In addition, I was unable to establish a representative sample of sufficient size and randomness to generalize about the peri-urban population of Zanzibar as a whole. With the time and resources available to me this was simply not feasible.

4.6.3 Limitations of water quality analysis

Because I did not have access to a formal laboratory in which to carry out water quality testing, I was not able to use an incubator during the growth period of the faecal coliforms and *E. coli*. As such the exact numbers counted may not be considered to be entirely reliable and valid; however, for this study the purpose of the tests was not necessarily to know exactly the number of coliform present. Knowing that there is any contamination at all is interesting in terms of discussing current and future vulnerability in this context, and was considered to be sufficient. My results showing the relative quantities of *E. coli* and coliform bacteria are also of significant interest for comparisons between the wells.

For the phosphate testing, there appears to have been an unknown variable that interfered with the results. Within samples taken from the same site at the same time, there was variation between results as high as a factor of ten. As such, the results of the phosphorous testing have been excluded from the results.

4.6.4 Ethical issues

According to WHO and national standards there should not be any detectable faecal coliform in water intended for drinking. Because of this, I was concerned at the outset of my study that if I were to find any faecal coliforms, I would be obligated to immediately report them to all participants in the study. However, I was uncertain of the benefit of telling people who may not have access to an alternative source, or who may already be aware of poor water quality. The solution I have chosen for this is to provide copies of my thesis results to all communities and stakeholders who participated in the study so that they are able to make informed decisions to prevent disease in the future.

4.6.5 Sensitive information

Some of the issues discussed in my study can be seen as very sensitive. Hygiene behaviour and health of household members may not be something that everyone is willing to discuss with a stranger. I expect that this may have been particularly disconcerting in the context of a foreigner and her male translator attempting to discuss these topics with women. Particularly with questions regarding prevalence of diarrhoea in the household, or household sanitation practices, respondents may have decided to tell me what they thought I wanted to hear rather than providing a fully honest answer.

4.6.6 Site selection

Because of some difficulties in translating the aim of the project, the wells in Kijito Upele were not exactly what I was initially looking for when the study began. For example, Well KB is only used by about 10 households, and is not commonly used as drinking water. I learned partway through the interview process that there is a well near the local mosque that is used as a primary drinking source for a large part of the neighbourhood. That would have been preferable as a site, but at that point I had already completed the water samples and did not have any more coliform plates or phosphate reagent available.

4.6.7 Confounding variables

The intention of this study was to focus on water-borne diseases, but it is important to also note that there are other possible vectors for disease in these communities, including consumption of food containing bacteria and handling of solid waste materials in and around the home.

5. Results

5.1 Household interviews

5.1.1 Characteristics of survey respondents

Thirty-five household interviews were conducted in the four study areas. Of the household interview participants: in Kijito Upele A, two were male and four were female; in Kijito Upele B, two were male and six were female; in Tomondo A, two were male and nine were female; and in Tomondo B, five were male and five were female. In total eleven male and twenty-four female respondents contributed to the study. Five respondents had completed primary school, twenty-eight had attended some secondary school, and two had attended university. Ages of respondents ranged from fourteen to fifty-one years old.

5.1.2 Time spent collecting water daily

Amount of time spent collecting water daily varied significantly between and within study areas (Figure 8). People were willing to wait much longer for water that they felt was clean. This was reported by several respondents who preferred ZAWA tap water because of its perceived cleanliness and safety. At times when the line was long they could spend three hours or more in line at the tap, but found this to be preferable to the free and freely available well water closer to their homes.

Male and female participants report spending approximately the same amount of time collecting water per day. 58.4% of women and 54.6% of men spend 30 minutes or less collecting water, and 25% of women and 27.3% of men spend more than 2 hours per day.

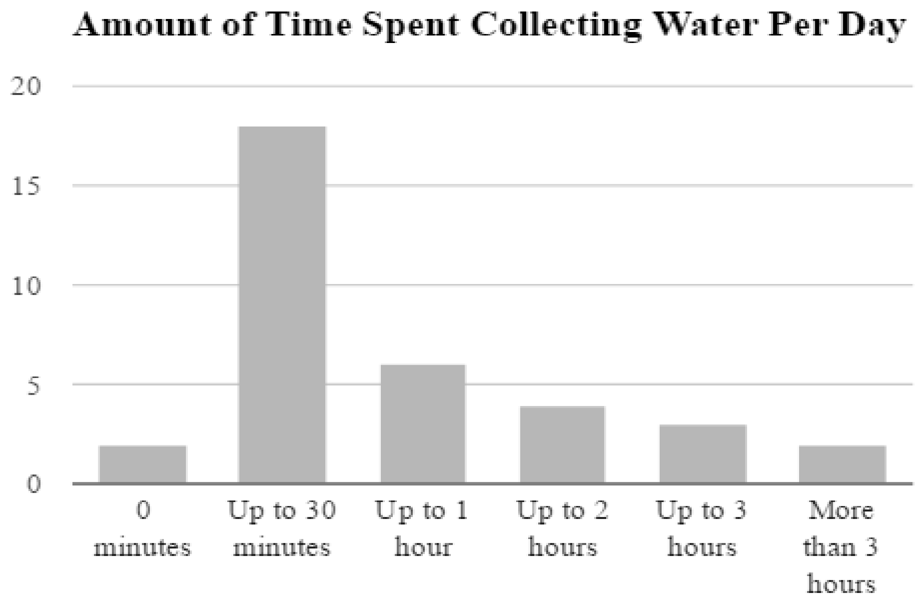

Figure 8. Responses to the question "How much time do you spend each day collecting water?"

In Tomondo B, where well water is pumped directly into many homes, two respondents reported spending almost no time collecting water on a daily basis. Others in the same area complained that due to insufficient electricity they were forced to turn on and off the pump repeatedly, sometimes spending more than three hours per day attempting to get enough water for domestic use. They claimed that in times of water scarcity, when the water is low and also when many households try to use the well at the same time, this is particularly problematic.

Some respondents described strategies they have in place to minimize their time spent collecting water, for example one person in Kijito Upele B deposits his plastic water cans at the water source and waits for them to be filled by someone else before he returns to pick them up. Another respondent said that they work during the day, so they pay someone from the neighbourhood to fill their water containers while they are gone. Many people also mentioned that they may not collect water every day, and instead fill as many vessels and containers inside their homes as possible for later use. This was prevalent in Kijito Upele A, where users pay a fee of 500 TSH for as much water as they can get in one day. It was also a normal occurrence in Tomondo A, where users of the ZAWA tap water reported that water is only available from the tap every other day.

5.1.3 Strategies for preparing water for drinking

Four respondents reported doing nothing to their water prior to drinking. Two of these four specified that they currently are doing nothing, but during rainy season or a reported outbreak of cholera they begin to boil water or use chemicals to treat it.

By far, the most commonly reported method for preparing water before drinking was boiling, with 54.3% of respondents claiming to boil their water at least part of the time. 48.6% of household interview subjects mentioned that they frequently use the chemical Water Guard to prepare water for drinking, and all users of Well KA in Kijito Upele know that the water in the tank is treated with Water Guard prior to use (Figure 9).

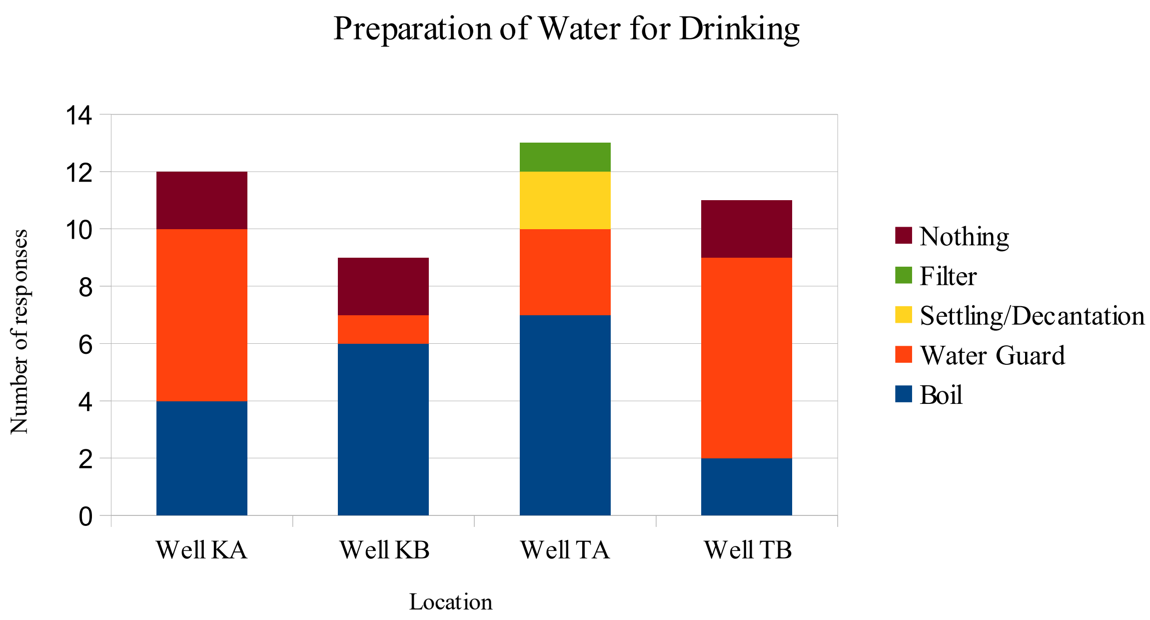

Figure 9. Responses to the question “What do you do to water before you drink it?”

5.1.4 Criteria for assessing water safety

One respondent in Kijito Upele said, “It is possible to know by looking at water whether it is clean, but not whether it is safe,” and this sentiment was echoed by several other interview participants. To assess cleanliness they commonly look at colour, taste, and smell to determine quality; however, a few participants clarified that they are aware that bacteria and other contaminants may not be visible to the naked eye, so it is still important to boil water or treat with Water Guard. It seemed that the majority of respondents assume that water from ZAWA taps is both clean and safe, although it is only intermittently available. Well water, on the other hand, is always available but is not believed to be safe in many cases.

5.1.5 Perceptions of sanitation and environment

In Kijito Upele, residents reported that their environment is currently clean due to their own behaviour and that of their neighbours. However, they also mentioned that in the rainy season water from nearby waste dumps and seasonal swamps can overflow and bring contaminated water into their vicinity. It was notable that several respondents claimed that their household environment was clean, but those of their neighbours as well as other areas of the *shehia* were not as clean and this causes problems for those respondents. None of the interview participants live in homes that are connected to a central sewer network. Of those with septic tanks, the majority of them only had one tank for wastewater from the toilet and threw their remaining grey water waste out in the streets behind their homes or, in the case of Tomondo A, into the swamp.

In both Kijito Upele A and Kijito Upele B areas, there was also a mix of responses regarding the prevalence of sewage contamination in the area. Over half of residents were generally aware of the existence of contamination, but they were unable to specify where exactly it was taking place. The seasonal nature of contamination was mentioned several times, with one respondent describing in detail the fact that in the rainy season water overflowing from dump sites can penetrate the soil elsewhere and get into underground water supplies.

In Tomondo A, the residents' homes are closer to the swamp and downhill from Tomondo B. There was a general consensus that the septic tanks in the area are effective at preventing water pollution, but many residents only have a septic tank for toilet waste, while grey water is tossed out in the street, behind homes or into the swamp. They are concerned that this water may be causing health issues, particularly for children who are likely to play outside in contaminated areas.

The behaviour of people in the vicinity is also worrying to residents of Tomondo A. Respondents were concerned that people in the neighbourhood regularly wash their clothes in the areas around one of the wells, potentially contaminating the water inside as it is not covered. Children also swim in the swamp nearby, and then wash their dirty bodies on the cement slab adjacent to the well. Furthermore, because of Tomondo A's location downstream from the rest of the *shehia,* they feel that the people upstream need to be far more careful about disposal of their waste so it does not flow untreated and unobstructed into their homes and surrounding areas.

Water from wells that are fully covered is generally considered to be clean. Several of the covered wells in Tomondo A that are used for drinking are regularly cleaned and treated, and these are considered particularly safe for drinking.

In Tomondo B, septic tanks and the sanitation conditions of the neighbourhood in general are considered to be clean and safe. Some respondents expressed concern that in rainy season the tanks may overflow and flood into the streets, but they generally seemed to think this was unlikely. As far as water pollution in the area, interview participants agreed that it is not common in their part of Tomondo, and that there have not been any water-related cases of diarrhoea in their neighbourhood since construction of Well TB. Participants do, however, expect that in the 'lower side' – where Well TA is located – there would be far higher risk of water contamination and pollution in general.

5.1.6 Resource dependence

Participants were asked about their ability to access alternative resources in the event that their current water source became contaminated or unavailable. 63.4% of respondents said that if their current primary source of water became contaminated or unavailable, they would have safe and sufficient alternative resources. Some said that they would just continue to use the resource if it were contaminated, but they would be more careful to always treat the water with Water Guard.

In Kijito Upele A residents are not very far away from ZAWA tap water if they are willing to pay, and when resources are not available ZAWA sends trucks of clean water to their neighbourhood. Well KA was constructed by the community very recently, so alternative water strategies are still in place.

In Kijito Upele B, respondents mentioned several alternative sources of water, including trucks sent by ZAWA in times of scarcity, buying bottled water from the shop, using private wells owned by their neighbours and sending men long distances with large plastic containers. Currently many residents in this area obtain their water from a well at a newly constructed nearby mosque, which they seem confident is very clean and safe.

Residents of Tomondo A had some of the most diversified strategies for obtaining water and also the most well thought out alternative strategies for finding water in the future if their current sources became contaminated. Some suggested alternative sources were the many wells in the area of differing levels of quality, a nearby borehole owned by a brick maker, bottled water from shops, or tap water from neighbours if it was available and affordable.

Tomondo B residents were the most likely to say that they had no alternative source of water available. They were largely unwilling to engage with the idea that their current source of water could become unavailable for some reason. Although when pressed, they suggested that they could be able to send people to other areas to bring back tap water or buy bottled water from shops for drinking, while continuing to rely on the well water for washing, bathing, and domestic purposes.

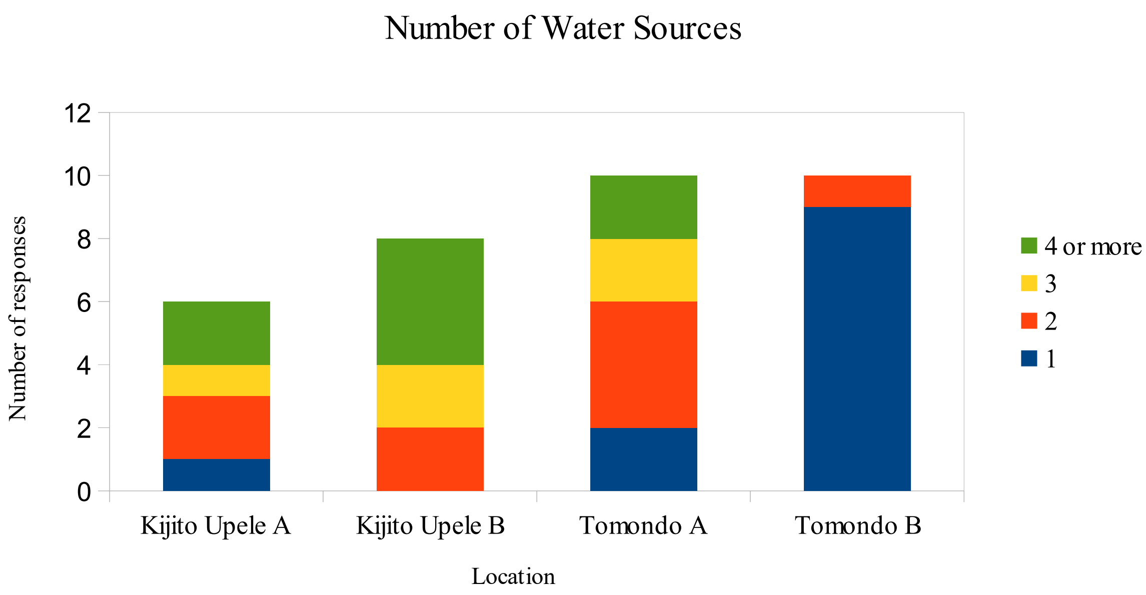

Figure 10. Number of water sources regularly used by each household for drinking and other domestic purposes

The average number of water sources used by each household is: Kijito Upele A, 2.7; Kijito Upele B, 3.3; Tomondo A, 2.4; Tomondo B, 1.1 (Figure 10).

5.1.7 Payment for water and response to changes in price

Users of Well KA and TB pay only enough to cover the cost of the electricity for the pumps in their wells; the water itself is free. In Kijito Upele A, that means 500 shillings for as much water as one wants to take within that day. In Tomondo B, the cost varies based on how much electricity is used, and users are also asked to contribute to the cost of any repairs and maintenance of their well and pump. The cost of water from public tap sources is 50 shillings per 20 Litre can, and water from community wells is generally free.

The participants seemed sceptical of the idea that water prices could change, as they have been more or less constant in recent years. When pressed to imagine a situation where water was more expensive, the general feeling was that, because water is so important to the health and well being of their families, they would make whatever sacrifices were necessary to ensure that they had enough. Most interview respondents claimed that regardless of any change in price of the water they would continue to use the same amount of water. Others reported that if water become more expensive they would use less of it, and if it became less expensive they would use more. In general respondents agreed that there are also constant d non-negotiable uses that cannot be reduced. One respondent said that for their family, any increase in water price would be too much, and they would leave their current residence temporarily and go back to their village home.

For those who do not currently pay for water, several of them expressed that they would be willing to pay if they were given access to water that is clean and safe, such as tap water in their neighbourhood provided by ZAWA.

Obtaining payments for water was mentioned by ZAWA staff as a particular challenge to expanding services into peri-urban areas. They claimed that it is very difficult to convince residents of these areas to pay, as they claim that water is their right and is provided to them by God. Furthermore, the meter system poses a challenge when someone arrives to collect money for a service that has already been used. However, there is a great opportunity for expansion in these areas, as the populations are quite large. If payments were successfully collected, the increase in revenue for ZAWA would be significant.

5.1.8 Water-borne diseases

No respondents in any area reported any cases of diarrhoea in their households in the past 24 hours, and only three reported one case in the past week. It is possible that this was under reported, as it is a sensitive topic. The interview participants may not have felt comfortable with me or with my male translator. It is also possible that many of the respondents (such as young men) are not involved in caring for sick members of the household and were therefore not aware of changes in the health of family members. However, because interviews were not done during the major rainy season, perhaps the incidence of water-borne diseases was relatively low and could peak at other times of year.

Eight participants described seasonal variations in diarrhoeal disease incidence. The main reason given was flooding of septic tanks during heavy rains. One claimed that there is variation, although it is not seasonal because diarrhoea is caused by factors other than water. One participant also explained her perception that there is no seasonal variation, but between years the risk of disease fluctuates. However, a large number of respondents at all sites claimed that there was no temporal variation, as there was never any disease present.

This is interesting, because sites were selected based on anecdotal reports that these areas are particularly susceptible to cholera in the event of an outbreak.

5.1.9 Perceived Vulnerability

Justifications given for why any one group is the most vulnerable have been summarized and grouped together in Table 1. The vast majority of respondents (70.3%) who answered this question said that children are the most vulnerable group, typically because of their own behaviours including playing outside in dirty places and eating food that is given to them without washing their hands.

Most vulnerable group	Reason	Number of responses
Children	Because they play in dirty water and may consume food without washing hands/ water without treatment	17
Children	Because they don't understand how to protect themselves	4
Children	Because they have low immunity	1
Children	Other/no reason	3
No one	The water here is clean	3
Everyone	Everyone consumes the same water	1
People who live on the lower side	That is where waste flows and accumulates so it is not clean	1
People who do not boil or treat their water	They are exposed to contamination	5

Table 1. Responses to the question "Who do you think is the most vulnerable to diarrhoeal disease in this community? Why?"

Participants were also asked who in their community is the least vulnerable. The most common answers had to do with individuals' perception and awareness, and thus their ability to take action to protect themselves from disease. Those who work outside of their home area and have access to alternative sources of water are also considered to be less vulnerable than those who remain in the neighbourhood and are dependent on local sources. These responses are summarized in Table 2 below.

Least vulnerable group	Reason	Number of responses
Youth (both genders)	Good perception and awareness	2
	No reason/don't know	2
Young men	Good perception and awareness	3
Leaders of households (men)	No reason/don't know	1
Adults/Elders	Good perception and awareness	7
	No reason/don't know	4
People who work outside the area	Drinking bottled water or water from other sources	4
People who take good measures to protect themselves	They are boiling/treating water so they are not exposed	4
People living on the upper side	Water and waste flow downhill away from their homes	1
Don't know		1
Everyone	No one here is vulnerable	1
No one	Diseases affect everyone, and everyone here is using the same water	3

Table 2. Responses to the question, "Who do you think is the least vulnerable to diarrhoeal disease in this community? Why?"

5.1.10 Prevention of future disease

Participants were asked to describe what they feel could be done to prevent future diarrhoeal disease in their communities by themselves, the government, the hospital, and others. They were allowed to give as many suggestions in each category as they chose.

On the individual level, twenty of the respondents felt that in order to prevent diarrhoeal disease they need to keep the environment clean, eight stated that they need to treat water for drinking, and seven stated that increasing education about these issues is a key factor. Further suggestions are shown in Table 3.

What can be done by you to prevent diarrhoeal disease?	Number of responses
Keep the environment clean	20
Treat water before drinking	8
Provide education to other people and/or become more educated	7
Keep children out of dirty places, stop them from consuming dirty food/water	5
Personal health and hygiene behaviours	4
Keep food safe	3
Be committed to what you know instead of blaming government	1

Table 3. Personal actions that can be taken to prevent diarrhoeal disease

On the part of the government, twelve interview participants would like to see the government educate people and provide information, eight mentioned that the government should be responsible for providing clean and safe water, and seven thought they should be responsible for providing medicine and water treatment chemicals.

What can be done by the government to prevent diarrhoeal disease?	Number of responses
Educate communities and provide information	12
Provide clean and safe water	8
Provide medicine and water treatment chemicals	7
Aid communities in cleaning the environment	2
Provide assistance to those who cannot afford to construct sanitation systems	2
On the ground health assessment and treatment	2
Penalize people who pollute the environment	2
Organize places to dump waste	1
Regulate food safety in restaurants and shops	1
Don't know	2

Table 4. Government actions that can be taken to prevent diarrhoeal disease

Hospitals were mentioned as another actor that could potentially take action to prevent diarrhoeal disease. Fourteen respondents suggested that the hospital should increase the quality and expediency of care throughout the year, fourteen felt that hospitals should provide medicine for treatment of the sick and preparation of water, and six suggested that they provide information and raise awareness in communities.

What can be done by hospitals to prevent diarrhoeal disease?	Number of responses
Increase quality and expediency of care	14
Provide medicine for treatment	14
Provide information and raise awareness	6
Implement strategies for prevention	2
Have more health centers closer to where people live	1
Ensure water people use is safe and clean	1
Don't know	3

Table 5. Hospital actions that can be taken to prevent diarrhoeal disease

5.1.11 Sources of information for disease prevention

Interview participants were asked where they have obtained information about prevention of diarrhoea in the past, and where they would go in the future were they to desire any more information. Mass media was a commonly cited source, although one respondent mentioned that the frequency of information is far greater during an outbreak than during other times of the year. Other common sources of information in the past have been schools, government representatives such as the *shehia* or district health officer, and friends and neighbours (Figure 11).

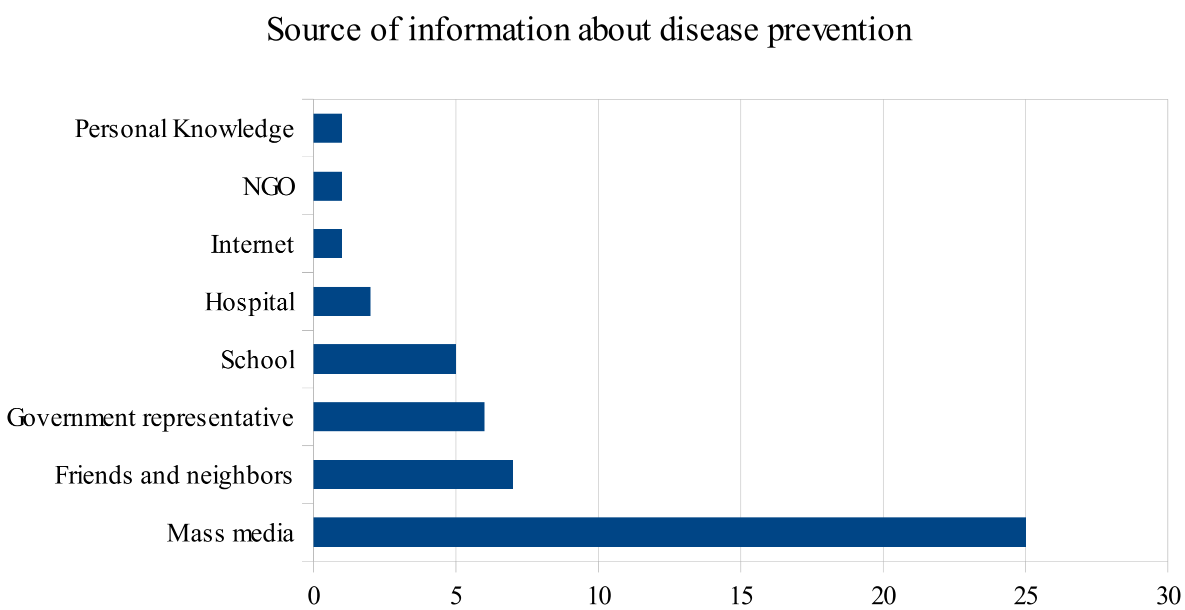

Figure 11. Responses to the question, “Where have you gotten information about disease prevention?”

As far as obtaining information in the future, the sources are largely the same. The hospital, *sheha*, mass media and friends and neighbours were most commonly listed as places where information could be found if one needed it (Figure 11). Three respondents stated that if they were to want more information, they would not know where to look for it.

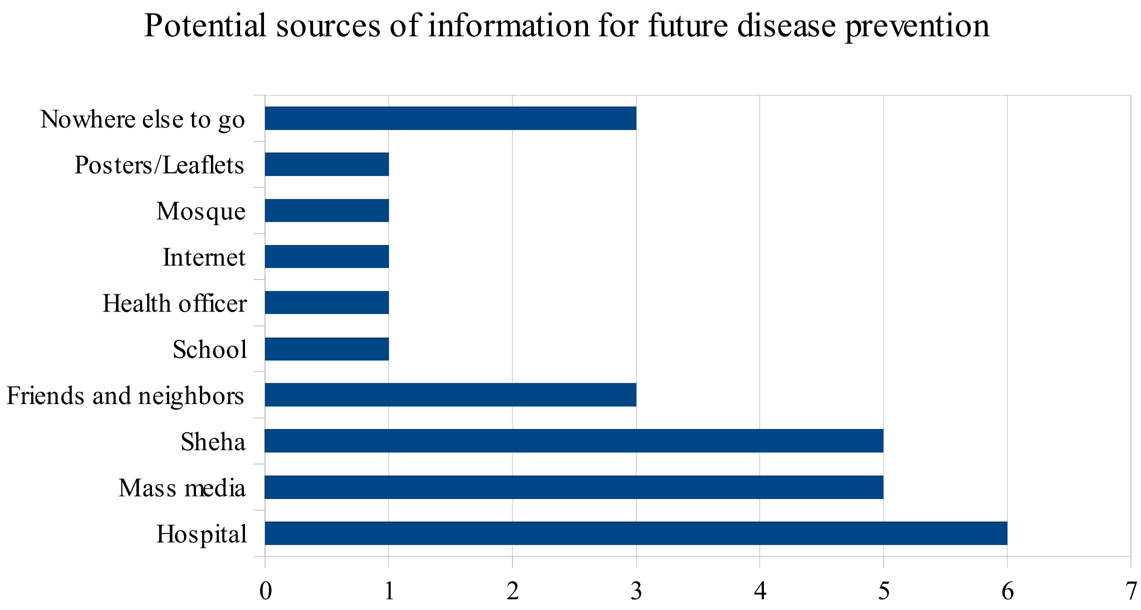

Figure 12. Responses to the question, “Where would you go if you wanted more information about preventing disease?”

5.2 Water quality tests

5.2.1 Kijito Upele Well KA

The water from Well KA had no coliforms or *E. coli* present in any sample. Results are shown for the six samples in Table 6 below.

	Phosphate (ppm)	Salinity (ppt)	Coliforms (cfu/mL)	E. coli (cfu/mL)
1	0.45	0	0	0
2	0.97	0	0	0
3	0.7	0	0	0
4	0.27	0	0	0
5	1.12	0	0	0
6	1.01	0	0	0
Average	0.75	0	0	0

Table 6. Water quality sampling results from Well KA

5.2.2 Kijito Upele Well KB

Well KB had an average of 99.5 cfu per mL of sample liquid and 5 *E. coli* colonies per mL. Results are shown for the six samples in Table 7.

	Phosphate (ppm)	Salinity (ppt)	Coliforms (cfu/mL)	E. coli (cfu/mL)
1	0.35	1	98	3
2	1.14	2	101	3
3	0.29	1	99	8
4	0.71	1	118	5
5	0.21	1	88	4
6	0.2	1	93	7
Average	0.48	1.17	99.5	5

Table 7. Water quality sampling results from Well KB

5.2.3 Tomondo Mshelishelini Well TA

Water samples taken from Well TA had a very large number of faecal coliforms per mL. An average of 234 cfu. *E. coli* was also present at an average of 1.67 cfu/mL. This was also the only well with detectable salinity, an average of 2.17 parts per thousand (ppt). Results are shown for the six samples in Table 8.

	Phosphate (ppm)	Salinity (ppt)	Coliforms (cfu/mL)	E Coli (cfu/mL)
1	0.4	3	220	1
2	0.03	2	206	2
3	0.25	2	180	1
4	1.04	2	326	1
5	0.12	2	226	2
6	0.53	2	246	4
Average	0.31	2.17	234	1.67

Table 8. Water quality sampling results from Well TA

5.2.4 Tomondo Mshelishelini Well TB

The average cfu of faecal coliforms per mL at Well TB was 66.3, and the average number of *E. coli* cfu per mL was 0.33. Results are shown in Table 9.

	Phosphate (ppm)	Salinity (ppt)	Coliforms (cfu/mL)	E Coli (cfu/mL)
1	0.49	0	101	0
2	1.8	0	94	0
3	0.22	0	48	0
4	0.27	0	54	1
5	0.18	0	49	0
6	0.31	0	52	1
Average	0.55	0	66.3	0.33

Table 9. Water quality sampling results from Well TB

No significant salinity was detected in any of the samples. Salty water was not mentioned as an issue by any interview respondents, except one respondent who said that in some cases inhabitants prefer to use well water, because ZAWA tap water can be too salty.

5.3 Field observations

- After only brief rain all of these areas begin to flood significantly. I was told informally (outside of an interview) that in the Tomondo B area during the rainy season the streets where we were walking could be navigated more easily in a boat.

- Young women seemed the most reluctant to participate in the study, largely because they were not confident in their answers. They were particularly unwilling to elaborate on their responses to questions which requested them to speculate on what could or would be possible in times of change, possibly because of the presence of a male translator.

6. Discussion

Hazards exist when an altered state of the environment creates dangerous conditions (Corvalán et al., 1999), and disasters occur when vulnerable populations are exposed to those hazards (Wisner et al., 2004). In the context of this study, the disaster in question is an outbreak of water-borne diarrhoeal disease. Through a combined analysis of trends in household and key stakeholder interview data, literature about environmental conditions in Zanzibar, and measured water quality data, the following section will elaborate on the progression of vulnerability first presented in Figure 2 in the Conceptual Framework chapter and based on the PAR Model created by Wisner et al. (2004).

6.1 Root Causes

The progression of vulnerability begins with an understanding of root causes: the social, economic, institutional, and environmental factors that contribute to vulnerability (Blaikie et al., 1994; Wisner et al., 2004; Birkmann & Wisner, 2006). Generally in academic literature and discussions about vulnerability, individual characteristics of respondents are considered to be defining factors. This is also true in the case of Zanzibar. The government identifies several vulnerable groups: youth, orphans and neglected children, the elderly, the very poor, women, widows, and those affected by HIV/AIDS (RGoZ, 2007).

This definition of vulnerability is reflected in the ways policies are developed, for example in the Zanzibar Environmental Policy of 2013:

> *"Without full and equal access to all levels of economic opportunity, education, and health care services, women and other vulnerable groups are more likely to suffer first from the adverse effects of environmental pollution, degradation of natural resources, climate change, and deterioration in the national health performance. In general, women, children and people with disabilities are more vulnerable to the effect and impacts of climate change, environmental pollution and degradation" (RGoZ, 2013, p. 23).*

The African Development Bank Multi-Sector Country Gender Profile for Tanzania in

Zanzibar has also hypothesized that because women are the main providers of food and care in households they are often more vulnerable to the impacts of poverty, including increased exposure to disease (African Development Bank, 2005).

In contrast to these reports, no interview participants mentioned socio-economic status as a contributing factor to vulnerability, and gender was brought up only obliquely in the sense that young men and male heads of household were perceived to be less vulnerable. Generally this was not attributed to any implicit aspects of gender as much as the fact that these people often leave their area of residence and are therefore obtaining drinking water elsewhere. A few people did mention that they would do a better job of properly disposing of waste water if they were better off financially, and two people suggested that the government should provide financial assistance to people who cannot afford to construct proper septic tanks. Respondents also never mentioned education level and disability as possible contributors to vulnerability. It is possible that because conditions like gender, disability, and socio-economic status are considered to be somewhat 'fixed' or obvious respondents did not consider them worth mentioning.

In this study, the root causes that were identified through household and key stakeholder interviews were economic disparity, social status and political inequality, and inadequate institutional capacity. The literature review and interviews with key stakeholders also highlighted the precarious environmental conditions in Zanzibar as a final root cause. Each of these root causes will be discussed individually in the following section.

6.1.1 Economic disparity

Unequal access to water, sanitation, and health resources appears to be influenced by economic level, both for individuals and for entire communities. This echoes the findings of a case study done by Mehta (2006) in Kutch, India which demonstrated that the wealthy have “more options and can resort to a wider array of coping strategies than the poor” (p. 660). While participants in this study were not asked directly about their current economic conditions, it is possible to draw some conclusions about the influence of household financial situation on vulnerability to water-borne diseases based on responses to other questions.

Socio-economic status encompasses not only wealth in terms of assets and status, but also the ability of individuals to obtain goods and services (Howard, Chave, Bakir & Hoque, 2006). For example, some respondents complained about the quality and speed of service in public hospitals, but said they have no other options for care. Others who can afford private hospitals are then more likely to have access to more consistent and higher quality care. In addition, within the communities, some individuals have access to piped water and others do not. This is determined by the location of their homes relative to water taps, availability of time to wait for piped water, and financial situation. One clear example of this was an interview with a member of a female-led household where the mother is currently unemployed. The household in question relies on charity from neighbours for access to private wells or discounted use of community wells for drinking water. They must obtain water for domestic use from unprotected hand dug wells. In Zanzibar overall, of those who are defined by the government as 'very poor', 58% of households have access to piped water in some form, while 19% are reliant on unprotected public wells (RGoZ, 2007, p. 23). In contrast, 78% of the non-poor have access to piped water and only 8% are utilizing unprotected public wells (RGoZ, 2007, p. 23).

The overall socio-economic conditions of communities can also influence the amount of contamination in their neighbourhoods, and thus the extent of hazards present (Schmoll et al., 2006). In Tomondo Mshelishelini A, multiple respondents mentioned that either they or their neighbours did not have the financial means to upgrade or properly maintain the sanitation systems in their homes. One woman said “I know that my septic tank has a crack in it and when it floods here it leaks, but I am not well financially now, and so I can't fix it yet.” In poor communities it may also be a problem that short-term needs can override long-term foresight, leading to use of poor quality but affordable resources in the short-term, or overexploitation and pollution of resources without full consideration of long-term consequences (Howard et al., 2006).

6.1.2 Social status and political inequality

Political power and social connections play an important role in the level of access communities and individuals have to resources (Halvorsen, 2003). In a sense, experiences of personal clout and ability to communicate with government can be seen as resources on their own, as they provide a path to accessing other resources. Interview subjects seemed hopeful that I would communicate with the government on their behalf in order to encourage further development of water resources in their areas, because they as individuals did not think it was possible to get in contact with decision makers. Some were confident of their ability to communicate with the *sheha* regarding their needs, but others were not even aware of the location of the *sheha*'s office for their *shehia*, as it was a great distance from their homes. When it came to a higher level of government, such as the municipality or government of Zanzibar, residents were not aware of any channels through which their concerns could be expressed. Low levels of belief in individual ability to change their situation, or even to express opinions and needs to those in power, place constraints on the capability of these communities to improve their environmental health.

Furthermore, in many cases peri-urban communities are not given the same priority as others when it comes to infrastructure development because of their position on the fringe of urban society (Howard et al., 2006). Low socio-economic and political status may influence the amount of investment that government and other actors are willing to put toward providing services in these communities (Howard et al., 2006). In Tomondo, for example, residents are largely recent migrants to Unguja from Pemba, and are also members of the opposition (personal communication, November 2016). Two interview respondents speculated that their outsider position could be a contributing factor to their lack of inclusion in public services. Wisner & Adams (2002) have also identified recent migrants as among the most vulnerable in a community, as they often have limited financial and social resources.

6.1.3 Inadequate institutional capacity

The capability of institutions to prevent, mitigate, or respond to disaster is an important factor in deciding the level of impact a disaster will have on a socio-ecological system. For successful protection from the spread of water-borne infectious disease vectors in well water there needs to be a well defined and implemented framework for institutional cooperation and effectively enforced legislation for protection of groundwater resources.

Recently there has been a lack of effective coordination to facilitate cooperation between actors in water and sanitation in Zanzibar (RGoZ, 2007). However, a representative of ZAWA did state that cooperation has improved, and now the Ministry of Health, the water authority, and the municipality are working together on water and sanitation issues. They were hopeful that in the near future this collaboration will lead to rapid expansion of the ZAWA water network; however, currently there are still large gaps in the service area, and many populations must find their own ways of obtaining safe and sufficient water. Until an effective institutional framework exists and all communities are provided with safe and sufficient water by the government, people will continue to put high levels of pressure on resources through unregulated drilling of private wells and improper disposal of waste.

The World Health Organization has claimed that "In a great number of cases, the failure to protect groundwater resources results not from a lack of appropriate legislation, but because of the poor enforcement of existing regulations" (Schmoll et al., 2006, p.152). A representative of ZAWA expounded on this idea: "there are three sides to protecting groundwater: 1) know the law 2) obey the law 3) enforce the law. 2 and 3 are lacking but I am sure that the people already know what they should do." In his opinion, the reason many residents of peri-urban areas are exposed to pathogens in their drinking water is that they are drilling private wells in their homes without consideration of safe distance from contaminants or consultation with authorities. Despite the fact that information is available and regulations exist to prevent these sorts of activities, they will continue, because the government does not have the capacity to enforce the law.

One interview participant also lamented the fact that there is little oversight of those who are creating harmful pollution. She suggested stronger regulation of and penalties for individuals who indiscriminately release waste into upstream areas that creates negative health impacts for their downstream neighbours. Because these penalties and regulations either do not exist or are not enforced currently, there are insufficient incentives for upstream households to appropriately manage their waste.

Once resources have become contaminated, the ability of institutions like governments and healthcare systems to cope with the consequences will also play a role in the extent of the disaster experienced in a community (Birkmann & Wisner, 2006). Common responses to questions about what governments and hospitals could do to protect people from diarrhoeal disease included: increasing quality and speed of care, providing education and information, ensuring that anyone who is sick gets enough medicine, and providing sufficient clean and safe water to communities. The current inability of institutions to effectively carry out these tasks is considered by residents to be a failure that makes them more vulnerable to disease. However, because Zanzibar has had to deal with frequent seasonal outbreaks of cholera in the past, the rate of response is improving, and hospital staff and other public health actors are becoming more experienced and prepared to quickly enter affected communities with information and medicine.

6.1.4 Precarious Environmental Conditions

The Background to Zanzibar section of the Introduction chapter (Section 1.3) highlighted Zanzibar's particular hydro-geological characteristics that place its aquifers at high risk of contamination. Porous carbonate rock made from fossilized coral reefs provides easy channels of mobility for water and contaminants through the ground and into subterranean water reserves (Gossling, 2001). During periods of heavy rain, large quantities of water recharge aquifers. If care is not taken to prevent human and industrial waste from accompanying that water, it will begin to accumulate in those aquifers. Furthermore, use of groundwater in excess of its potential for natural recharge will allow for the intrusion of highly saline seawater (Gossling, 2001).

These somewhat unique conditions mean that Unguja is at a higher risk of water scarcity and groundwater contamination than cities of similar size on the mainland. Rapidly expanding tourism and urbanization around Zanzibar Town serve to exacerbate this issue, placing residents at risk of exposure to water-borne diseases in the case of contamination or to severe water scarcity in the case of salinisation of their wells. ZAWA representatives expressed concern that climate change will further increase these difficulties in the future.

Peri-urban communities exist in an even more precarious situation than other parts of the island. The close proximity of homes and their associated on-site waste treatment, along with their frequent location in low lying areas prone to flooding mean that waste exists in places where it is very likely to infiltrate drinking water wells. An employee of ZAWA emphasized this, saying “so many people, so many houses, so many septic tanks next to wells, and no drainage system... it is very dangerous.” They expressed concern that without large-scale improvements in these areas, the condition could continue to deteriorate.

6.2 Dynamic Pressures

Dynamic pressures that influence the level of impact caused by hazards fluctuate in response to social, environmental and institutional conditions. These pressures determine the extent to which communities and individuals come into contact with unsafe conditions and hazards (Wisner et al., 2004). In peri-urban informal settlements on the fringe of Zanzibar Town, rapid urbanization and accelerating population growth are leading to increasing pressure on resources and the communities that depend on them (Myers, 2010). The dynamic pressures caused by these changing conditions are lack of access to piped water, possible salinisation of aquifers, and insufficient sanitation infrastructure.

6.2.1 Lack of access to piped water

Interview respondents from all study areas expressed that they feel tap water from ZAWA to be the cleanest and safest option, but their access to it is intermittent and often insufficient to provide for all of their needs. According to the ZAWA Strategic Business Plan, there is a “mismatch between demand from a growing population […] and installed production, supply and distribution capacity”, which means that “ZAWA customers experience frequent interruption of supply, pressure is quite often unacceptably low and in certain areas the public is without water for several days at a time” (ZAWA, 2013, p. 12). Thus, even households that are connected to the ZAWA water network may experience sporadic exposure to pathogens in well water during periods of scarcity. There are also large areas of Zanzibar that are not yet covered by ZAWA water services and are therefore reliant on well water of unknown quality.

6.2.2 Possible salinisation of aquifers

In this study salinity was not detected; nevertheless, it is possible that in the future it will occur, as previous research done in coastal areas and sites around Zanzibar Town has shown a trend in increasing salinity, total dissolved solids, conductivity, and chloride (Mato, 2014). A member of the ZAWA monitoring and evaluation section also expressed concern over the potential for increasing salinity around Zanzibar to lead to difficulties in providing sufficient water in the future. This is already a problem in areas closer to the coast and may move inland if pressure on the aquifer is not managed in a sustainable way. Another ZAWA representative also speculated that if salinisation became more widespread it would lead to increases in the cost of high quality water, customers would leave the ZAWA water services, and life would become much more difficult for many of the people of Zanzibar. For these reasons, salinisation is still considered as a possible dynamic pressure on the system. This could, theoretically, lead to water scarcity in Tomondo and Kijito Upele in the future, making residents more dependent on what limited resources remain and more vulnerable to contamination of those resources.

6.2.3 Insufficient sanitation infrastructure

Development of infrastructure for water and sanitation in peri-urban areas poses unique challenges. The informal and unplanned nature of these areas means that there is often not enough space for traditional large scale water or wastewater treatment facilities, or even for pipelines to connect new areas to existing systems. As one representative of ZAWA also pointed out, people in peri-urban areas are already living there. They have established strategies to get what they need, and so they may not be enthusiastic about large and expensive projects in their communities, particularly if they require homes to be destroyed to provide space.

In the newly developing areas of Zanzibar Town, access to piped water is limited, and there is no large-scale organized system for management of wastewater or solid waste (ZAWA, 2013). The vast majority of households, including all survey respondents in this study, rely on on-site disposal of both black and grey water. For sewage and human waste (black water), this includes pit latrines and septic tanks. Other domestic wastes (grey water) are often tossed out in the street. These conditions, combined with the limited drainage capacity of many neighbourhoods, create significant risk of local pollution of the aquifer and private wells, particularly during periods of heavy rain (ZAWA, 2013). Sanitation and waste management services are constrained by dilapidated infrastructure, limited human and financial resources, low stakeholder participation, and lack of technology and equipment for collection and disposal of waste (RGoZ, 2007).

6.3 Unsafe Conditions

In the model PAR framework, the ways in which the social and environmental peculiarities of a system limit positive responses to a hazard are called unsafe conditions. In the PAR framework adapted for this study, the unsafe conditions are: lack of overall awareness of water quality, lack of knowledge of preventative measures, and limited access to alternative resources.

6.3.1 Lack of awareness of water quality

Awareness and understanding of the existence of a hazard is a key aspect of vulnerability, as it creates opportunity for individuals and communities to take action towards preventing harm (Wisner et al., 2004). Perceptions and preferences can be used to explain different levels of risk and vulnerability experienced by otherwise identical subjects (Smith, Barrett & Box, 2000). This was reiterated by interview respondents who largely felt that education and awareness are critical to protecting communities and individuals from disease.

When users of a resource are unable to ascertain whether or not that resource is safe, they cannot make informed decisions about how to use that resource. If a well has consistently been clean and then becomes contaminated, users who are not aware of that change will not know to change their behaviour and may suffer consequences to their health. Multiple household survey respondents expressed that they are able to tell if their water is clean, but not if it is safe. Without widespread monitoring of bacterial loads in wells used for drinking, this problem will persist, and users of well water will be vulnerable to water-borne diseases.

The following section will compare the relationship between interview responses and measured water quality data. Level of agreement between perceptions and indicators will be considered in terms of the influence this could have on vulnerability in each of the four study areas.

6.3.1a Well KA

In Kijito Upele Well KA interview respondents generally felt that the water was clean, as the water in Well KA is treated with water guard before being dispensed through the taps. It is therefore not surprising that there were no faecal coliforms or *E. coli* found in the water samples taken from this well. The high level of agreement between community perceptions of the water quality and measured water quality data indicate a low level of vulnerability to health impacts of consuming unsafe water.

6.3.1bWell KB

Interview data collected at Well KB showed that respondents were aware of the unsafe conditions present in the water. As such, they made the decision to use it only for domestic purposes, rather than consuming the water for drinking. However, the United States EPA guidelines on recreational and bathing water quality state that there should be no more than 126 cfu per 100 mL of *E. coli.* By this criterion, none of the samples taken at Well KB are safe for bathing use without risk of gastrointestinal illness. The number of colony forming units of *E. coli* at Well KB were particularly concerning, as they ranged in number of *E. coli* colonies from 300 to 700 cfu per 100 mL (3-7 cfu per mL). Interview participants did state that they believe Well KB to be unsafe for drinking, but did not express any awareness that it could potentially be a danger to their health if used for bathing or other household use. Lack of knowledge about the potential impacts of using Well KB as a source for bathing and other household use without treatment may increase vulnerability to disease in this area.

6.3.1cWell TA

Respondents in Tomondo A felt that Well TA is safe and clean for drinking. Their reasoning for this assumption is that the well is fully covered, so contaminants are not able to enter. Unfortunately, this was not found to be the case in the water quality analysis. Water from well TA contained the highest levels of faecal coliforms of the four wells measured, along with a significant presence of *E. coli.* Participants in this area did not express any awareness of the potential for contaminants to move underground into well water, which is concerning because their primary well is in very close proximity to several septic tanks and also a swamp where waste water accumulates and likely seeps into the water table and the well itself.

The majority of residents of this area boil or treat their drinking water with Water Guard, which somewhat decreases their risk of exposure to contaminants. Despite this, according to Wisner et al.'s (2004) theories about the relationship between perception and vulnerability, this community is particularly vulnerable to the negative health impacts of water contamination. Because they may not be aware that contamination exists, they will not be as motivated to consistently take action to protect themselves. This is evident in the frequency of waste disposal in the swamp, despite its proximity to drinking water sources that can be easily contaminated from below.

6.3.1d Well TB

Perception of water quality in the Tomondo B area is also not well aligned with the water quality sampling results. Though the water was significantly cleaner than in the lower side of Tomondo A, there were still both faecal coliforms and *E. coli* present in all samples, making the water unfit for human consumption according to the WHO Guidelines for Drinking Water Quality (2011). Respondents claimed that in their area there is no water pollution, and as such all water from their well should be clean and safe for consumption. Many respondents still treat their water with water guard or boil it to be safe, but two respondents claimed that they do nothing to prepare the water for drinking, placing them at risk of exposure to pathogens.

6.3.2 Lack of knowledge of preventative measures

When it comes to health, understanding is key to seeking appropriate and prompt prevention measures (Bates et al., 2004). Prevention of water-borne diseases can take two forms. Household interview respondents only expressed awareness of one of these forms. At the personal and individual level, one can keep their environment clean and take measures to treat water before drinking and maintain good personal hygiene behaviours Alternatively, if water sources are sufficiently protected, pathogens can be kept out of water sources, thus removing the need to treat water before consumption.

Interview participants were largely aware of actions that they could take as individuals and communities to prepare water for use. Information about prevention of disease seems to emphasize these strategies, particularly during outbreaks of disease. Mass media, in the form of radio and television, was claimed as the primary source of information by 25 of the 35 household interview participants, meaning that it is likely that these people are hearing the same message. The focus of these mass media public service announcements is largely on personal hygiene, water treatment, and environmental cleanliness.

The strategy that received much less attention was protection of water within the wells and in aquifers. While a few respondents expressed concern that uncovered wells could be contaminated by objects dropped into them from above, results confirmed a statement by Howard et al. (2006) that generally people understand surface water can easily become contaminated or polluted but think that groundwater is guaranteed to be safe and clean. Only one respondent mentioned contamination from below by water moving underground between septic tanks and wells. Because groundwater is hidden from view, it is difficult to imagine and understand the ways that pollutants can move within it (Schmoll et al., 2006). This lack of understanding of the potential for groundwater contamination could be a serious constraint to communities growing in a safe way. If people are not aware, they will not take precautions like building their septic tanks far enough away from water sources.

6.3.3 Limited access to alternative sources

Sensitivity to exclusion is a key aspect of vulnerability; the more exclusion from a resource can potentially lead to negative impacts, the more vulnerable a system is (Adger, 2006). The final unsafe condition identified by this study is a lack of sufficient alternative resources for communities to turn to if their primary source of water becomes unavailable. For communities and individuals that are bound to one resource -such as groundwater- by lack of alternative, their risk of exposure when that resource becomes unsafe is quite high. Though the number of resources currently used varied between communities, all households interviewed were dependent on groundwater in some form for the majority of their water needs. It is therefore a concern that in all of Zanzibar, not only the peri-urban areas, residents are highly sensitive to exclusion from this resource. Should groundwater become contaminated with widespread pathogens or saline from intrusion of seawater, residents will have to turn to other, not yet identified, sources of water. If alternative sources cannot be found, there will be no choice but to continue to use these resources despite the high risk of exposure to disease causing pathogens.

Birkmann et al. (2013) define exposure as the extent to which a unit of exposure falls within the area of occurrence of the hazard. This can be mitigated on an individual and community level by diversifying sources from which water is obtained. Many of the interview subjects obtain water from a diverse range of sources for different uses. The average number of sources used across all study areas was 2.3, with averages at different sites ranging from 1.1 in Tomondo B to 3.3 in Kijito Upele B. They also have contingency plans in place for when their first choice is not available. This is typical of peri-urban areas around the world, as residents often access water "through a host of unconventional means" depending on accessibility, price, and personal preference (Marshall et al., 2009, p. 17). As Adger (2006) defines vulnerability as a function of both sensitivity and exposure, this creativity and flexibility can also be seen as a way to reduce dependence on a particular resource, thus lowering the level of vulnerability to disease should that resource become contaminated.

6.3.3a Diverse strategies in Kijito Upele and Tomondo

Residents of Kijito Upele B, where the well in closest proximity to their homes is quite contaminated, claimed that they prefer to use piped water from ZAWA for drinking and all domestic purposes. However, because the availability of piped water is sporadic and inconsistent, they have alternative sources in mind which they may feel the need to boil or treat with Water Guard. Residents of this area reported regularly obtaining water for various uses from more than three sources, depending on the type of use and current conditions of availability and quality. According to Adger's (2006) definition of vulnerability, this makes this community not very vulnerable to exclusion from their primary resources. The strategies in place for individuals of this area mean that they are prepared to protect themselves from health impacts of contaminated water by shifting to cleaner resources or treating water before use.

Based on this criterion, the area of Tomondo B, which had much cleaner water than Kijito Upele B at the time of sampling, is still more vulnerable to contamination of (or exclusion from) Well TB. This is because, in general, residents of that area are reliant on Well TB as their only source of water for all uses. Residents of this area reported that if they were unable to continue obtaining water from Well TB or other similar wells in the area, they would be forced to travel long distances or pay more for water.

In Tomondo A as well, residents described an array of possible sources of water for consumption and domestic use. Should they become aware that Well TA was contaminated, residents were willing to use private wells in the homes of their neighbours, other community wells in areas that were not experiencing contamination, privately owned boreholes, tap water from ZAWA, or even bottled water. Residents of this area have experienced outbreaks of diarrhoeal disease in the recent past and are prepared to respond to water contamination by taking necessary measures. Thus, residents of Tomondo A are not sensitive to exclusion from any one resource, making them less vulnerable to contamination of their primary source.

Residents of Kijito Upele A are also not heavily dependent on Well KA. While they prefer the water from Well KA because it is treated, the well is quite new, and alternative strategies are still in place. In addition, interview respondents seemed confident that if water scarcity occurred in their area water would be delivered by trucks from ZAWA. This diversity in potential water sources decreases the community's vulnerability to exclusion from Well KA as their primary resource and any associated health impacts of continuing to utilize the resource if it became unsafe.

The issue of dependency also came up within communities. Interview responses highlighted the low level of vulnerability of young working men, as they often leave the peri-urban areas where they live during the day and are therefore consuming water from sources outside the potentially contaminated areas. Thus, those residents who spend the majority of their time in other locations are less dependent on well water for drinking than those who remain.

6.4 Further factors mediating exposure

According to Adger (2006) exposure can be characterized by the magnitude, frequency, duration, and areal extent of hazards. The magnitude of contamination varied in each of the four wells studied, and the communities in greater proximity to more highly contaminated resources have an increased risk of exposure. Magnitude of contamination is affected by the hydro-geological conditions of each area. For example in Zanzibar, the sand and coral based soil is conducive to effective and rapid transport of groundwater as well as the pathogens, minerals, and other contaminants that may be carried within that water (Gossling, 2001). It is also impacted by the type and intensity of human activity in an area. Particularly in peri-urban areas, where unregulated construction has led to wells and septic tanks often being located very close together, rising magnitudes of contamination are increasingly likely.

Water resources in close proximity to on-site disposal of human waste are in particular danger. For example, a study done in informal settlements in Kisumu City, Kenya, found when the distance between wells and pit latrines was between zero and fifteen meters, the level of contamination was twice as high as when the distance was greater than thirty meters (Opisa et al., 2012). At all study sites in Tomondo and Kijito Upele, it was observed that septic tanks were located within fifteen meters or less of wells. Residents of Tomondo

A were also aware of the fact that their part of the neighbourhood- the lower side- is in an area of much higher risk than the upper side, as contaminants accumulate in the swamp near their homes.

Frequency is defined in this case by seasonal variations in flooding and aquifer recharge that may carry waste into groundwater that later appears in wells. Climate models for Zanzibar predict increasing risks of both flood and drought in the coming decades. This could alter the frequency and duration of exposure of communities (Watkiss et al., 2012). The time element to vulnerability has been studied using meteorological and hydrological data. A study done by Hashizume et al. (2007) in Bangladesh compared hospital admissions for cholera to variations in temperature and rainfall on a time lag. They found that cases of cholera increased in response to high temperature and heavy rainfall in the weeks following weather changes.

The duration of an outbreak following contamination and infection varies in response to changing environmental conditions and also the efficacy of responses. As discussed in section 6.1.3, there is a lack of institutional capacity for large-scale rapid public health response in the case of an outbreak in Zanzibar; however, the situation is improving. In peri-urban communities, where the drainage systems are often inadequate, the amount of time a particular area spends inundated with flood waters after a heavy rain event can also influence the length of exposure residents experience to pathogens carried in water in and around their homes. While these temporal factors are interesting, Wisner et al. (2004) claim that this aspect is less important in understanding vulnerability and exposure to long term slow disasters than the spatial element. The areal extent of a hazard influences the number of people that are within the range of potential contact with hazards, whenever they do occur.

6.5 Coping Mechanisms

6.5.1 Community collective action

In both Kijito Upele A and Tomondo B communities are working together to upgrade shared infrastructure on a small scale. Both Well KA and Well TB were constructed by groups of community members who continue to maintain the well and support repairs by donations. According to Adger (2003) this is a type of social capital, supported by social networks and sharing of information that is used to mitigate environmental risks and co-manage shared resources. By leveraging networks as an asset, individuals and communities are ensured greater access to natural capital such as water resources.

This willingness to work together is especially important in the absence of consistent state support and in dynamic and changing communities (Adger, 2003). For the study sites in Tomondo and Kijito Upele, where one respondent claimed she has lived for twenty years without ever seeing any state managed water resources, the ability of communities to organize and manage construction of drinking water wells is an important way to cope with the lack of support from the state. Social capital in this context has the potential to "...lead to measurable outcomes of material well being..." and has important implications for management of vulnerability and coping with risk (Adger, 2003, p. 395).

As these communities in the peri-urban fringe of Zanzibar are growing quite rapidly, the state does not have the capacity to adapt to change on the scale that is needed. Acting collectively on a highly local scale is a coping mechanism for the risks posed by contaminated water resources and scarcity. For larger scale infrastructure development and disaster management, civil society action at this level is not sufficient (Adger, 2003). Nevertheless, the individuals who participated in this study have been able to significantly improve their access to safe and sufficient water resources by working together.

6.5.2 Personal Action

In interviews of both households and key stakeholders there was a trend of emphasis on the role of personal behaviour in preventing disease. When asked what role the government or hospital could do to reduce risk of disease, some respondents were unable to give any examples. A representative of ZAWA reiterated this, saying that "The government does enough to protect people already. The most vulnerable people are the ones who ignore health messages and do not treat their water." This may be the case in terms of raising awareness and education about health, but the government is not capable at this time of providing access to safe and sufficient water for all citizens. Personal strategies are merely a coping mechanism for mitigating the unsafe environment in which residents of peri-urban areas find themselves.

Differential vulnerability within communities was another challenging question for many respondents. If at first a respondent did not understand the questions about differences in vulnerability, they were presented with a list of potentially vulnerable groups such as women, poor people, or the elderly. Even then, respondents often were unwilling to name one group as more vulnerable than others within a community. For users of a shared water source, all were considered to be equally vulnerable, with only their own decisions to treat water and maintain cleanliness determining their health status. Among those who did respond freely to the questions about vulnerability, the most common group put forward as the most vulnerable was children, due to the locations where they play and their parents not being able to control them. The least vulnerable groups were hypothesized to be less vulnerable because of their "good perception and awareness". Therefore, the people who are the least vulnerable are the ones who are taking measures to ensure their water is clean and safe and their environment is clean, and the most vulnerable are the ones who drink water indiscriminately without any preparation.

These beliefs about the role of personal behaviour in preventing disease lead to a focus on awareness raising and education by actors who aim to decrease vulnerability. That has already been done in Zanzibar. In general, most people know what they can do personally to prevent disease, and clearly it is not enough. Seasonal outbreaks of cholera continue to occur, primarily in poor communities and in peri-urban areas. In one sense, this could be because education does not always immediately or effectively translate into behavioural change (Bates et al., 2004). It is also possible that the magnitude and extent of contamination in wells in some peri-urban areas has progressed beyond the point where it is manageable at an individual level. As discussed in section 6.3.1b the well water in Kijito Upele B is no longer safe according to WHO bathing water quality standards, yet this is not a commonly heard message. In addition, the cost of continuously buying Water Guard or charcoal to treat or boil drinking water can become a significant expense for some households, meaning that even if the knowledge exists, the actions may be out of reach (Obrist, 2003).

According to the perspectives garnered from participants in this study, personal actions are more of a defining factor in vulnerability than the "root causes" described in section 6.1 of this chapter. Without understanding of the crucial role of these root causes in enabling or constraining the ability of individuals and communities to protect themselves from disease, the burden of responding to and preventing disease is placed squarely on individuals rather than their communities or governments. While this can be positive in the sense that it encourages individuals to take action to improve their situation, it also takes some pressure off institutions that are responsible for creating and maintaining the structural inequalities that allow for exposure in the first place. Activities to urgently address poverty, inadequate infrastructure, and political inequity can be swept under the rug if all the blame for illness lies with individuals rather than the conditions in which they find themselves.

On a deeper level, believing those who experience diarrhoeal disease are at fault makes them more vulnerable, because they do not see the ways that they could be advocating for protection and support from the government and other institutions. It also reduces empathy for those who fall ill, because it seems that they did something to deserve what is happening to them, as if they had only been cleaner or more careful they could have avoided exposure to disease. The already powerless and marginal people living on the fringes of society with limited resources should not be held responsible for the global and national-level forces that have put them at risk.

6.6 Suggested solutions

In this section, I have attempted to use my findings to make suggestions about what could be done to decrease vulnerability in peri-urban communities of Zanzibar in the future. As a Master's student with only two-months of field time in Zanzibar, I recognise that my perspectives are highly limited, but I felt it an important exercise for me to speculate potentially actionable outcomes based on my experiences.

My responses and suggestions combine those which address both first order and second order scarcity (as discussed in Chapter 2.4). In Zanzibar first order, absolute biophysical, scarcity is not yet occurring, but there is a threat that if aquifers are not managed sustainably it may occur. It may be possible to avoid this by implementing technical solutions to more efficiently provide and conserve water. Ohlsson and Turnton's (1999) concept of third order adaption could also be useful, by encouraging society-wide shifts in consumption and use patterns. Second-order scarcity is a contemporary issue in Zanzibar, and thus in order to ensure equitable and consistent distribution of water to all members of the population at all times we must be aware of the social and political conditions in target communities. Solutions that exacerbate or reinforce existing inequalities will have the same winners and losers, and will likely not improve conditions for those who are most in need.

My focus has generally been on the benefits of preventative action to improve health and access to clean and safe water in peri-urban communities. This is because, “In addition to the human and ethical aspects, it may cost less and be much more feasible to provide good curative services so that poor people avoid becoming poorer than it is, once they are poorer, to enable them to claw their way back up again” (Chambers, 2007, p. 23). If we view illness as a side-effect of poverty, then working to alleviate the many aspects of poverty in a community will not only improve their current standard of living, it may also enable and empower them to achieve a better future.

Examining the variations that lead to disparate experiences of water availability and quality may allow one to identify options for decreasing vulnerability at both the individual and community level. As the continued presence of water-borne diseases implies, it is not enough for individuals to be more conscientious about hand-washing or boiling water, nor is it enough for the government to dig more and deeper boreholes in communities that have experienced contamination or salinisation in the past. Neither technical nor social responses are likely to be sufficient on their own. For future reduction in vulnerability to water-borne diseases in peri-urban Zanzibar, a holistic approach could be taken by actors at all levels in order to more comprehensively address these problems.

Understanding of hazards is an important first step to reducing vulnerability (Wisner & Adams, 2002). However, “although exposure to a pollutant or other environmentally mediated health hazard may be the immediate cause of ill health, the "driving forces” and "pressures" leading to environmental degradation may be the most effective points of control of the hazard” (Corvalán et al., 1999, p. 657). In this study the “driving forces”, also known as root causes, were theorized to be economic disparity, social and political inequality, and inadequate institutional capacity. Widespread poverty, gender inequality, and lack of education in Zanzibar have also been put forward as possible root causes of vulnerability. To truly reduce vulnerability in the long-term, all of these issues would need to be addressed, but this is a difficult and slow process that requires structural change throughout a society.

A comprehensive approach to reduction in disease in peri-urban communities is also challenging because of the lack of prior planning and infrastructure in these areas. Affordable alternative technologies exist, and could be more widely adopted (Marshall et al., 2009). Decentralized wastewater treatment and community level treatment of water, for example, can decrease the need for buildings that require large quantities of valuable land to provide drinking-water of acceptable quality (Parkinson & Tayler, 2003). Treating water in the tank at Well KA is one example of this working in Zanzibar, as is a Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) project to bring potable water to poor areas using small-scale seawater desalination technology. These smaller and less expensive technologies help to address the fact that people are already living in peri-urban areas and will not support projects that require houses and other buildings to be destroyed to make space. One representative of ZAWA in the project planning department mentioned the potential for rainwater harvesting and conservation and reuse of waste water as another way to potentially address water scarcity issues in the future. Unfortunately, "conventional planning mindsets […] experience difficulty conceptualizing sustainable and locally-appropriate solutions (Marshall et al., 2009, p. 19)". It will take time and education of engineers and urban planners for these solutions to become more widely accepted.

Another activity with great potential for reducing vulnerability is monitoring of water quality, not just for tap water provided by ZAWA but for all water that is used for human consumption. This could potentially be an opportunity for capacity building in each *sheha*, with the introduction of mobile laboratories or training of local people in each *sheha* to carry out regular and on-demand testing of resources. This would increase knowledge of water quality, and empower communities by providing them with a means of obtaining information about their water quality at a hyper local level.

Engaging whole communities in activities to protect groundwater resources, and the well water that many people depend on could also be an important way to sustainably prevent overuse and pollution of water. As Howard et al. (2006) have said, "Protection of groundwater resources is a public concern and a public responsibility and therefore requires public participation" (p. 144). In Zanzibar, Mohammed (2002b) expresses concern that community participation in decision making regarding environment and health does not receive enough emphasis. As such, communities may not fully understand the benefits of maintaining water quality through the protection of resources. Raising awareness of these future benefits through community meetings and use of mass media, along with consulting communities in an inclusive way could encourage comprehensive and sustainable conservation of resources. The government could also provide subsidies and incentives for the poor to develop and maintain waste water treatment infrastructure or consult with the government before constructing illegal boreholes.

Furthermore, contingency plans can be developed for potential future salinisation of groundwater and contamination of drinking water resources. If alternative water sources that are safe and meet demand are identified, it could help to mitigate potential future scarcity while also providing increased access to safe water in peri-urban communities currently. Ideally, these sources would be affordable and available all year round to protect people from the dangers of using contaminated water in their homes.

Once pollutants are present in groundwater, degradation and dilution occur very slowly, meaning that unless pollution is stopped at the source, concentrations of contaminants will continuously increase (Mohammed, 2002b). If ZAWA and other organizations wait until the aquifers of Unguja Island are depleted or polluted before beginning to develop alternative strategies for water provision and protection, the population of Zanzibar will suffer the consequences.

7. Conclusion

The data collected in this study has explored some aspects of vulnerability to water-borne diarrhoeal disease in wells in four peri-urban communities in Zanzibar. Environmental, institutional, social, and economic determinants of vulnerability were considered, and the role of hazard awareness and perception was particularly emphasized.

Peri-urban communities, because of their crowded nature and lack of infrastructure for drainage, waste management, and piped water, are more vulnerable to diarrhoeal disease than many urban or rural communities. This is not a uniform condition, however. Results illustrated that within very small areas there is great variation in the amount of vulnerability. Households located within a few meters of each other may experience disparate susceptibility to hazards. These differences stem from a combination of environmental and socio-economic characteristics and also perception and awareness of impacts of using well water for household needs.

It is also important to remember that vulnerability is dynamic (Birkmann et al., 2013). Even the most holistic and comprehensive vulnerability assessment is only accurate for the particular moment in time and precise position in space at which it was completed. Communities grow and change in different ways depending on their initial conditions and prevailing dynamic pressures. With effective institutional frameworks and urban planning, growth can be a positive thing. Without those conditions, growth can lead to pollution and overuse of resources. In peri-urban Zanzibar, the rate of population expansion in informal settlements has created a situation in which many residents are very vulnerable to water-borne diseases, as their primary water sources are not sufficiently protected from contamination with pathogens.

Furthermore, a unit of analysis cannot be said to be either "vulnerable" or "not vulnerable". Vulnerability can be viewed as a spectrum where an individual or community is more or less vulnerable relative to others, but this is never an absolute. The highly complex nature of socioecological systems defies solely quantitative analysis and studying these systems requires for a certain level of flexibility, reflexivity, and understanding of the important role that perception and understanding can play in changing vulnerability over time.

Residents of the peri-urban areas studied have many strategies for avoiding disease. These take the shape of both personal and collective actions for prevention, including hygiene and sanitation activities and building and maintaining of shared community wells. Problems arise when there are constraints on these actions (including lack of access to resources or low socio-economic status), or when individuals are unaware of what actions would most benefit them. For example, if an individual is aware that their local well is contaminated but is unable to afford piped or bottled water, charcoal for boiling water, or chemicals to treat the water, they have no alternative but to continue to consume the water. Further, individuals may know that environmental cleanliness is key to preventing disease, but if they do not understand the potential for groundwater to become contaminated by neighbouring septic tanks or waste disposal sites, they have no incentive to take precautions when constructing wells or household sanitation systems.

It seems that in Zanzibar the most common understanding of disease prevention emphasizes strongly the role of personal understanding and responsibility. In an ideal situation, the population would be educated and aware, but the burden would not be entirely on their shoulders to maintain their health. As the Water Act of 2004 states, one of the most important challenges faced by the RGoZ is to transition to the “some or all rather than more for some” approach. The poor have just as much of a right to clean and safe water as the rich, and ensuring access to safe and sufficient resources is a responsibility that should be shared between individuals and their government.

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Appendix I. Household interview guide

Interview Number: _____________ Date: ______________ Location name: _________________

Demographic information

1. Gender:
2. Age:
3. Level of completed education:
4. Main sources of income in the household:

Household Water Use

5. Where do you obtain water for your family to drink? Is it the same place you obtain water for other household activities?
____

6. Please rank sources in order of how dependent you are on them (most-least)

    1.
    2.
    3.
    4.

7. Do you have to pay for water, and if so, how much?

    1. What would you do if the price of water went up?
    2. What would you do if the price of water went down?

8. How much time do you spend each day collecting water?

- 0 minutes
- Up to 30 minutes
- Up to 1 hour
- Up to 2 hours
- Up to 3 hours
- More than 3 hours
- Don't know

9. What do you do to the water before you drink it?

- Nothing
- Boil it
- Filter it
- Add Chemicals
- Settling (Decantation)
- Don't know
- Other___________

10. Do you feel that you have enough water? Enough clean water for drinking?

Household Sanitation

11. Can you tell me about the type of sewage system in your house?
    1. Type of toilet
    2. Connected to a central sewer system (Y / N)
    3. Shared with other households (Y /N)
        1. If yes, how many?

12. Does the toilet water go in the same place as the rest of the wastewater?

13. What do you think about the sanitation system of your house and neighbourhood?

14. Do you think it has impacts on the health of your household?

15. Are you aware of sewage pollution in this area? Where do you think it is most prevalent?

16. Do you think it has impacts on the health of your household?

17. What aspects of sewage pollution have the potential to impact health?

Water Quality

18. What do you think about the quality of water in (XXXX) well?
    1. Is it clean?
    2. Is it safe?
    3. Has it changed over time?

19. Are there any indicators you use to assess the safety of the water?

20. Do you think that using this well has impacts on the health of your household?
    1. If yes, what sort of impacts?

21. If you feel that the water is not clean/safe at any given time, do you feel that you have access to safe and sufficient alternative sources?
    1. If so, where and how far away?

Health

22. What are the major diseases/illnesses that your household experiences?

23. Have there been any cases of diarrhoea in the house that you know of in the last 24 hours?
    1. If yes, what do you think caused them?

24. Have there been any cases of diarrhoea in the house that you know of in the past week?
    1. If yes, what do you think caused them?

25. Do you feel that the incidence of diarrhoea in your household changes throughout the

year?

1. Why/Why not?
2. Has this changed over time?

26. Who do you think is the most vulnerable to diarrhoeal disease in this community? Why?

27. Who is the least vulnerable? Why?

28. What could be done to protect your household from diarrhoea?
    1. By you ____
    2. By the government _____________________________________
    3. By hospitals ____
    4. Anyone else ____

29. What information do you have about protecting your household from diarrhoea?
    1. Where did it come from?
    2. Where would you go if you wanted more information?

Appendix II. Other stakeholder interviews
Health workers, city planners/managers, any group that is working to study or address water, sanitation and health in the target areas
Interview Number: _____________ Date: _________________ Location: _________________

Background Information
1. Name:
2. Organization:
3. Position:
4. Number of years in position:
5. What are your responsibilities and tasks in this position?

Water Quality
6. What is your opinion of water in ______________ district?
    1. Is it clean?
    2. Is it safe?
    3. Has it changed over time?

7. What affects the quality of the water?

Health and Vulnerability

9. Who do you think is the most vulnerable to diarrheal disease in this community? Why?

10. Who is the least vulnerable? Why?

11. What factors contribute to household vulnerability to diarrhoeal disease within these communities? (elaborate on each category if possible)
    1. Social ____
    2. Economic ____
    3. Political ____
    4. Demographic ____
    5. Geographic/ Spatial ______________________________________
    6. Seasonal/ Temporal ______________________________________
    7. Other ____

12. What do you think could be done to improve the health of people in __________ neighbourhood?
    1. By individuals ____
    2. By the government _______________________________________
    3. By hospitals ____
    4. Anyone else ____

13. Do you think educating people to improve their understanding of the risks associated with poor water quality would be helpful?

14. Where do you see opportunities to decrease vulnerability to diarrhoeal disease in this community?

15. What obstacles are there to reducing vulnerability to diarrhoeal disease in this community?

Appendix III. Information and consent form

Request for participation in research project: "Vulnerability to Effects of Groundwater Contamination in a Peri-Urban Community in Zanzibar"

Background and Purpose

My name is Elizabeth MacAfee and I am a Masters student in International Environmental Studies in Ås, Norway at the Norwegian University of Life Sciences (NMBU). As a requirement for my degree I am carrying out field research in Zanzibar in preparation for completion of a master's thesis project. The project is being carried out as a part of a larger research collaboration between NMBU and the State University of Zanzibar (SUZA) called: Vulnerability, Resilience, Rights and Responsibilities: Capacity Building on Climate Change in Relation to Coastal Resources, Gender and Governance in Coastal Tanzania and Zanzibar.

As a student, NMBU has provided me with a small stipend to aid in the costs of research, and any further costs will be covered by my personal funds. The purpose of this project is to examine environmental, social and economic contributors to vulnerability to diarrhoeal disease through a combination of qualitative interviews and water quality sampling in wells. I will collect data about the incidence of diarrhoeal disease in this community from both personal interviews and conversations with health workers in the area, and attempt to better understand the causes of vulnerability by exploring the characteristics of those who are vulnerable and their own perceptions of the sources of this vulnerability (or lack thereof).

Participants in household interviews have been selected for inclusion based on the proximity of their household to the wells that will be sampled for water quality. My goal in sampling is to include a diverse group of participants within well users with different perspectives and understandings, however, it is expected that women often bear responsibility for both water collection and health of the household. As such, the majority of interview participants will be women.

Other stakeholder interview participants (healthworkers, city planners/managers, NGOs, government offices) will be selected based on their relevant work in water, sanitation and health in the target community.

What does participation in the project imply?

Study participants in households will be asked to complete a 30-45 minute interview at a location of their choosing. The questions will include demographic information (age, gender, occupation, etc.) and also questions about personal experiences and perceptions of water quality and health in their community. A translator will be used to facilitate communication between the student researcher and the interview participant, and notes will be taken by the student researcher throughout the interview.

If possible, interviews will also be conducted with health workers, city managers, and any other groups working to improve water, sanitation and health in the target community. These interview questions will include information about their personal experiences and perceptions of water quality and health in the target communities.

Any community member or participant in the study who would like to receive an electronic

copy of the final thesis project may request it. The electronic results will be provided by June 2017 at the latest.

What will happen to the information about you?

All personal data will be treated confidentially. Only the student researcher, supervisor and translator will have access to the data, and once the thesis is completed and submitted all personal data will have been fully anonymized so no participant will be individually recognizable. This data will not be shared with any external parties for any purpose. Data will be stored on a password-protected personal laptop that is stored in a secure location. Once data collection is complete the information will be transferred to a secure university server. For the purposes of protecting confidentiality, participant names and identifying information will be stored in a separate encrypted file from other interview data.

The data collection and field work portion of this project is scheduled for completion by December 15, 2016. The final thesis will be submitted for review by May 18, 2017 before which time all of the data will be made completely anonymous.

Voluntary participation

Participation in this project is voluntary, and you can at any time choose to withdraw your consent without stating any reason. If you decide to withdraw, all your personal data will be made anonymous and will not be included in the study.

If you would like to participate or if you have any questions concerning the project, please contact:

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The study has been notified to the Data Protection Official for Research, NSD – Norwegian Centre for Research Data.

Consent for participation in the study

I have received sufficient information about the project and am willing to participate. I understand that my information will be stored anonymously and if at any time I choose to withdraw from the study I may do so.

(Signed by participant, date)*

*If a participant is unable to read the information provided they will be verbally informed of all pertinent information and verbal consent will be obtained and recorded.

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