An Evaluation of a World Vision Water, Sanitation, and Hygiene (WASH) Project in Tanna, Vanuatu

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A thesis submitted for the degree of

Master of Public Health

University of Otago, Dunedin, New Zealand

29th February 2016

Abstract

Background

In 2013, World Vision Vanuatu and World Vision New Zealand implemented a three-year water, sanitation, hygiene (WASH), and nutrition project (the Project) in south west Tanna, Vanuatu. The overall goal of the Project was to reduce child undernutrition, with short- and medium-term objectives to increase WASH infrastructure, and improve caregiver WASH and nutrition knowledge and practices. In January 2015, after two completed years of the Project, we designed and undertook an evaluation.

Methods

For households with children aged under five years of age in the Project villages we conducted: WASH and child health surveys; WASH infrastructure observations; anthropometric measurements of children under five years of age and their mothers; and microbiological drinking water testing. We compared our data with those gathered at baseline and at the end of year one of the Project. We undertook logistic regressions to investigate associations between: child health outcomes and WASH and nutrition factors; and household microbiologic water safety and WASH factors.

Results

Complete enumeration of households with children under five years of age was attempted. Overall, 220 households and 320 children participated in the evaluation.

There was a significant increase over time in the proportion of households with access to improved latrines, from 39 (26.4%) of 148 households in 2013, to 202 (97.1%) of 208 in 2015 ($p<0.001$); and in the proportion of handwashing facilities from 31 (21.0%) of 148 in 2013, to

172 (82.7%) of 208 in 2015 (p<0.001). Caregiver WASH knowledge improved over the course of the project.

A total of 12 (4.0%) of 303 children were wasted (<-2 Z-score weight-for-height), 145 (48.8%) of 297 children were stunted (<-2 Z-score height-for-age), and 59 (19.1%) were underweight (<-2 Z-score weight-for-age). In the two weeks prior to the survey 35 (11.6%) of 303 children had diarrhoea.

Factors associated with a lower prevalence of stunting included using improved water sources (PR: 0.69, 95% CI:0.56–0.85, p=0.001) and a greater maternal height (PR: 0.95, 95% CI: 0.91–0.99, p=0.006). Using an improved water source was associated with a lower prevalence of being underweight (PR: 0.45, 95% CI: 0.27–0.74, p=0.002).

Of the 201 households with microbiological water testing, 10 (5.0%) had *E. coli* levels safe for drinking at <1/100 mL, whereas 145 (72.1%) had *E. coli* levels indicating very high health risk at >100/100 mL. Factors associated with lower odds of very high risk drinking water included the source being rainwater (OR: 0.10, 95% CI: 0.02–0.59, p=0.009), and having a water container with a spigot (OR: 0.34, 95% CI: 0.13–0.77, p=0.010). Additionally, households with severely stunted children or underweight children had higher odds of having very high risk drinking water (OR: 3.02, 95% CI: 1.13–8.03, p=0.027 and OR: 2.51, 95% CI:1.02–6.19, p=0.045.

Conclusions

We found that the Project achieved most of its short- and medium-term objectives to improve WASH and nutrition infrastructure, knowledge, and practices. Microbiologic testing indicated that most drinking water in the Project households was unsafe. Undernutrition remained high in the Project population and was associated with having very high risk drinking water. Providing the Project population with improved drinking water as planned in the third Project year, is likely to contribute to achieving the Project's overall goal to reduce child undernutrition.

Preface

The World Vision Tanna integrated WASH Project (the Project) was originally a three-year project beginning in 2013. This was later extended to four years due to the devastation caused by cyclone Pam in March 2015 to the island of Tanna. The Project was funded by World Vision New Zealand through the New Zealand Aid Programme (NZ Aid), and implemented by World Vision Vanuatu. According to the Project design, monitoring on a number of project outcomes was to occur annually. A memorandum of understanding exists between World Vision and the University of Otago and the Centre for International Health, University of Otago initiated talks regarding a possible mid-term evaluation of the Tanna WASH Project. Alex Morrison, Master of Public Health (MPH) candidate from the Centre for International Health began working on the evaluation on November 2014. World Vision New Zealand stipulated the evaluation should take place in January–February 2015 in Tanna, Vanuatu, to align with their reporting requirements to NZAID in April 2015.

The roles of the candidate and others involved in the evaluation are outlined below:

Alex Morrison, MPH candidate.

- Determined the objectives of the evaluation based on the original aims of the Project.
- Prepared and gained University of Otago Research Advisory Committee (RAC) approval and University of Otago Human Ethics Approval.
- Prepared survey questionnaires for the evaluation and with the assistance of the World Vision Tanna team contextualized the survey questions so they were appropriate for the population of south west Tanna.
- Programmed the questionnaires into the smartphone data collection platform FieldTask (Smap Consuting, Niel Penman, VIC, Australia).
- Prepared training material for the Smartphone application.

- Trained the World Vision Tanna survey team on how to use the FieldTask data collection application
- Prepared consent forms and information sheets for participants.
- Assisted in training the World Vision Tanna survey team in anthropometry techniques.
- Made sure all necessary preparation for data collection was undertaken.
- Supervised the data collection component of the evaluation.
- During the survey, assisted in conducting anthrompetric measurements of children, observation questionnaires, and water testing.
- Led a debriefing session every day after data collection.
- Was responsible for quality control of survey questionnaires during data collection.
- After data collection extracted preliminary results for the Tanna World Vision team.
- Manually cleaned and pre-processed datasets.
- Conducted statistical analyses of the data with advice and assistance from a statistician.
- Wrote a report of preliminary results for World Vision New Zealand to assist in their reporting requirements.
- Wrote a report of preliminary results to NZ Aid as part of the NZ Aid Postgraduate Field Research Award.
- Write up of thesis.
- Writing of a paper for publication.

Professor John Crump (candidates primary supervisor) contributed to preparing the University of Otago RAC application and Human Ethics Committee application, as well as contributing to the design of the evaluation and giving advice during field work. Prof. Crump reviewed drafts of the candidate's reports and thesis.

Dr Susan Jack (candidate's supervisor) led the initial discussions with World Vision that resulted in the evaluation, and liaised with World Vision New Zealand throughout the evaluation. Dr Jack contributed significantly to the planning of the evaluation and gave advice during data collection. Post data collection she contributed to analyzing and collating preliminary data for reports. She also reviewed drafts of the candidate's reports and thesis.

Associate Professor Katrina Sharples (candidate's statistics supervisor) gave advice during the planning of the evaluation and undertook initial sample size calculations. Assoc. Prof. Sharples also gave advice to the candidate during data collection and post data collection and assisted the candidate with statistical methods for analysing the data. She also checked the candidates resulting outputs and interpretations for accuracy and reviewed drafts of the candidate's thesis.

Associate Professor Lisa Houghton, Senior Lecturer of Human Nutrition at the University of Otago, contributed to planning the child nutrition and anthropometry sections of the evaluation. Assoc. Prof. Houghton prepared the training material for anthropometric measuring, and led the training of the World Vision Tanna team on these techniques prior to data collection. She also reviewed the nutrition questions included in the child health survey and helped to ensure other aspects of the evaluation were prepared prior to the survey.

Ms. Hanneke Lewthwaite, University of Otago medical student and Centre for International Health summer scholarship student assisted the MPH candidate in the preparation and data collection stages of the evaluation. Specifically, pre data collection Ms. Lewthwaite researched Compartment Bag Tests (CBTs) (Aquagenx, NV, USA) for water microbiological quality testing, undertook positive and negative controls for each batch of CBTs, and tested CBTs at variable room temperatures. She also helped to prepare water quality related household questions and trained three Tanna World Vision team members on CBT survey methods. Throughout data collection she undertook and supervised the water quality

testing, and post data collection was responsible for preparing preliminary water quality results for use by the Tanna World Vision team.

World Vision New Zealand funded the evaluation. Elise Bryce-Johnson (World Vision New Zealand, Grants Programme Manager, Papua New Guinea and Vanuatu) facilitated contact between World Vision Vanuatu and the University of Otago. Dr Raul Schneider (World Vision Regional Health Adviser) assisted in obtaining ethics approval for the evaluation from the Vanuatu Ministry of Health, and reviewed evaluation questions. The World Vision Vanuatu employees at the Tanna office, led by Jimmy Daniel (Area Programme Manager) and Peter Brown (Volunteer Services Abroad WASH adviser) assisted in planning the evaluation, including consulting with chiefs of Project communities and further contextualizing questionnaires. The World Vision Tanna employees undertook data collection for the evaluation, supervised and assisted by Alex Morrison and Hanneke Lewthwaite. World Vision had access to preliminary results for their own reporting requirements and internal dissemination. World Vision had no input in the interpretation and writing of results presented in this thesis, nor in the decision to submit papers for publication.

NZ Aid funded the Tanna WASH Project through World Vision New Zealand and supported the candidate through a NZ Aid Postgraduate Field Research Award. NZ Aid had no input in the interpretation and writing of results presented in this thesis, nor in the decision to submit papers for publication.

Acknowledgements

Firstly, I would like to acknowledge my amazing supervisors Dr Susan Jack, Prof. John Crump, and Assoc. Prof. Katrina Sharples for their ready assistance in all aspects of the evaluation. Just a few of the many ways which they have helped include communicating with World Vision and Vanuatu WHO staff; gaining ethics approval from the Vanuatu ministry of health; hashing out evaluation details and statistics over skype calls from Vanuatu; and the many meetings, advice given and readings of my reports and thesis.

I would like to thank Assoc. Prof. Lisa Houghton for helping me with the nutrition aspects of this project and making the journey to Vanuatu to conduct anthropometry training in Vanuatu. I would also like to thank Hanneke Leuthwaite who took charge of the water testing component of the evaluation in Vanuatu for her summer studentship, and who was an enormous help during the planning and data collection stages of the evaluation.

I am indebted to a number of World Vision staff who helped with the evaluation. Firstly, World Vision WASH advisor Peter Brown for assisting with numerous aspects of the evaluation. Secondly, Elise Bryce-Johnson (World Vision New Zealand, Grants Programme Manager, Papua New Guinea and Vanuatu) for assisting in planning the evaluation from afar; and Dr Raul Schneider (World Vision Regional Health Adviser) for assisting with obtaining ethics approval from Vanuatu Ministry of Health and reviewing evaluation questionnaires. Thirdly, a special thanks to the World Vision Tanna staff, who did a fantastic job planning and carrying out the second year evaluation, led by Jimmy Daniel (Area Programme Manager). Tanna World Vision staff members consisted of Rosilyn, Maurice, Norolyn, Harold, Anita, Rosninel, Joseph, Kerryn and David. Ruth, a local nurse from the hospital, also helped carry out the survey.

Lastly, I would I like to thank my family and friends for their never ceasing support and encouragement.

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List of Abbreviations

ARI	Acute respiratory infection
BCG	Bacille de Calmette et Guérin
CAP	Community Action Plan
CBT	Compartment Bag Test
CI	Confidence interval
DALY	Disability adjusted life year
DTP	Diphtheria, tetanus pertussis combination vaccine
EndoCAB	Endotoxin core antibody
EED	Environmental enteric dysfunction
GEE	Generalised-estimating equation
GUS	*β*-D-glucuronidase
HAZ	Height-for-age Z-score
H_2S	Hydrogen sulfide
IgG	Immunoglobulin G
IYCF	Infant and young child feeding
JMP	Joint Monitoring Programme
LF	Lymphatic filariasis

L:M	Lactulose:mannitol
LMIC	Low-and-middle-income country
MAL-DD	Etiology, Risk Factors and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development study
MDG	Millennium Development Goal
MAD	Minimum acceptable diet
MDD	Minimum dietary diversity
MMF	Minimum meal frequency
MPN	Most Probable Number
NZAID	New Zealand AID Programme
NGO	Non-Governmental Organisation
PHAST	Participatory Hygiene and Sanitation Transformation
POU	Point of use
PET or PETE	Polyethylene terephthalate
PR	Prevalence Ratio
ORS	Oral Rehydration Salts
ORT	Oral Rehydration Therapy
RCT	Randomised Control Trial
SAFE	Surgery, antibiotics, facial cleanliness, and environmental improvement
SODIS	Solar water disinfection

STH	Soil Transmitted Helminth
TSC	Total Sanitation Campaign
UK	United Kingdom
UNICEF	United Nations Children's Emergency Fund
URI	Upper respiratory infection
VDHS	Vanuatu Demographic and Health Survey
VIP	Ventilated improved pit
WASH	Water, sanitation, and hygiene
WAZ	Weight-for-age Z-score
WHO	World Health Organisation
WHZ	Weight-for-height Z-score
WMC	WASH Management Committee
X-gluc	5-bromo-4-chloro-3-indoly-beta-D-glucuronic acid

Chapter one – Introduction

1.1 Introduction

Three fundamentals to health are: safe drinking water in adequate quantities; improved, clean sanitation facilities; and adequate hygiene practices (1). In developed countries these fundamentals are taken for granted, yet for a large proportion of the world they remain absent. In 1990 2.7 billion people, 51% of the world's population, did not have access to improved sanitation facilities, and 1.3 billion people, 24% of the world's population, did not have access to improved water facilities (2). Thus, in an age where the knowledge and skills exist to eliminate water, sanitation and hygiene (WASH) related diseases, they still contribute substantially to the global burden of illness and premature death. Of all deaths in children under five years of age 9% can be attributed to diarrhoea, which is more than HIV/AIDS, tuberculosis, and malaria (3). Additionally, inadequate WASH infrastructure and practices combine with poor child nutrition practices that are common in low-and-middle-income countries (LMICs), to contribute to child undernutrition (4). It is estimated that universal access to microbiologically safe water and improved sanitation facilities would prevent 2.4 million deaths worldwide annually (5).

The Millennium Development Goals (MDGs) emerged from the United Nations Millennium Summit in 2000. The eight MDGs were international development goals that United Nations member states committed to achieve by the end of 2015 (6). Goal 7: ensure environmental sustainability, included target 7C: to halve the proportion of the population without sustainable access to safe drinking water and basic sanitation by 2015. The World Health Organisation (WHO) and United Nations Children's Emergency Fund (UNICEF) Joint Monitoring Programme (JMP) measured progress towards these targets. The JMP defined improved sanitation as latrine facilities where human excreta is hygienically separated from human contact (7). Improved water is a water source protected from contamination via its

construction or an active intervention (7). Table 1 shows examples of water and sanitation facilities considered improved and unimproved according to the JMP.

Table 1: Joint Monitoring Programme definitions of improved and unimproved drinking water and sanitation, 2000-2015 definitions

Joint Monitoring Programme terminology	Use of following sources:
Improved drinking water	- Piped water into dwelling, yard or plot - Piped water to public tap or standpipe - Tubewell or borehole - Protected dug well - Protected spring - Rainwater collection
Unimproved drinking water	- Unprotected dug well - Unprotected spring - Cart with small tank or drum - Tanker truck - Surface water: river, dam, lake, pond, stream, canal, irrigation channel - Bottled water
Improved sanitation	- Flush or pour-flush to: • piped sewer system • septic Tank • pit latrine - Ventilated improved pit (VIP) latrine - Pit latrine with slab - Composting toilet
Unimproved sanitation	- **Shared facilities of <u>any</u> type** - Flush or pour-flush to elsewhere than above - Pit latrine without slab/open pit - Bucket - Hanging latrine - No facilities: bush or field

Joint monitoring Programme (7)

Overall, the proportion of the world's population with access to improved water and sanitation, increased from a 1990 baseline of 76% and 54%, to 91% and 68% respectively by 2015. The global MDG target 7.C, of 88% of people with access to improved water was achieved in 2010, although the improved sanitation target of 75% was missed (6). Moreover, progress was not uniform, with some regions achieving great success in meeting water and sanitation indicator targets and others falling short. In the 2015 MDG report, Oceania and sub-Saharan Africa had the lowest proportion of their population with improved water and sanitation of all regions (6).

The Oceania region of the MDGs include the countries American Samoa, Australia, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Palau, Papua New Guinea, Pitcairn Islands, Marshall Islands, Nauru, New Caledonia, New Zealand, Niue, Norfolk Island, Northern Mariana Islands, Samoa, Solomon Islands, Tokelau, Tuvalu, Vanuatu, Wallis and Futuna. The Pacific sub-region, as defined by UNICEF, consists of 14 Pacific Islands (Cook Islands, Fiji, Kiribati, Marshall Islands, Federated states of Micronesia, Nauru, Niue, Palau, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, and Vanuatu) and Papua New Guinea (8). This Pacific sub-region plus Papua New Guinea represents a challenge for improved water and sanitation progress because of low levels of existing potable freshwater, further threatened by urbanization, population growth, changing land-use patterns, deforestation, and climate change (8). Climate change, in particular, affects island nations for several reasons: rising sea levels, causing intrusion into aquifers; increasing temperatures; altering rainfall patterns, which are relied upon by many islands for drinking water; and increasing frequency of events such as tropical cyclones, droughts, and depressions (8).

The Oceania region as a whole did not achieve its improved water goal, with only a 6% increase in coverage between 1990 and 2015, from 50% to 56%. Between 1990 and 2011, improved water coverage increased in the Pacific region by 8%, from 45% to 53%, one of the lowest increases seen in any WHO region. In addition the proportion of people with piped water on premises, as opposed to public standpipes, decreased over this period. Substantial differences exist between Pacific nations, and also within nations. The Cook Islands, Tuvalu, and Niue had over 80% coverage of piped water to premises, whereas Vanuatu, Solomon Islands, and Papua New Guinea all had less than 30% coverage (8). Within Pacific nations, there are substantial inequalities in access to improved water between urban and rural areas. The proportion of people with piped or other improved water in urban areas was 93% in 2011, compared to 43% in rural areas (8).

The Oceania region also did not achieve its improved sanitation goal. Access to improved sanitation facilities remained static at 35% coverage from 1990 to 2015. Progress with sanitation coverage was also negligible in the Pacific sub-region between 1990 and 2011, with a 1% increase from 29% to 30% (8). However, these proportions are heavily influenced by the very low percentage with improved sanitation in Papa New Guinea, 19%, which

contributes 75% of the Pacific population (8). In 2011 the proportion of Vanuatu that had improved sanitation was 58% according to UNICEF (8).

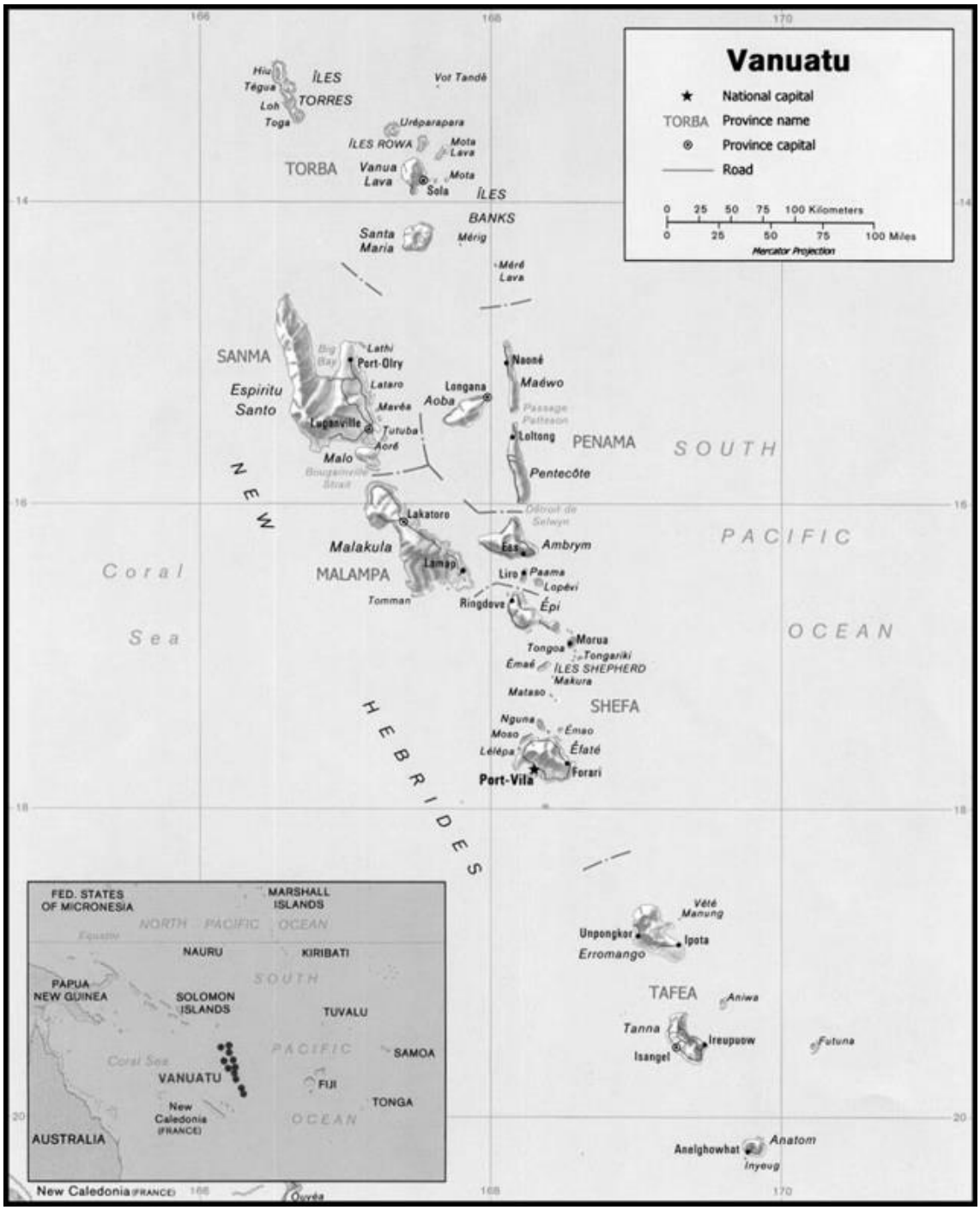
1.2 Vanuatu context

Geography and economy

The Republic of Vanuatu is a Melanesian island nation in the South Pacific Ocean, situated east of Australia, southeast of the Solomon Islands, and northeast of New Caledonia, as shown in Figure 1. It consists of 83 mountainous islands of volcanic origin, 65 of which are inhabited. Vanuatu has a relatively small population of 266,900 people recorded in the last census in 2009 (9), with 80% of the population living in rural areas where agriculture is the main source of livelihood. The age structure is young, with 37% of the population under 15 years of age, and only 4% over 64 years of age (10). The nation's largest town is the capital Port Vila, located on the island of Efate in the Shefa province. The national language of Vanuatu, is Bislama, a pidgin language combining Melanesian grammar with mostly English vocabulary.

Economic development has been hindered in Vanuatu by: vulnerability to natural disasters, including cyclones, volcanoes, and earthquakes; distance to markets and between the many islands; and relatively few commodity exports, of which copra, kava, cocoa, beef, and timber are the largest (10). Vanuatu's gross domestic product per capita in 2013 was US$ 2,500, slightly higher than Papua New Guinea, but lower than the majority of Pacific Island nations (10). Two-thirds of the population make a living by small-scale agriculture, selling fruits, vegetables, kava, fish, and other products at local markets (10).

Figure 1: Map of Vanuatu in the Pacific Ocean



Administrative map of Vanuatu from Nations Online Project

Most Ni-Vanuatu (people of Vanuatu) can achieve a good standard of living through self-sufficiency, relying on local foods and building materials, despite low incomes (11). However, in rural areas the lack of access to basic services, like education, health services, and improved water and sanitation, combined with little opportunity to earn cash income besides selling agricultural products at local markets, can lead to so called 'poverty of opportunity' (11). This poverty is compounded by vulnerability to natural disasters.

Government and services

Before Independence in 1980, the Vanuatu government was a British-French Condominium, with completely separate governmental systems, only coming together in a joint court (12). Post independence in 1980, a parliamentary democracy was established with a president, who is the head of the Republic, and a prime minister, who is head of government. In addition the national Council of Chiefs advises the government on cultural and language matters. Substantial government instability is a long-standing issue in Vanuatu, with regular votes of no confidence and divisions and 'reshufflings' of political parties, which has been described to result in insecure governments with less ability to exact change (12). There is also a disconnection between members of parliament and the people they represent in the outer islands, with much distrust stemming from a failure to follow up on pre-election promises, compounded by corruption allegations and charges (12).

The governmental health service in Vanuatu has a major challenge in providing basic health care to the 65 inhabited islands and the many rural, isolated villages on the islands. This situation leads to high unit costs for services and a reliance on donor support, which is the major funding source for health infrastructure (13). Adding to the challenge is a shortage of trained personnel, with 700 of 950 available health positions occupied in 2009, and the majority of physicians and paramedics not Ni-Vanuatu (13). There are two tertiary hospitals in Vanuatu, in Port Vila, the capital, and in Luganville, on the island of Santo. There are also three provincial hospitals located in Lenakel on Tanna, Lolowai on Ambai, and Norsup on Malekula (13). Supplementing the hospitals are 89 primary health care centres, known as dispensaries, and 180 aid posts. Aid posts are situated in many rural villages and are funded

and staffed by the community, with basic medicine and training provided by the Ministry of Health (13).

Similar geographic and financial challenges exist with delivering education services to rural Ni-Vanuatu children. Schooling is not compulsory and enrollments are low by Pacific standards, with a primary enrolment of 74%, and 3% of children who enroll in primary school continuing to year 13 of secondary school (13). Education is often cut short by parents' inability to meet compulsory contributions to school fees, restricted entry to secondary schools, and distance to secondary schools (14). The curriculum of schools in Vanuatu has been described as 'too academic' and not providing the skills relevant to adults living in Vanuatu (13). Schools also remain split into French and English medium. Furthermore, French and English are often the second or third language spoken. Many Ni-Vanuatu, especially adults, have not attended any schooling and are unable to speak Bislama. Instead many adults may speak just one of the 113 indigenous languages (15). There is one main university in Vanuatu, in the capital Port Vila, and a number of vocational institutes delivering agriculture, business, nursing, teacher education, and other programs, also in Port Vila (14).

Child health

Despite the substantial challenges in delivering health services, child health In Vanuatu has improved over recent decades. The under five year old mortality rate in 1989, pre-MDG agenda, was 58 per 1,000 lives births, and in 2007 was 30 per 1,000 live births; 27 per 1,000 live births in urban areas and 32 per 1,000 live births in rural areas (16, 17). The infant mortality rate in 1989 was reported to be 45 per 1,000 live births, decreasing to 25 per 1,000 live births in 2007 (16, 17). The most recent, and first ever Vanuatu Demographic and Health Survey (VDHS) in 2013, reported the under 5 year old mortality rate was 31 per 1,000 live births, and the infant mortality rate was 28 per 1,000 live births, although these statistics are not comparable to the 2007 rate as different methods were used to generate the 2007 rates (18).

There remains a substantial burden of undernutrition in Vanuatu, largely unrecognised because of the abundance of fresh food. Children are not hungry, yet diets often do not have

sufficient diversity or micronutrient content to support the high growth needs of children. Compounding the problem is the introduction of cheap energy-dense foods high in carbohydrates and low in nutrient content (19). Inadequate WASH with high exposure to common child infectious diseases, such as diarrhoeal diseases, worsen the problem of undernutrition. In 1996 the prevalence of underweight, stunted, and wasted children under five years of age in Vanuatu were 21%, 20%, and 6% respectively (16). Although there was a decrease in the prevalence of underweight and wasted children, the prevalence of stunting increased between 1996 and 2013 to 28% (18).

Water and sanitation

Access to improved water and sanitation has been increasing in Vanuatu. In 2012, 91% of the population was reported to have access to an improved water source, an increase from 71% in 2000 (2). However, access was lower in rural areas at 88%, with 17% having access to piped water on premises, and the majority of improved water sources being protected springs or wells, public standpipes, boreholes, or rainwater (2). Furthermore, in rural areas, 8% of people still used surface water as their primary drinking water source (2). Progress on improved sanitation is particularly poor. As of 2012, just 58% of the total population had access to improved sanitation facilities (2). Although this has increased from 42% in 2000, it improved by 2% between 2010 and 2012. Additionally in rural areas 55% had access to improved sanitation facilities and 2% still reported open defecation (2).

The lack of sanitation facilities in Vanuatu is somewhat surprising, considering that UNICEF Pacific carried out a rural sanitation project in the late 1980s and early 1990s, with the main goal of increasing the use of ventilated improved pit (VIP) latrines from 12% to 65% (20). VIP latrines are pit latrines altered to include a vent pipe from the pit to outside with a fly screen, trapping flies into the pit and reducing odours in the latrine that may attract flies (refer to sanitation section for more detailed description). The project included the provision of materials to construct the latrines and media and education campaigns. However, political upheaval and restructuring in the 1990s led to a lack of political will and funding for the project and its workers ceased. The project was terminated by UNICEF in 2001. In 2001 it was reported that 60% of the toilets that had been constructed since 1988 were functioning poorly or not functioning at all (20). An evaluation of the outputs of the project on Tanna

specifically, found a contributing factor to the lack of VIP latrines use was inadequate knowledge around construction and maintenance (20). This exemplifies the need for continued training and maintenance support for WASH interventions.

In response to international focus on water, hygiene and sanitation as basic human rights and for improving health outcomes, spurred by the MDGs and the United Nation's 'International Decade for Action: Water for Life,' water and sanitation were on the government of Vanuatu's agenda in 2013. The provision of better basic services in rural areas was a government priority, with a goal of increasing the proportion of households with an improved drinking water source and an improved sanitation facility to 84% and 64% respectively by 2015 (16). Although this goal for improved drinking water has been reached, according to the most recent estimates the sanitation goal has still not been achieved. Additionally there are pockets in rural Vanuatu that have substantially less access to improved water and sanitation.

Tanna island

The island of Tanna is located in the Tafea province, south east of the main island Efate. At the last census in 2009 Tanna had a population of 29,000, with a Melanesian majority (9). Although it is the largest island in the province and contains the provincial administrative capital, Isangel, it is just 40 km long and 19 km wide (9). Despite the small size, geographically close villages are very isolated from one another due to poor, or no road access and mountainous terrain.

The people of Tanna are more traditional in their lifestyle, beliefs and customs than the majority of Vanuatu's populated islands. Although this is largely a product of the spatial isolation of communities, active cultural resistance to western ways can be traced to back to the 19th century when missionaries and traders arrived in Tanna. Following World War One, and the exposure to western technology, many so called 'cargo cults' emerged in Tanna. Cargo cults, which surfaced in many Melanesian islands after colonization, derive from the belief that ritualistic acts will lead to the bequeathing of material wealth (21). The largest, and still very active cargo cult in Tanna is the John Frum cargo cult, which actively bans western technology, in the belief that this will one day be bestowed upon them. Later, in the

1970s a secessionist movement arose and declared Tanna as an independent nation in March 1974, suppressed by the British-French Condominium three months later. Again, in January 1980 the secessionist movement declared the Tafea Province a nation, although later in the year it became apart of the newly independent nation of Vanuatu.

The Ni-Vanuatu of Tanna practice subsistence agriculture. Buildings and facilities are made from local materials. Many families make an income selling produce, kava, coffee, and coconuts. Tourism is also increasing due to the attractions of the active volcano, Mt Yasur and the 'kastom village experience', where locals provide tours to some of the most traditional villages on Tanna. Although opportunities for cash incomes are increasing in Tanna, poverty of opportunity is very apparent. The isolation of villages and the lack of transport limits access to services, such as health care and education. There is a single hospital on the island staffed by one doctor, and a number of aid posts and dispensaries located in rural areas, mostly staffed by community health workers with informal training. There are a number of primary schools on Tanna, which are commonly under-resourced (22). There are also secondary schools on the island, all which require families to pay school fees.

1.3 Project Context

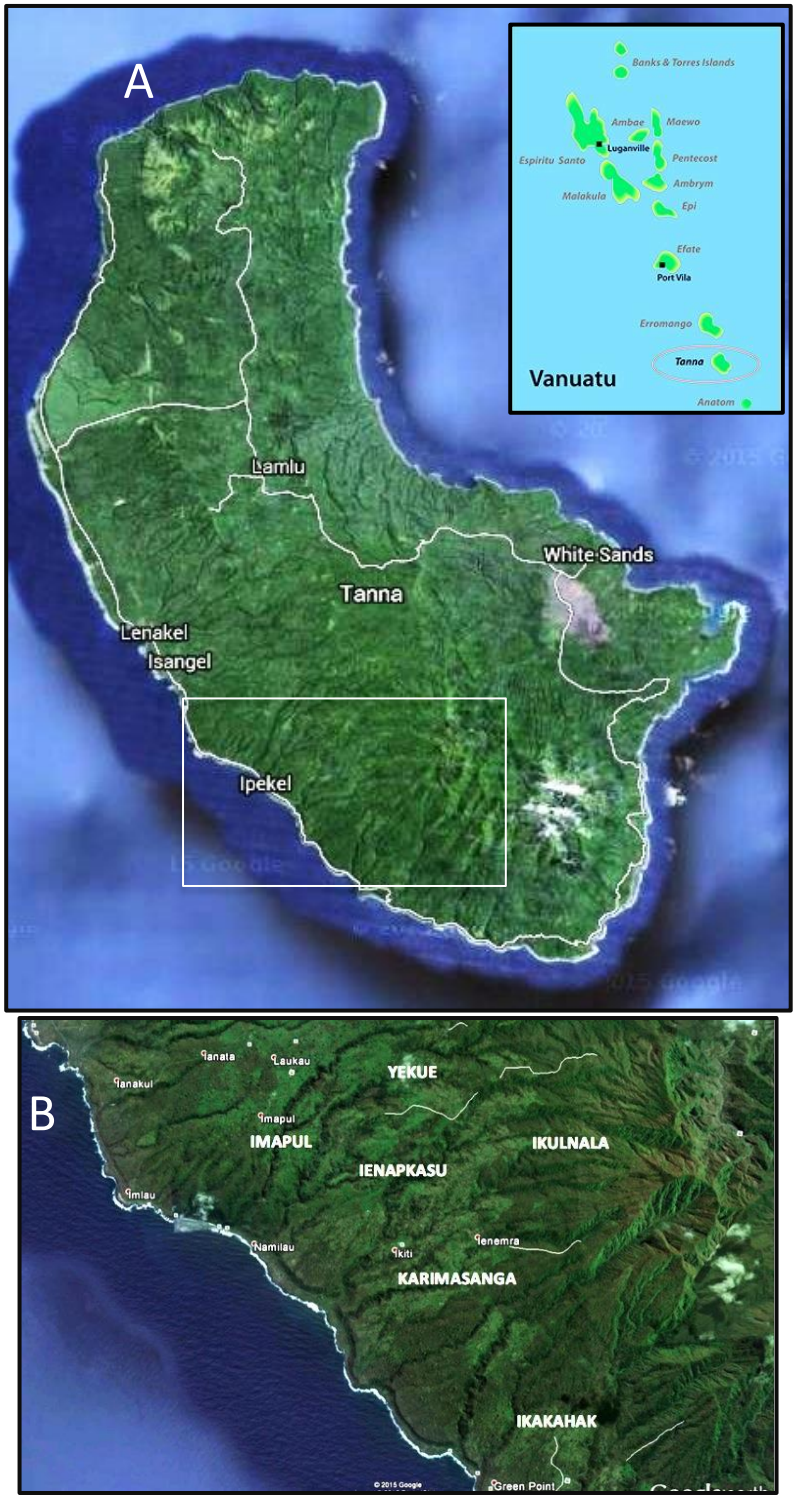
Many institutions, such as governments and non- government organisations (NGOs) have implemented strategies for improving WASH indicators to fulfill international commitments. One such strategy being carried out in Vanuatu is the Integrated WASH Project, hereafter referred to as the Project, developed by World Vision New Zealand. This three year Project was being implemented by World Vision Vanuatu on the islands of Tanna and Santo, with funding from the New Zealand Aid Programme of the New Zealand Ministry of Foreign Affairs and Trade. Implementation was originally planned for 2013–2015. However, due to the devastation caused by Cyclone Pam in March 2015, project implementation was extended to June 2016.

Within Tanna, communities in the south west of the island were identified to World Vision by the Rural Water Supply Office as being an area of particularly high need. Additionally, a

separate World Vision project in close proximity to the proposed area showed high levels of undernutrition in children under 5 years, with a 46% prevalence of stunting compared to a national average of 20% in 2011 (23). Villages in the Project area are without electricity or cell phone reception. The villagers live in thatched houses built from local materials and cook on indoor open fires. The society, like the majority of Vanuatu, remains patriarchal. Women's responsibilities are mainly looking after the household, the children, and selling produce at the local market. Men's responsibilities are to attend meetings and make decisions. The chief is the leader of the community, and disputes are handled with village meetings, with punishments, such as confiscation of pigs and kava, handed down by the chief without outside involvement (Personal Communication, World Vision Tanna Team, January 2015).

The Project began implementation in January 2013, in five rural communities within this area. Figure 2 shows the location of Tanna in relation to the other main island of Vanuatu and the Project communities in relation to the island's largest settlement, Lenakel. Each of the communities has between two and nine villages. Late in 2013 one large village in the Yekue community, Ienapek, pulled out of the project, and, after consultation with chiefs and community leaders, this was replaced with a separate community, Imapul. Therefore, from the beginning of 2014, the Project area consisted of six communities, with a population of around 2,241 (11, 24).

Figure 2: Map of Tanna, Vanuatu and World Vision WASH Project area



A: Tanna with square showing Project area. **B**: Project area showing six Project communities. Maps are from Google Earth. B is edited to include communities from information provided by World Vision

The overarching goal and long-, medium-, and short-term outcomes of the Project were as follows:

Goal:

Reduce child malnutrition.

Long-term outcome:

Healthier children and families.

Medium-term outcome:

Improve WASH and nutrition infrastructure, behaviors, and practices.

Short-term outcomes:

Improve local WASH governance (WASH Management Committees); Increase health, WASH and nutrition knowledge; and Increase access to toilets and clean water.

The underlying strategy of the project was a participatory approach, whereby Project beneficiaries were involved in all aspects of the project from planning to implementation and monitoring. This approach has the advantage of encouraging community ownership of development, WASH infrastructure, and health outcomes (13). This participatory strategy is particularly important in communities that follow traditional lifestyles where any suggestion of foreign governance is viewed as undermining the chief's power. Former WASH projects in the area have reportedly failed due to lack of consultation with chiefs, resulting in the sabotage of pipes carrying water to villages (11). The participatory strategy used to encourage community involvement and ownership was participatory hygiene and sanitation transformation (PHAST) training, resulting in two specific outputs: the setting up of WASH management committees (WMCs) and the development of community action plans (CAPs).

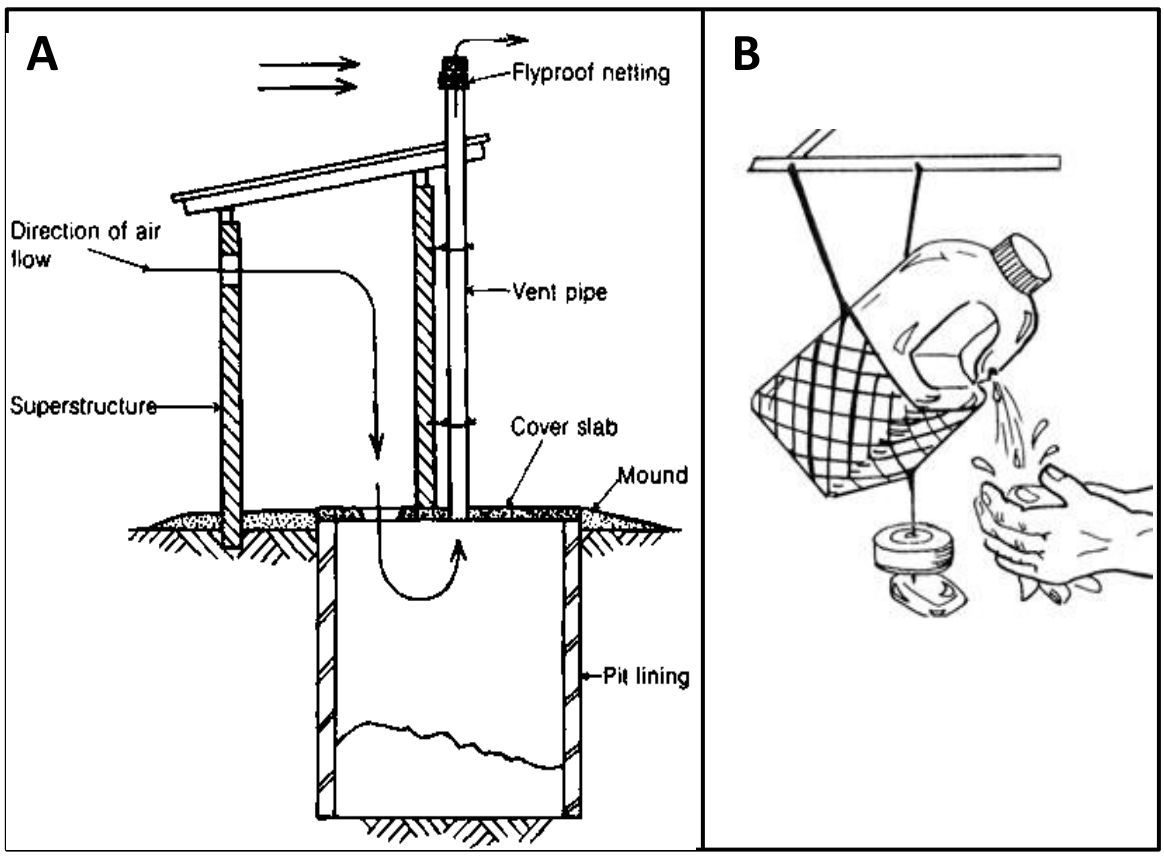
The PHAST approach, developed by WHO and the United Nations Development Programme (UNDP)-World Bank Water and Sanitation Program, is based around the understanding that an enduring change in behavior will only occur when people fully appreciate reasons for the change (25). It involves using participatory tools to educate the community on sanitation and

hygiene, such as drama, calendars, community mapping, and investigative tools like pocket charts to tabulate where people defecate and collect water (25). Communities then develop their own priorities and solutions based on their knowledge and consensus of which solutions work best in their own community. Training beyond PHAST activities also took place on broader subject matter including health, nutrition, hygiene, and boiling drinking water before use.

Establishing committees in charge of WASH related activities in each community furthers community ownership of the Project. Committee members were elected by their communities and the involvement of women was strongly encouraged. In addition to PHAST and subject matter trainings in local communities, WMC training took place regularly at the World Vision office in Lenakel, where committee members were trained in more detail in WASH and nutrition topics including construction, maintenance, and monitoring. Each member of a committee had a specific role, which varied between committees. Roles included a chairperson, secretary, treasurer, hygiene officer, nutrition and health officer, water officer, chief representative, church representative, and youth representative. Along with WMCs, CAPs were another output from the PHAST training. The CAPs were established by the communities from the priorities and solutions identified, and were intended to be regularly updated as solutions were put into practice and new priorities were defined. The primary responsibility of WMCs are to provide a local governance system to promote WASH changes in the community in accordance with their CAP.

Once PHAST training was completed, CAPs established and WMCs set up, World Vision and the WMCs worked together jointly to install WASH infrastructure, including VIP latrines (Figure 3A), hand washing facilities beside each latrine (Figure 3B), and gravity fed water systems. Communities were responsible for providing the materials for a cement floor and shelter for latrines, while World Vision provided vent pipes, slab frames, and mesh wire. The particular hand washing facility encouraged by the project was tippy-taps: a low cost option which uses a container suspended by string or on a branch, with a hand operated lever,

Figure 3: Sanitation and hygiene infrastructure used in the World Vision WASH Project in Tanna Vanuatu.



A: Ventilated improved pit (VIP) latrine (26). **B**: Tippy tap for hand washing (27)

A gravity fed water system is a piped water supply where the source (river, stream, or spring) is upland from the tap and is delivered via gravity (28). In the Project the water systems were planned for implementation from 2015–2016, and were not implemented at the time of the end of second year evaluation. Proposed gravity fed sources for the Project were springs with spring collection structure called a spring box. A spring box consists of a

protective structure, made of concrete, galvanized steel, or masonry, that collects spring water and protects it from contamination by leaves, debris, animals, and other matter and thus provides a source of protected ground water (29). Gravity fed systems may also include a community water treatment step, such as sedimentation or filtration. However, as the water source utilized in the Project is protected groundwater, this was deemed unnecessary in south west Tanna.

In order to allow for monitoring and evaluation of the Project, a baseline evaluation was carried out in April 2013 by World Vision. This aimed to assess the child health and nutrition status, and WASH and nutrition knowledge, behaviors, and facilities, before project activities began. This was followed by a review at the end of the first completed year of the Project, January 2014, tracking a number of Project indicators for each of the Project outcomes, described on Table 2. Activities of the Project by year are summarised on Figure 4.

Table 2: Outcomes and monitoring indicators for the World Vision WASH Project in Tanna, Vanuatu 2013–2015

Outcomes	Indicators	Comments
Long-term outcome: *Healthier children and families*	Proportion of children under five years of age who are underweight	
	Proportion of children under five years of age who are stunted	
	Proportion of children under five years of age who are wasted	Added in 2014
Medium-term outcome: *Improved hygiene, water, sanitation and nutrition infrastructure, behaviours, and practices*	Proportion of caregivers who know how to store water safely	
	Proportion of caregivers who's self reported water storage method is deemed to be safe.	
	Proportion of people with access and utilising an improved water source all year round	
	Proportion of people with access to and utilising an improved sanitation facilities	
	Proportion of households with a child/children under five who report at least one child with diarrhoea in the past month	Replaced by 2 week recall indicator in 2015
	Prevalence of diarrhoea in children under five years (defined as percentage of children aged 0–59 months who have suffered from a diarrhoea episode anytime in the past two weeks)	
	Proportion of children under 5 with diarrhoea who received effective treatment of diarrhoea	Added in 2014
Short-term outcomes: *1. Improved local governance*	Number of WASH committees established and meeting regularly	

(WASH committees and Provincial level)	Number of CAPs updated at least annually	
	Proportion of caregivers who can state 3 valid causes of diarrhoea	
Outcomes	**Indicators**	**Comments**
2. Increased knowledge of good hygiene, water, sanitation, health and nutrition practices	Proportion of households using safe water storage containers	
	Proportion of household with access to improved sanitation facilities (non-defecation) i.e. rubbish pits	
	Proportion of children receiving minimum dietary diversity (i.e. children receiving food from each of the 3 food groups during the previous day)	
	Number of people provided with access to new/improved sanitation facilities	
3. Increased access to toilets and clean water	Number of people provided with access to new/improved drinking water sources	

Figure 4: Year of implementation and corresponding activities of the World Vision WASH Project, in Tanna, Vanuatu

Activity	2013										2014										2015*									
	Jan									Dec	Jan									Dec	Jan									Dec
IMPLEMENTATION YEAR ONE																														
Preparation, consultation																														
Baseline study																														
PHAST** training																														
CAPs*** formulated,																														
WMCs† established and trained																														
End of year one study																														
IMPLEMENTATION YEAR TWO																														
VIP‡ maerials delivered to communities																														
WMC† training																														
Refresher training																														
Planning and building VIPs‡ and Tippy Taps overseen by WMCs†																														
End of second year Evaluation																														
IMPLEMENTATION YEAR THREE																														
Construction of gravity fed systems																														
Refresher training																														

* Project was extended into 2016 after Cyclone Pam, March 2015. Although specific activities of this year are unknown, they likely include construction of gravity fed systems that may have been post-poned due to rebuilding houses, and sanitation and hygiene facilities.

** PHAST = Participatory Hygiene and Sanitation Transformation.

***CAPs = Community Action Plans.

† WMC = WASH Management Committee.

‡ VIP = Ventilated Improved Pit latrine.

The study described in this thesis reports the end of second year evaluation, January 2015, and aimed to be an accurate assessment of the health status of the children in the Project area. The project looked at the WASH infrastructure available to the population; the WASH knowledge of caregivers with young children, and WASH and nutrition practices. In addition, in preparation for the establishment of gravity fed water systems to commence later in 2015, a review of the current sources of drinking water was undertaken, including their microbiological safety. A comparison of outcomes measured at baseline, end of year one to our 2015 evaluation was conducted to track progress on Project indicators. However, due to methodological issues in some measures carried out in baseline and first year, we limited this comparison to indicators able to give us accurate and meaningful comparisons.

The next chapter outlines the literature on WASH related diseases and WASH interventions. This is followed by the evaluation methods used, and the key results from the study, including: outcomes of interest related to Table 2; a comparison of these outcomes to previous years; and analysis of relationships between WASH behaviours, water microbiological quality, and child health outcomes. Chapter 10 outlines our key findings in comparison to the existing literature, and gives recommendations to World Vision for the final year of Project implementation.

Chapter two - Literature Review

In this literature review I firstly describe WASH related diseases, the global impact of theses disease, the Vanuatu-specific impact, and the burden of these disease that can be attributed to failures in WASH. I then go on to describe and analyse WASH and nutrition interventions relevant to the scope of this study. A number of systematic reviews and meta-analysis have investigated the health and environmental impact of these interventions, individually, and in combination. For the purpose of obtaining the most up to date information, I limited my search of intervention studies to those published post MDG commencement in the year 2000, which marks an increase in the attention given to improving water and sanitation. Search engines used were Google Scholar and PubMed. Where possible, studies from LMIC were used, which are more relevant to the Vanuatu context than studies from high-income countries. Preference was given to the results reported in systematic reviews and meta-analyses, particularly Cochrane reviews, followed by well-conducted randomised control trials (RCTs) and other intervention studies. Due to the nature of WASH interventions it is often impossible to blind participants or researchers to intervention status or randomize participants. This is an inherent limitation of these intervention studies, which only some researchers controlled for.

2.1 WASH related disease pathways

A lack of improved water and sanitation, and good hygiene can impact human health via interrelated pathways. Improving one or more of these components could reduce the incidence of a range of diseases, both directly, through reducing transmission of pathogens causing diarrhoea; and indirectly, by reducing environmental contamination and improving nutrient absorption (30, 31). Although the transmission pathways for WASH related diseases are connected, interventions differ (32). This section will consider how WASH components are related, and how they may prevent disease.

Drinking or having skin contact with microbiologically unsafe drinking water can cause disease via a number of ways. In particular, water-borne diseases from the ingestion of water contaminated with pathogens from human or animal excreta, or ingestion of food washed or irrigated by this water is associated with a higher risk of enteric infections (33). Additionally a lack of water, whether microbiologically safe or unsafe can lead to water-washed diseases typically caused by low infectious dose pathogens, such as many *Shigella* species (spp) and Norovirus. Water-washed diseases can be overcome by having access to adequate volumes of water for personal hygiene. Water-washed disease are those that favor poor hygiene practices (33). Organisms entering the skin through skin contact with contaminated water cause water-based diseases. Causes of water-related infections were first classified by David Bradley in 1972 and are summarized with examples in Table 1.

Table 3: Classification of water-related diseases (34)

Category of disease	Description	Examples
Water-borne	Ingestion of water containing pathogens from human or animal excreta	Cholera, typhoid, dysenteries and other diarrhoeal diseases
Water-washed	Caused by poor personal hygiene. Majority of water-borne diseases with a low infectious dose can also be water-washed	Trachoma, scabies, *Shigella*
Water-based	Caused by parasites living in aquatic intermediate organisms, such as snails	Schistosomiasis, dracunculiasis, guinea worm
Water-related insect vector	Transmitted via insect vectors that breed in water	Malaria, dengue, yellow fever, trypanosomiasis

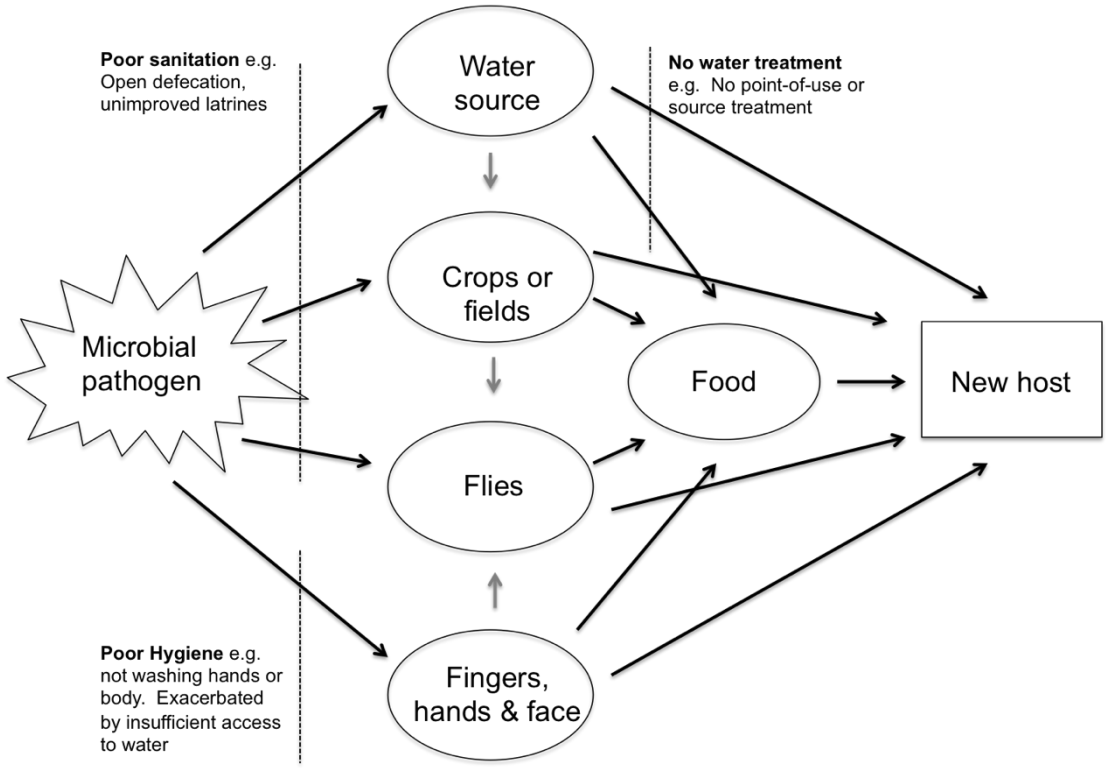
Since this first classification, these definitions have been expanded to include infections that are more closely related to hygiene and sanitation, and non-microbiological water-related diseases. When estimating the burden of disease from WASH components, Prüss-Ustün et al included additional categories (35). Firstly, transmission caused by poor personal, domestic, or agricultural hygiene, and secondly, transmission through contaminated aerosols from inadequate water systems (35). Furthermore, there are other non-microbiological determinants of water quality that can cause ill health. These are chemical mediated

diseases, which are caused by naturally high levels of compounds such as arsenic and fluoride (36, 37).

The majority of categories of water-related diseases defined here were relevant to the experiences of our study population. This includes chemically mediated diseases as Tanna has an active volcano, which spills ash into open water reservoirs, potentially leading to an increase in heavy metals and an increase in the microbiological load as a result of turbidity (38). Any issues with geologic fluorosis or arsenic on Tanna was unknown and not investigated in our evaluation. Therefore, for the purpose of this study we will focus on the following categories: water-borne diseases; water-washed diseases; and diseases caused by poor personal, domestic or agricultural hygiene. These diseases are not mutually exclusive, with many able to be spread via multiple pathways.

Faecal-oral diseases dominate the negative health outcomes from poor WASH behaviours, practices and facilities (39). Figure 5 illustrates faecal-oral interrelated transmission pathways due to inadequate WASH components. The microbiological contaminant enters the pathway via the faeces of humans or animals and can contaminate water supplies via poor sanitation facilities such as latrine run-off, and behaviors such as open defecation. The contaminated water may then cause disease when it is ingested, or when it is used to wash food for human consumption. Food crops and fields can also be contaminated by open defecation and latrine run-off, as well as through irrigation with contaminated water and using human faeces as fertiliser. This can cause disease via consumption of contaminated crops and direct contact with faeces. Flies can also be mechanical vectors, mediating the spread of diseases where infectious dose is low by landing on faeces, then landing on and contaminating food. This is a known pathway in the transmission of shigellosis (40).

Figure 5: Faecal-oral disease transmission pathways



Adapted from Wagner and Lanoix (41).

Poor personal hygiene promotes transmission of water-washed pathogens via fingers, hands, and face. Adequate hand washing requires a reliable water supply (1). Water insufficiency prevents hand washing with soap after direct contact with faeces, or other contaminants, promoting transmission to people, food, and drinking water from contaminated hands. Additionally, a lack of face washing increases the risk of trachoma and other eye-infections (1).

2.2 Water, sanitation, and hygiene diseases and attributable burden

This section will discuss the diseases commonly related to WASH and their burden in LMICs. As not all disease burden stems from inadequacies in WASH, we will discuss the burden that can be reasonably attributed to WASH. The focus will be on diseases that are clearly linked to WASH and relevant to the Vanuatu context, specifically: diarrhoeal diseases;

undernutrition; soil-transmitted helminth (STH) infections; environmental enteric dysfunction (EED); and trachoma.

2.2.1 Diarrhoeal diseases

Diarrhoeal diseases make up the majority of the disease burden associated with WASH components, and are caused by bacterial, viral, and parasitic aetiological agents. Diarrhoea is defined as the passage of three or more loose or liquid stools per 24 hours (42), and is usually a symptom of an infection in the intestinal tract. The contaminating organism is spread via the ingestion of contaminated drinking water or food, or from person-to-person as a result of poor hygiene. The 2013 Global Enteric Multicenter Study, a large case control study across seven countries in Africa and Asia, reported that moderate to severe diarrhoea cases in infants and young children were mostly attributable to rotavirus, *Cryptosporidium*, enterotoxigenic *Escherichia coli*, and *Shigella* spp (43).

Clinically, diarrhea can been classified as: acute diarrhoea, acute bloody diarrhoea, and persistent diarrhoea (42). The vast majority of global diarrhea illnesses are acute diarrhoea, lasting less than 14 days. Acute diarrhoea is a major public health problem, associated with two million deaths annually and mostly affecting children under five years of age in LMIC (44). Acute bloody diarrhoea, also called dysentery, occurs when the infecting organism damages the intestinal lining, causing an inflammatory immune response leading to fever, abdominal cramping, and intestinal wall edema and tissue damage. Acute bloody diarrhoea is defined as visible blood appearing the stools, and is often a result of infections from *Shigella* spp., *Entamoeba histolytica,* and *Salmonella enterica* (45).

Persistent diarrhoea is defined as diarrhea lasting 14 days or longer. Persistent diarrhoea both increases the likelihood of further episodes of diarrhoea by leaving the patient immunocompromised, and can result in undernutrition due to reduced nutrient absorption (46). Persistent diarrhoea results more often from bloody diarrhoea than non-bloody diarrhoea, and, although it accounts for fewer diarrhoeal episodes, it is disproportionately associated with diarrhoea mortality (46). Among children in LMIC, enteroaggregative and enteropathogenic *E. coli* are the most commonly implicated bacterial pathogens in

persistent diarrhoea (47). The parasites *Giardia* and *Cryptosporidium* are also commonly implicated (47).

Diarrhoeal disease is second to pneumonia as a leading single cause of mortality in children one to five years of age, causing 558, 000 deaths in this age group in 2013 (3). Globally there are around 1.7 billion cases of diarrhoea each year, killing 760,000 children under five years of age (42). Mortality from diarrhea has decreased globally, reflecting decreases in all cause child mortality. Likely contributors to the decrease in diarrhoea mortality include improvements in case management, and reduced exposure to enteric pathogens by improving WASH (42). The majority of deaths from diarrhoea occur as a result of dehydration due to water and electrolyte loss. These deaths are easily preventable by administering a rehydration therapy, such as oral rehydration salts (ORS) solution, a mixture of clean water, salt, and sugar. Zinc supplements can also reduce the duration of a diarrhoea episode by 25% (42). In Vanuatu, it is estimated diarrhoea is associated with 6% of all deaths in children and infants under five years of age (48).

2.2.2 Undernutrition

Undernutrition is an important indicator for monitoring the nutritional status of populations and is generally defined as the outcome of nutrient deficiency resulting from a poor diet or infectious diseases. Young children are at the greatest risk of undernutrition, and are also the most vulnerable to the effects of undernutrition's synergistic relationship with other diseases (49).

Many determinants of health contribute to undernutrition (49) illustrated by Figure 6. Poverty, often due the political and economic context of the geographical region, is one determinant strongly linked to undernutrition through household food insecurity, poor maternal nutrition, low parental education, unhealthy environments, and lack of available health care. These factors can lead to low birth-weight infants, inadequate breastfeeding and complementary feeding practices, and exposure to infectious diseases (49), causing inadequate dietary intake and/or disease.

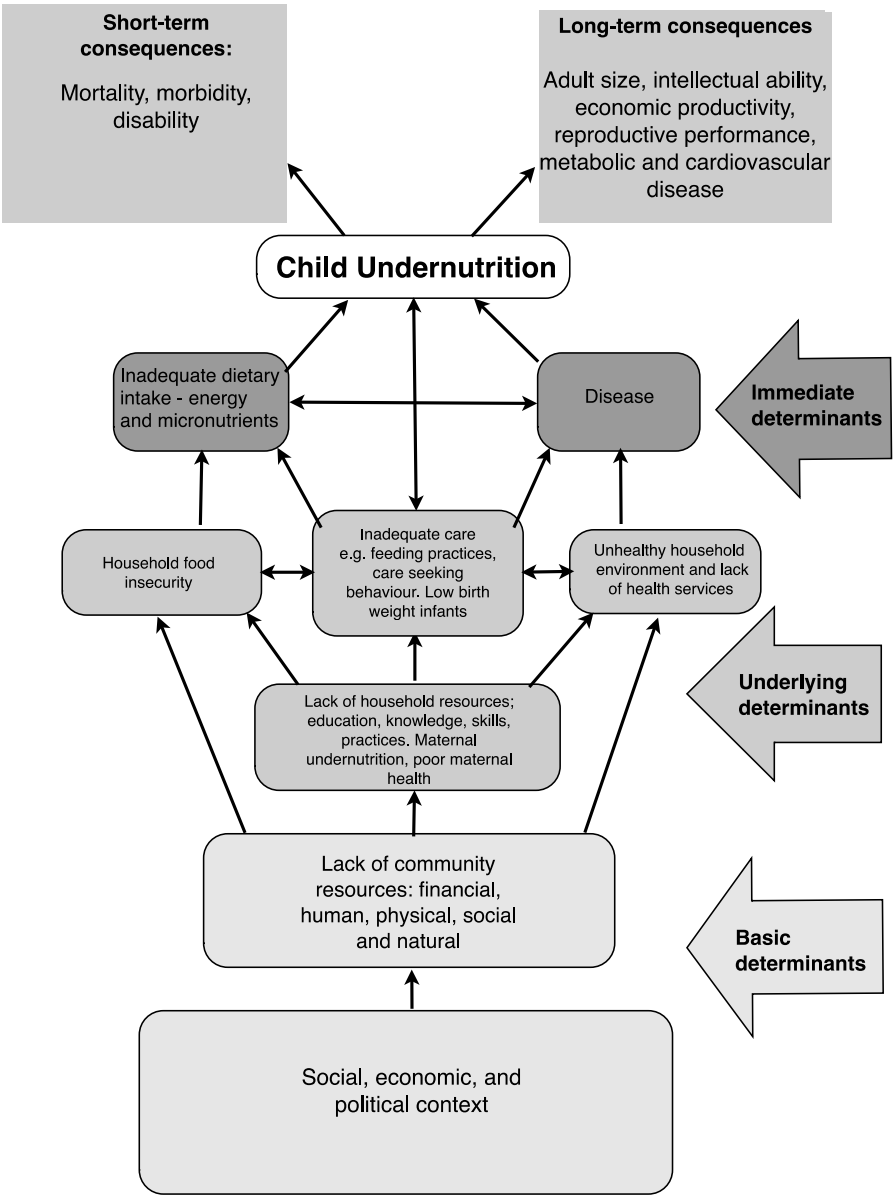
Reduced nutrient absorption is the direct cause of undernutrition. This can occur due to insufficient feeding; sufficient feeding but with inappropriate foods, such as those that are

micro or macronutrient deficient; or reduced ability to absorb food in the intestinal tract. Reduced absorption could be due to persistent diarrhoea, STH infections, or EED (see section 2.2.3). These latter causes can be mediated through poor WASH.

When undernutrition occurs, many normal physiological functions can fail. These include physical growth, immune function and disease recovery, and cognitive ability (50). This leaves individuals more susceptible to further infections, a reduced ability to learn, reduced mental and physical development, and low economic performance (49, 51). Children in their first two years of life are at particular risk of negative consequences. This is because of their high growth rate, which needs to be supported by adequate calories, protein, essential fats, vitamins, and minerals (49).

Typically, infants under six months of age being exclusively breastfed should not be at risk of undernutrition. Breastmilk contains all their nutrient intake requirements and exclusively breastfed infants should not be exposed to diarrhoeal diseases causing agents through the ingestion of contaminated food or water (52). However, many infants are given other fluids, which lack nutrients and may contain infectious agents. Optimally, breastfeeding is continued beyond six month of age to one or two years of age, with complementary feeding (53). However, even if breastfeeding is continued, complementary foods are often given in insufficient amounts, or lack nutritional content (54). The period, between six months and two years of age, when children are most at risk of undernutrition, is also the window of time where improvements in nutrition and WASH can be most effective in reversing any negative consequences. Interventions occurring after this window are believed to be limited in restoring full health (55).

Figure 6: Causes and consequences of undernutrition



Black et al's version of the UNICEF model of undernutrition (50). Adapted with permission by Dr Susan Jack (56).

To determine whether children are undernourished, anthropometric indices are used to ascertain weight-for-age, height-for-age, and weight-for-height. These are expressed as standard deviation units from the mean or median of the WHO international reference population, called Z-scores (57). A weight-for-height Z-score (WHZ) <-2 is classified as wasting, indicative of short-term inadequate nutrition, such as that caused by a diarrhoeal illness leading to inadequate intake and/or absorption of food (57). A height-for-age Z-score (HAZ) <-2 is classified as stunting. Stunting, when the child is not reaching their height potential, may indicate long-term inadequate nutrition (57). A weight-for-age Z-score (WAZ) <-2 is classified as underweight, and is a composite indicator of WHZ and HAZ. The WHO has provided a classification of undernutrition severity for countries or geographical areas according to the prevalence of each of stunting, underweight, and wasting (58). These ranges, shown on Table 4, are often used to guide public health decisions in populations. However, these ranges are from global surveillance data, and may not reflect severity relative to normal prevalence levels in populations (58).

Table 4: WHO classification of undernutrition severity (58)

Indicator	Severity of undernutrition by prevalence ranges (%)			
	Low	Medium	High	Very high
Stunting	<20	20–29	30–39	≥40
Underweight	<10	10–19	20–29	≥30
Wasting	<5	5–9	10–14	≥15

Globally maternal and child undernutrition is estimated to be responsible for 3.5 million deaths, one third of all deaths in children under five years of age, and 11% of disability adjusted life years (DALYs) (50). Around 90% of the burden from undernutrition occurs in just 36 countries, with the highest prevalence in South Asia (50). In 2005, 20% of children under five years of age in developing countries were underweight, 32% were stunted and 3.5% were wasted. The Vanuatu national prevalences of undernutrition reported from the 2013 VDHS were 10.7%, 28.8%, and 4.4% of underweight, stunted, and wasted children under five years of age respectively (Table 5) (18). However, excluding households in, or within easy access to, the largest urban areas Port Vila and Luganville, the prevalence was

13% underweight, 31.9% stunted and 5.3% wasted in children under 5 years of age (Table 5) (18).

Table 5: Vanuatu Prevalences of undernutrition from the 2013 Vanuatu Demographic and Health Survey

Anthropometry indicator	Total	Lowest wealth quintile	'Rural 2'
Stunting (<-2z)	28.5	39.4	31.9
Wasting (<-2z)	4.4	1.9	5.3
Underweight (<-2z)	10.7	11.9	13.0

2.2.3 Environmental enteric dysfunction (EED)

Environmental enteric dysfunction, also called tropical enteropathy and environmental enteropathy, is a subclinical condition rising from constant exposure to microbes within faecal matter, resulting in sustained inflammation and structural changes to the small bowel including villi blunting and crypt hyperplasia (59). Functional changes follow, including increased gut permeability, impaired gut immune function, and malabsorption (59). Although EED itself is largely asymptomatic (59), it has been proposed as the missing link between poor sanitation and hygiene, and undernutrition, specifically stunting (60, 61). Additionally, it is also thought to explain, at least in part, why oral vaccines such as the rotavirus vaccine and polio vaccine exhibit reduced efficacy in LMIC (62-64).

Although EED has been described since the 1950s and 1960s in the tropics, and been the focus of several expert opinion panels (65, 66), there is no published consensus case definition, principal causes, or disease severity indicators (67). Like other enteric diseases, such as celiac disease and Crohn's disease, EED is thought to develop from uninhibited T cell activation in the small intestine, leading to activation of an inflammatory immune response with the production of inflammatory cytokines such as Immunoglobulin G (IgG) (60). The resulting inflammation of the small intestine leads to increased permeability, allowing translocation of antigens into the lumen, exacerbating immune cell stimulation and systemic responses. In the case of EED, the immune cells are thought to be stimulated by persistently high concentrations of ingested faecal bacteria (68). At has been postulated that chronic systemic responses caused by EED could lead to growth hormone resistance in children (69).

Although there is agreement that high environmental contamination and ingestion of faecal bacteria are likely involved in disease progression, it is unclear how much diet contributes. In a recently described murine model of EED, both high exposure to microbes, including commensal bacteria and *E. coli*, and a poor diet was required for the murine small intestine to resemble EED (70). Furthermore zinc and vitamin A deficiencies have been associated with abnormal gut function (71, 72).

Diagnoses of EED is usually based on dual sugar absorption tests; usually the lactulose:mannitol (L:M) test (73). Lactulose is a large sugar not normally absorbed by the small intestine, whereas mannitol, a smaller sugar, is absorbed by the normal gut. After an oral dose, mannitol in the urine relates to absorptive capacity, and lactulose in the urine represents impaired gut permeability. Higher ratios of L:M indicates poor gut function (73). Faecal markers of EED have also been used in recent studies (64, 74), and include neopterin, myeloperoxidase, and alpha-1-antitrypsin (74).

A study by Lunn et al in the Gambia found the L:M ratio explained 39% of ponderal growth (weight for height/length), and 43% of linear growth in children two to fifteen months of age (75). In the same children they did not find an association between diarrhoea and growth failure, or dietary inadequacy and growth failure (75). Additionally, Lunn et al carried out a follow up longitudinal study looking at EED markers of increased levels of the pro-inflammatory antibody IgG and IgG-endotoxin-core-antibody (EndoCAB) in Gambian infants. EndoCAB indicates IgG from immune responses stimulated by Gram negative, probably faecal, bacteria. At two months of age levels of IgG and EndoCAB, as well as anthropometric indices and L:M urine concentrations, were similar to normal values of children from the United Kingdom (UK). By 15 months of age, children had two-fold and five-fold higher IgG and EndoCAB concentrations than UK children of the same age; increased L:M concentration, where in UK children it decreased; and lower HAZ and WAZ scores (68).

Ingesting high concentrations of faecal bacteria can result from living in a highly contaminated environment. Recent cross-sectional and cohort studies have found associations between levels of WASH and risk of EED in children (74, 76). Lin et al, 2013 found Bangladeshi children under 48 months of age living in households with improved water, sanitation, and handwashing facilities had higher HAZ scores and lower L:M ratios,

meaning decreased gut permeability, than children in households with poor water quality and a lack of infrastructure (76). In 2015 George et al found Bangladeshi children with animal enclosures in their sleeping room had elevated faecal markers of EED and higher odds of stunting (74).

In the 1960s studies of expatriates, migrants, and Peace Corps volunteers in LMIC with EED, showed EED resolved after stays of one to two years in the United States or Europe (77, 78). This suggests EED is reversible if exposure to highly contaminated environments ceases. Therefore, good personal and domestic hygiene, access to sanitation facilities and safe water could be effective at reducing EED by reducing environmental contamination. However, this resolution has not yet been investigated in an intervention study.

Much remains unknown about EED, including its prevalence in LMIC (59). In the Gambian study an abnormal L:M test was present in almost all infants by the end of the study (75). There is also a lack of knowledge of biomarkers for more specific identification and in identifying children at risk (59). Future studies may elucidate some of these unknowns, such as the Etiology, Risk Factors and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development (MAL-ED) study, which is a birth cohort study currently being conducted in eight LMIC (67).

2.2.4 Soil-transmitted helminth (STH) infections – ascariasis, trichuriasis, hookworm

Soil transmitted helmith (STH) infections are among the most common infections globally, affecting over 1 billion people. The vast majority of infections occur in developing countries, although infections do occur in immunocompromised populations in developed countries (79). Parasitic species can cause infections in places where sanitation and hygiene practices are poor and eggs present in human faeces can contaminate soil or water. Of particular importance for humans are ascariasis, trichuriasis, and hookworm infection (79). As these three leading STH infections have the same risk factors, notably poor sanitation and hygiene practices, as well as warm, humid climates, it is common for children in developing countries to be chronically infected with all three. Consequences of STH infections may include undernutrition, stunting, and cognitive and learning defects (80).

Ascariasis is caused by the parasitic roundworm *Ascaris lumbricoides*, and is spread via the ingestion of food or water contaminated by faeces containing *Ascaris* eggs. It is reported to infect between 800 million and 1.2 billion people globally (81). The eggs hatch in the intestine, migrate to the lungs, are coughed up and swallowed. Once back in the intestine they become adult worms. While the majority of infections are asymptomatic, around 8–15% of infected people experience morbidity linked to how many worms are present and the immune status of the host. Acute symptoms include lung inflammation, difficulty breathing and fever; while chronic ascariasis symptoms include abdominal distention, pain, nausea, and diarrhoea (82). In more extreme cases entangled worms can cause intestinal obstruction necessitating removal of sections of the intestine. Additionally, ascariaisis can lead to undernutrition via malabsorption and appetite loss (82).

Trichuriasis, also known as whipworm infection, is caused by *Trichuris trichiura*, and, like aschariasis, is spread via ingestion of *Trichuris* eggs, through food, water, or dirty hands. Between 600 and 800 million people are infected globally, with the highest prevalence in tropical areas with poor sanitation, especially where open defecation is commonly practiced (83). The worm lives in the large intestine, and although lightly infected individuals will show no symptoms, more heavily infected individuals can present with abdominal pain, abdominal distention, and frequent, painful passage of stools, often with blood or mucus (83). Long-term consequences of serious infections in children include severe anemia, growth retardation and impaired cognitive development (83).

Hookworm infections in humans are most often caused by the species *Ancylosoma duodenale* and *Necator americanus.* Like ascariasis and trichuriasis, hookworm eggs are passed in the faeces of infected individuals, contaminating the environment where sanitation practices are poor. However, hookworm eggs mature and hatch in the environment, releasing larvae that can penetrate the skin of humans. Thus, infection is most often spread through walking barefoot on contaminated soil. In addition, *Ancylosoma duodenale* larvae can cause disease via ingestion. Once the larvae have penetrated into the human host, they migrate to the lungs via blood vessels. In the lungs they ascend to the pharynx and are swallowed. The larvae mature to adults in the small intestine, where they then attach to the intestinal wall. Between 550 and 750 million people are infected globally (84). Symptoms include itching at the site of penetration, abdominal pain, diarrhea, loss of

appetite, fatigue, and anemia, although people with light infections may have no symptoms. The most serious results of infection are anemia and protein deficiency caused by loss of blood when adult hookworms attach to the intestinal wall. The long-term consequences of iron and protein deficiency are growth and mental impairment (83).

Although hookworm infection is the most prevalent helminth infection reported in Oceania, with around 5.5 million cases, in Vanuatu the 88,000 cases of hookworm are second to trichuriais, which has an estimated 150,000 cases, compared to 59,000 cases of ascariasis (85). Ongoing control measures for hookworm infection, ascariasis, and trichuriasis include deworming with mass drug administration, health education, and improving sanitation (86). Mass drug administration is occurring in Vanuatu (87).

2.2.5 Trachoma

Trachoma is an eye infection caused by the bacteria *Chlamydia trachomatis*, and is the leading cause of preventable blindness from an infection (88). The infection is common in areas where hygiene practices are inadequate, especially when there is a limited access to water and health care (89). Infectious bacteria are easily transferred via direct contact on hands, shared clothing or towels, and flies landing on the face of an infected person.

Infection usually occurs in childhood, with a single infection resulting in a self-limiting conjunctivitis (88). However, repeated infections result in the gradual manifestation of disease, leading to scarring inside the eyelid. If left untreated the scarring contracts the eyelid, causing the lid to turn inwards and the eyelashes to scratch the cornea (88). The cornea can rapidly become damaged and opacification will occur. Once the cornea is opaque, irreversible blindness has occurred (88).

Trachoma can be avoided by adequate personal and household hygiene. However, for those with little access to water, water may be prioritized for other purposes (90). Improved WASH practices are a large part of the World Health Organisation (WHO)-endorsed strategy for control of trachoma, called the SAFE strategy. The SAFE strategy endorses simple, low-cost Surgery for patients with advanced disease; treatment with Antibiotics tetracycline or azithromycin; Facial cleanliness and Environmental improvement through better sanitation and water access (91, 92).

In 2011 active trachoma defined as severe conjunctival inflammation was estimated to affect 21 million people worldwide, with 2.2 million people blind or severely visually impaired as a result of the infection (93). A further 7.3 million people have trichiasis, the stage of trachoma where the eyelashes touch the cornea (93). The majority of trachoma cases occur in the poorest and most remote parts of Africa, the Middle East, and Asia (90). However, trachoma is also known to occur in the Western Pacific, including Papua New Guinea, Fiji, Vanuatu, the Solomon Islands, and in certain populations in Australia (85). The most recent data from 2009 suggests that within high risk communities in Vanuatu, Fiji, and the Solomon Islands, the prevalence of active trachoma in children aged one to nine years was 22-23%, and thus remains a public health concern (94).

2.2.6 Attributable Burden

Understanding the burden of disease that could be prevented if WASH conditions were improved is important for public health policy as it allows us to assess whether the WASH risk factor represents opportunity for substantial disease control (95). A number of researchers have investigated this by estimating the proportion of diseases that could be attributed to poor WASH collectively, and by WASH components. The majority of studies use comparative risk assessment methods, where knowledge of the proportion of people exposed to the risk factor, such as poor WASH, and the relative risk of disease from the exposure is necessary (5). The method estimates a proportional reduction in disease or death that would occur if the exposure was reduced to the level of minimum risk, while other conditions remain the same (5). Diarrhoea causes around 53% of the mortality and morbidity due to inadequate WASH and has sufficient evidence to obtain attributable fractions (1, 95). Thus the majority of studies investigating the WASH-attributable disease burden focus of diarrhoea.

The WHO Global Burden of Disease Study (GBD) is a comprehensive global collaboration programme assessing mortality and morbidity from major diseases, injuries and risk factors. Its preferred metric is DALYs, which incorporates the years of life lost due to premature mortality, and the years of life lived with a disability, weighted for severity (96). One such

risk factor is unimproved water and sanitation, where the disease outcome is 'diarrhoea' (broadly defined to include hookworm, ascariasis, trichuriasis and dracunculiasis) (96). The most recent GBD used estimates from 2010 and demonstrated a reduction in disease attributable to unimproved water and sanitation compared to the first GBD in 1990, from 6.8% to 0.9% of global DALYs (97). This reflects the global decrease in diarrhoeal disease, as well as a reduction in unimproved water and sanitation (97).

The number of deaths and DALYs, estimated by the GBD study, attributable to unimproved water and sanitation in 2010 was 337,000 deaths and 21,187,000 DALYs (97). However, estimates such as these have been criticized as there is substantial heterogeneity in the importance of water and sanitation as a risk factor between developed and developing countries (98). In sub-Saharan Africa for example, diarrhoea remains a leading killer, and water and sanitation remains one of the most important risk factors that may be underestimated in the GBD study.

A more recent estimate by Prüss-Ustün et al focuses specifically on LMIC, where data from 145 countries were combined (95). Estimates of death and disability attributable to inadequate WASH were higher than that estimated by the 2010 GBD study, but still much lower than estimates from earlier years. They estimated 37% of diarrhoea in LMIC was attributable to inadequate water sources alone in 2012, which equated to 502,000 deaths and 33,793,000 DALYs (95). Inadequate sanitation was estimated to contribute 19% of diarrhoea burden, and poor hand hygiene contributed 20%, although the hand hygiene effect size was not statistically significant (95). An estimated 58% of diarrhoea was attributed to a combined inadequate WASH risk factor in 2012, equating to 842, 000 deaths. When hand hygiene is not included in the estimate, inadequate water and sanitation attributed 685, 000 deaths (95).

Unlike the GBD estimates, Prüss-Ustün et al used a stricter definition of diarrhoea that did not capture hookworm, ascariasis, trichuriasis, and dracunculiasis. The fraction of these diseases attributed to inadequate WASH has been estimated via systematic reviews and expert opinion and is summarized on Table 6. Ascariasis, hookworm, trichuriasis, schistomiasis, and trachoma have all been estimated to be wholly attributable to inadequate

WASH, although together they only account for up to 7% of disease proportion preventable by WASH improvements (1, 99).

Table 6: Fraction (range) of specific diseases globally attributable to WASH

Not quantified at global level	0–33% attributable	33–66% attributable	66–100% attributable
Hepatitis A, E, F	Onchocerciasis	Lymphatic filariasis	Ascariasis
Legionellosis		Malaria	Hookworm
Scabies		Undernutrition and its consequences	Trichuriasis
Arsenicosis		Drowning	Dengue
Fluorosis			Schistomiasis
Methaemoglobinaemia			Japanese encephalitis
			Trachoma

Adapted from: Prüss-Ustün et al (2014) and Prüss-Ustün and Corvalán (95, 99)
Based on assessments combining systematic reviews and expert opinion

Estimates of attributable burden from the WASH risk factor underestimate morbidity and mortality by not including undernutrition as a further outcome, despite the fact undernutrition and its consequences contribute to around 36% of disease preventable by WASH improvements (1). The reason undernutrition is not included is due to inadequate information about the extent to which the risk of undernutrition is directly or indirectly due to poor WASH. However, one systematic review has estimated 50% of the burden from undernutrition is attributable to environmental factors, in particular water, sanitation, and hygiene (99). Poor WASH could therefore be attributable to an addition 860, 000 deaths due to undernutrition annually (100).

2.3 Water, sanitation, and hygiene interventions and their impact on health

Strategies to reduce the impact of inadequate WASH on health revolve around blocking one or more of the transmission pathways in Figure 5, ultimately preventing microbial pathogens, usually contained in faeces, contaminating susceptible individuals. The relationship between faecal-oral dose and probability of infection has been described as log-linear for many diseases, where a plateau of disease is reached in highly faecally contaminated environments (39). This has consequences on the effectiveness of interventions to reduce disease, where an intervention aimed to eliminate a single transmission pathway may have negligible impacts on disease prevalence if overall

environmental contamination is not substantially reduced. In another situation, the same intervention may have large impacts (39). Interventions are generally grouped into those focusing on: improving water quality or supply; improving sanitation, such latrine access and faecal disposal; and improving personal, domestic, or community hygiene.

2.3.1 Impacts of hygiene interventions

Good hygiene is a barrier to the spread of infectious diseases, leading to better health and wellbeing. Encouraging good hygiene can block pathways of infection, such as faecal-oral, person-to-person, food-borne, and animal-transmitted pathways (101). Hygiene interventions can involve education on personal, domestic, and community hygiene, or active promotion of hand washing with the provision of soap (102). Personal hygiene measures include keeping the body clean by washing hands and regular bathing. Domestic hygiene measures include keeping the household clean by cleaning floors, cleaning toilets, washing utensils after meals, and washing bedding. Community hygiene measures are those undertaken by the whole community, such as animal husbandry practices to keep animals away from the household (102).

Washing hands with soap is important to halt the spread of infectious diseases, and is important after contact with faecal matter through defecation or cleaning a child who has defecated, before preparing food, and before eating food (102). Washing hands after contact with faecal matter prevents pathogens reaching the household environment, and washing hands before food preparation and eating prevents their subsequent ingestion via food or water (103). Promoting handwashing is the most studied hygiene intervention. Systematic review and meta-analysis generally group all hygiene education interventions together.

A number of systematic reviews and meta-analysis have been published since the year 2000 reporting impacts of hygiene interventions on the health of the community (103-113). The majority of systematic reviews do not look exclusively at developing countries. Most reviews focus on diarrhoea as the health impact measure, and all conclude hygiene interventions have a protective impact on diarrhoea.

The most recent systematic review and meta-analysis by Freeman et al in 2014, reported all hygiene promotion interventions, including both handwashing promotion and general hygiene education, could reduce diarrhoea by 33% (95% CI:0.61–0.74) (103). This is a similar or slightly lower reduction than previous estimates. One previous review, which compared pooled impacts between less developed and developed countries, found interventions in less developed countries had a larger impact on health, with a 37% reduction in gastrointestinal illness compared to a 27% reduction in high income countries, although confidence intervals overlapped (95% CI: 0.53-0.82 and 0.58-0.92) (108).

Hygiene interventions generally rely on self-reported results, which are known to be biased (114-116). It is also usually impossible to blind participants to the intervention. Freeman et al, made adjustments to account for non-blinding using subjective health outcomes (19). After the adjustment, the pooled estimate of the reduction in diarrhoea decreased to 14%, which was not statistically significant (95% CI: 0.36-2.09).

All systematic reviews that compared the two general hygiene interventions, promoting handwashing with soap and general hygiene education, found promoting handwashing with soap consistently had a larger impact on diarrhoeal disease compared to general hygiene education (103, 108, 110, 113). Freeman et al, found studies with the intervention of promoting handwashing with soap could reduce diarrhoea by 40% (95% CI: 0.53-0.63). Adjusting for non-blinding reduced the impact of handwashing promotion to a 23% reduction in diarrhoea, which was not statistically significant (95% CI: 0.32-1.86). General hygiene education had a 24% reduction in diarrhoea (95% CI: 0.67-0.86), although when this was adjusted for non-blinding there was found to be no effect on diarrhoea (Adjusted effect estimate of 0.97, 95% CI: 0.40-2.36) (103).

Two systematic reviews have investigated hygiene interventions on respiratory illness (107, 108). One of these reviews included the three studies undertaken in LMIC. By pooling the results of these three studies, Aiello et al reported hand hygiene interventions could reduce respiratory illness by 37% (95% CI: 0.45-0.87) in LMICs. However, when the 13 studies from developed countries were included, this was reduced to 21% (95% CI: 0.66-0.95) (108). In a systematic review and meta-analysis Strunz et al investigated associations between hygiene components and STH infections (112). They found the odds of having a STH infection was

47% lower in households that had soap, or access to soap (95% CI: 0.29–0.98). They also found the odds of having a STH infection were 53% lower in participants who washed their hands after defecation (95% CI: 0.24–0.90). All studies included in these pooled estimates were observational studies, and thus represent lower quality evidence. However, all of the intervention studies they reviewed showed statistically significant reductions in one or more STH infections after some sort of hygiene education intervention (112).

2.3.2 Impact of sanitation interventions

Sanitation in public health encompasses services and facilities for safely disposing human waste, and may include garbage collection and wastewater disposal. Providing hygienic disposal of human faeces can interrupt a number of disease transmission pathways as shown on Figure 5. Having systems to dispose of human faeces reduces open defection and the amount of pathogen-containing faeces in the environment that can contaminate waterways where people collect water, agricultural systems where food is grown, and the soil people walk on. Some sanitation facilities can also prevent the spread of disease by vectors such as flies, by preventing them landing on faeces, or preventing exit once they have. The intervention most commonly implemented to deal with inadequate sanitation is the provision of latrines - providing a safe place for excreta disposal.

There are a number of different types of latrines that can be implemented in resource poor settings, such as: simple pit latrines; ventilated improved pit (VIP) latrines; Reed's odourless earth closet (ROEC); pour flush latrines; composting latrines; and aquaprivies (in order of increasing expense). The VIP latrine is an upgraded simple pit latrine. Like the simple pit latrine, it consists of a pit, at least 1.5 metres deep, lined with a material such as concrete blocks, bricks, or cement; a floor or slab to cover the pit, with a squat hole; and a shelter with a door for privacy (26). However, the VIP latrine has the addition of a vent pipe connecting the pit with the outside air. This acts to circulate air, reducing fly-attracting odours to the shelter (26). In addition, the vent pipe has a fly proof mesh on its top side, so if the shelter of the latrine is kept semi-dark, flies in the pit are attracted to the light from the vent pipe, cannot get out, and eventually die (26). Thus, VIP latrines have the advantage over simple pit latrines of removing odours and controlling flies, while remaining relatively cheap and easy to maintain (26).

Sewerage, the removal of human waste and household sullage through a sewer connection to a treatment plant or disposal point, is a high cost technology, involving water for flushing (117). It is usually reserved for urban situations when there is sufficient water and finance for operation and maintenance. A sewer system is much more convenient for the user and can remove large amounts of waste and sullage. However, its high capital cost makes it unrealistic in many resource-poor situations, particularly rural areas (117).

Improving sanitation, particularly by providing latrines, plausibly should have positive impacts on health, as exposure to faecal matter should substantially decrease. However, evidence of this health impact is lacking, and to date, any evidence of an effect is based on observational or poorly designed studies (118). Four systematic reviews or meta-anlayses have been conducted investigating the impact of improved sanitation on diarrhoea in LMIC since 2000 (110, 113, 119, 120). Further reviews looked at the impact of improved sanitation on trachoma and STH infections (112, 121-124). The most recent review by Wolf et al, concluded that interventions providing improved sanitation with no sewer from an unimproved baseline could reduce diarrhoea by 16% (95% CI: 0.77-0.91) (120). This pooled effect size included evidence from seven observational studies, one non-randomised control trial, and one before-after trial. Wolf et al, also reported interventions introducing a sewage connection from an unimproved baseline could reduce diarrhoea by 69% (95% CI: 0.27-0.36), although this was based on evidence from two studies, one of which was observational (120).

Based on Wolf et al's systematic review and meta-analysis it appears improved sanitation, such as VIP latrines, can improve child diarrhoea outcomes (120). This effect size is much greater when sewage-connection studies are included, with an overall reduction in diarrhoea of 28% (95% CI: 0.59-0.88) (120). Although none of the studies included in this meta-analysis were from randomized control trials (RCTs), it did include studies published in multiple settings, countries, and languages, which previous reviews lacked, and thus was the best pooled evidence available (120). In 2014 WHO updated its evidence for WASH interventions and reducing diarrhoea, using the results of Wolf et al's meta-analysis for sanitation interventions (101). However, sanitation systematic reviews and meta-analyses based on evidence from well-conducted epidemiological studies are still lacking.

In 2014 the findings of two additional RCTs on sanitation interventions became available. Both studies assessed the health impacts of India's Total Sanitation Campaign (TSC) that provided a subsidy for pour-flush latrines and latrine promotion. The first, by Patil et al, followed randomized villages from baseline in May 2009 until February 2011, after programme delivery. Although the TSC increased the proportion of latrines and reduced open defecation compared to the control group, there was no accompanying decrease in diarrhoea, highly credible gastrointestinal illness, parasitic infections, anemia, or child growth deficiencies (125). However, this study had a short follow up period, reasonably low uptake (41% uptake in intervention group versus 22% in the control group), and evidence of programme cross contamination. The second, and better-designed RCT of India's TSC, by Clasen et al, was conducted from May 2010 to December 2013. The intervention group received a latrine subsidy and promotion among 50 villages consisting of 4,586 households, and the control group of 50 villages consisting of 4,894 households. In the intervention group village-level latrine coverage increased from 9% to 63% over the course of the study, while the control group coverage increased from 8% to 12% (126). Over the three years of the study, there was no evidence of the intervention having an effect on diarrhoea prevalence in children under five years of age (PR: 0.97, 95% CI: 0.83-1.12), STH infections (PR: 0.97, 95% CI: 0.72-1.32), or mean weight-for-age Z-score (126). Clasen et al suggested the lack of observable change in disease may be due to continued open defecation practices despite access to latrines.

A recent RCT, published in November 2015, assessed a Community-led total sanitation (CLTS) programme implemented by the government of Mali between 2011 and 2015 (127). The study, by Pickering et al, found that there was no change the prevalence of diarrhoea in the 2365 children in intervention villages, compared to 2167 childen in control villages. Despite this, Pickering et al found that the prevalence ratio for stunting was 0.86, indicating that children in intervention villages were 14% less likely to be stunted (PR: 0.86, 95% CI: 0.74–1.00) (127). The authors concluded that increasing access to toilets may prevent growth failure via pathways other than diarrhoea, such as EED.

One systematic review that looked at sanitation effects on STH infections, namely ascariasis, trichuriasis, and hookworm, found that availability or use of latrines was associated with a lower odds of any STH infection (OR: 0.66, 95% CI: 0.57-0.76), ascariasis and trichuriasis in

particular (112). However, the quality of evidence of this meta-analysis is low due to the inclusion of observational studies, and it did not include the most recent RCT evidence from Clasen et al.

Although sanitation measures can plausibly introduce barriers in disease transmission pathways, there is currently insufficient evidence to support the impact of improved sanitation on health. This may be due to a high coverage of improved sanitation required to see health impacts. Additionally these health impacts may not be seen if the environment is still heavily faecally contaminated through other pathways, such as unimproved water sources. Future studies may also support the finding by Pickering et al that improved sanitation could halt growth decline in young children through EED rather than diarrhoea (127).

Despite uncertainties in health impacts, improved sanitation, as well as access to clean drinking water, has been declared as a basic human right, as it is essential to the promotion of human dignity (128). Thus there is a convincing argument that the lack of evidence for actual health impacts does not lessen the importance of sanitation interventions. However, when government decisions are being made with limited funds, as in resource-poor situations, better evidence would be useful to determine where funds should go (118).

2.3.3 Impacts of water quality and provision interventions

The Joint Monitoring Programme for Water Supply and Sanitation (JMP) of WHO/UNICEF defines an improved drinking water source as one which is protected from contamination, especially faecal contamination, via its construction or through active intervention (7). Unimproved drinking water sources include those that do not prevent external contamination or are unsustainable. Examples of improved and unimproved sources are outlined on Table 1. The improved indicator does not truly reflect water safety, as no microbiological testing is undertaken and piped water from sources like surface water and unprotected springs are still likely to be contaminated, despite their improved status (129).

In 2014 a systematic review and meta-analysis investigated the association between improved water sources and level of faecal contamination in LMIC (130). The review found the odds of water from improved sources being contaminated were 85.0% lower than water

from unimproved sources (OR: 0.15, 95% CI: 0.10-0.21). However, 73 (38%) of the 191 studies testing improved sources were still faecally contaminated, defined as having indicators of faecal contamination, such as *Escherichia coli* (130). Thus, although improved water sources are less likely to be faecally contaminated than unimproved sources, this varies by setting and source type and does not equate to microbiological safety. The estimate by Bain et al (130) is also based on cross-sectional studies where microbiological testing has been carried out and does not reflect results from studies testing before and after interventions. The most recent systematic analysis reporting on interventions changing water systems from all unimproved to all improved did not find a statistically significant reduction in diarrhoea (RR: 0.89, 95% CI: 0.78-1.01). This reflects the inclusive definition of 'improved', which can include water without any active treatment or sources which have had no protection (120). Therefore, it is necessary to investigate in more detail the specific types of water improvement interventions.

Water interventions can be divided into those improving the safety of water for consumption, and those increasing the amount of water available to the household. Both intervention types can have positive impacts on health, albeit through different pathways. Interventions to improve water quality assume water is microbiologically contaminated from contaminants such as human and animal faeces. Treatment measures are utilized, either at the community or household level to eliminate any pathogens, with the aim of water becoming safe for human consumption by disinfection (131). Interventions focusing on provision of adequate quantities of water, aim for households to have a larger water supply available to them at less effort. This includes piping water from water sources to public standpipes close to households, or even into each household or plot. This can improve health by increasing the amount of water available for personal and domestic hygiene, as water prioritization for cooking and drinking is no longer an issue.

The majority of studies comparing water quality interventions to water supply interventions find water quality interventions have a larger impact on health (110, 113, 120). For example Waddington et al (113), found water quality interventions could reduce the risk of diarrhoea by 42% (RR: 0.58, 95% CI: 0.50-0.67), whereas water supply interventions did not have a statistically significant reduction (RR: 0.98, 95% CI: 0.98-1.06). However, this is largely dependent on the specific type of water supply intervention. When water supply

interventions are broken down to community supply and household connection, Wolf et al (120), reports household, yard, or plot connections reduce the risk of diarrhoea by 32% (RR: 0.68, 95% CI: 0.64-0.92). If this connection is of higher quality, defined as both continuous and safe as is standard in developed countries, it could reduce the risk of diarrhoea by 79% (RR: 0.21, 95% CI: 0.08-0.55). However, community supply interventions, of which there are far more studies than household or yard supply studies, did not demonstrate a statistically significant reduction in diarrhoea risk when pooled (RR: 0.89, 95% CI: 0.78-1.01) (120).

However, as with sanitation, there are factors beyond the health impact influencing the intervention of choice. Water is a basic human right and 7.5 liters of water per person, per day, has been estimated to be required for basic living (132). This rises to 50 litres per person per day when all domestic cleaning and food washing is taken into account (132). In rural communities, individuals can walk long distances, often twice or thrice a day to collect water. Thus they are unlikely to obtain their minimum water requirement every day, and water will be prioritized for drinking and cooking above domestic and personal hygiene (133). Water supply interventions can substantially increase the amount of water available to households, reducing the need for prioritization. It also decreases the amount of time spent collecting water, which is often viewed by communities as a larger issue than water quality or effects on health (133).

Broadly speaking there are two types of water quality improvement interventions – those implemented at the source and those implemented at the point of use (POU) in the household. Source water can be improved by providing protection from external contamination. For spring sources this can be achieved by a spring box: a brick, concrete or masonry structure built around the spring, so water can flow directly from the box into a pipe or cistern without outside exposure (7). Protected dug wells can be protected from runoff water contamination by a well lining, raised above ground level; a platform, to ensure spilled water does not return to the well; and a covering to prevent further environmental contamination (7).

Water can also be treated at the source, or an alternative point in the distribution, by disinfection (for example chlorination or filtration). Water microbiological quality interventions at the source are often accompanied with water supply interventions, such as

piping water to a community standpipe, and therefore it is often difficult to separate the impact of these two interventions. Despite water quality interventions at the source often being in conjunction with water supply interventions, water treatment at POU has consistently greater impacts on diarrhoea. Waddington et al (113), reported water quality interventions at the POU could reduce diarrhoea by 46% (RR: 0.54, 95% CI: 0.48-0.65), whereas at the source, the reduction was not statistically significant (RR: 0.79, 95% CI: 0.62-1.02) (113). This is a similar finding to previous systematic reviews (110, 134).

Many systematic reviews have also been more specific in their analysis of POU water quality interventions by comparing the treatment method used. Boiling is the most commonly reported treatment method globally (135). Boiling water is an effective form of thermal disinfection of water and is effective at reducing microbiological contaminants under a variety of conditions including turbidity, temperature, and pH (136). However, there are also a number of limitations to this method. Adherence is often compromised by the labour associated with collection of fuel, the cost of purchasing fuel, or the prioritization of fuel for cooking (136). Another concern for promoting boiling of water is indoor air pollution from the burning of biomass (such as wood, charcoal and crop residues), which is associated with increased respiratory illnesses, such as pneumonia; cardiovascular events; and all cause mortality in both children and adult (137). Thus alternative household treatment methods are usually promoted for POU treatment interventions.

Point of use treatment methods include: disinfection methods, such as filtration, solar disinfection, combined flocculation and disinfection, and chlorination; and turbidity mitigation, such as flocculation alone, cloth filtration, and sedimentation or settling. The most commonly implemented and compared methods are ceramic and biosand filtration, solar disinfection (SODIS), combined flocculation and disinfection where chlorine is the most common disinfection agent, and chlorine alone. Ceramic filters are made of a porous ceramic material and filter microbes based on size. Biosand filters are modified slow-sand filters (large-scale, continuously operated filters), which are used at the household and allow for discontinuous use (138). The SODIS method uses transparent polyethylene terephthalate (PET or PETE) bottles exposed to sunlight and a combination of solar ultraviolet and heat energy disinfects the water inside (138). Combined flocculation and disinfection incorporates a coagulation-flocculation step, and a disinfection step, where chlorine is usually the

disinfectant of choice. Chlorination alone, involves the disinfection step without pre flocculation.

A meta-analysis looking at the effect of POU treatments on diarrhoea found filtration had a statistically significant 34% decrease in diarrhoea outcomes (RR: 0.66, 95% CI:0.47–0.92) (120). Wolf at al (120), reported SODIS and chlorination had similar effects and thus were pooled. When studies on chlorination and SODIS treatment were combined, they had a non-statistically significant trend towards reduction on diarrhoea of 16% (RR: 0.84, 95% CI:0.61-1.16) (120). An earlier Cochrane review in 2006 estimated larger impacts on diarrhoea, but this was only statistically significant for chlorination (134). They reported a pooled estimate for filtration of 44% reduction in diarrhoea, although this was not statistically significant (RR: 0.56, 95% CI:0.25–1.27) (134). The Cochrane review also looked at combined flocculation and disinfection, and found, when one possible outlier study was excluded, the intervention could reduce the prevalence of diarrhoea by 40% (RR: 0.60, 95% CI:0.43–0.83) (134).

The reliability of results from these systematic reviews and meta-analyses have been questioned because of significant heterogeneity in individual studies and biases in self-reported results (139). There is also evidence of diminishing effectiveness post-implementation as participants revert to prior habits of non-treatment (139). Some experts have suggest filtration is the best form of POU treatment, as it only requires a one-off cost and can be easily used post-implementation (138). However, others have suggest promoting one household treatment over others and over source treatments is premature, as estimates of health effects may be entirely due to bias, due to participants being actively involved in treating the water (140).

All POU treatment methods have their own advantages and disadvantages, and one single method is unlikely to be the optimum for all situations and conditions. Filtration is highly effective at removing dirt and bacterial pathogens, may reduce diarrhoeal diseases, only requires a one-off investment, and is reasonably simple to operate. However, some filters are not easily transportable, maintenance of the filter will need to occur after a period of time, and they are not as effective at filtering viruses, because of their small size, or when the water is highly turbid (134, 136). One study has shown chlorination is the most cost-effective household treatment method, and it is also simple to use (141, 142). However

there are also issues with uptake because of aesthetic concerns over taste and odour (142). The SODIS method is a very low cost treatment solution requiring little effort. However, its effectiveness can be greatly reduced if it is not followed correctly. For example, if the water is not left in the sun for long enough, or the bottles are too old and scratched. The effectiveness of SODIS also depends on the climate and turbidity of water (143). Combined flocculation and disinfection is effective in turbid water, but requires optimization in individual settings, which can be difficult without training or equipment (142). Because of these advantages and disadvantages often a combination of methods are recommended, such as a turbidity mitigation method (e.g. settling), followed by a disinfection method (e.g. filtration or SODIS), and storage in a safe vessel preventing any new contamination. Safe storage vessels are covered with a lid and having a narrow mouth or spigot to prevent dipping of hands or other vehicles of contamination (144).

2.3.4 Combined WASH interventions

Water, sanitation and hygiene are often referred to as a combined risk factor because of their interrelated pathways of disease transmission. A single intervention blocking a single pathway may have negligible effects on disease if it is not a major pathway of transmission. Because the relationship between faecally contaminated environments and disease is probably log linear (39), for interventions to reduce disease they need to prevent faecal contamination beyond a certain threshold (1). Thus, there is a strong argument for implementing combined WASH interventions, to block multiple transmission pathways, making the environment safer, and reduce more disease.

There may be detrimental effects of focusing on too many interventions, as they are typically more expensive, harder to implement, and harder to scale up. Having multiple interventions occurring at one time can potentially diminish the possible effect each of the single interventions can achieve, as there is less focus on individual interventions (145). This is reflected in results from systematic reviews and meta-analysis, where there is generally no additional reduction in diarrhoea from interventions that have focused on a number of interventions, rather than just one (110, 113). Waddington et al (113), 2009, reported that multiple WASH interventions, consisting of interventions in all three WASH components, could reduce the risk of diarrhoea by 38% (RR: 0.62, 95% CI: 0.46–0.83) (113). This is similar

to Waddington et al's (113) estimate of the effects of individual sanitation and hygiene measures, and less than their estimate of water quality interventions. However, these studies do not take into account a possible reduction in EED in by reducing contamination in living environments, and therefore possible improvements in child growth in the long term.

One major, large-scale study, called the WASH Benefits study is currently being undertaken to answer whether combined WASH interventions can improve child health outcomes better than single purpose interventions (146). This study consists of two cluster RCTs in Bangladesh and Kenya. However, although there is no current evidence that combined interventions improve disease outcomes more than single interventions, improved water and sanitation, and hygiene knowledge, are basic fundamentals of health that increase quality of life (1).

2.4 Education interventions of infant and young child feeding (IYCF) practices

2.4.1 Infant and young child feeding

In 2008 WHO released a set of global infant and young child feeding (IYCF) indicators in response to a lack of useful, simple indicators for feeding practices for infants and young children from birth to two years of age (147). Although breastfeeding indicators had been published in 1991, there were no widely used complementary feeding indicators other than whether children consumed complementary food or not (148). From 2002, WHO began the process of developing complementary feeding guidelines and indicators. The IYCF indicators describe five complementary feeding indicators and three breastfeeding indicators, updated to reflect developments in evidence, such as extending the exclusive breastfeeding recommendation indicator from four months to six months (148).

The IYCF indicators for breastfeeding include: early initiation of breastfeeding; exclusive breastfeeding under six months of age; and continued breastfeeding at one year and two years of age (148). WHO defines early initiation of breastfeeding as the infant being put to the breast within one hour of birth, and ensures the infant receives colostrum, the first milk, which is rich in protective antibodies, lowering the risk of neonatal infection and mortality

(148, 149). Exclusive breastfeeding is protective against infectious diseases, and has been shown to provide infants with all the nutrition they need up to six months of age (150). Beyond six months of age WHO recommends continued breastfeeding up to, or beyond, two years of age (151).

The IYCF complementary feeding indicators include: introduction of solid, semi-solid or soft foods; minimum dietary diversity; minimum meal frequency; minimum acceptable diet; and consumption of iron-rich or iron-fortified foods. The introduction of solid, semi-solid or soft foods refers to the timely introduction of complementary foods to meet the nutritional requirements of infants from 6 months of age. Minimum dietary diversity refers to the recommendation children 6–23 months of age should be receiving food from at least four of the seven IYCF food groups. The IYCF food groups are: grains, roots and tubers; legumes and nuts; dairy products; flesh foods; eggs; vitamin-A rich fruits and vegetables; and other fruits and vegetables (148). Minimum meal frequency is a proxy for energy intake from solid, semi-solid, or soft foods. Children who are being breastfed should be fed food other than breast milk two times a day for infants aged six–eight months, and three times a day for children aged 6–23 months (148). Children not being breastfed require more feeds than breastfed infants – four times a day for infants and children 6–23 months of age (148). The minimum acceptable diet indicator combines the two previous indicators, minimum dietary diversity and minimum meal frequency. Iron is an essential component of an infants diet to help brain development, and therefore a further IYCF indicator is assessing whether infants and children are receiving iron-rich foods (e.g. animal source foods) or iron-fortified foods (152).

Reviewing IYCF indicator findings can inform stakeholders about the nutritional practices of populations, identify populations at risk, and assess whether interventions or national programmes have improved these outcomes. Improving nutrition practices for children less than two years of age should plausibly have beneficial effects on anthropometric outcomes, such as stunting, underweight and wasting, as birth to two years of age has been described as the ‘critical window’ for nutrition interventions (153). Since one use of the indicators is to identify populations at risk of undernutrition outcomes, a number of studies have investigated the extent to which the indicators can actually predict anthropometric deficiencies. Marriot et al (154) used demographic information from 14 low-income countries to investigate this relationship. They found for infants 6-8 months of age,

consuming solid, semi-solid, and soft food; meeting IYCF minimum dietary diversity guidelines and minimum acceptable diet guidelines; and consuming iron-rich food, were all associated with lower stunting and underweight prevalences (154). However, whereas the risk of being underweight was lower when early initiation of breastfeeding was practiced, the risk was higher when continued breastfeeding at age 12-15 months was practiced (154). This may be due to displacement of food by breast milk, which is not nutritionally sufficient for normal growth beyond six months of age (154). A more recent study also investigated this relationship, and found heterogeneity between counties (147). This suggests IYCF indicators are too simplistic to predict the complexity of undernutrition, which is effected by many upstream and downstream determinants (147).

Despite the complex relationship with undernutrition outcomes, IYCF indicators are useful in providing simple measures of assessment and evaluation in response to interventions that aim to increase child nutritional intake. These interventions are typically based on educating mothers, either ante- or post-natally, in the community, at hospitals, or at clinics. There are also interventions that go beyond education to provide financial incentives for mothers exclusively breastfeeding or complementary feeding, and also the provision complementary food (155, 156). The provision of complementary food is usually only recommended for food insecure populations, where the food provided is often nutrient or energy dense (156). As the Vanuatu population is food secure, this literature review focuses on breastfeeding and complementary feeding education interventions and their ability to improve IYCF outcomes, and improve child nutrition status.

The most common indicator investigated to explore breastfeeding habits is exclusive breastfeeding, defined as the infant only receiving breastmilk from mother or wet nurse and no other type of liquid or solids, excluding those used as medicines, such as oral rehydration salts (ORS) and vitamins. Exclusive breastfeeding rates remain below optimum in low, middle, and high-income countries (157). Reasons for not exclusively breastfeeding vary globally, especially between developed and developing countries due to differences in baseline maternal education, availability of milk formula, women employment and the social environment (158). Reasons for the lack of breastfeeding in developing countries usually include a lack of knowledge around breastfeeding and cultural beliefs around delayed breastfeeding, e.g., colostrum is dirty milk (158). Other, more universal reasons, include

emotional stress, perception the mother does not have enough breast milk, and pressure from relatives to introduce other foods (158). Many education interventions have been developed to encourage good exclusive breastfeeding practices (158-164).

In 2013, Haroon et al reviewed the literature on breastfeeding promotion, where they included studies educating and/or supporting antenatal or postnatal mothers, via lay counselors or health professionals, and in individual or group sessions (164). Like previous reviews, they found breastfeeding promotion interventions had the greatest effect in developing countries, where exclusive breastfeeding prevalence could be increased by 157% at birth (RR: 2.57, 95% CI: 1.35-4.77), 35% up to one month after birth (RR: 1.35, 95% CI: 1.15-1.58), and 188% at 1-5 months after birth (RR: 2.88, 95% CI: 2.11-3.93) (164). They also found a statistically significant reduction in the rates of "no breastfeeding" (164). An earlier systematic review by Imdad et al, found breastfeeding promotion could increase exclusive breastfeeding six-fold at six months after birth in developing countries (158).

The advantages exclusive breastfeeding gives infants, namely protection from contaminated food and liquids, is not recommended after six months, as infants require further nutrition to sustain growth (165). To reduce the risks of negative health consequences, complementary food should be safe, and of adequate nutritional value and quantity (166). In a meta-analysis, Lassi et al investigated the ability of complementary feeding education interventions to improve feeding practices and found that education improved uptake of recommended foods by 63% (RR: 1.63, 95% CI, 1.17-2.26) (165). Furthermore they found complementary feeding education alone could reduce the relative risk of stunting by 29% in food secure and insecure populations (RR: 0.71, 95% CI: 0.60-0.76) (165). When food secure populations were considered separately, the effect on stunting was no longer significant, although there was a significant effect on height and weight gain, and HAZ scores (165).

2.4.2 Combined WASH and nutrition interventions

There is a growing body of evidence suggesting that nutritional interventions alone, including those providing breastfeeding and complementary feeding education, are unable to prevent a large amount of undernutrition, notably stunting, by 24 months of age (146). This is believed to be due to the effects of environmental contamination, leading to

repeated or persistent diarrhoeal diseases and EED. Thus, combined WASH interventions in addition to nutritional interventions could be more effective in improving child nutrition outcomes than nutrition interventions on their own (146). Many NGOs, including UNICEF, and World Vision are combining WASH interventions and nutritional interventions when focusing on reducing undernutrition outcomes (167-169). In 2015 WHO revised its nutrition recommendations to integrate WASH interventions into programmes aimed at nutrition (170).

Good quality evidence of the ability of WASH interventions to improve child nutrition outcomes is lacking. Several observational studies have found hygienic environments, and access to improved water and sanitation is associated with less EED and stunting outcomes. However, this is yet to be seen in well-designed RCT studies. A 2013 Cochrane review by Dangour et al did not find any effect of WASH interventions on weight (WAZ score), and only a marginally significant effect on height (HAZ score) (mean decrease [MD] 0.08, 95% CI:0.00-0.16) (171). Studies investigating the relationship between WASH interventions and nutrition status may not have been of significant length and power to detect effects on nutrition status. With increasing knowledge of EED and its role in undernutrition, it is likely that well designed intervention studies in the future will support findings from observational studies with positive effects on EED and stunting (73).

Chapter Three – Methods

3.1 Evaluation objectives

With the help of Otago University supervisors and the World Vision Tanna team, I designed and carried out an evaluation of the Tanna WASH Project for World Vision which took place in January 2015, marking the second completed year of the three-year implementation. A number of components in the evaluation were included in order to gain a detailed understanding of how the Project interventions may have been translated into knowledge and behaviors of community members. I identified six key evaluation objectives to understand the current status of the community of south west Tanna, how this may have changed from previous years, and investigate factors associated with disease and water microbiological quality. These objectives were as follows:

1) **To describe WASH infrastructure, knowledge, and practices for households with children under five years of age:**

    a. WASH infrastructure: Proportion of households who had access to improved water sources, improved latrines, and hygiene facilities.

    b. WASH knowledge: Proportion of caregivers who recalled World Vision training. Proportion of caregivers who had basic knowledge of hygiene and diarrhoea.

    c. WASH practices: Proportion of caregivers who washed their hands and used the latrine. Proportion of caregivers who treated and stored drinking water adequately.

2) **To assess aspects of child health including: prevalence or period prevalence of common health outcomes; infant and young child nutrition; and immunisation, vitamin A, and deworming status:**

a. Two week period prevalence of diarrhoea and treatment received.

b. Two week period prevalence of Acute Respiratory Illness (ARI).

c. Prevalence of wasted, stunted, and underweight children.

d. Proportion of children who had received WHO IYCF nutrition regarding breastfeeding, complementary feeding and dietary diversity.

e. Proportion of children who had received immunisations, vitamin A doses, and deworming medication.

3) To investigate the associations between child health outcomes and child, caregiver, and WASH factors. Also investigate associations between health outcomes:

a. Investigate associations between health outcomes - diarrhoea, ARI, and undernutrition - and child, caregiver, and WASH variables, where numbers were sufficient,

b. Investigate associations between health outcomes to assess whether children were at risk of having multiple health outcomes.

4) To compare WASH and child health variables in January 2015 to baseline in 2013 and year one in 2014:

a. Compare WASH and nutrition variables where methodology allowed for comparison and results were available from previous years.

b. Compare child health outcomes where methodology allowed for comparison and results were available from previous years.

5) To describe microbiological safety of the drinking water of households with children under five years of age in January 2015:

a. Proportion of households with safe or unsafe drinking water as defined by WHO using *Escherichia coli* most probable number (MPN), an indicator of faecal contamination.

b. Proportion of village water collection points that have safe or unsafe drinking water.

6) **To investigate associations between drinking water microbiological safety and household WASH and child health outcomes:**

a. Investigate association between drinking water microbiological safety, and WASH infrastructure and practices.

b. Investigate associations between child health outcomes and water microbiological safety.

In addition, the activity of community WASH management committees (WMCs) and WMC member opinions on project progress was established through key informant interviews.

3.2 Evaluation study design and components

The second year evaluation was undertaken in six communities in south west Tanna, Vanuatu that were included in the WASH project at the time of the evaluation. The evaluation consisted of five components: 1) household interviews with the primary caregiver of the children under five years of age; 2) observation of WASH facilities and practices; 3) anthropometric measurements of children under five years of age and their mothers; 4) microbiological testing of drinking water; and 5) key informant interviews with members from each of the nine WMCs.

3.2.1 Study design

Our evaluation used a cross-sectional study design. All components reported here relate to the point in time of our data collection, 19th–29th January 2015. All comparisons reported

here were internal comparisons of those within the Project area. Whenever possible, the results of the second year evaluation were compared with the Project baseline from 2013 and end of year one survey in 2014, as well as the VDHS.

3.2.2 Household and child questionnaires

The first component of the evaluation was a survey conducted with the primary caregiver of each household, consisting of both a household (Appendix 1) and child questionnaire (Appendix 2). The household questionnaire included: demographic questions, such as age, gender, and schooling; WASH facility questions; and WASH and IYCF knowledge and behavioral questions. The child questionnaire included: health questions, such as diarrhoea and ARI; child vaccination, deworming, and vitamin A status; and child dietary questions. As far as possible, questions in the household and child questionnaires were kept the same as the baseline questionnaires to allow for comparisons. However, I amended or added questions to align with the recent VDHS in 2013 (18). Interviewers had the option of reading the questionnaire in English or Bislama. Often in communities these were translated verbally to a number of traditional languages.

3.2.3 Observations

Where possible, the data collection team undertook WASH related observations to overcome potential bias in self-reported results (Appendix 3). WASH factors observed at each household included: latrines and tippy-taps; water storage; presence of soap and rubbish puts; and general household cleanliness. A different person than the household and child questionnaire interviewer made the observations. Interviewers conducting the observations were shown WASH facilities by a member of the household; the household member was not necessarily the respondent to the questionnaires. Interviewers recorded information about each facility, such as the type, operational status, and cleanliness.

3.2.4 Anthropometry

The data collection team undertook anthropometric measurements of all children under five years of age who were available in the village on the day of data collection, and of their mothers. Trained team members made measurements using calibrated equipment,

standardized procedures (159), and conventional protocols (172). Children were measured in light clothing without footwear, and infants were measured without a nappy. We undertook duplicate measurements of each child, with a third measurement taken when the first two measurements did not agree within specified limits, 0.1 kg for weight and 0.7 cm for length and height (159). Children under two years of age were measured by recumbent length using a length board, and children between two and five years of age standing, using a portable stadiometer. Length and height were measured in centimeters (cm) to the nearest 0.1 cm. Weight was measured in kilograms (kg) using portable electronic scales measuring to the nearest 0.01 kg. Weights were recorded to the nearest 0.1 kg. Infants were weighed in their mother's arms, and the mothers weight was subtracted from the total to give the infant's weight.

3.2.5 Water microbiological testing

Trained individuals from the data collection team tested water microbiological quality using the Compartment Bag Test (CBT) method (Aquagenx, USA). Compartment Bag Tests were conducted at the household, using stored drinking water. Additionally we took samples from the drinking water collection points, and source water for existing gravity fed systems, when they were within feasible walking distance, i.e. up to one hour for a round trip. We also tested water from all water spring sites that had been selected for new gravity fed water systems.

Trained individuals from the data collection team also estimated and categorized the Most Probable Number (MPN) of the indicator organism *Escherichia coli*. The CBT method has been evaluated in comparison to the conventional standard approach membrane filtration and another MPN approach Colisure/Colilert-Quantitray (IDEXX USA, 2012), and in low-resource settings (173, 174). Stauber et al found CBT has a sensitivity of 94.9% and a specificity of 96.6% when compared with membrane filtration (174). The advantage of CBT over standard tests of drinking water quality in field situations is affordability, and no requirement for laboratory equipment or professionally trained personnel (174). This made it well suited for use in rural or remote settings such as the Project area.

3.2.6 Key Informant Interviews

World Vision local staff undertook key informant interviews with WMC members, to collect information about WMC activities, and progress of the implementation of WASH Project components. Key informant interviews involved a standard questionnaire used in the baseline study with a comments section (Appendix 4). The results of the key informant interviews were of importance for World Vision monitoring and were presented in a report to World Vision (175) along with the preliminary results of this study, in May 2015. However, the key informant interview findings were not a major focus of this evaluation and will not be discussed further. The findings are presented in Appendix 5, for reference.

3.3 Evaluation preparation

Throughout November 2014 to January 2015, I prepared components of the evaluation, with help from a Centre for International Health summer student, Hanneke Lewthwaite and Senior Lecturer of Human Nutrition at the University of Otago, Associate Professor Lisa Houghton. Components needing the most preparation were developing the survey and observation questionnaires, setting up the smartphone questionnaire, and the water microbiological testing. Throughout the preparation period we also reviewed, adapted or developed training material for the data collection methods, and anthropometric methods, ready for training for the Tanna World Vision survey team.

Survey preparation and mobile data collection

The evaluation included four questionnaires: a household questionnaire; a child questionnaire; an observation questionnaire; and a key informant interview questionnaire. I based the questionnaires on those used at the baseline assessment of the project. Where possible, I kept questions the same as baseline. However, many questions were amended to align with the VDHS, and current best practice indicator questions as recommended by the WHO/UNICEF JMP. I included more questions in the observation component of the evaluation than at baseline and end of year one, to allow for comparisons of self-reported and observed results. Questionnaire questions were reviewed by Dr. Susan Jack, Senior Research Fellow at the Centre for International Health, University of Otago and Dr. Raul

Schneider, World Vision's regional health adviser, Vanuatu. Additionally, nutrition questions were reviewed by Assoc. Prof. Lisa Houghton. Questionnaires were developed in English and then sent to the World Vision Tanna team for translation to Bislama.

The World Vision team collected data in the field using smartphones (Samsung Group, Seoul, South Korea) for all components of the evaluation except key informant interviews. We used a smartphone application developed by Smap Consulting (Neil Penman, VIC, Australia). After household, child, and observation questionnaires were finalized, an Otago Smap server was set up by Smap Consulting to allow the downloading of Microsoft Excel (Redmond, WA, USA) templates and programme questionnaires into the Smap template using manuals provided by Smap consulting. Once I had programmed the questionnaires into the Smap template I could upload them onto the server and test the questionnaires on smartphones that had the Smap Consulting data collection application, "FieldTask". World Vision Vanuatu was planning to use the application for data collection for all their projects from 2015. Thus training Tanna World Vision staff on use of the application, and using it in the evaluation, had probable benefits for successful data collection in subsequent World Vision projects.

Compartment Bag Test (CBT) preparation

During December 2015, Ms Lewthwaite prepared the water microbiological testing component of the evaluation. Ms Lewthwaite undertook positive and negative control testing of each batch of CBTs at the University of Otago, Department of Microbiology, prior to data collection in Tanna. Positive controls were required to be tested at the University of Otago because of the lack of laboratory facilities or *E. coli* isolates in Tanna.

Aquagenx recommend incubating CBTs for: 20–24 hours at 35–44.5°C; 24–30 hours at 30–35°C; or 40–48 hours at 25–30°C. Anticipating variable ambient temperatures in the field that would possibly be lower than 25°C, and no electricity for a portable incubator, Ms Lewthwaite undertook controlled temperature CBTs at a range of temperatures below the lowest recommended temperature of 25°C, at the Otago University Microbiology department. All positive samples, and no negative samples, from all temperatures tested had undergone a colour change before the 48 hour incubation was completed, meaning that even at lower temperatures the CBT would give accurate results.

Training material preparation

During December 2015 training materials were developed for the World Vision survey team. These included an anthropometry training manual developed by World Vision International (Appendix 6), and prepared by Assoc. Prof. Houghton; a protocol for CBTs developed by Aquagenx (176), and prepared by Ms. Lewthwaite; and a manual for carrying out the survey on the Smap application in smartphones (Appendix 7), prepared by myself.

3.4 Evaluation logistics

Timeline

The evaluation took place in January 2015 at the completion of two years of the Project. Figure 7 shows the evaluation calendar.

Figure 7: Timeframe of the World Vision water, hygiene and sanitation project in Tanna, Vanuatu, 2015

Activity	2014		2015													2016	
	Nov	Dec	Jan				Feb	Mar	Apr	May	Jun	Jul	Oct	Nov	Dec	Jan	Feb
PREPARATION			1st	8th	15th	22nd											
RAC* application																	
Questionaire preparation																	
Smap templates programmed and tested																	
Otago human ethics approval																	
CBTs** ordered, batch tested, controlled temperatue tests																	
Arrive in Vanuatu																	
Vanuatu ministry of health ethivs approval																	
TRAINING																	
Survey training, contextualising questionnaires, translating questionnaire																	
Anthropometric training and practice																	
CBT** theory (all), and training (two staff)																	
Training of FieldTask application for data collection.																	
Phones arrived and set up with questionnaires, short training session																	

Activity	2014		2015													2016	
	Nov	Dec	Jan				Feb	Mar	Apr	May	Jun	Jul	Oct	Nov	Dec	Jan	Feb
DATA COLLECTION																	
Community: Ikakahak, Karimasanga																	
Community: Karimasanga, Ikulnala, Ienapkasu, Yekue, Imapul																	
Uploading results, debriefing																	
REPORTING REQIREMENTS			1st	8th	15th	22nd											
Preliminary results to Tanna World Vision for refresher training																	
Full preliminary report to World Vision New Zealand																	
Report to NZAID																	
DATA ANALYSIS AND WRITE UP																	
Descriptive results																	
Univariate and multivariate analyses																	
Comparisons to baseline and end of year one																	
Thesis write up																	

* RAC = Research advisory committee

**CBT: Compartment Bag Test for water microbiological testing

Training

Prior to data collection, a four-day training workshop, from 13-16th January 2015, was conducted for World Vision Tanna staff to review and practice conducting the survey questionnaire, and to learn and practice anthropometric measuring techniques. In addition one staff member, Harold Nakao, and WASH adviser, Peter Brown, were trained to conduct water microbiological testing. The training workshop was conducted by Assoc. Prof. Houghton, Ms. Lewthwaite. And myself. Practice and standardization of anthropometry took place in the Imapul community prior to data collection.

Data collection

From January 19–29th, 2015 we carried out data collection in the six communities of the Project. Data collection consisted of four or five 12-hour days of collection per week, and staying three or four nights in project villages per week. World Vision staff and University of Otago students were separated into two data collection teams of seven people each, and survey roles were assigned for each team member: interviewing; observations; anthropometry; or water testing; for the duration of the survey. On some occasions roles changed due to three staff becoming ill during the second week.

Data monitoring

I held a full staff debriefing session after each day of data collection to review and address any survey issues or misinterpretation of questions. Additionally, Ms. Leuthwaite and I monitored individual completed questionnaires daily for completeness.

3.5 Study population

The study population comprised members of households in south west Tanna in the WASH Project who had one or more children under five years of age. All households that met the criteria of at least one child under five years of age, a caregiver present at the time of the interview, and who gave written consent were eligible to be included in the evaluation. Originally sample size calculations were made and a randomized sampling framework was

produced by Associate Professor Katrina Sharples, Dunedin School of Medicine, University of Otago, using household lists supplied by World Vision. However, it became apparent after arrival in community areas that the household lists were inaccurate and outdated, and the number of households with children under five years of age was smaller than expected. Due to the relatively small population, we attempted complete enumeration. The inaccurate pre-existing lists of households in each community were supplemented with information from a knowledgeable community member, usually the chief or WMC chairperson in order to enumerate the total number of households with children under five years of age. Village members were informed in advance of the date of data collection in their area and families were encouraged to be present in the village on the proposed data collection day.

One major change in the study population from baseline was the addition of a community not included at the baseline of the Project. The Imapul community was added in late 2013 to replace one large village, Ienapek, consisting of 26 households, which decided not to take part in the Project due to strong traditional beliefs resulting in unwillingness to make sanitation and hygiene changes, or establish local WASH governing bodies. The added community, Imapul, consists of two villages, Imapul village and Ekyo, of which 25 households in total were included in the study. There were a few additional minor changes in villages within the population due to redefining of village boundaries. These minor changes did not affect which households were included or not included in the study.

Adults were defined as those aged 15 years and older, a younger age for defining adults than commonly used by the United Nations which is 18 years of age, (177), and WHO, 19 years of age (178). This younger age was chosen to reflect cultural norms in Tanna, where females often marry and have children at a relatively young age. The minimum legal age for marriage in Vanuatu is 16 years old for females and 18 years old for males (179), although in 2007, 7% of married women reported they were married before the age of 15 years (17).

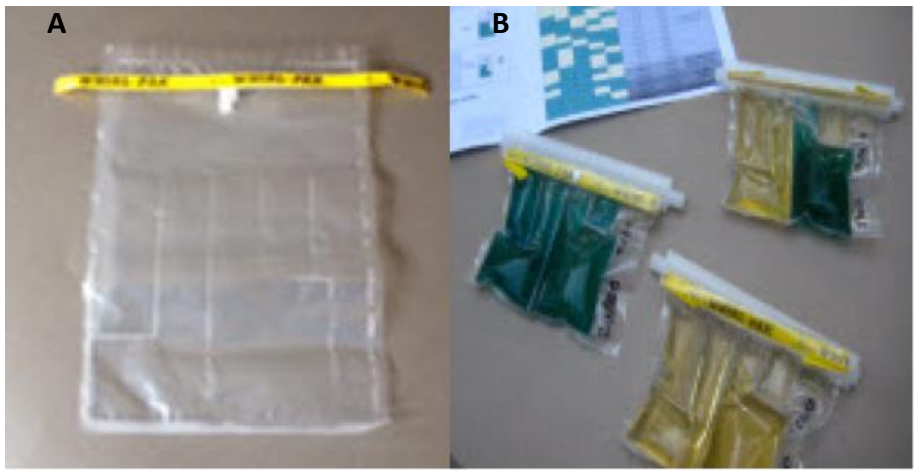
3.6 Compartment bag test protocol

At households with one or more children under five years of age and water collection points, samples of 100 mL of water were collected by team members into sealed sterile bottles. We

processed samples within six hours of being obtained according to the manufacturers instructions (Aquagenx, USA) (176). In brief, we added a growth bud containing 5-bromo-4-chloro-3-indoly-beta-D-glucuronic acid (X-gluc) to each 100 mL sample and left samples for 15-20 minutes with regular shaking to allow for medium dissolution. The water samples were then poured into the compartment bags.

Compartment bags were made of clear plastic with five internal compartments of varying volumes: 1; 3; 10; 30; and 56 mL. To ensure each compartment received enough of the sample, we gently squeezed the bag exterior to transfer contents, as described by Stauber et al (174). We then sealed bags with a clip spanning the width of the bag that isolated each compartment, and placed in an insulated container. We recorded colour changes, shown on Figure 8, 48 hours later unless all compartments had become positive prior to 48 hours. The highest and lowest temperatures recorded inside the insulated container during the incubation periods were recorded, with all CBT being incubated between 22°C and 41°C in our study.

Figure 8: Compartment bags used in Compartment Bag Test (CBT).



A: empty compartment bag. B: compartment bags with clip after incubation showing positive (top two bags) and negative (bottom bag) results for *Escherichia coli* contamination. The number of positive compartments (blue-green) in a bag corresponds to an MPN of *E. coli.* Photos from Aquagenx website (176).

After incubation, colour changes indicated the presence of *E. coli.* Colour changes were due to the break down of chromogenic X-gluc by *β*-D-glucuronidase (GUS), produced by *E. coli.* Compartments with positive results were indicated by a blue-green colour change, whilst negative results were a yellow-brown colour (Figure 8). A standardized system developed by Aquagenx was used to interpret positive and negative compartments within each bag to corresponding MPN of *E. coli* (Appendix 9). The MPN of *E. coli* corresponds to levels of health risk, as classified by WHO in Table 7.

Table 7: World Health Organisation guidelines for drinking water quality (2011)

Escherichia coli MPN/CFU* per 100 mL	Health Risk category
<1	Safe
1-10	Intermediate risk
>10-100	High risk
>100	Very high risk

*MPN = Most Probable Number, CFU = Colony Forming Units

During data collection, water samples were generally processed outside. Although hands were disinfected with alcohol hand sanitizer before and after processing, additional negative controls were carried out using store-bought sealed bottled water to ensure contamination of the samples was not occurring. After the incubation period and recording of results, all equipment was disinfected with chlorine tablets and disposed of safely by World Vision staff.

3.7 Comparisons to past surveys and the Vanuatu Demographic and Health Survey (VDHS)

We were able to compare our evaluation results to the baseline, 2013 and end of first year, 2014 surveys. Otago university students did not take part in these previous surveys at baseline and end of first year. We obtained datasets from World Vision New Zealand and World Vision Vanuatu and used them with permission. Many variables were not asked in previous years and could not be compared. No CBT or other water quality testing occurred in previous years. In addition, we compared our anthropometry results from the end of second year evaluation, 2015 to results from the VDHS, 2013.

Baseline, 2013

The baseline survey was conducted in April 2013 by an external consultant and the World Vision Tanna team and involved a number of components. These included: a household and child questionnaire; observation questionnaire; anthropometry measurements of children under five years of age; and key informant interviews. In our end of second year evaluation, we modeled questions on baseline questionnaires, to allow for comparisons. However, many questions were amended to fix known biases, such as recall periods, and were aligned for comparison with VDHS. The baseline sample size was based on the number of adults, not children and the selection of participants was based on convenience, rather than a random sample. The sample also included households without children under five years of age. Anthropometric flaws in the baseline survey included inaccurate height measurements for many children, likely resulting in the overestimation of stunting, and the age of many children reported to year, not month. These, and further limitations, are discussed in our limitations section (Chapter 10).

End of year one survey, 2014

The end of year one survey was conducted in January 2014 by the World Vision Tanna team. The survey included questionnaires, observations, and anthropometric measurements of children under five years of age. However, the survey was solely for monitoring purposes and questions included only those relating to outcome and monitoring indicators on Table 2. Many questions asked at baseline and the end of second year evaluation were not investigated in the end of year one survey. Accounts from World Vision team members present at the end of year one survey suggest that no sample size calculation was done, convenience sampling was used, and the survey included households without children under five years of age (World Vision Tanna, personal communication, January 2015). Some villages surveyed at the end of year one had also been exposed to a previous World Vision project focusing on maternal, child health and nutrition, which may have influenced the results (24). There were also anthropometric measurement flaws, discussed further in Chapter 10.

Vanuatu Demographic and Health Survey (VDHS), December 2013

The 2013 VDHS was a nationally representative cross sectional study undertaken at 2,200 households. The VDHS study methods were similar to our end of second year evaluation, including anthropometric methods. Due to the probable inaccuracies of 2013 and 2014 anthropometry data compromising any comparisons in anthropometric results throughout the Project, we undertook an ecological comparison of our data to the anthropometric results reported by the VDHS. As anthropometric results were reported in the VDHS as proportion only, and the dataset was not available to us, the spread around the proportion was unknown and is not presented here.

Results from the VDHS study were disaggregated by urban; 'rural 1'; and 'rural 2'. Urban households were those households within Port Vila or Luganville. 'Rural 1' households were those households in the surrounding areas with easy access to Port Vila or Luganville, plus households living in administrative centres of other provinces, such as Isangel in Tanna, the Tafea province. 'Rural 2' households comprised households in the rest of Vanuatu in rural, more traditional areas (18). The population of south west Tanna was classified as 'rural 2', and anthropometric comparisons were therefore made to this population.

Additionally, VDHS used an asset survey-based approach to disaggregate data by wealth index, a measure of the long-term standard of living in a household based on household characteristics, drinking water source, toilet facilities, land and animal ownership, and ownership of consumer goods such as televisions and mobile phones (18). Quintiles from 1, poorest, to 5, wealthiest, were established via principle component analyses and standardization in relation to a standard normal distribution. In our evaluation we did not use a wealth index or measure enough variables to establish one. South west Tanna is particularly isolated, with no electricity, improved water, mobile reception, and no observed vehicles. Therefore, it is likely south west Tanna would fit into the poorest quintile, and so we also compared our anthropometric results to this population.

3.8 Statistical analysis methods

All evaluation data was downloaded from the Smap domain into Stata/IC statistical package version 13.1 (StatCorp, College Station, TX, USA). Datasets from the study included: child questionnaires; household questionnaires; observations; water testing; and anthropometry. We manually cleaned and pre-processed datasets for errors and duplicates prior to merging. We aimed for complete enumeration of households with children under five years of age in the Project area; statistical inference methods were used to describe the influence of random variation in the population over time and place.

We included all households from 28 villages that made up six communities in total. Hence the data were nested in structure: villages within a community, households within a village, and children under five years within a household. For univariate and multivariate analyses we used generalised-estimating equation (GEE) models (xtgee command in stata), to allow for this nested structure of our data. Within xtgee we specified village as a panel value and used independent working correlations with robust standard errors, which takes into account the two levels of nesting (village and household). A p-value of ≤0.05 was considered significant in all final analyses. We chose a working Poisson model (a log link, Poisson errors) (180) to compare prevalences of health outcomes; the robust standard errors account for the fact that the data were binary rather than Poisson. Model selection for the multiple regression models was carried out using backwards selection wherever numbers of outcomes allowed. However, in most cases full backwards selection was not possible so we pre-selected variables based on the size of the p-value in univariate analyses (all plausible associations with p-values ≤0.1 were included) then used backwards selection. Known confounders were adjusted for in multivariate analyses, regardless of significance.

Chapter four statistics: WASH infrastructure, knowledge, and practices (objective one)

Descriptions of WASH infrastructure and knowledge, and WASH and nutrition practices are presented as numbers and proportions for binary or categorical variables, or medians and ranges or interquartile ranges for continuous variables. We investigated differences in caregiver training recall and knowledge using GEE models described above with village as the panel variable to generate Chi^2 p-values.

Chapter five statistics: Child health aspects (objective two)

Duplicate or triplicate height and weight measurements were averaged. The Smap application was able to test whether duplicates or triplicates were within the required range, and generate the averaged result automatically. We compared the downloaded results to hardcopies of anthropometric results to double check measurement information, fill in any missing information, and check for duplicates. We uploaded the cleaned anthropometry data into Stata 13.1 and merged it with the household and child questionnaires. We used Zanthro Stata commands (181) to generate height-for-age Z-scores (HAZ); weight-for-age Z-scores (WAZ); and weight-for-height Z-scores (WHZ) based on WHO 2006 child growth charts (182). We used WHO recommended Z-score cutoffs of: <-2 Z-score to classify stunting, wasting, and underweight; and <-3 Z-score to classify severe stunting, wasting, and underweight respectively. Child health outcomes, diarrhoea, undernutrition, and ARI, are displayed as numbers and proportions with 95% CIs. We adjusted for similarities in children at the same household by clustering on household identifiers.

Chapter six statistics: associations between: child health outcomes and child, caregiver and WASH factors; and between individual child health outcomes (objective three)

Two or more multivariate models were presented for each child health outcome where there were sufficient numbers for investigation. We first investigated associations between WASH and nutrition variables. The WASH and nutrition variables investigated were determined based on prior hypotheses and all factors that met our criteria were included in a single multivariate model, unless they involved a different subset of children (12–59 months of age as opposed to under five years). To investigate relationships between the specific health outcome and the other health outcomes we used separate analyses due to the strong correlation between many health outcomes that would have been inappropriate to control for. These analyses are presented on a single table, showing unadjusted and adjusted results. Relationships between the undernutrition outcomes, stunting, underweight and wasting, were not examined as correlations are well known and were not the focus of this evaluation. We used GEE models with the Poisson working model described above to give prevalence ratios (PRs), 95% CIs and Chi^2 p-values.

Variables were first investigated for associations with child heath outcomes in univariate analyses, then multivariate models estimating adjusted prevalence ratios were built as described above. Known confounders adjusted for in the diarrhoea and ARI analyses included the age of the child in six month categories. Known confounders adjusted for in the undernutrtion analyses included the age of the child in six month categories, child gender, caregiver education, and maternal height. Socio-economic index is also a known confounder in child heath outcomes. However, there was not sufficient information about households to generate a wealth index.

Chapter seven statistics: Comparisons to baseline and end of year one (objective four)

Baseline and end of year one datasets were obtained from World Vision Vanuatu, and merged with results from our evaluation, 2015. As village boundaries and names were not constant over the years we used community as the panel variable for household variables and household identifier as the panel variable for child health variables. We recognise that this may not fully capture the structure in the data, and consequently have interpreted the analysis results with some caution. Proportions with 95% CIs are reported on graphs. We used GEE models as above to investigate whether there were statistically significant differences in variables between years; these p-values are reported with the graphs.

Chapter eight and nine statistics: Water microbiological safety and associations (objective five and six)

Our water testing results were categorized according to WHO cut-off points for MPN of *E.coli*, indicating water quality as shown in Table 7. The number and proportion if households with drinking water in each risk category is displayed. We used multivariate analyses to investigate household factors associated with microbiological quality of drinking water at the household. We also used multivariate analyses to investigate whether households with higher risk drinking water had higher prevalences of child health outcomes. We followed the same approach as above of using GEE models with village as a panel variable and robust standard errors to account for the nested structure of the data. However we used a logistic model to generate odds ratios (ORs) describing the associations between water safety and other variables. This choice was driven in part by the small numbers with

safe water, but also because odds ratios are symmetric with respect to outcome and exposure, and therefore water safety could more reasonably be used as an "outcome" in the model. Investigations of associations between water quality and health outcomes were undertaken via separate analyses for the reasons described in the previous section. Known confounding factors controlled for were the same as the previous section.

We undertook three separate groups of analyses for associations with household water quality. These were as follows

- Analysis one: By households that had safe water (MPN *E.coli* <1/100 mL) versus unsafe water (MPN *E.coli* >1/100 mL); to investigate factors associated with unsafe water.

- Analysis two: By households that had safe to intermediate risk water (MPN *E.coli* 0–10/100 mL) versus high risk to very high risk water (MPN *E.coli* >10/100 mL); to investigate factors associated with high to very high risk water.

- Analysis three: By households that had very high risk water (MPN *E.coli* >100/100 mL) versus households in all other risk categories (MPN *E.coli* <100/100 mL); to investigate factors associated with very high risk water.

3.9 Ethics, consent, and funding

3.9.1 Ethics

We sought and obtained ethics approval for the second year evaluation from the University of Otago Human Ethics Committee (Number 14/224). In addition, we obtained ethics approval from the Ministry of Health, Vanuatu before the commencement of the evaluation (Appendix 10). Caregivers were informed of the methods of the evaluation and their right to refuse involvement or discontinue involvement at any time. Information sheets were supplied to caregivers in English or Bislama, and were translated verbally when the caregiver could not read either language. Consent forms were signed by the caregiver prior to the evaluation components taking place. When the caregiver could not sign their name, thumb

prints were used. Examples of the information sheets and consent forms is provided in Appendix 10, 11 and 12.

3.9.2 Funding

The World Vision Vanuatu WASH Project is funded by the New Zealand Aid Programme through World Vision New Zealand. The second year evaluation was funded by a combination of World Vision New Zealand, NZ Aid Programme through the Postgraduate Field Research Scholarship, and the University of Otago through the Department for Preventative and Social Medicine. The masters student also received University of Otago Masters Scholarship.

World Vision reviewed the study design and local World Vision Vanuatu staff assisted the data collection. World Vision New Zealand facilitated contact between Otago university students and the World Vision Tanna team. World Vision New Zealand reporting requirements to funding bodies determined the dates and time-frame of this evaluation. The Pacific regional child health advisor from World Vision reviewed the questionnaire to ensure they covered all that was required for World Vision reporting requirements. Further, the survey questions were contextualized and translated into Bislama by the World Vision Tanna team. No funding body had input in the interpretation and writing of results presented in this thesis, nor the decision to submit papers for publication.

Chapter four – Household water, sanitation, and hygiene results (objective one)

4.1 Description of the study population

The numbers of households participating in our evaluation are shown in Figure 9. A total of 233 households had children under five years of age. Caregivers from eight (3.4%) households were not present at the time of data collection and one (0.4%) household refused to participate. At one village, Ekyo, the day of arrival was one day earlier than planned which lead to the exclusion of one small sub-village due to a household members attending a village meeting. Local World Vision team members estimated that four (1.7%) households were likely to have been missed in this sub-village. Of the 220 available households, both household questionnaires and observations were carried out at 196 (89.1%) households. An additional 12 household questionnaires and 12 observations were carried out at separate households. Therefore, of the 220 households, there were a total of 208 (94.6%) household questionnaires and 208 (94.6%) household observations completed. Household water microbiological tests were attempted in 213 (96.8%) of the 220 households, with 201 (91.4%) completed. Additionally, water from 19 drinking water collection points or sources were tested for microbiological safety.

The numbers of children participating in our evaluation is shown in Figure 10. From the 220 households with children under five years of age, 320 children were listed. Of the 320 children, 314 (98.1%) were present at the time of data collection and 312 (97.5%) could be accurately measured. A total of 12 (3.8%) of 320 children had missing child questionnaires due to interviewer error and a further 5 (1.6%) were incomplete. Therefore 303 (94.7%) child questionnaires were completed to a sufficient standard for analysis.

Figure 9: Numbers of households participating in the end of second year evaluation, Tanna Vanuatu, 2015

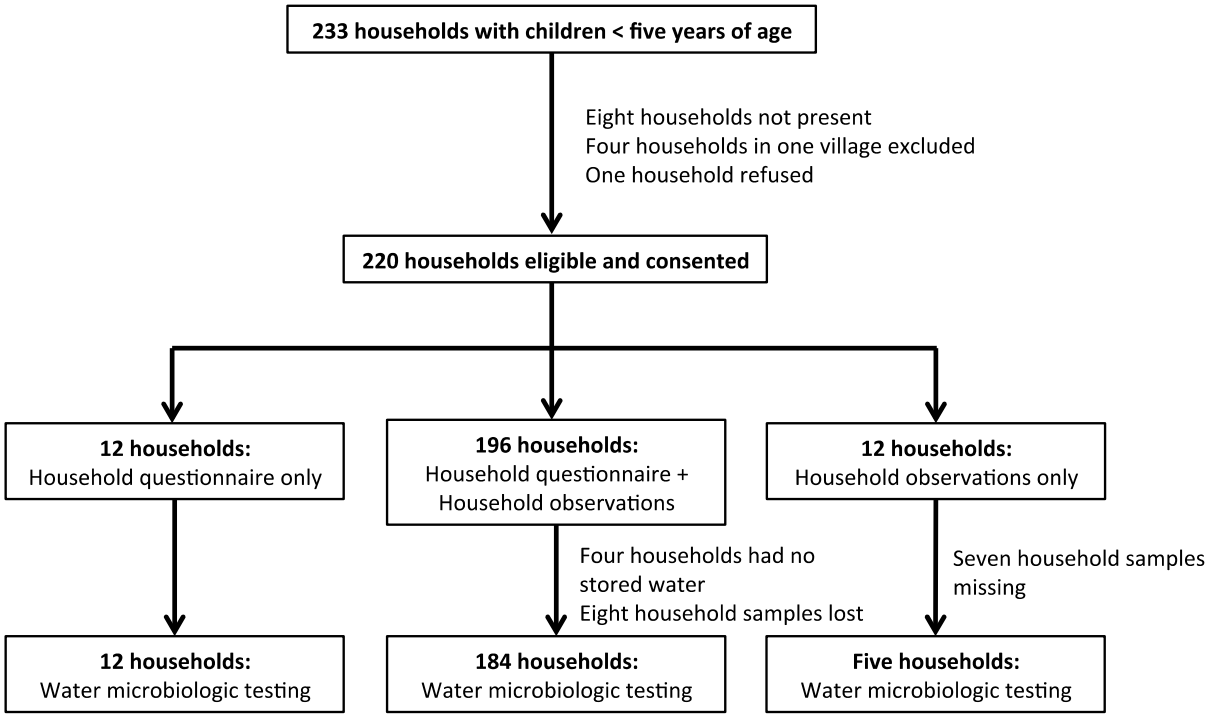
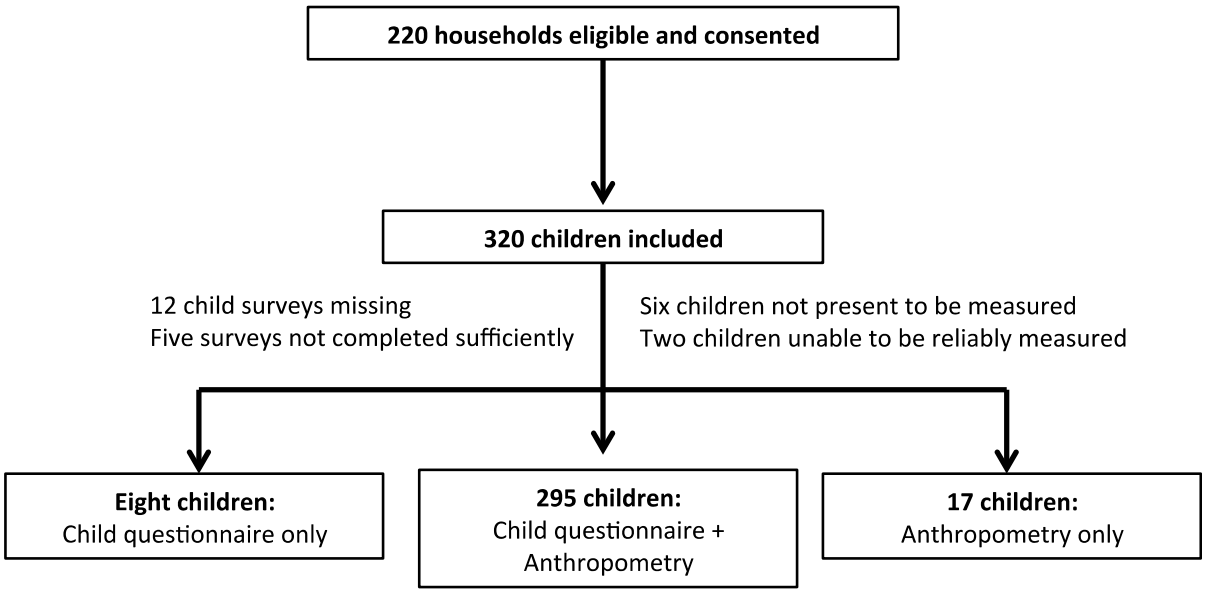


Figure 10: Numbers of children under five years of age participating in the end of second year evaluation, Tanna Vanuatu, 2015



Supplementary Table 1 describes the study population of south west Tanna that was evaluated, by community and village (Appendix 13). Among the 208 households that took part in the household questionnaire, there were 503 adults aged 15 years and over, with 268 (53.3%) female. The number of children under 15 years of age in the sample was 709, consisted of 354 (49.93%) females. Of these children, 318 (44.9%) were under five years of age. Table 8 shows general descriptive characteristics of the households, caregivers, and children within the households by community. The median (interquartile range) number of people in a single household in the study population was six (4–7), with a median of three children under 15 years of age (2–5), and one children under five years of age (1–2). The median number of children in each household was similar in between communities.

Of the 208 household questionnaires, the mother was the respondent in 195 (93.8%), the grandmother was the respondent in 10 (4.8%), and the father was the respondent in 3 (1.4%). Of the 176 (84.6%) caregivers who could state their age, the median age was 28 years, ranging from 16 through to 69 years. Of the 208 caregivers, 107 (51.4%) reported they had not received any schooling, 71 (32.1%) reported their highest level of schooling was primary school, and 27 (13.0%) reported their highest level of schooling was secondary school. One caregiver reported having tertiary education, and one caregiver reported vocational education.

Table 8: Household and participant characteristics by community in Tanna Vanuatu, 2015

Variable	Ienapkasu	Ikakahak	Ikulnala	Imapul	Karimasanga	Yekue	Total
Households:	**N=59**	**N=34**	**N=19**	**N=25**	**N=29**	**N=42**	**N=208**
	m (IQR)*	**m (IQR)**	**m (IQR)**	**m (IQR)**	**m (IQR)**	**m (IQR)**	**m (IQR)**
No. people household	5 (4–7)	7 (5–8)	5 (4–7)	5 (4–6)	5 (4–8)	6 (4–8)	6 (4–7)
Children <15 years	3 (2–5)	4 (3–5)	3 (2–5)	3 (2–4)	3 (2–4)	4 (2–5)	3 (2–5)
Children <5 years	1 (1–2)	2 (1–3)	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–2)
Caregivers:	**N=59**	**N=34**	**N=19**	**N=25**	**N=29**	**N=42**	**N=208**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Age, years [median (range)] (N=176)	27 (16–44)	26 (16–49)	28 (19–69)	30 (1845)	27 (18–48)	30 (17–57)	28 (16–69)
Relationship to child							
Mother	57 (96.6)	21 (84.0)	19 (100.0)	30 (88.24	28 (96.6)	40 (95.2)	195 (93.8)
Father	1 (1.7)	0 (0.0)	0 (0.0)	2 (5.9)	0 (0.0)	0 (0.0)	3 (1.4)
Grandmother	1 (1.7)	4 (16.0)	0 (0.0)	2 (5.9)	1 (3.5)	2 (4.8)	10 (4.8)
Highest education							
No education	49 (83.1)	9 (36.0)	13 (68.4)	2 (5.9)	3 (10.3)	31 (73.8)	107 (51.4)
Any education	10 (17.0)	16 (64.0)	6 (68.4)	32 (94.1)	26 (89.7)	11 (26.2)	101 (48.6)
Any Secondary	3 (5.1)	5 (20.0)	1 (5.3)	10 (29.4)	7 (24.1)	1 (2.4)	27 (13.0)
Children age <60 months	**N=85**	**N=65**	**N=34**	**N=33**	**N=45**	**N=58**	**N=320**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Age in months [median (range)]	21.8 (0.9–59)	20.6 (2.6–56.6)	26.3 (0.7–59.1)	26.2 (0.0–57.9)	27.7 (1.0–59.4)	29.3 (0.5–59.9)	26.0 (0.0–59.9)
0–5 months	7 (8.2)	4 (12.1)	4 (11.8)	10 (15.4)	8 (17.8)	5 (8.6)	35 (11.6)
6–11 months	17 (20.0)	5 (15.2)	5 (14.7)	8 (12.3)	4 (8.9)	6 (10.3)	43 (14.2)
12–17 months	10 (11.8)	4 (12.1)	3 (8.8)	9 (13.9)	3 (6.7)	4 (6.9)	33 (10.9)
18–23 months	15 (17.7)	6 (18.2)	4 (11.8)	2 (3.1)	3 (6.7)	4 (6.9)	31 (10.2)
24–59 months	36 (42.4)	14 (42.4)	18 (52.9)	36 (55.4)	27 (60.0)	39 (67.2)	161 (53.1)
Female	47 (55.3)	18 (54.6)	13 (38.3)	38 (58.5)	20 (44.4)	27 (46.6)	163 (50.9)
WASH: Households**	**N=59**	**N=34**	**N=19**	**N=25**	**N=29**	**N=42**	**N=208**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Improved water	2 (3.4)	7 (28.0)	14 (73.7)	23 (67.7)	16 (55.2)	0 (0.0)	62 (29.8)

Variable	Ienapkasu	Ikakahak	Ikulnala	Imapul	Karimasanga	Yekue	Total
Improved sanitation	52/54 (96.3)	25/25 (100.0)	23/24 (95.8)	33/35 (94.3)	31/31 (100.0)	38/39 (97.4)	202/208 (97.1)
Handwashing facility	40/54 (74.1)	23/25 (92.0)	20/24 (83.3)	27/35 (77.1)	27/31 (87.1)	35/39 (89.7)	172/208 (82.7)

* m (IQR) = median (interquartile range)

** WASH = water, sanitation, and hygiene

4.2 Community WASH and nutrition training and knowledge

Table 9 shows how many caregivers recalled someone in their household being trained by World Vision, either in the community, or at the Tanna office. This question relied on the recall of the caregiver, and primarily gave an indication as to which training sessions caregivers found most memorable rather than which training sessions they actually attended. Attendance records of World Vision training in the community were not kept, thus the latter could not be verified independently. The World Vision training question was answered by 207 (99.5%) of the 208 caregivers. Of these 207 caregivers, 157 (75.9%) reported that someone in the household had attended some form of World Vision training; 49 (23.7%) reported no one in the household had received any World Vision training; and 1 (0.5%) did not know. There was no significant difference in the proportion of caregivers who reported attending training between communities (p=0.223). Supplementary Table 2 lists WASH and nutrition training topics included in the training stage of the Project and the proportion of caregivers remembering each topic (Appendix 13).

Table 9 also shows caregiver knowledge in relation to diarrhoea causes and treatment, and hygiene. Examples of correct causes of diarrhoea included: drinking dirty water; having dirty hands; and animal faeces. Overall, 112 (53.85%) of 207 caregivers could identify three or more correct causes of diarrhoea. There was a statistically significant difference between communities in the proportion of caregivers who could identify three or more correct causes. Supplementary Table 10 describes the most commonly identified causes of diarrhoea, correct and incorrect, as well as other biologically plausible answers that were identified less often (Appendix 13).

Table 9: WASH related training recall and knowledge in Tanna, January 2015

Training & knowledge variables	Ienapkasu	Ikakahak	Ikulnala	Imapul	Karimasanga	Yekue	Total	p-value
World Vision training	**(N=58) n (%)**	**(N=34) n (%)**	**(N=19) n (%)**	**(N=25) n (%)**	**(N=29) n (%)**	**(N=42) n (%)**	**(N=207) n (%)**	
Any training attended*	43 (74.1)	20 (80.0)	11 (57.9)	28 (82.4)	18 (62.1)	37 (88.1)	157 (75.9)	0.223
Knowledge of causes of diarrhoea	**(N=59) n (%)**	**(N=34) n (%)**	**(N=19) n (%)**	**(N=25) n (%)**	**(N=29) n (%)**	**(N=42) n (%)**	**(N=208) n (%)**	
≥ 3 causes correct	23 (39.0)	19 (76.0)	8 (42.1)	23 (67.7)	15 (51.7)	24 (57.1)	112 (53.9)	<0.001*
Knowledge of diarrhea treatment	**(N=59) n (%)**	**(N=34) n (%)**	**(N=19) n (%)**	**(N=25) n (%)**	**(N=29) n (%)**	**(N=42) n (%)**	**(N=208) n (%)**	
≥ one treatment correct	46 (78.0)	24 (96.0)	15 (79.0)	33 (97.1)	24 (82.8)	37 (88.1)	179 (86.1)	0.155
≥ two treatments correct	31 (52.5)	15 (60.0)	7 (36.8)	27 (79.4)	19 (65.5)	24 (57.1)	123 (59.1)	
Knowledge of when to wash own hands	**(N=59) n (%)**	**(N=34) n (%)**	**(N=19) n (%)**	**(N=25) n (%)**	**(N=29) n (%)**	**(N=42) n (%)**	**(N=208) n (%)**	
≥ 3 situations identified	52 (88.1)	25 (100.0)	17 (89.5)	27 (79.4)	28 (96.6)	41 (97.6)	190 (88.1)	Omitted
Knowledge of when to wash children's hands	**(N=59) n (%)**	**(N=34) n (%)**	**(N=19) n (%)**	**(N=25) n (%)**	**(N=29) n (%)**	**(N=42) n (%)**	**(N=208) n (%)**	
Both situations identified**	30 (50.9)	17 (68.0)	11 (57.9)	18 (52.9)	18 (62.1)	32 (76.2)	126 (60.6)	0.139

Extreme values of 0% or 100% were not able to be tested using our model and are labeled as Omitted.

*p-value obtained by GEE models, controlling for village and household similarities, statistical significance level: p≤0.05

**Situations were before eating and after going to the toilet

We asked caregivers to identify what caused diarrhoea, and all responses were recorded. Correct diarrhoea treatments included ORS, green coconut water, other Government approved remedies such home made oral rehydration solution, and giving extra fluids. We did not classify traditional medicine as a correct treatment due to uncertainty around safety and effectiveness. Of the 208 caregivers, 179 (86.1%) could name at least one correct diarrhoea treatment, and 123 (59.1%) could identify at least two correct treatments (Table 9). Supplementary Table 4 shows the most commonly identified correct or incorrect treatments (Appendix 13).

We used handwashing as an indicator of knowledge of hygiene practices. Caregivers were asked to identify situations in which they would wash their own hands and their children's hands. Examples of correct situations were: after going to the toilet; before preparing food; and before eating food. Of 208 caregivers, 190 (88.1%) could identify three or more correct situations where washing their own hands was necessary for good health (Table 9). Supplementary Table 5 lists the most common situations reported by caregivers where washing hands was deemed necessary (Appendix 13). Caregivers were classified as having knowledge of when to wash children's hands if they identified both after the child had gone to the toilet and before the child eats food, per the Project's baseline definition. Of the 208 caregivers 126 (60.6%) identified both these situations (Table 9).

4.3 Description of sanitation and hygiene facilities and practices

Sanitation and hygiene facilities and practices were established using caregiver self report in the household questionnaire and observations at the household. In the household questionnaire, we asked caregivers whether they had sanitation and hygiene facilities and whether they used these facilities.

4.3.1 Sanitation

As World Vision promoted the construction and use of VIP latrines, the proportion of households with access to VIP latrines, and other types of latrines were established. Table 10 shows that of the 208 households, 197 (94.7%) reported they had a VIP latrine. The self-

reported proportion of VIP latrines was slightly more than observed, where, of the 208 households, 186 (89.4%) had a VIP latrine observed. A further 16 (7.7%) households were observed to have a simple pit latrine, three (1.4%) an unimproved or bush toilet, and three (1.4%) no toilet (Table 10). No caregivers reported open defecation, although 80 (38.5%) of 208 households reported that they shared their toilet with another household.

According to the JMP, improved latrines should not be shared with other households. To determine the number of households that fit the JMP definition of improved sanitation, households where caregivers reported sharing the latrine with other households were excluded from the observed overall VIP and improved toilets. Observation results were used for numbers of each toilet type, as these were considered to be more accurate compared to self-report. Of the 196 households that had questionnaire and observation results, 116 (59.2%) had an improved toilet defined as a VIP or simple pit latrine, that they did not share with any other households (Table 10).

Table 10: Reported and observed latrines in Tanna, Vanuatu, 2015

Latrine types	Self report (N=208) n (%)	Observation N=208 n %
Improved -share or no share	-	**202 (97.1)**
VIP latrine	197 (94.7)	186 (89.4)
Improved Pit latrine	-	16 (7.7)
Improved and no share		**116/196 (59.2)**
Unimproved pit	-	3 (1.4)
No toilet access	0 (0.0)	3 (1.4)

A behavioral question was also asked in the household questionnaire in regards to whether the household use their available latrine. Of the 208 caregivers, 2 (1.0%) reported they did not use the toilet. These two caregivers were mothers with access to VIP latrines that they shared with other households. During the observations the interviewer also examined latrines to establish use. Latrines in use, were defined as those that were not overgrown with plants constraining access to the latrine or the squatting hole, kept relatively clean, and usually had materials such as leaves available for anal cleansing. Of the 205 households that were observed to have a latrine, 199 (97.1%) were observed to be in use. Of the 6 latrines not observed to be in use, 4 (66.7%) were VIP latrines, and 2 (33.3%) were simple pit latrines.

4.3.2 Hygiene

Table 11 shows the hygiene facilities and practices in the study population. Of the 208 caregivers participating in the questionnaire, 193 (92.8%) reported they had a handwashing facility. Of the 208 households with observations carried out, handwashing facilities were observed at 172 (82.7%). Typically, handwashing facilities near the toilet were variations of tippy-taps, described earlier. However, there were also local handwashing solutions, such as large bamboo shoots with a hole and plug instead of plastic containers. Facilities also included any standpipes that were close to the household.

Interviewers carrying out the observations were asked to assess the operational status of the handwashing facility. Operation was defined as whether it could be used to wash hands at the time of observation. The most common barrier to operation was whether the handwashing facility had water available. Of the 208 households observed, 106 (51.0%) households were deemed to have an operational handwashing facility (Table 11).

Table 11: Hygiene facilities and practices in Tanna, Vanuatu, 2015

Hygiene variable	Self report	Observation
Handwashing facilities:	**(N=208)** **n (%)**	**N=208** **n %**
Any handwashing facility	193 (92.8)	172 (82.7)
Facility near toilet only	-	54 (31.4)
Facility near household only	-	23 (13.4)
Facilities near both*	-	95 (55.2)
Operational only	-	106 (51.0)
Soap for washing hands:	**(N=208)** **n (%)**	**(N=172)** **n %**
Soap at handwashing facility or household	159 (76.4)	28 (16.3)
Report washing hands with soap in past 24 hours	155 (74.5)	-
Household and environmental hygiene:	**(N=208)** **n (%)**	**(N=208)** **n %**
Rubbish pit	195 (93.8)	174 (83.7)
Pit operational	-	165 (94.8)
Dish drying rack	107 (51.4)	-
Household rated clean**	-	134 (64.4)

*Close to both, or one at each

**No unrestrained animals in household or animal faeces near household

Furthermore, if the household had a handwashing facility interviewers conducting the observations noted whether the facility had soap or a soap alternative. A commonly observed acceptable soap alternative was ash from the fire. If no soap or alternative was observed at the facility itself, a member of the household was asked if they had soap for washing hands, and to show the interviewer the soap. Concealment of soap was common for fear of soap being stolen. Of the 172 households where handwashing facilities were observed, 28 (16.3%) had soap or a soap alternative present at the handwashing facility or at the household (Table 11). In the household questionnaire interviewers also asked the caregiver whether there was soap or ash for washing hands at the household. Of the 208 caregivers asked 159 (76.4%) reported they had soap or ash (Table 11). A handwashing behavioural question was asked in the household questionnaire. Of the 208 caregivers asked, 155 (74.5%) reported they had washed their hands with soap in the past 24 hours.

Further observations were made of household and environmental hygiene, shown on Table 11. Interviewers conducting the observation were asked to rate the cleanliness of the household. Cleanliness was a largely a subjective measure, although conditions for cleanliness were agreed upon prior to data collection. Conditions included no unrestrained animals in the household or household area, and no animal faeces. Interviewers had the option of rating the household very clean, clean, unclean, or very unclean. Of the 208 households, none were rated as very clean, 134 (64.4%) as clean, 73 (35.6%) as unclean, and 1 (0.5%) as very unclean.

Interviewers were also asked to observe whether the household had a rubbish pit. Rubbish pits are particularly important in rural areas, such as south west Tanna, where residents must dispose of their own rubbish. We defined an acceptable rubbish pit as a pit for rubbish that could be buried when full, away from social areas. Open dumping in a specified area was not considered an acceptable rubbish pit. Of the 208 households, 174 (83.7%) were observed to have a rubbish pit. However, of 174 with a rubbish pit, 9 (5.2%) were no longer operational due to collapse in times of flooding, or being full. Therefore there were a total of 165 (79.3%) households with operational rubbish pits (Table 11). Additionally in the household questionnaire caregivers were asked whether they had a dish drying rack. Storing wet dishes and utensils promotes the growth of bacteria, and allowing them to dry before

storage is an important household hygiene factor. Of the 208 caregivers, 107 (51.4%) reported they had a dish drying rack (Table 11).

4.4 Description of household drinking water practices

Establishing gravity fed systems from protected sources to supply drinking water to villages was one of outcomes of the Project. However the implementation of these water systems was scheduled for 2015-2016, and as of January 2015, no World Vision water systems had been completed. Any existing gravity fed systems were from old government initiatives that were piped from unprotected sources and reported by World Vision to be in various states of disrepair (personal communication, World Vision Tanna staff, January 2015). Therefore in the water section of this evaluation we aimed to describe current drinking water sources and practices.

4.4.1 Sources of household water

Table 12 shows sources of household water by community. Primary, preferred, and secondary, when primary not available, water sources for drinking water, and water for cooking and cleaning were established. Of the 208 caregivers who took part in the household questionnaire, 133 (63.9%) reported their household's primary source was from an unprotected spring, 13 (6.3%) reported they collected surface water, 46 (22.1%) reported gravity fed systems, and 16 (7.7%) reported rainwater catchment systems. When we enquired further into gravity fed systems, all were from unprotected springs or surface water. According to JMP definitions, of 208 households 62 (29.1%) were collecting water from improved sources, and 146 (70.2%) were collecting water from unimproved sources.

We also established the availability of the primary drinking water source. Of the 208 households, 133 (63.9%) had their primary source available all year round. Of the 133 households whose primary source was available all year round, 114 (85.7%) were collecting water from unprotected springs, 11 (8.3%) from river sources, and 8 (6.0%) from gravity fed systems. No rainwater catchment systems were functional all year round, with the dry season from May to October identified as the period where these systems were often not

functional due to a lack of rain. Furthermore, of the 46 gravity fed systems, 8 (17.4%) were operational all year round. Therefore, of the 208 households, 8 (3.9%) had water that was both improved and available all year round.

Of the 75 households that reported they did not have access to their primary source all year round, 51 (68.0%) used unprotected spring water as a secondary source of drinking water, 12 (16.0%) used rainwater, 7 (9.3%) used water from the river, 9 (12.0%) used a gravity fed system, and 1 (1.4%) used seawater. Thus, of the secondary sources of drinking water, 21 (28.0%) were defined as improved. We also enquired about water used for cooking and cleaning purposes as opposed to drinking. Of the 208 caregivers, 149 (71.6%) reported they used water from an unprotected spring, 30 (14.4%) used a gravity fed system, 19 (9.1%) used river water, and 10 (4.8%) used a rainwater catchment system.

Table 12: Sources of water used at households in Tanna Vanuatu, 2015

Water purpose	Ienapkasu (N=59) n (%)	Ikakahak (N=34) n (%)	Ikulnala (N=19) n (%)	Imapul (N=25) n (%)	Karimasanga (N=29) n (%)	Yekue (N=42) n (%)	Total (N=208) n (%)
Primary water source:							
Improved	**2 (3.4)**	**23 (67.7)**	**14 (73.7)**	**7 (28.0)**	**16 (55.2)**	**0 (0.0)**	**62 (29.8)**
Gravity fed system	1 (50.0)	13 (56.5)	14 (100.0)	6 (85.7)	12 (75.0)	0 (0.0)	46 (74.2)
All year	0 (0.0)	2 (15.4)	3 (21.4)	1 (16.7)	2 (16.7)	0 (0.0)	8 (17.4)
Rain water	1 (50.0)	10 (43.5)	0 (0.0)	1 (14.3)	4 (25.0)	0 (0.0)	16 (25.8)
All year	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Unimproved	**57 (96.6)**	**11 (32.4)**	**5 (26.3)**	**18 (72.0)**	**13 (44.8)**	**42 (100.0)**	**146 (70.2)**
Unprotected spring	52 (91.2)	11 (100.0)	3 (60.0)	17 (94.4)	12 (92.3)	38 (90.5)	133 (91.2)
Surface water	5 (8.8)	0 (0.0)	2 (40.0)	1 (5.6)	1 (7.7	4 (9.5)	13 (8.9)
Secondary water sources*:							
Improved	**9 (15.3)**	**13 (38.2)**	**6 (31.6)**	**4 (16.0)**	**10 (34.5)**	**3 (7.1)**	**45 (21.6)**
Gravity fed system	0 (0.0)	2 (15.4)	6 (100.0)	1 (25.0)	4 (40.0)	0 (0.0)	13 (28.9)
Rain water catchment	9 (100.0)	11 (84.6)	0 (0.0)	3 (75.0)	6 (60.0)	3 (100.0)	32 (71.1)
Unimproved	**50 (84.8)**	**24 (70.6)**	**14 (73.7)**	**21 (84.0)**	**20 (69.0)**	**41 (97.6)**	**170 (81.7)**
Unprotected spring	45 (90.0)	23 (95.8)	7 (50.0)	20 (95.2)	20 (100.0)	38 (92.7)	153 (90.0)
Surface water	5 (10.0)	1 (4.2)	7 (50.0)	1 (4.8)	0 (0.0)	3 (7.3)	17 (10.0)
Water source for cooking and cleaning*							
Improved	**0 (0.0)**	**18 (52.9)**	**9 (47.4)**	**4 (16.0)**	**9 (31.0)**	**0 (0.0)**	**40 (19.2)**
Gravity fed system	0 (0.0)	11 (61.1)	9 (100.0)	3 (75.0)	7 (77.8)	0 (0.0)	30 (75.0)
Rain water catchment	0 (0.0)	7 (38.9)	0 (0.0)	1 (25.0)	2 (22.2)	0 (00.0)	10 (25.0)
Unimproved	**59 (100.0)**	**16 (47.1)**	**10 (52.6)**	**21 (84.0)**	**20 (69.0)**	**42 (100.0**	**168 (80.8)**
Unprotected spring	55 (93.2)	15 (93.8)	4 (40.0)	20 (95.2)	19 (95.0)	36 (85.7)	149 (88.7)
Surface water	4 (6.8)	1 (6.3)	6 (60.0)	1 (4.8)	1 (5.0)	6 (14.3)	19 (11.3)

*Caregivers could select more than one answer

4.4.2 Drinking water storage

Table 13 shows the proportion of households who reported safely storing water, compared to the observation of safe storage. World Vision and WHO define safe storage as: drinking water kept in a separate container from water used for other household purposes such as cooking and cleaning; covered to prevent flies, animals, and debris contaminating the water; and having a safe apparatus for pouring the water out of the container such as being narrow-mouthed or having a spigot. A narrow mouth or spigot means that other apparatus such as cups or bowls were not dipped into the container to extract water, thereby further preventing contamination from hands (11, 144).

Of the 208 households that were surveyed, 196 (94.2%) reported they stored water at the household for drinking. Of these 196, 194 (99.0%) had storage method responses. Table 13 shows the proportion of households who reported safely storing water, compared to the observation of safe storage. Of the 194 households who responded to the water storage question, 115 (59.3%) reported safe storage methods, defined as drinking water stored separately from water for washing and cleaning in either, a narrow-mouthed container with a lid, a jerry can, or a container with a lid and spigot (144). Of 208 households, 195 (93.8%) had stored water to observe. The addition of allowances for leaf lids was recommended by World Vision Vanuatu to reflect local practices. Safely stored water was observed at 11 (5.6%) of the 195 households, and no households were reported by interviewers to have a spigot. However, this storage question may have been misunderstood by interviewers conducting observations, who focused on whether the container was covered, as per previous surveys in the Project area, and neglected specifying whether the container had a narrow mouth or spigot (Table 13). Therefore further analysis in later chapters we have assumed that households who self-reported having containers with a spigot, did indeed have a container with a spigot.

Table 13: Drinking water storage methods in Tanna Vanuatu, 2015

Water Storage	Self report (N=194) n (%)	Observation N=195 n %
Separate to water used for cooking and cleaning	182 (93.8)	141 (72.3)
Inadequate:		
Separate and uncovered	12 (6.2)	36 (18.5)
Separate and covered with lid or leaf lid (wide mouthed)	55 (28.4)	78 (40.0)
Adequate:		
Separate, covered with lid and narrow mouthed or jerry can	13 (6.7)	11 (5.6)
Separate, covered with lid and tap or spigot	102 (52.6)	0 (0.0)
Total adequate	115 (59.3)	11 (5.6)

4.4.3 Drinking water treatment

We enquired about water treatment practices in the household questionnaire, as shown on Table 14. In World Vision trainings, communities were advised to boil their drinking water as an interim measure before new World Vision gravity fed systems were completed. Of the 208 caregivers in the survey, 89 (43.0%) reported that they treat their household drinking water. Of the 89 caregivers who reported treating water, 63 (70.8%) reported boiling, 40 (44.9%) reported they put water in a container with a lid and cap, 15 (16.9%) reported letting water stand and settle, 13 (14.6%) reported straining it through a cloth, and 1 (1.1%) reported they used a water filter. No caregivers reported chemical or solar disinfection. To be classified as adequate water treatment, the caregiver must have included a disinfection step in their report of how they treat their water. Overall, of the 208 caregivers, 75 (36.2%) reported adequate treatment of water, included one caregiver who reported both filtering and boiling drinking water.

Table 14: Drinking water treatment in Tanna Vanuatu, 2015

Water treatment for disinfection	(N=207) n (%)
Inadequate disinfection:	
Let water stand and settle	6 (2.9)
Strain through a cloth	2 (1.0)
Let settle + strain through a cloth	0 (0.0)
Adequate:	
Boil	54 (26.1)
Boil + let it stand and settle	9 (4.3)
Boil + strain it through a cloth	11 (5.3)
Boil + filter	1 (0.5)
Filter	0 (0.0)
Total adequate	**75 (36.2)**

4.4.4 Water collection logistics

In the household interview we asked water logistics questions to gain an understanding of normal water collection habits in the communities. These included the amount of time it took to collect water, the number of times water was collected per day, and by whom in the household the water was normally collected by, described on Table 15. These questions related only to the household's primary source of drinking water.

The time taken to collect water included the journey to the water collection point, collecting the water, and the journey back to the household. If caregivers did not know how to estimate measures of time in minutes, interviewers would estimate by asking further questions about the distance and where the sun usually is in the sky when they left and returned. The median distance reported for all 208 households was 19 minutes for one round trip, ranging from 0 minutes to 180 minutes.

The average number of times water was collected per day was twice, with 138 (66.4%) of the 208 caregivers reporting this (Table 15). A further 29 (13.9%) caregivers reported collecting water three times a day. The person collecting the water for the household was most commonly an adult female, reported from 139 (67.2%) of the 208 households. At a further 55 (26.6%) households an adult male was responsible for collecting water, and at 13 (6.3%) households it was the children's responsibility.

Table 15: Water collection logistics in Tanna Vanuatu, 2015

Water logistics variables	Total
Water collection time	**(N=208)** **n (range)**
Time taken to collect water (one round trip) (minutes)	19 (0-180)
Times per day water collected	2 (0-5)
Water collected by:	**(N=207)** **n (%)**
Adult Women	139 (67.2)
Adult Man	55 (26.6)
Female child	8 (3.9)
Male child	5 (2.4)

Chapter five – Child health results (objective two)

5.1 Prevalence and treatment of diarrhoea

Table 16 shows the prevalence of diarrhoea in under five year olds in the two weeks preceding the survey. We defined diarrhoea according to the WHO definition of three or more loose stools in 24 hours (42). The time period of interest was two weeks prior to the survey, a commonly used duration for this indicator, which aligns with the VDHS child diarrhoea question (18). Of the 303 children with completed diarrhoea responses in south west Tanna, 35 (11.6%) reported having diarrhoea in the two weeks preceding the survey. Of the 35 children with diarrhoea, 1 (2.9%) was reported having blood in their stools.

Table 16: Proportion of children under five years of age with diarrhoea in Tanna, Vanuatu, 2015

Diarrhoea Variables	
Diarrhoea in past two weeks	**N=303** **n (%, 95% CI)***
Diarrhoea (acute, non-bloody)	34 (11.2)
Bloody diarrhoea	1 (0.3)
Total (95% CI)	**35 (11.6) (7.5–15.6)**
Advice sought for children with diarrhoea	**N=35** **n (%)**
Aid post only	13 (37.1)
Traditional practitioner only	7 (20.0)
Both aid post and traditional practitioner	15 (42.9)
No advice sought	0 (0.0)
Total	**35 (100.0)**
Treatment given to children with diarrhoea**	**N=35** **n (%)**
ORT†	
ORS†	12 (34.3)
Gov. approved remedy‡	9 (25.7)
Increased fluid	10 (28.6)
ORT or Increased fluids	28 (80.0)
Other	
Antimicrobials	0 (0.0)
Traditional/herbal medicine	10 (28.6)
No Treatment	2 (5.7)

Diarrhoea Variables	
Effective treatment given to children with diarrhoea	**N=35** **n (%)**
Effective treatment – without traditional medicines	23 (65.7)
Effective treatment – with or without traditional medicines	28 (80.0)

*95% CI:= 95% confidence interval

**More than one answer allowed

† ORS = Oral Rehydration Salts and ORT = Oral Rehydration Therapy

‡ Government approved remedy included correctly homemade oral rehydration solution (6 teaspoon sugar, ½ teaspoon salt to 1 litre of water), green coconut water, or starchy water (such as water that starchy vegetables have been cooked in)

Caregivers who had children with diarrhoea were then asked whether help was sought for the child, and what type of treatment, if any, was given (Table 16). Of the 35 children who had diarrhoea, 13 (37.1%) caregivers sought advice from the health aid post only, 7 (20.0%) sought advice from a traditional practitioner only, and 15 (42.9%) caregivers sought advice from both a health aid post and a traditional practitioner. No caregivers reported not seeking any medical advice.

Treatment for diarrhoea was separated into oral rehydration therapy (ORT), which included: ORS; a government approved remedy; increased fluids; or other treatments which included antimicrobials and traditional or herbal medicine. A Government approved remedy included correctly homemade oral rehydration solution comprising six teaspoons of sugar and half a teaspoon of salt to one litre of water; green coconut water; or starchy water, such as water that starchy vegetables have been cooked in.

For the majority of children with diarrhoea, antimicrobials are not needed or effective, and are reserved for bloody diarrhoea. Thus, antimicrobials were only considered effective in this analysis if the child was reported to have had bloody diarrhoea (183). Traditional medicine was not considered an effective treatment because of the uncertainty of the medicine elements. Some Pacific traditional medicines are known to be harmful, for example drinking seawater and eating charcoal. Common traditional treatments on Tanna include leaf medicines and information about their effectiveness or harmfulness is unknown.

In accordance with the VDHS 2013, effective treatment for acute, non-bloody diarrhoea was considered any of the oral rehydration therapy (ORT) constituents: ORS, a government recommended remedy or increased fluids, alone or in combination (18). We present effective treatment divided into: effective treatment without any traditional medicine; and effective treatment with or without traditional medicine. As shown on Table 16, 23 (65.7%) of the 35 children had effective treatment without traditional medicine, and 28 (80.0%) children received effective treatment with or without traditional medicine.

5.2 Prevalence of undernutrition

We undertook anthrometric measurements of children under five years of age in our study population who were available to be measured, and classified their weight for height (WHZ), height for age (HAZ), and weight for age (WAZ) Z-scores into normal (≥-2z), moderately wasted, stunted, or underweight (-2z – -3z), or severely wasted, stunted, or underweight (<-3z). Of the total 320 children under five years of age participating in our evaluation, 312 (97.5%) were available for anthropometric measurements. Of the 312 children measured, 3 (1.0%) were excluded from the WAZ and HAZ analysis due to missing age information; and 2 (0.6%) were excluded from HAZ and WHZ analysis due to missing height information. Children were also excluded from individual analyses if their measurements were five standard deviations from the mean or greater, indicating probable measurement error (182). Measurement error exclusion resulted in ten further children excluded from HAZ analysis and four children excluded from WHZ analysis. A total of 303 children were included in the WHZ analyses, 297 in the HAZ analysis, and 309 in the WAZ analysis.

Table 17 shows the proportion of children under five years of age with normal or abnormal anthropometric measurements. Of the 303 children included in the WHZ analysis, 12 (4.0%, 95% CI: 1.8–6.1) were wasted, with WHZ scores of <-2, including 10 (3.3%) moderately wasted (-2z – -3z) children, and 2 (0.7%) severely wasted children (<-3z). The number of girls wasted was 9 (5.8%) of 154 compared to 3 (2.0%) of 149 boys.

Of the 297 children included in the stunting (HAZ) analysis, 145 (48.8%, 95% CI: 42.8–54.8) were stunted, with a HAZ score of <-2, including 93 (31.3%) children with Z-scores indicating

moderate stunting (-2z – -3z), and 52 (17.5%, 95% CI: 13.0–22.0) children with Z-scores indicating severe stunting (<-3z). The number of boys that were severely stunted was 32 (22.1%) of 145, compared to 20 (13.2%) of 154 girls. Of the 309 children included in the underweight (WAZ) analysis, 59 (19.1%, 95% CI: 14.4–23.8) were underweight, with a WAZ score of <-2, including 40 (13.0%) children who were moderately underweight (-2z – -3z), and 19 (6.2%, 95% CI: 3.3–9.0) who were severely underweight (<-3z). There was a similar prevalence of underweight children between girls and boys.

Table 17: Proportion of children under five years of age underweight, stunted, and wasted in Tanna Vanuatu, 2015

Anthropometric indices	Girls	Boys	Total
Total Wasting (Weight for Height Z-Score)	**N=154**	**N=149**	**N=303**
	n (%)	**n (%)**	**n (%, 95% CI)***
Normal (≥ -2z)	145 (94.2)	146 (98.0)	291 (96.0)
Wasted (<-2z)	**9 (5.8)**	**3 (2.0)**	**12 (4.0, 1.8–6.1)**
Moderate wasting (-2z to -3z)	7 (4.6)	3 (2.0)	10 (3.3)
Severe wasting (< -3z)	**2 (1.3)**	**0 (0.0)**	**2 (0.7%**)**
Total Stunting (Height for Age Z-Score)	**N=152**	**N=145**	**N=297**
	n (%,)	**n (%)**	**n (%, 95% CI)**
Normal (≥-2z)	76 (50.0)	76 (52.4)	152 (51.2)
Stunted (<- 2z)	**76 (50.0)**	**69 (47.6)**	**145 (48.8, 42.8–54.8)**
Moderate stunting (-2z to -3z)	56 (36.8)	37 (25.5)	93 (31.3)
Severe stunting (< -3z)	**20 (13.2)**	**32 (22.1)**	**52 (17.5, 13.0–22.0)**
Total Underweight (Weight for Age Z-Score)	**N=157**	**N=152**	**N=309**
	n (%)	**n (%)**	**n (%, 95% CI)**
Normal (≥-2z)	127 (80.9)	123 (80.9)	250 (80.9)
Underweight (<-2z)	**30 (19.1)**	**29 (19.1)**	**59 (19.1, 14.4–23.8)**
Moderate underweight (-2z – -3z)	18 (11.5)	22 (14.5)	40 (13.0)
Severe underweight (< -3z)	**12 (7.6)**	**7 (4.6)**	**19 (6.2, 3.3–9.0)**

* 95% confidence interval

**Numbers too low to generate 95% CI

5.3 Prevalence of acute respiratory infection, presumed pneumonia

The prevalence of respiratory problems was ascertained via the child questionnaire. Of the 303 children under five years of age with completed child questionnaires, 300 (99.0%) had complete responses for respiratory infection questions. Of those 300 responses, 171 (57.0%)

children under five years of age were reported to have had a cough in the two weeks preceding the survey.

Details about the type of cough, acute respiratory infection (ARI), or upper respiratory tract infection (URTI), were determined by the accompanying caregiver-reported symptoms. A cough with accompanying chest problems, including either difficulty breathing or short rapid breaths, was considered to be an ARI, otherwise referred to as presumed pneumonia, as per WHO/UNICEF definitions (184). A cough that was not consistent with involvement of the lower respiratory tract was indicative of an URTI, including seasonal coughs and colds.

Of the 300 children with responses to respiratory questions, 22 (7.3%, 95% CI: 4.1%–10.6%) had symptoms consistent with an ARI in the two weeks preceding the questionnaire. A further 149 (49.7%, 95% CI: 43.6–55.7) children had symptoms consistent with an URTI.

5.4 Infant and young child nutrition

In the household survey, we asked caregivers about their infant and young child feeding practices related to breastfeeding and complementary feeding. These questions were asked only of the youngest child representing the most recent breastfeeding and complementary feeding experience, to reduce recall bias. Additional questions about the diet of all children over six months of age and under five years of age were asked in the child questionnaire. Of the 208 households with children under five years of age, 205 (98.6%) had nutrition answers regarding the youngest child in the household.

5.4.1 Breastfeeding practices

Table 18 shows the breastfeeding practices of the caregiver in regards to their youngest child. Of the 205 children, 188 (91.7%) were reported by the caregiver to have ever been breastfed. Early breastfeeding initiation practices were answered for 186 (90.7%) of 205 children. Of the 186 children, 151 (81.2%) were reported to have been put to the breast within one hour of birth.

A combination of breastfeeding and complementary feeding practices allowed us to assess whether the youngest child was currently being exclusively breastfed, as shown in Table 18. Of the 205 youngest children, 41 (20.0%) were under six months of age. Of the 41 children under six months of age, 29 (70.7%) had received only breast milk in the past 24 hours and thus, by WHO IYCF indicator definitions, were exclusively breastfed. Of the 41 children, 6 (14.6%) had not had breast milk in the last 24 hours. Of these six children under six months of age that had not received breast milk, two were 5.9 months, one was 4.7 months, one was 3.2 months, one was 1.8 months, and one was 0 months.

Of the 188 youngest children who had ever been breastfed, 92 (48.9%) were no longer being breastfed. Of these 92 children, 32 (34.8%) had been breastfed beyond 12 months, and 26 (28.3%) had been breastfed for 24 months or more (Table 18).

Table 18: WHO Infant and Young Child Feeding (IYCF) breastfeeding practices in Tanna Vanuatu, 2015

WHO Infant and Young Child Feeding: breastfeeding indices	
Ever breastfed	**N=205** **n (%)**
Yes	188 (91.7)
No	17 (8.3)
Early initiation – hours after birth first put to breast	**N=186** **n (%)**
Under 1 hour	**151 (81.2)**
Between 1 and 24 hours	34 (18.3)
Over 24 hours	1 (0.5)
Exclusive breastfeeding – youngest child <6 months of age in past 24 hours	**N=41** **n (%)**
Breast milk only	**29 (70.7)**
Breast milk and fluids/solids other than breast milk	6 (14.6)
Fluids/solids other than breast milk	6 (14.6)
Length of time breastfed	**N=92** **n (%)**
Less than 12 months	37 (40.2)
12 months	23 (25.0)
Beyond 12 months (13 months and more)	32 (34.8)
24 months or more	26 (28.3)

5.4.2 Complementary feeding and dietary diversity

Table 19 shows the complementary feeding and dietary diversity practices in the study population. Caregivers were asked when solid foods had been introduced to their youngest child if their youngest child was over six months of age. Of the 205 youngest children, 162 (79.0%) were over six months of age and had responses for this question. Of the 162 children, 132 (81.5%) had been six months old when solids were introduced.

The caregiver was also asked what food each of their children under five years of age had consumed in the past 24 hours. The dietary diversity of children six months and older was then established according to global IYCF recommendations, and World Vision's definition of a diverse diet (Table 19). Of 303 children, 102 (33.7%) were 6–23 months of age and had full responses to dietary questions. Of these 102 children, 60 (58.8%) had eaten four or more of the seven IYCF food groups: grains; roots and tubers; legumes and nuts; dairy products; flesh foods; eggs; vitamin-A rich fruits and vegetables; and other fruits and vegetables, meeting WHO's minimum dietary diversity (MDD). Of the 303 children, 160 (52.8%) were 24–59 months of age and had full responses to dietary questions. Of these 160 children, 97 (60.6%) had received IYCF MDD. Dietary diversity scores on how many individual WHO food groups were consumed, was also measured as they are a more precise measure of diverse diets (185). These are also reported on Table 19.

Animal sourced foods, dairy, and foods rich in vitamin A protein are especially important for growth of young children. Animal sourced foods in our study population included flesh foods and eggs. Of 102 children 6–23 months of age with full responses to the survey, 52 (51.0%) had either flesh foods or eggs in the 24 hours prior to the survey. Of the 102 children, 32 (31.4%) had a source of dairy foods in the 24 hours prior to the survey, which could include milk, cheese, and yoghurt, as well as breast milk. Of the 102 children, 75 (73.5%) had consumed foods rich in vitamin A in the 24 hours prior to the survey, including yellow or orange fruits and vegetables such as kumara. Of the 159 children 24–59 months of age, 88 (55.0%), 7 (4.5%), and 128 (80.0%) were reported to have consumed an animal sourced food, dairy, and food rich in vitamin A in the past 24 hours, respectively.

World Vision defines dietary diversity as receiving foods from the three main food groups: carbohydrates; fruit and vegetables; and protein (11). Of the 261 children between 6 and 59

months, 136 (53.2%) had received food from all three groups. Of the three groups, protein was the least consumed, with 140 (53.6%) having consumed a source of protein, either meat, fish, or eggs in the 24 hours prior to the questionnaire.

We asked the caregiver the number of meals and snacks received by children in the 24 hours prior to the evaluation. This information was combined with information regarding whether the children is being currently breastfed, and the age of the child to determine minimum meal frequency (MMF). WHO defines MMF for non-breastfed children as children 6–23 months of age who have had four or more meals or snacks in the past 24 hours. Breastfed children MMF is defined as two or more meals or snacks, and three or more meals or snacks, for children 6–8 months of age, and 9–23 months of age respectively.

As we only asked breastfeeding status of the youngest child in the household, 14 (13.7%) of the total 102 children 6-23 months of age were left out of MMF analysis. A further 9 (8.8%) children were excluded due to missing breastfeeding or meal frequency information. Of the 79 children that were included in the MMF analysis, 63 (79.8%) met WHO IYCF MMF requirements.

Table 19: Infant and young child feeding (IYCF) complementary feeding and dietary diversity in Tanna Vanuatu, 2015

Complementary feeding and dietary diversity variables	**n (%)**
Age when solids were Introduced	**N=162** **n (%)**
0-4 months	9 (5.6)
5 months	4 (2.5)
6 months	132 (81.5)
7 months or older	17 (10.5)
World Health Organisation IYCF MDD* - Children 6–23 months of age	**N=102** **n (%)**
Food groups consumed in past 24 hours:	
Grains, roots and tubers	96 (94.1)
Legumes and nuts	26 (25.5)
Vitamin A rich fruit and vegetables	75 (73.5)
Other fruits and vegetables	98 (96.1)
Flesh foods (meat, fish, poultry, and liver/organ	46 (45.1)

meats)	
Eggs	11 (10.8)
Dairy products or breast milk	32 (31.4)
Dietary diversity score:	
≤1 group	6 (5.9)
2 groups	11 (10.8)
3 groups	25 (24.5)
4 groups	28 (27.5)
≥5 groups	32 (31.4)
MDD* ≥ 4 of the IYCF food groups	**60 (58.8)**
Complementary feeding and dietary diversity variables	**n (%)**
IYCF MDD* - Children 24–59 months of age	**N=160** **n (%)**
Food groups consumed in past 24 hours:	
Grains, roots and tubers	159 (99.4)
Legumes and nuts	64 (40.0)
Vitamin A rich fruit and vegetables	128 (80.0)
Other fruits and vegetables	160 (100.0)
Flesh foods (meat, fish, poultry, and liver/organ meats)	85 (53.1)
Eggs	13 (8.1)
Dairy products or breast milk	7 (4.5)
Dietary diversity score:	
≤1 group	0 (0.0)
2 groups	12 (7.5)
3 groups	51 (31.9)
4 groups	53 (33.1)
≥5 groups	44 (27.5)
MDD* ≥ 4 of the IYCF food groups	**97 (60.6)**
World Vision defined MDD* – children 6–59 months of age	**N=261** **n (%)**
Carbohydrates or starch	253 (96.9)
Fruit and vegetables	261 (100.0)
Protein	140 (53.6)
World Vision MDD - ≥3 groups	**136 (53.2)**
IYCF MMF**– children 6–23 months of age	**N=79** **n (%)**
Breastfed children:	
6-8 months - ≥2 feeds	12/15 (80.0)
9-23 months - ≥3 feeds	30/39 (76.9)
Non breastfed children:	
6-23 months - ≥4 times a day	21/25 (84.0)
Breastfed and non breastfed children	**63 (79.8)**

*MDD = Minimum dietary diversity

**MMF = Minimum meal frequency

5.5 Vaccinations and supplements

Table 20 shows the immunisation status of children in the study population. World Vision Vanuatu considers children to be fully vaccinated when they have had all three doses of vaccines effective against diphtheria, tetanus, and pertussis (DTP combination), which are scheduled to be received at age 6, 10 and 14 weeks; and a measles vaccination, received at 12–15 months. The Bacille de Calmette et Guérin (BCG) vaccine against tuberculosis is given at birth or first clinical contact, and the polio vaccine is given at the same time as DTP. It is assumed that children who received three doses of DTP and measles vaccinations, also have had BCG and polio vaccinations. If the children had an immunisation card available, immunisation status was recorded directly from the immunisation card. If not, caregivers were prompted whether each child had received three doses of the DTP vaccine and a single measles vaccination, described as injections in the thigh or arm. I analysed these questions for children 12–23 months of age, as done in the VDHS survey. However, as there were only a small number of children in 12–23 month age group in our survey, I also analysed a broader age range, 12–59 months of age. Because of technical issues with the smartphone application, measles responses were missing for some children.

Of the 303 children that had a child questionnaires completed, 64 (21.1%) were between 12 and 23 months of age. Of the 64 children, 57 (89.0%) had responses to vaccination questions. Of these 57 children, 39 (68.4%) were recorded to have had their third dose of the DTP vaccine. Responses of measles vaccination status were missing for 13 (22.8%) of the 57 children. Of the 44 children with both DTP and measles responses, 18 (40.9%) had been vaccinated for both (Table 20).

Of the 303 children, 225 (74.3%) were between 12 and 59 months of age. Of these 225 children, 198 (88.0%) had responses to vaccination questions. Of these 198 children 139 (70.2%) were recorded to have had their third dose of the DTP vaccine. Responses of measles vaccination status were missing for 37 (18.7%) of the 198 children. Of the 161 children with both DTP and measles responses, 84 (52.2%) had been vaccinated for both (Table 20).

We established whether each child had received a vitamin A dose and de-worming medication in the last 6 months, also shown on Table 20. The vitamin A dose was explained to caregivers as a capsule with a red liquid that would have been cut open and fed to the child. The de-worming medication was described as a tablet that the child could chew. I analysed the vitamin A question for children 6–59 months of age and the de-worming question was analyzed for children 12–59 months of age, reflecting the current Vanuatu Ministry of Health schedule (186).

Of the total 303 children, 269 (88.8%) were between 6 and 59 months of age. Of the 269 children, 237 (88.1%) had vitamin A dose responses. Of these 237 children, 170 (71.7%) had received a vitamin A dose in the last six months. Furthermore, of the 225 children between 12 and 59 months of age, 199 (88.4%) had de-worming responses. Of these 199 children, 152 (76.4%) had received a de-worming tablet in the last six months.

Table 20: Child immunisations, vitamin A supplementation, and de-worming medication in Tanna Vanuatu, 2015

Immunisations, vitamin A and de-worming	**n/N**	**(%)**
Age: 12–23 months		
DTP	39/57	(68.4)
Measles	19/44	(43.2)
DTP* + measles	**18/44**	**(40.9)**
Age 12–59 months		
DTP*	139/198	(70.2)
Measles	90/161	(55.9)
DTP* + measles	**84/161**	**(52.2)**
Age: 6–59 months		
Vitamin A dose in last 6 months	**170/237**	**(71.7)**
Age: 12–59 months		
De-worming medicine in last 6 months	**152/199**	**(76.4)**

***DTP =** diphtheria, tetanus, and pertussis combination vaccine

Chapter six – Factors associated with child health outcomes (objective three)

I investigated associations between child health outcomes of children under five years of age and child, caregiver, and WASH factors using univariate and multivariate analyses. Additionally, I investigated the association between different health outcomes by univariate and multivariate analyses to indicate whether unwell children were at a higher risk of further health outcomes.

Health outcomes investigated included the period prevalence of diarrhoea in the two weeks prior to the evaluation, the prevalence of stunting, and the prevalence of underweight. Wasting and ARI were not investigated because numbers were too low. All plausible associations with diarrhoea, underweight, and stunting health outcomes that met our inclusion criteria described in the methods were included in multivariate analyses. Backward elimination was used to establish the final model, as per methods.

6.1 Factors associated with child diarrhoea

6.1.1 Child, caregiver, and WASH factors

To investigate child, caregiver, and WASH factors that were associated with diarrhoea in children under five years of age I used univariate and multivariate analyses, Table 21 and Table 22.

Univariate analysis

Table 21 shows that the median age of children with diarrhoea was 20.9 (range: 1.3–54.8) months compared to 27.0 (range: 0.3–59.9) months for children without diarrhoea. The prevalence of diarrhoea was 2% lower for every one month increase in child age (PR: 0.98, 95% CI: 0.97–1.00), which was statistically significant (p=0.036). I did not find a difference in

the prevalence of diarrhoea by child gender (p=0.317), although the confidence interval for the PR was wide.

I did not find a difference in IYCF practices that were looked at between children with and without diarrhoea, including ever being breastfed (p=0.805), MDD (p=0.499), dietary diversity score (p=0.823), and MMF (p=0.540). For the majority of IYCF indicators confidence intervals for the PRs were relatively wide. I could not investigate differences in exclusive breastfeeding practices because of low numbers.

There was no significant difference in the proportion of children 12–59 months of age who were fully immunised among children with and without diarrhoea (PR: 0.39, 95% CI: 0.15–1.02, p=0.054). There was also no significant difference in the proportion of children 12–59 months of age who had received de-worming medication in the past six months among children with and without diarrhoea (p=0.333).

The median age of caregivers with children who had diarrhoea was 24.5 (range: 19.0–41.0) years, compared to 27.0 (range: 16.0–69.0) years for caregivers without children who had diarrhoea. For every one year increase in caregiver age there was a corresponding 8% reduction in child diarrhoea prevalence (PR: 0.92, 95% CI: 0.87–0.97), which was statistically significant (p=0.002). I did not find any statistically significant difference in caregiver education between children with and without diarrhoea (p=0.694). Nor did I find any difference in caregiver height, weight or body mass index (BMI) among children with and without diarrhoea (p=0.930, p=0.947, and p=0.849).

The prevalence of child diarrhoea was 51% lower among households where the caregiver demonstrated they knew when they should wash their children's hands, by giving examples of before the child eats, and after the child goes to the toilet, compared to households where the caregiver could not (PR: 0.49, 95% CI: 0.21–0.95), which was statistically significant (p=0.011). There was no statistically significant difference in child diarrhoea prevalence between caregivers who could and could not identify situations when they should wash their own hands (p=0.301). A hand hygiene composite indicator was established to identify caregivers who knew four or more situations where they should wash their own hands and the two situations when they should wash their children's hands. The prevalence of child diarrhoea was 55% lower in households where the caregiver could

identify when to wash their own, and their children's hands (PR: 0.45, 95% CI: 0.21–0.95), which was statistically significant (p=0.036).

I did not find any difference in using improved sources for drinking water among children with and without diarrhoea (p=0.217). Nor was there any difference in reported household water treatment or reported household water storage among children with and without diarrhoea (p=0.921 and p=0.708).

I did not find any difference in access to Improved or VIP latrines between children with and without diarrhoea (p=0.392 and p=0.0.355). However the confidence intervals for the PRs were wide because of the majority of households with access. I also did not find any difference in having a handwashing facility or caregiver self-reported handwashing practices between children with and without diarrhoea (p=0.344 and p=0.741).

Table 21: Univariate analysis of child, caregiver, and WASH factors associated with diarrhoea in children under five years, Tanna Vanuatu, 2015**

Variable	Diarrhoea	No diarrhoea	PR (95% CI)	p-value
Child factors				
Age and gender	**(N=35) n (%)**	**(N=268) n (%)**		
Age				
0-6 months	**4 (11.4)**	**31 (11.6)**		
6-12 months	**7 (20.0)**	**36 (13.4)**		
12-18 months	**6 (17.1)**	**27 (10.1)**		
18-24 months	**4 (11.4)**	**27 (10.1)**		
24-60 months	**14 (40.0)**	**147 (54.9)**		
Age in months (median [range])	20.9 (1.3–54.8)	27.0 (0.3–59.9)	0.98 (0.97–1.00)	0.036*
Gender				
Female	19 (54.3)	132 (49.3)	1.28 (0.79–2.08)	0.317
Male	16 (45.7)	136 (50.8)		
IYCF practices	**n/N (%)**	**n/N (%)**		
Ever breastfed - (N=189)	22/24 (91.7)	153/165 (92.7)	0.86 (0.26–2.88)	0.805
Early initiation, <1 hour after birth (N=187)	16/24 (72.3)	123/163 (81.5)	0.69 (0.23–2.03)	0.500
Timely complementary feeding† (>6 months of age) (N=151)	17/20 (85.0)	108/131 (82.4)	1.15 (0.34–3.83)	0.826
WHO MDD‡ achieved (>6 months of age)(N=262)	19/30 (63.3)	136/232 (58.6)	1.31 (0.60–2.85)	0.499
Dietary diversity score (6–23 months of age):	**(N=17)**	**(N=85)**		
≤1 group	1 (5.9)	5 (5.9)	1.06 (0.65–1.71)	0.823
2 groups	2 (11.8)	9 (10.6)		
3 groups	3 (17.7)	22 (25.9)		
4 groups	5 (29.4)	23 (27.1)		
≥5 groups	6 (35.3)	26 (30.6)		
WHO MMF‡ achieved (6-23 months of age)(N=74)	12/14 (85.7)	47/60 (78.3)	1.53 (0.39–5.93)	0.540

Variable	Diarrhoea	No diarrhoea	PR (95% CI)	p-value
Immunisation, vitamin A, and deworming status	**n/N (%)**	**n/N (%)**		
Fully immunised (≥12 months of age)	**6/19 (31.6)**	**78/142 (54.9)**	**0.39 (0.15–1.02)**	**0.054**
Received vitamin A dose in last 6 months (≥6 months of age)	20/28 (71.4)	150/209 (71.8)	1.02 (0.46–2.26)	0.953
Received deworming medication in past 6 months (≥12 months of age)	14/21 (66.7)	138/178 (77.5)	0.62 (0.24–1.63)	0.333
Caregiver factors				
Age and education	**(N=35) n (%)**	**(N=268) n (%)**		
Age in years, median(range) (N=265)	**24.5 (19.0-41.0)**	**28.0 (16.0–69.0)**	**0.92 (0.87–0.97)**	**0.002***
Any education	15 (42.9)	135 (50.4)	0.85 (0.37–1.95)	0.694
Secondary or above	4 (11.4)	41 (15.3)	0.83 (0.33–2.06)	0.682
Maternal Health	**(N=35) n (%)**	**(N=257) n (%)**		
Weight kg (median [range]) (N=292)	58.2 (42.9–70.9)	57.8 (38.8–90.4)	1.00 (0.96–1.04)	0.930
Height cm (median [range]) (N=292)	158.2 (47.5–166.4)	156.6 (146.2–186.7)	1.00 (0.93–1.08)	0.947
BMI*** (median [range]) (N=290)	23.3 (19.7–30.8)	23.5 (17.9–38.7)	0.99 (0.90–1.10)	0.849
Normal	28 (80.0)	184 (72.2)		
Underweight	0 (0.0)	4 (1.6)		
Overweight	5 (15.3)	59 (23.1)		
Obese	2 (5.7)	8 (3.1)		
Knowledge	**(N=35) n (%)**	**(N=268) n (%)**		
Any World Vision training	29 (74.3)	210 (78.4)	0.88 (0.43–1.78)	0.719
Know when to wash hands: three or more situations	33 (94.3)	247 (92.2)	1.18 (0.52–3.63)	0.518
Know when to wash hands: four or more situations	18 (51.4)	164 (61.2)	0.67 (0.32–1.43)	0.301
Know when to wash children's hands	**15 (42.9)**	**168 (62.7)**	**0.49 (0.28–0.85)**	**0.011***

Variable	Diarrhoea	No diarrhoea	PR (95% CI)	p-value
Knowledge	**(N=35)** **n (%)**	**(N=268)** **n (%)**		
Knows when to wash own and children's hands	9 (25.7)	122 (45.5)	0.45 (0.21–0.95)	0.036*
Know causes of diarrhoea: three or more	20 (57.1)	149 (55.6)	1.09 (0.51–2.32)	0.822
Knowledge of diarrhoea treatment	17 (48.6)	163 (60.8)	0.62 (0.29–1.31)	0.209
WASH factors**				
Water	**(N=35)** **n (%)**	**(N=268)** **n (%)**		
Improved source	14 (40.0)	81 (30.2)	1.52 (0.78–2.96)	0.217
Gravity fed system	10 (28.6)	58 (21.2)	1.33 (0.63–2.81)	0.461
Rainwater catchment	4 (11.4)	23 (8.6)	1.62 (0.76–3.48)	0.211
Self-reported water treatment: disinfection methods only	5/34 (14.7)	82/256 (32.0)	1.03 (0.53–2.02)	0.921
Appropriate water storage observed	3/34 (8.8)	14/256 (5.5)	0.89 (0.39–1.89	0.708
Takes >30 min to collect	19 (54.3)	155 (57.8)	0.79 (0.40–1.57)	0.496
Sanitation and hygiene	**(N=34)** **n (%)**	**(N=256)** **n (%)**		
Any improved latrine observed	33 (97.1)	244 (95.3)	1.87 (0.45–7.86)	0.392
VIP§ latrine observed	31 (91.2)	220 (85.9)	1.55 (0.61–3.93)	0.355
Operational handwashing facility observed	9 (26.5)	86 (33.6)	0.71 (0.35–1.44)	0.344
Caregiver washed hands in past 24 hours	25/35 (71.4)	197/268 (73.5)	0.88 (0.40–1.92)	0.741

PR and 95% CI obtained using GEE models, controlling for village and household similarities
Bolded variables represent factors included in multivariate analyses
* Statistically significant = p≤0.05
** WASH= water, sanitation, and hygiene
*** BMI = body mass index
† Timely complementary feeding defined here as introducing complementary food at 5–6 months of age
‡ WHO IYCF MDD = World Health Organisation Infant and Young Child Feeding Minimum Dietary Diversity, WHO IYCF MMF = World Health Organisation Infant and Young Child Feeding Minimum Meal Frequency
§ VIP = ventilated improved pit latrine

Multivariate analyses

The final multivariate model is shown on Table 22. In the univariate analysis, child, caregiver, and WASH variables that were significantly associated with a lower two week period prevalence of diarrhoea included: older child age; younger caregiver age; and good hand hygiene knowledge. In the final model the two week period prevalence of diarrhoea was 8% lower for every one year increase in caregiver age (PR: 0.92, 95% CI: 0.86–0.98), which was statistically significant (p=0.015). The association between diarrhoea and hand hygiene knowledge was no longer statistically significant when child age and caregiver age were adjusted for (p=0.460)

Table 22: Multivariate analysis of child, caregiver, and WASH* factors associated with diarrhoea in children under five years of age, Tanna Vanuatu, 2015

Child, caregiver and/or WASH factors	Univariate analysis		Multivariate analysis**	
	PR (95% CI)	p-value	PR (95% CI)	p-value
Caregiver age	0.92 (0.87–0.97)	0.002	0.92 (0.86–0.98)	0.015*
Knowledge of when to wash children's hands	0.45 (0.21–0.95)	0.036	0.71 (0.29–2.92)	0.460

Multivariate analysis included age of child in six month age groups.
* Statistically significant in multivariate analysis = p≤0.05.
** WASH = water, sanitation, and hygiene

I also investigated Immunisation status via multivariate analysis, as the p-value was under the cut-off for inclusion, as specified in our methods. I used a separate analysis for immunization status as it involved only child 12–59 months of age. When child age and caregiver age were controlled for, child immunization status was not significantly associated with diarrhoea (p=0.124), as shown on Supplementary Table 6 (Appendix 13).

6.1.2 Child health outcomes

To investigate whether other child health outcomes were associated with a higher prevalence of diarrhoea in children under five years of age I used univariate and multivariate analyses, Table 23 and Table 24.

Univariate analysis

In the univariate analyses on Table 23, I found there was no statistically significant association between total wasting and diarrhoea (PR: 2.32, 95% CI: 0.85–6.29, p=0.99). However the prevalence of diarrhoea was over four times higher among children who were severely wasted (PR: 4.17, 95% CI: 1.12–15.49), which was statistically significant (p=0.033). Additionally, the prevalence of diarrhoea was two times higher among children who were underweight, compared to children who were not underweight (PR: 2.04, 95% CI: 1.16–3.58), which was statistically significant (p=0.014). The prevalence of diarrhoea was more than three times higher in children who had an ARI in the two weeks prior to the survey (PR: 3.12, 95% CI: 1.54–6.30), which was statistically significant (p=0.002). I did not find any statistically significant association between stunting and diarrhoea (PR: 1.33, 95% CI: 0.85–2.09, p=0.956).

Table 23: Univariate analysis of health outcomes associated with diarrhoea in children under five years, Tanna Vanuatu, 2015

Health outcome	Diarrhoea	No diarrhoea	PR (95% CI)	p-value
Wasting (N=287)	**(N=35)** **n (%)**	**(N=252)** **n (%)**		
WHZ** score (median [range])	-0.9 (-4.1–2.6)	0.1 (-3.3–2.7)	0.81 (0.61–1.07)	0.133
Moderate	2 (5.7)	7 (2.8)		
Severe	**1 (2.9)**	**1 (0.4)**	**4.17 (1.12–15.49)**	**0.033***
Total	**3 (8.6)**	**8 (3.2)**	**2.32 (0.85–6.29)**	**0.099**
Underweight (N=293)	**(N=35)** **n (%)**	**(N=258)** **n (%)**		
WAZ** score (median [range])	-1.2 (-4.6–2.2)	-0.95 (-4.9–3.5)	0.87 (0.67–1.13)	0.292
Moderate	9 (25.7)	31 (12.0)		
Severe	3 (8.6)	15 (5.8)	1.31 (0.78–2.34)	0.328
Total	**12 (34.3)**	**46 (17.8)**	**2.04 (1.16–3.58)**	**0.014***
Stunting: (N=282)	**(N=35)** **n (%)**	**(N=247)** **n (%)**		
HAZ** score (median [range])	-2.4 (-4.3–4.5)	-1.9 (-4.9–2.5)	0.99 (0.77–1.28)	0.956
Moderate	13 (37.1)	73 (29.6)		
Severe	7 (20.0)	45 (18.2)	1.04 (0.58–1.88)	0.890
Total	20 (57.1)	118 (47.8)	1.33 (0.85–2.09)	0.215

Health outcome	Diarrhoea	No diarrhoea	PR (95% CI)	p-value
Respiratory infection in past two weeks (N=299)	**(N=35) n (%)**	**(N=264) n (%)**		
ARI**	**7 (20.0)**	**15 (5.7)**	**3.12 (1.54–6.30)**	**0.002***
URTI†	22 (62.9)	126 (47.3)	1.72 (0.74–3.97)	0.279
ARI or URTI†	**29 (82.9)**	**140 (53.2)**	**3.67 (1.56–8.65)**	**0.003***

PR and 95% CI obtained using GEE models, controlling for village and household similarities
Bolded variables represent factors included in multivariate analyses
* Statistically significant = p≤0.05
** ARI = acute respiratory infection
† URTI = upper respiratory tract infection

Multivariate analyses

Table 24 shows the associations between diarrhoea and other health outcomes investigated in multivariate analyses, included wasting, severe wasting, underweight, ARI, and ARI or URTI. Because of the correlation between health outcomes, I investigated each association with diarrhoea in separate analyses, adjusting for priori factors and child, caregiver, and WASH factors that remained significant in the final model in Table 22. Priori variables for undernutrition outcomes included age of the child in six month groups; child gender; caregiver education; and maternal height. The priori variable for respiratory outcomes was child age in six month groups. Table 24 shows unadjusted and adjusted associations.

The adjusted period prevalence of diarrhoea was over eight times higher among children who were severely wasted (PR: 8.14, 95% CI: 4.15–15.96), which was statistically significant (p<0.001). The period prevalence of diarrhoea was over two times higher in children who were underweight (PR: 2.34, 95% CI: 1.55–3.54), which was statistically significant (p<0.001). Furthermore the prevalence of diarrhoea was 3.63 times higher in children who had an ARI in the two weeks prior to the survey (PR: 3.63, 95% CI: 1.87–7.74), which was statistically significant (p<0.001). The association between diarrhoea and total wasting remained non-significant when adjusted (p=0.171).

Table 24: Multivariate analyses of child health outcomes associated with diarrhoea in children under five years of age, Tanna Vanuatu, 2015

Child health outcome	Unadjusted PR		Adjusted PR**	
	PR (95% CI)	p-value	PR (95% CI)	p-value
Wasting	2.32 (0.85–6.29)	0.099	1.91 (0.76–4.80)	0.171
Severe wasting	4.17 (1.12–15.49)	0.033	8.14 (4.15–15.96)	<0.001*
Underweight	2.04 (1.16–3.58)	0.014	2.34 (1.55–3.54)	<0.001*
ARI†	3.12 (1.54–6.30)	0.002	3.63 (1.87–7.04)	<0.001*
ARI† **or URTI**‡	3.67 (1.56–8.65)	0.003	6.56 (2.24–19.26)	0.001*

*Significant p-value = p≤0.05.

**Undernutrition variables adjusted for age of the child in six months age groups, child gender, maternal height, maternal education, and caregiver age in years. Respiratory variables, ARI and URTI, adjusted for the age of the child in six month age groups, and caregiver age in years.

† ARI = acute respiratory infection

‡ URTI = upper respiratory tract infection

6.2 Factors associated with stunted children

6.2.1 Child, caregiver, and WASH factors

To investigate child, caregiver, and WASH factors that were associated with stunting in children under five years of age I used univariate and multivariate analyses, Table 25, Table 26 and Table 27.

Univariate analysis

In the univariate analysis on Table 25 the median age of stunted children was 29.5 (range: 2.7–59.9) months compared to 18.0 (range 0.3–59.7) months for children who were not stunted. The prevalence of stunting was 1% higher for every one month increase in child age (PR: 1.01, 95% CI: 1.01–1.02), which was statistically significant (p=0.001). I did not find a difference in the prevalence of stunting by child gender (p=0.545).

In the univariate analysis timely complementary feeding and receiving minimum dietary diversity were associated with higher prevalences of diarrhoea, which were statistically significant (p=0.001 and p=0.021). However, as the direction of the relationships were not plausible in a causal sense, I did not investigate further in the multivariate analysis.

The prevalence of stunting was 25% lower in children 1–5 years of age who were reported to have had deworming medication in the previous six months (PR: 0.75, 95% CI: 0.61–0.92),

which was statistically significant (p=0.007). I did not find any difference in the prevalence of stunting between children who had and had not received a vitamin A dose in the past six months, or by immunization status (p=0.217 and p=0.955).

The median age of caregivers with stunted children was 29 (range: 16.0–69.0) years compared to 28 (range: 17–53) years among caregivers without stunted children. The prevalence of stunting was 1% higher for every one year increase in caregiver age (PR: 1.01, 95% CI: 1.00–1.03), which was statistically significant (p=0.027). The prevalence of stunting was 31% lower in households where the caregiver had received any education (PR: 0.69, 95% CI: 0.54–0.87), which was statistically significant (p=0.002).

The median height of mothers with stunted children was 155.1 cm (range: 146.2–170.9), compared to a median height of 158.9 cm (range: 149.2–186.7) in caregivers without stunted children. The prevalence of stunting was 5% lower for every 1 cm increase in maternal height (PR: 0.95, 95% CI: 0.92–0.98), which was statistically significant (p=0.002). I did not find a difference in maternal weight or BMI between children who were and were not stunted (p=0.930 and p=0.631).

In the univariate analyses the caregiver's ability to identify four or more situations when they should wash their hands was associated with a higher stunting prevalence, which was statistically significant (p=0.007). However, as the direction of this relationship was not plausible in a causal sense, it was not investigated further in the multivariate analysis. The prevalence of stunting was 20% lower in households where caregivers had knowledge of diarrhoea treatments (PR: 0.80, 95 CI: 0.65–0.98), which was statistically significant (p=0.035).

The prevalence of stunting was 45% lower in households with an improved drinking water source (PR: 0.55, 95% CI: 0.43–0.70), which was statistically significant (p<0.001). When I disaggregated improved water sources into type, the association with stunting only remained statistically significant for gravity fed piped water. The prevalence of stunting was 45% lower in households where the primary drinking water was from gravity fed piped water (PR: 0.55, 95% CI: 0.42–0.73, p<0.001). I did not find any difference in reported household water treatment or reported household water storage among children who were and were not stunted (p=0.364 and p=0.882). The prevalence of stunting was 26% higher in

households where it took over 30 minutes to collect drinking water (PR: 1.26, 95% CI: 0.97–1.64), although this was not statistically significant (p=0.083).

Having a VIP latrine was associated with a higher prevalence of stunting, although this was not statistically significant (p=0.061). Although the statistical significance of the association between stunting and VIP latrines met the cut-off for inclusion into multivariate analysis, the direction of the relationship was not considered plausible in a causal sense, and was not investigated further. I did not find any difference in access to Improved latrines or handwashing facilities among children who were and were not stunted (p=0.233 and p=0.709). There was no statistically significant difference in stunting prevalence between households where caregivers they did or did not wash their hands in the past 24 hours (PR: 0.77, 95% CI: 0.57–1.05, p=0.100).

Table 25: Univariate analysis of child, caregiver, and WASH factors associated with stunting in children under five years of age, Tanna Vanuatu, 2015**

Variable	Stunted	Not stunted	PR (95% CI)	p-value
Child factors				
Age and gender	**(N=145) n (%)**	**(N=152) n (%)**		
Age				
0-6 months	**2 (1.4)**	**32 (21.1)**		
6-12 months	**15 (10.4)**	**30 (19.7)**		
12-18 months	**17 (11.7)**	**14 (9.2)**		
18-24 months	**20 (13.8)**	**11 (7.3)**		
24-60 months	**91 (62.8)**	**65 (42.8)**		
Age in months (median [range])	29.5 (2.7–59.9)	18.0 (0.3–59.7)	1.01 (1.01–1.02)	<0.001*
Gender				
Female	76 (52.4)	76 (50.0)	1.08 (0.84–1.40)	0.545
Male	69 (47.6)	76 (50.0)		
IYCF practices	**n/N (%)**	**n/N (%)**		
Ever breastfed youngest (N=191)	80/88 (90.1)	95/103 (92.7)	0.88 (0.53–1.44)	0.603
Early initiation (N=189)	69/87 (79.3)	72/102 (70.6)	1.29 (0.78–2.16)	0.325
Timely complementary feeding† (>6 months of age) (N=153)	79/85 (92.9)	49/68 (72.1)	3.00 (1.67–5.38)	<0.001*
WHO IYCF MDD‡ (>6 months of age)(N=246)	84/132 (63.6)	63/114 (55.3)	1.39 (1.08–1.80)	0.012*
WHO MMF achieved (6-23 months of age)(N=75)	27/31 (87.1)	34/44 (77.3)	1.53 (0.74–3.16)	0.251
Dietary diversity score:	(N=49)	(N=49)		
≤1 group	0 (0.0)	6 (12.2)	1.10 (1.00–1.22)	0.051
2 groups	5 (10.2)	5 (10.2)		
3 groups	9 (18.4)	14 (28.6)		
4 groups	17 (34.7)	11 (22.5)		
≥5 groups	18 (36.7)	13 (26.5)		
Immunisation, vitamin A and deworming status	**n/N (%)**	**n/N (%)**		
Fully immunised (>12 months of age)	52/99 (52.5)	24/49 (49.0)	0.99 (0.75–1.31)	0.955

Variable	Stunted	Not stunted	PR (95% CI)	p-value
Received vitamin A dose in last 6 months (>6 months of age)	98/126 (77.8)	63/94 (67.0)	1.23 (0.89–1.70)	0.217
Immunisation, vitamin A and deworming status	**n/N (%)**	**n/N (%)**		
Received deworming medication in past 6 months (>12 months of age)	81/112 (72.3)	58/70 (82.9)	0.75 (0.61–0.92)	0.007*
Caregiver factors				
Age and education	**(N=143) n (%)**	**(N=148) n (%)**		
Age (median [range]) (N=257)	**29.0 (16.0–69.0)**	**28.0 (17.0–53.0)**	**1.01 (1.00–1.03)**	**0.027***
Any education	**59 (41.3)**	**89 (60.1)**	**0.69 (0.54–0.87)**	**0.002***
Secondary or above	15 (10.5)	27 (18.2)	0.76 (0.49–1.20)	0.242
Maternal health	**(N=142) n (%)**	**(N=148) n (%)**		
Weight kg (median [range]) (N=290)	55.7 (38.8–89.6)	58.1 (43.7–90.4)	0.99 (0.97–1.01)	0.334
Height cm (median [range]) (N=289)	**155.1 (146.2–170.9)**	**158.9 (149.2–186.7)**	**0.95 (0.92–0.98)**	**0.002***
BMI*** (median [range]) (N=288)	23.4 (17.9–38.7)	23.3 (18.4–38.7)	1.01 (0.97–1.06)	0.631
Underweight	2 (1.4)	2 (1.4)		
Normal	105 (73.9)	110 (75.3)		
Overweight	31 (21.8)	27 (18.5)		
Obese	4 (2.8)	7 (4.8)		
Knowledge	**(N=144) n (%)**	**(N=148) n (%)**		
Any WV training	117 (81.3)	107 (72.3)	1.29 (0.84–1.99)	0.245
Know when to wash hands: three or more situations	134 (93.1)	132 (89.2)	1.12 (0.73–2.05)	0.441
Know when to wash hands: four or more situations	93 (64.6)	77 (52.0)	1.32 (1.08–1.62)	0.007*
Know when to wash children's hands	87 (60.4)	88 (59.5)	1.06 (0.81–1.39)	0.685
Knows when to wash own and children's hands	69 (47.9)	53 (35.8)	1.32 (1.09–1.60)	0.004*

Variable	Stunted	Not stunted	PR (95% CI)	p-value
Knowledge of causes of diarrhoea: three or more	76 (52.8)	88 (59.5)	0.88 (0.73–1.06)	0.173
Knowledge of diarrhoea treatment	**77 (53.5)**	**98 (66.2)**	**0.80 (0.65–0.98)**	**0.035***
WASH factors				
Water	**(N=144) n (%)**	**(N=148) n (%)**		
Improved source	**31 (21.5)**	**65 (43.9)**	**0.55 (0.43–0.70)**	**<0.001***
Gravity fed system	22 (15.3)	48 (32.4)	0.55 (0.42–0.73)	<0.001*
Rainwater catchment	9 (6.3)	17 (11.5)	0.77 (0.44–1.34)	0.349
Self reported water treatment: disinfection methods only	41 (28.5)	51 (34.5)	0.87 (0.65–1.17)	0.364
Appropriate storage observed	8/138 (5.8)	9/146 (2.6)	0.97 (0.64–1.48)	0.882
Takes >30 min to collect	**90 (62.5)**	**77 (52.0)**	**1.26 (0.97–1.64)**	**0.083**
Sanitation and hygiene	**(N=138) n (%)**	**(N=146) n (%)**		
Any improved latrine observed	134 (97.1)	139 (95.2)	1.34 (0.83–2.15)	0.233
VIP§ latrine observed	124 (89.9)	120 (82.2)	1.40 (0.99–1.99)	0.061
Operational handwashing facility observed	46 (33.3)	47 (32.2)	0.94 (0.69–1.29)	0.709
Caregiver washed hands in past 24 hours (N=292)	**105/144 (72.9)**	**112/148 (75.7)**	**0.77 (0.57–1.05)**	**0.100**

PR and 95% CI:obtained using GEE models, controlling for village and household similarities
Bolded variables represent factors included in multivariate analyses
* Statistically significant in multivariate analysis = p≤0.05
** WASH = water, sanitation, and hygiene
*** BMI = body mass index
† Timely complementary feeding defined here as introducing complementary food at 5–6 months of age
‡ WHO IYCF MDD = World Health Organisation Infanct and Young Child Feeding Minimum Dietary Diversity
§ VIP = ventilated improved pit latrine

Multivariate analyses

Table 26 shows the final multivariate model. In our univariate analysis, child, caregiver and WASH factors that met the inclusion criteria outlined in our methods and subsequently included in the model were: caregiver age; caregiver education; caregiver handwashing practices; maternal height; caregiver knowledge of diarrhoea treatments; using an improved water source; and taking over 30 minutes to collect water. We also controlled for child gender and age in six month age groups. Caregiver education and maternal height were included in the final model regardless of statistical significance, as per methods.

In Table 26, the prevalence of stunting was 5% lower for every 1 cm increase in maternal height (PR: 0.95, 95% CI: 0.92–0.98), which was statistically significant (p=0.001). The prevalence of stunting was 34% lower in households using an improved water source (PR: 0.66, 95% CI: 0.53–0.82), which was statistically significant (p=0.001). Associations between stunting and caregiver age, caregiver education, caregiver handwashing practices, knowledge of diarrhoea treatment, and taking over 30 minutes to collect water were not statistically significant in our multivariate analysis.

Table 26: Multivariate analysis of factors associated with stunting in children under five years of age, Tanna Vanuatu, 2015

Variable	Univariate analysis		Multivariate analysis Original model		Multivariate analysis Final Model	
	PR (95% CI)	P-value	PR (95% CI)	P-value	PR (95% CI)	P-value
Caregiver age	1.01 (1.00–103)	0.027	1.01 (1.00–1.02)	0.272	-	-
Caregiver education	0.69 (0.54–0.87)	0.002	1.01 (0.79–1.31)	0.889	0.89 (0.72–1.11)	0.315
Caregiver washed hands in past 24 hours	0.77 (0.57–1.05)	0.100	0.79 (0.601.03)	0.085	0.77 (0.59–1.01)	0.054
Maternal height	0.95 (0.92–0.98)	0.002	0.95 (0.92–0.99)	0.006*	0.95 (0.92–0.98)	0.001*
Knowledge of diarrhoea treatment	0.80 (0.65–0.98)	0.035	0.89 (0.71–1.13)	0.341	-	-
Improved water source	0.55 (0.43–0.70)	<0.001	0.70 (0.56–0.88)	0.002*	0.66 (0.53–0.82)	<0.001*
Takes >30 minutes to collect water	1.26 (0.97–1.64)	0.083	1.15 (0.93–1.41)	0.200	-	-

Multivariate analysis included age of child in six month age groups and child gender. Backwards elimination was used to deduce the final model.

* Statistically significant = p≤0.05.

As deworming is only relevant to a subset of children in the previous multivariate analysis, we investigated the association in a separate analysis on Table 27. Table 27 shows the association between stunting and deworming in the previous six months, unadjusted, and adjusted for various factors by multivariate regression. When adjusted for child gender and age in six month groups, maternal height, caregiver education, and using an improved water source, stunting was 27% lower in children that had received deworming medication in the previous six months (PR: 0.73, 95% CI: 0.59–0.92), which was statistically significant (p=0.006). However, when immunization status and receiving a vitamin A supplements in the previous six months (usually received at the same time as de-worming medication) were also adjusted for, this association was no longer statistically significant (p=0.092).

Table 27: Adjusted association between stunting and receiving deworming medication in Tanna Vanuatu, 2015

Variable	Unadjusted PR		Adjusted PR – Model 1**		Adjusted PR – Model 2†	
	PR (95% CI)	p-value	PR (95% CI)	p-value	PR (95% CI)	p-value
Deworming medication in last 6 months	0.80 (0.61–0.92)	0.007	0.73 (0.59–0.92)	0.006*	0.69 (0.45–1.06	0.092

*Significant p-value (p≤0.05)
**Model 1: Adjusted for age of the child in six months age groups, child sex, maternal height,, caregiver education and improved water source.
† Model 2: Adjusted for immunisation status, receiving a vitamin A supplement in the previous six months, child in six months age groups, child sex, maternal height, maternal education and improved water source.

6.2.2 Child health outcomes

To investigate whether other child health outcomes were associated with a higher prevalence of stunting in children under five years of age we used univariate and multivariate analyses, Table 28 and Supplementary Table 7.

Univariate analysis

Table 28 shows univariate associations between stunting and other health outcomes. A lower WHZ score and WAZ score were associated with higher prevalences of stunting, which were statistically significant (p=0.003 and p<0.001). The prevalence of stunting was over twice as high in children that were underweight. We did not find a statistically significant association between stunting and having diarrhoea or ARI in the past two weeks (p=0.303

and p=0.941). The prevalence of stunting was 26% higher in children that had an URTI in the past two weeks (PR: 1.26, 95% CI: 0.98–1.62), although this was not statistically significant (p=0.075).

Table 28: Univariate analysis of health outcomes associated with stunting in children under five years, Tanna Vanuatu, 2015

Health outcome	Stunted	Not stunted	PR (95% CI)	p-value
Wasting: (N=295)	**(N=143) n (%)**	**(N=152) n (%)**		
WHZ** score (median [range])	-0.2 (-4.1–2.6)	0.3 (-3.3–2.32)	0.87 (0.79–0.95)	0.003*
Moderate	6 (4.2)	3 (2.0)		
Severe	1 (0.7)	1 (0.7)	0.85 (0.17–4.18)	0.842
Total	7 (4.9)	4 (2.6)	1.24 (0.86–1.81)	0.253
Underweight: (N=296)	**(N=144) n (%)**	**(N=152) n (%)**		
WAZ** score (median [range])	-1.6 (-4.6–2.8)	-0.4 (-3.4–2.3)	0.58 (0.51–0.66)	<0.001*
Moderate	38 (26.4)	1 (0.7)		
Severe	15 (10.4)	2 (1.3)	1.72 (1.42–2.08)	<0.001*
Total	53 (36.8)	3 (2.0)	2.46 (2.08–2.91)	<0.001*
Diarrhoea (N=282)	**(N=138) n (%)**	**(N=144) n (%)**		
Diarrhoea in past two weeks	20 (14.5)	15 (10.4)	1.13 (0.90–1.42)	0.303
Respiratory infection in past two weeks (N=289)	**(N=137) n (%)**	**(N=142) n (%)**		
ARI	10 (7.3)	11 (7.8)	0.98 (0.59–1.63)	0.943
URTI	**78 (56.9)**	**65 (45.8)**	**1.26 (0.98–1.62)**	**0.075**
ARI or URTI	87 (64.0)	76 (53.5)	1.26 (0.89–1.79)	0.185

PR and 95% CI:obtained using GEE models, controlling for village and household similarities
Bolded variables represent factors included in multivariate analyses
* Statistically significant = p≤0.05
** WHZ = weight-for-height Z-score; WAZ = weight-for-age Z-score
† ARI = acute respiratory infection
‡ URTI = upper respiratory tract infection

Multivariate analysis

Associations between stunting and other undernutrition outcomes were expected and were not of primary interest to our evaluation, thus they were not investigated further by

multivariate analyses. The association between stunting and URTIs met the cutoff for investigation by multivariate analysis. The results of this multivariate analysis is shown on Supplementary Table 7 (Appendix 13). The association between stunting and URTI remained non statistically significant (p=0.241).

6.3 Factors associated with underweight children

6.3.1 Child, caregiver, and WASH factors

To investigate child, caregiver, and WASH factors that were associated with underweight children under five years of age we used univariate and multivariate analyses, Table 29 and Table 30.

Univariate analysis

In our univariate analysis, shown in Table 29, we did not find a difference in the prevalence of underweight children by age or gender (p=0.245 and p=0.739). We also did not find a difference in IYCF practices among underweight and not underweight children, including ever being breastfed (p=0.804), MDD (p=0.499), dietary diversity score (p=0.432), and MMF (p=0.146). For the majority of IYCF indicators confidence intervals for the PRs were relatively wide, so we were not able to exclude a difference in these practices. There was also no evidence of a difference in immunisation status, or receiving a vitamin A dose or deworming medication in the last six months (p=0.268, p=0.981, and p=0.874).

The prevalence of underweight children was 50% lower among households where the caregiver had received any education compared to no education (PR: 0.50, 95% CI: 0.19–0.88), which was statistically significant (p=0.016). However, I did not see a statistically significant difference in diarrhoea prevalence between households where the caregiver had received secondary education compared to lesser or no education (PR: 0.66, 95% CI: 0.29–1.51, p=0.322). Mothers of underweight children had a median height of 155.2 cm (range: 147.4–167.1), compared to 157.1 cm (range: 146.2–186.7) among mothers of children who were not underweight. This corresponded to a 4% reduction in the prevalence underweight

children for every 1 cm increase in maternal height (PR: 0.96, 95% CI: 0.92–0.99), which was statistically significant (p=0.017)

The prevalence of underweight children was 38% lower in households where the caregiver could identify three or more causes of diarrhoea (PR: 0.62, 95% CI: 0.40–0.97), which was statistically significant (p=0.037). We did not find a difference in the prevalence of underweight children between caregivers who had handwashing knowledge and those who did not (four or more situations, p=0.280).

The prevalence of underweight children was 57% lower in households that were using an improved water source (PR: 0.43, 95% CI: 0.24–0.78), which was statistically significant (p=0.006). When improved water was disaggregated into gravity fed piped water and rainwater catchments, the association with underweight children remained significant in households with rainwater sources, but not households with gravity fed sources. The prevalence of underweight children was 56% lower in households that were using rainwater as their source water compared to households using all other sources (PR: 0.44, 95% CI: 0.21–0.93, p=0.031). We did not find any difference in reported household water treatment or reported household water storage among children who were and were not stunted (p=0.364 and p=0.882).

We did not find any difference in access to Improved or VIP latrines between children underweight and not underweight (p=0.870 and p=0.420). However the confidence intervals for the PRs were wide because the majority of households had access, so we were not able to exclude a difference. We did not find any difference in having a handwashing facility or caregiver self-reported handwashing practices between children underweight and not underweight (p=0.885 and p=0.352).

Table 29: Univariate analysis of child, caregiver and WASH factors associated with underweight children under five years of age, Tanna Vanuatu, 2015**

Variable	Underweight	Not underweight	PR (95% CI)	p-value
Child factors				
Age and gender	**(N=59) n (%)**	**(N=250) n (%)**		
Age				
0-6 months	2 (3.4)	34 (13.6)		
6-12 months	9 (15.3)	36 (14.4)		
12-18 months	6 (10.2)	27 (10.8)		
18-24 months	11 (18.6)	22 (8.8)		
24-60 months	31 (52.5)	131 (52.4)		
Age in months (median [range])	26.4 (2.7–59.9)	25.7 (0.3–59.7)	1.01 (1.00–1.02)	0.245
Gender				
Female	30 (50.9)	127 (50.8)	1.07 (0.73–1.57)	0.739
Male	29 (49.2)	123 (49.2)		
IYCF practices	**n/N (%)**	**n/N (%)**		
Ever breastfed – youngest (N=201)	37/40 (92.5)	147/161 (91.3)	1.14 (0.41–3.20)	0.804
Early initiation (N=199)	33/39 (84.6)	115/160 (71.9)	1.80 (0.73–4.42)	0.201
Timely complementary feeding† (>6 months of age) (N=159)	30/36 (83.3)	103/123 (83.7)	1.11 (0.57–2.15)	0.762
WHO MDD‡ achieved (>6 months of age)(N=263)	31/52 (59.6)	121/201 (60.2)	1.21 (0.75–1.94)	0.432
WHO MMF‡ achieved (6–23 months of age)(N=79)	15/17 (88.2)	48/62 (77.4)	2.53 (0.72–8.82)	0.146
Dietary diversity score:				
≤1 group	1 (4.2)	5 (6.5)	1.05 (0.82–1.34)	0.694
2 groups	2 (8.3)	9 (11.7)		
3 groups	7 (29.2)	17 (22.1)		
4 groups	5 (20.8)	23 (29.9)		
≥5 groups	9 (37.5)	23 (29.9)		
Variable	**Underweight**	**Not underweight**	**PR (95% CI)**	**p-value**

Immunisation, vitamin A and deworming status	**n/N (%)**	**n/N (%)**		
Fully immunised (>12 months of age)	24/40 (60.0)	54/113 (47.8)	1.44 (0.76–2.75)	0.268
Received vitamin A dose in last 6 months (>6 months of age)	37/50 (74.0)	126/178 (70.8)	1.00 (0.64–1.55)	0.981
Received deworming medication in past 6 months (>12 months of age)	33/42 (78.6)	110/178 (74.3)	1.05 (0.55–2.01)	0.874
Caregiver factors				
Age and education	**(N=59) n (%)**	**(N=243) n (%)**		
Age (median [range]) (N=269)	28.0 (19.0-48.0)	28.0 (16.0–69.0)	1.00 (0.98–1.02)	0.976
Any education	**20 (33.9)**	**135/242 (55.8)**	**0.50 (0.19–0.88)**	**0.016***
Secondary or above	5 (8.5)	40/242 (16.5)	0.66 (0.29–1.51)	0.322
Maternal health	**(N=57) n (%)**	**(N=244) n (%)**		
Weight kg (median [range])	55.0 (38.8–71.6)	58.0 (41.8–90.4)	0.97 (0.94–1.01)	0.104
Height cm (median [range])	**155.2 (147.4–167.1)**	**157.1 (146.2–186.7)**	**0.96 (0.92–0.99)**	**0.017***
BMI*** (mean ± sd) (N=299)	23.4 (17.9–29.3)	23.4 (18.2–38.7)	0.95 (0.85–1.06)	0.341
Underweight	1 (1.8)	3 (1.2)		
Normal	44 (77.2)	175 (72.3)		
Overweight	12 (21.1)	53 (21.9)		
Obese	0 (0.0)	11 (4.6)		
Knowledge	**(N=59) n (%)**	**(N=244) n (%)**		
Any WV training	46 (78.0)	187 (76.6)	1.01 (0.58–1.77)	0.960
Know when to wash hands: three or more situations	57 (96.6)	220 (90.2)	2.28 (0.58–9.03)	0.239
Know when to wash hands: four or more situations	40 (67.8)	138 (56.6)	1.37 (0.77–2.44)	0.280
Know when to wash children's hands*	34 (57.6)	148 (60.7)	0.94 (0.56–1.58)	0.815
Variable	**Underweight**	**Not underweight**	**PR (95% CI)**	**p-value**

Knowledge	**(N=59)** **n (%)**	**(N=244)** **n (%)**		
Know when to wash own and children's hands	28 (47.5)	100 (41.0)	1.19 (0.74–1.93)	0.471
Knowledge of causes of diarrhoea: three or more	**27 (45.8)**	**145 (59.4)**	**0.62 (0.40–0.97)**	**0.037***
Knowledge of diarrhoea treatment	31 (52.5)	152 (62.3)	0.88 (0.47–1.63)	0.681
WASH factors				
Water	**(N=59)** **n (%)**	**(N=244)** **n (%)**		
Improved source	**10 (16.7)**	**91 (36.9)**	**0.43 (0.24–0.78)**	**0.006***
Gravity fed system	8 (13.6)	65 (26.6)	0.54 (0.28–1.04)	0.067
Rainwater catchment	2 (3.4)	25 (10.3)	0.44 (0.21–0.93)	0.031*
Self reported water treatment: disinfection methods only	21 (35.6)	77 (31.6)	1.22 (0.72–2.09)	0.458
Appropriate water storage observed	3/34 (8.8)	14/256 (5.5)	1.59 (0.86–2.93)	0.139
Takes >30 min to collect	36 (61.0)	137 (56.2)	1.13 (0.66–1.94)	0.644
Sanitation and hygiene	**(N=56)** **n (%)**	**(N=237)** **n (%)**		
Any improved latrine observed	54 (96.4)	226 (95.4)	1.11 (0.31–4.02)	0.870
VIP§ latrine observed	50 (89.3)	201 (84.8)	1.25 (0.72–2.18)	0.420
Operational handwashing facility observed	21 (37.4)	75 (31.7)	1.05 (0.53–2.10)	0.885
Caregiver washed hands in past 24 hours	43/59 (72.9)	180/244 (73.8)	0.81 (0.52–1.26)	0.352

PR and 95% CI obtained using GEE models, controlling for village and household similarities
Bolded variables represent factors included in multivariate analyses
* Statistically significant = p≤0.05
** WASH = water, sanitation, and hygiene
*** BMI = body mass index
† Timely complimentary feeding defined here as introducing complementary food at 5–6 months of age
‡ WHO IYCF MDD = World Health Organisation Infanct and Young Child Feeding Minimum Dietary Diversity
§ VIP = ventilated improved pit latrine

Multivariate analyses

Table 30 shows the final multivariate model. In our univariate analysis, child, caregiver, and WASH variables that were statistically significantly associated with a lower underweight prevalence included: caregivers having any education; higher maternal height; improved drinking water source; and knowledge of diarrhoea causes. We investigated these variables in our multivariate analysis, controlling for factors known to be associated with the underweight outcome.

In our final model, the adjusted prevalence of underweight children was 55% lower in households with an improved water source (PR: 0.45, 95% CI: 0.27–0.74), which was statistically significant (p=0.002). No other variables remained statistically significant.

Table 30: Multivariate analysis of child, caregiver and WASH factors associated with underweight children under five years of age, Tanna Vanuatu, 2015**

Variable	Univariate analysis		Multivariate analysis Original model		Multivariate analysis Final Model	
	PR (95% CI)	P-value	PR (95% CI)	P-value	PR (95% CI)	P-value
Any caregiver education	0.50 (0.19–0.88)	0.016	0.61 (0.38–1.04)	0.071	0.60 (0.35–1.00)	0.051
Maternal height	0.96 (0.92–0.99)	0.017	0.97 (0.93–1.01)	0.093	0.97 (0.93–1.01)	0.112
Improved water source	0.43 (0.24–0.78)	0.006	0.47 (0.29–0.76)	0.002	0.45 (0.27–0.74)	0.002*
Caregiver knows 3 or more causes of diarrhoea	0.62 (0.40–0.97)	0.037	0.77 (0.51–1.17)	0.218	-	-

Multivariate analysis also included child gender and age in six month age groups, maternal height, and caregiver education. Backwards elimination was used to deduce the final model.
*Statistically significant in multivariate analysis = p≤0.05
**WASH = water, sanitation, and hygiene

6.3.2 Child health outcomes

To investigate whether other child health outcomes were associated with a higher prevalence of underweight children under five years of age we used univariate and multivariate analyses, Table 31 and Table 32.

Univariate analysis

Table 31 shows univariate associations between diarrhoea and other health outcomes. The prevalence of underweight children was over five times higher in children that had were wasted (PR: 5.24, 95% CI: 3.74–7.34), which was statistically significant (p<0.001). The prevalence of underweight children was also over 18 times higher in children that were stunted (PR: 18.88, 95% CI: 6.20–57.49), which was also statistically significant (p<0.001).

The prevalence of underweight children was 77% higher in children that had diarrhoea in the past two weeks (PR: 1.77, 95% CI: 1.10–2.85), which was statistically significant (p=0.019). Furthermore the prevalence of underweight children was 88% higher in children that had a respiratory illness, ARI or URTI, in the past two weeks (PR: 1.88, 1.24–2.86), which was also statistically significant (p=0.003).

Table 31: Univariate analysis of health outcomes associated with underweight children under five years, Tanna Vanuatu, 2015

Health outcome	Underweight	Not underweight	PR (95% CI)	p-value
Wasting (N=301)	**(N=59) n (%)**	**(N=242) n (%)**		
WHZ** score (median [range])	-1.2 (-4.1–0.5)	0.3 (-2.3–2.7)	0.42 (0.35–0.51)	<0.000*
Moderate	8 (13.6)	1 (0.4)		
Severe	2 (3.4)	0 (0.0)	Omitted	-
Total	10 (16.9)	1 (0.4)	5.24 (3.74–7.34)	p<0.001
Stunting: (N=296)	**(N=56) n (%)**	**(N=240) n (%)**		
HAZ** score (median [range])	-3.0 (-4.9– -0.7)	-1.7 (-3.9–4.5)	0.42 (0.35–0.81	<0.001*
Normal	3 (5.4)	149 (62.1)		
Mild	27 (48.2)	66 (27.5)		
Severe	26 (46.4)	25 (10.4)	3.97 (2.50–6.30)	<0.001*
Total	53 (94.6)	91 (37.9)	18.88 (6.20–57.49)	<0.001*
Diarrhoea (N=293)	**N=58 n (%)**	**N=235 n (%)**		
Diarrhoea in past two weeks	**12 (20.7)**	**23 (9.8)**	**1.77 (1.10–2.85)**	**0.019***
Respiratory infection in past two weeks (N=289)	**(N=58) n (%)**	**(N=231) n (%)**		
ARI†	**7 (12.1)**	**15 (6.5)**	**1.74 (0.88–3.43)**	**0.110**

Health outcome	Underweight	Not underweight	PR (95% CI)	p-value
Respiratory infection in past two weeks (N=289)	**(N=58) n (%)**	**(N=231) n (%)**		
URTI‡	**34 (58.6)**	**112 (48.3)**	**1.44 (0.96–2.16)**	**0.075**
ARI† or URTI‡	**41 (70.7)**	**126 (54.6)**	**1.88 (1.24–2.86)**	**0.003***

PR and 95% CI:obtained using GEE models, controlling for village and household similarities
Extreme values of 0% or 100% were not able to be tested using our model and are labeled as omitted
Bolded variables represent factors included in multivariate analyses.
* Statistically significant in multivariate analysis: p≤0.05
** WHZ = weight-for-height Z-score; HAZ = height-for-age Z-score
† ARI = acute respiratory infection
‡ URTI = upper respiratory tract infection

Table 32 shows unadjusted and adjusted associations between underweight and other child health outcomes: diarrhoea, ARI, and URTI. Associations between stunting and other undernutrition outcomes were expected and were not of primary interest to our evaluation, thus they were not investigated further by multivariate analyses. Associations were adjusting for child age in six month groups, child gender, caregiver education, and maternal height, as well as improved water source.

The adjusted prevalence of underweight children was 99% higher in children that had diarrhoea in the past two weeks (PR: 1.99, 95% CI: 1.34–2.97), which was statistically significant (p=0.001). The prevalence of underweight children was also over two times higher in children that had an ARI in the past two weeks (PR: 2.18, 95% CI: 1.10–4.33), which was statistically significant (p=0.026).

Table 32: Multivariate analysis of child health outcomes associated with underweight children under five years of age, Tanna Vanuatu, 2015

Child health outcomes	Unadjusted PR		Adjusted PR**	
	PR (95% CI)	p-value	PR (95% CI)	p-value
Diarrhoea	1.77 (1.10–2.85)	0.019	1.99 (1.34–2.97)	0.001*
ARI†	1.74 (0.88–3.43)	0.110	2.18 (1.10–4.33)	0.026*
URTI‡	1.44 (0.96–2.16)	0.075	1.15 (0.72–1.84)	0.562
ARI† or URTI‡	1.88 (1.24–2.86)	0.003	1.58 (1.01–2.48)	0.046*

*Significant p-value = p≤0.05
**Adjusted for age of the child in six months age groups, child sex, maternal education, maternal height, and improved water source
† ARI = acute respiratory infection
‡ URTI = upper respiratory tract infection

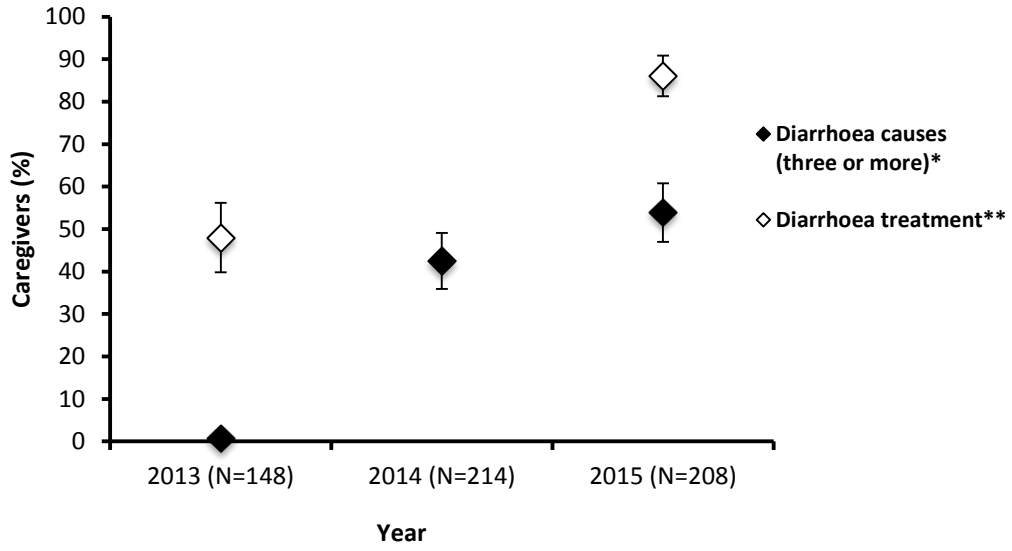
Chapter seven – Comparisons of the end of second year evaluation 2015, to baseline 2013, and end of first year 2014 surveys (objective four)

Comparing our results to baseline and end of first year results allowed us to observe how the Project had progressed on many key outcomes over two completed years of implementation. A limited number of comparisons were possible due to differences in methods and questions asked over the Project years as explained in our methods. For simplicity, all graphs in this section use the year each survey was conducted: baseline survey, 2013; end of first year survey, 2014; and end of second year evaluation, 2015.

7.1 Diarrhoea and hygiene knowledge and reported practice

Figure 11 shows the proportion and 95% CIs of caregivers who knew three or more causes of diarrhoea, and caregivers who knew one or more correct treatments for diarrhoea, by Project year. In 2014 caregivers were asked about their knowledge of diarrhoea causes only, not their knowledge of diarrhoea treatment. There was a significant increase in the proportion of caregivers who knew causes of diarrhoea from 1 (0.7%) of 148 caregivers identifying three or more causes of diarrhoea in 2013, to 112 (53.9%) of 208 caregivers in 2015 ($p<0.001$). There was also a significant increase in the proportion of caregivers with knowledge of diarrhoea treatments from 71 (48.0%) of 148 caregivers identifying one or more correct treatment in 2013, to 179 (86.1%) of 208 in 2015 ($p=0.007$).

Figure 11: Proportion and 95% CI of caregivers knowledge of three or more causes of diarrhoea and at least one diarrhoea treatment in Tanna, Vanuatu, 2013–2015

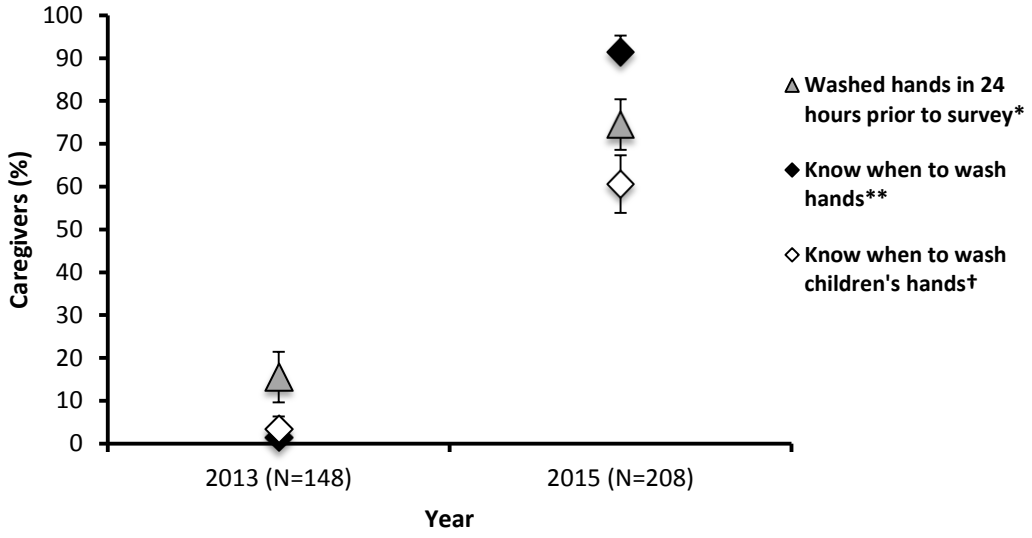


Differences in diarrhoea knowledge over the three years were investigated. Separate tests were carried out for each knowledge variable, as indicated by the asterisks. *p<0.001 **p=0.007

Figure 12 shows the proportion and 95% CIs of caregivers who reported handwashing behaviours and had handwashing practice knowledge. These questions were not asked in 2014, therefore our results were compared to the 2013 baseline only. There was a significant increase in the proportion of caregivers who reported washing their hands in the 24 hours prior to the survey from 23 (15.5%) of 148 in 2013, to 155 (74.5%) of 208 in 2015 (p<0.001).

There was a significant increase in the proportion of caregivers who knew when to wash their own hands from 2 (1.4%) of 148 identifying three or more situations when they should wash their hands in 2013, to 190 (91.4%) of 208 in 2015 (p<0.001). Furthermore, their was a significant increase in the proportion of caregivers who could identify when to wash their children's hands from 5 (3.4%) of 148 caregivers identifying both after going to the toilet and before eating in 2013, to 126 (60.6%) of 208 in 2015 (p<0.001).

Figure 12: Proportion and 95% CI of caregiver handwashing knowledge and reported practices in Tanna, Vanuatu, 2013–2015



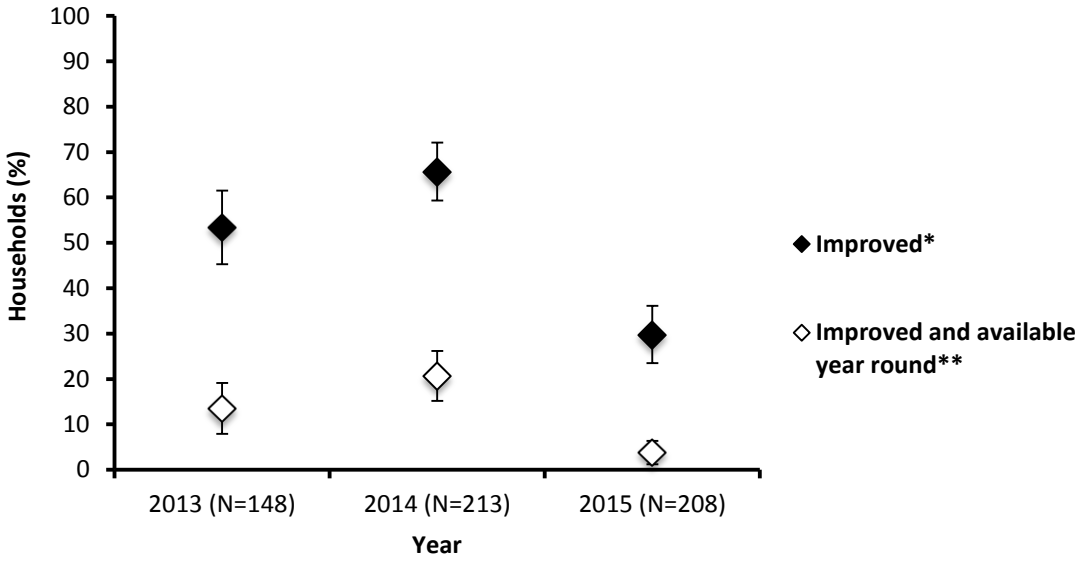
Differences in handwashing knowledge and practices from 2013 to 2015 were investigated. Handwashing questions were not asked in 2014. Separate tests were carried out for each variable, as indicated by the asterisks. *p<0.001 **p<0.000 †p<0.001

7.2 Water, sanitation, and hygiene facilities and reported practices

7.2.1 Water

Figure 13 shows the proportion of households using an improved water source, gravity fed system or rainwater, by Project year. As the water component of the Project was yet to be implemented in 2014, all gravity fed systems in use were from previous government initiatives (personal communication, World Vision staff, January 2015) and in various states of disrepair. There was a significant reduction in the proportion of households using improved drinking water sources from 79 (53.4%) of 148 in 2013 to 62 (29.8%) of 208 in 2015 (p=0.027). We also assessed if the proportion of improved sources that were available all year round had changed over the course of the Project. Figure 13 also shows that there was a significant reduction in the proportion of households using improved water sources available all year round from 20 (13.5%) of 148 in 2013 to 8 (2.8%) of 208 in 2015 (p<0.001).

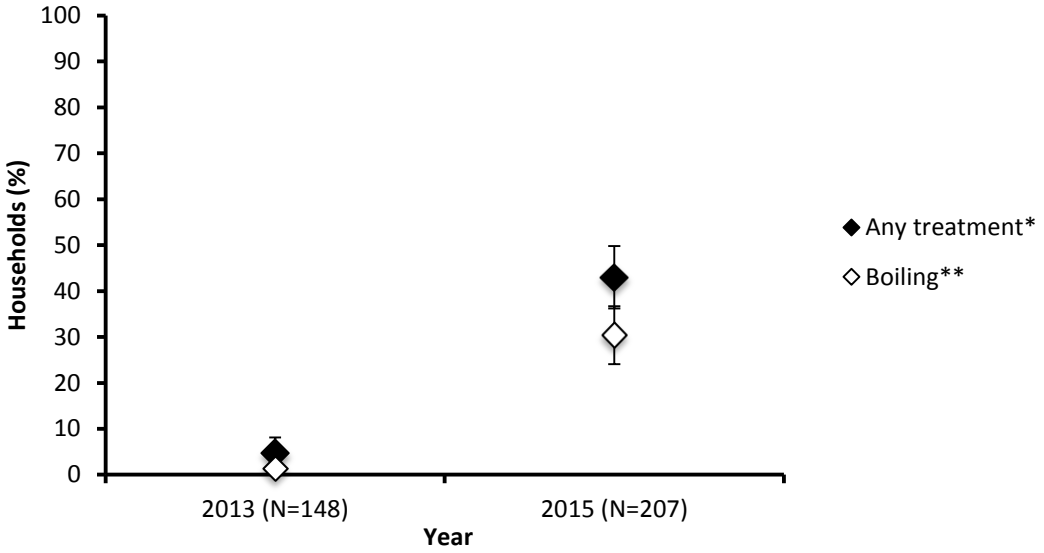
Figure 13: Proportion and 95% CI of households using improved water sources in Tanna, Vanuatu, 2013–2015



Differences in access to improved water over the three years were investigated. Separate tests were carried out for improved, and improved and available all year round, as indicated by the asterisks. p=0.027 **p<0.000.

Any changes in water treatment practices from baseline were assessed. This question was not asked in 2014. In Figure 14, 'any treatment' includes treatments that are not effective for disinfection on their own, such as sedimentation and straining through a cloth. Boiling was looked at separately from any treatment, as it was the method recommended by World Vision, and all effective treatment methods reported in the 2015 questionnaire involved a boiling step. There was a significant increase in the proportion of households that reported treating their water from 7 (4.7%) of 148 reporting any treatment method in 2013 to 89 (43.0%) of 207 in 2015 (p<0.001). There was a similar significant increase in the proportion of households that reported boiling their water from 2 (1.4%) of 148 in 2013 to 63 (30.4%) of 208 in 2015 (p=0.004).

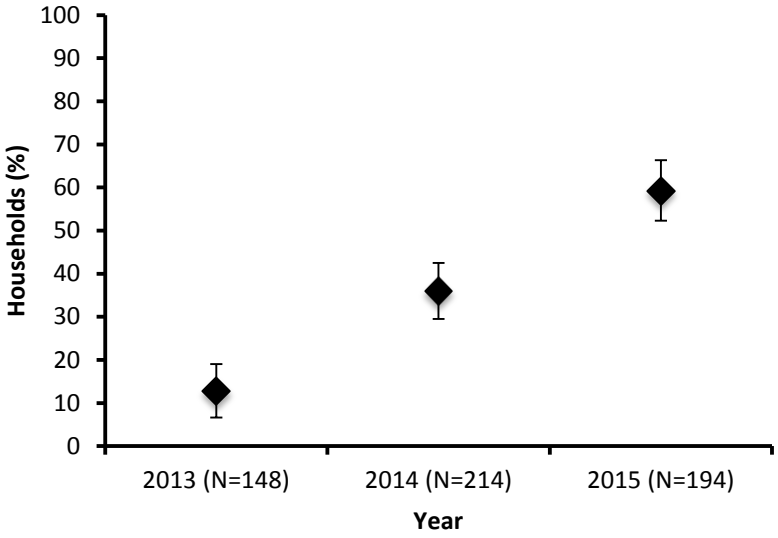
Figure 14: Proportion and 95% CI of households reporting water treatment in Tanna, Vanuatu, 2013–2015



Differences in self reported water treatment between 2013 and 1015 were investigated. Water treatment questions were not asked in 2014. Separate tests were carried out for any treatment (disinfection and non disinfection methods) and boiling (the most common disinfection method used), as indicated by the asterisks. *p<0.001 **p=0.004.

In addition to water treatment, Project beneficiaries were taught to safely store water, as part of PHAST training. Figure 15 shows the proportion of households that reported adequate storage of drinking water, that is water stored separately from non-drinking water, in a covered container, with a narrow mouth or spigot, by year. Observed storage methods were not available for previous years, thus self-reported results were used for comparison. There was a significant increase in the proportion of households where self-reported storage methods were adequate to prevent contamination from 19 (12.8%) of 148 households in 2013, to 115 (59.3%) of 208 households in 2015 (p<0.001).

Figure 15: Proportion and 95% CI of households reporting safe storage of drinking water in Tanna, Vanuatu, 2013–2015



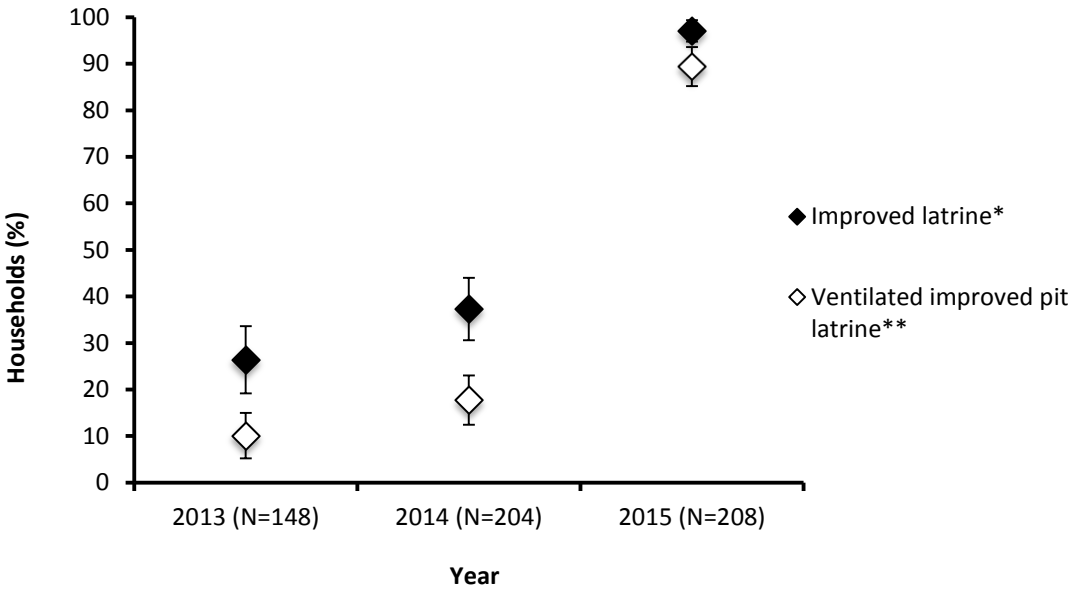
Differences in self-reported safe water storage over the three years were investigated, giving a p-value of <0.001.

7.2.2 Sanitation and hygiene

Sanitation and hygiene facilities, including latrines, rubbish pits, and handwashing facilities were observed in all years of the project. Figure 16 shows the proportion of households that were observed to have a VIP latrine, or an improved latrine, by year. Shared latrines were included in this analysis, as sharing was not specified in previous surveys. There was a significant increase in the proportion of households that had VIP latrines from 15 (10.1%) of 148 households in 2013 to 186 (89.4%) of 208 in 2015 ($p<0.001$).

When improved pit latrines and VIP latrines were considered together, there was a significant increase from 39 (26.4%) of 148 households in 2013 to 202 (97.1%) of 208 in 2015 ($p<0.001$). This definition of improved latrine does not take into account whether households are sharing their latrines, as this was not established in previous questionnaires.

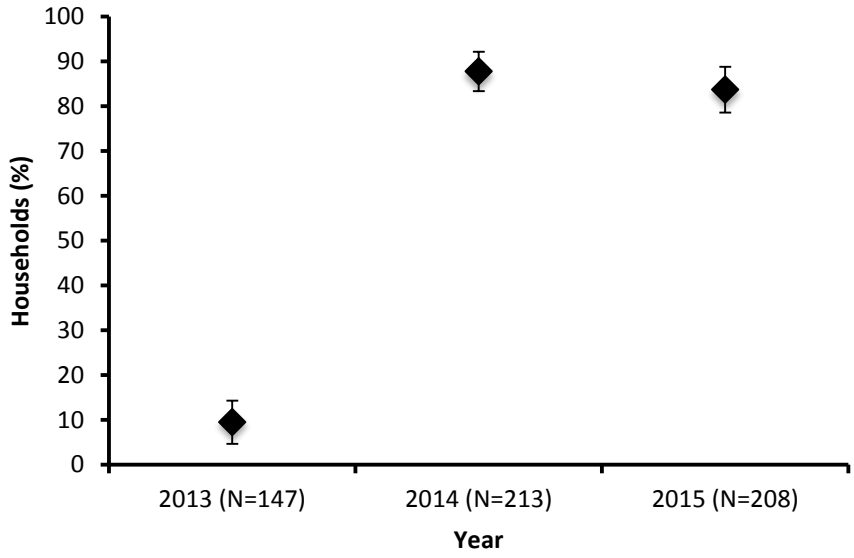
Figure 16: Proportion and 95% CI of households with improved latrines and ventilated improved pit latrines in Tanna, Vanuatu, 2013–2015



Differences in the proportion of households with improved (shared or not shared), and ventilated improved pit latrines over the three years were investigated. Separate tests were carried out for each variable, as indicated by the asterisks. *p<0.001 **p<0.001.

Figure 17 shows the proportion of households with rubbish pits by year. There was a significant increase in the proportion of households with rubbish pits, from 14 (9.5%) of 147 in 2013 to 178 (83.7%) of 208 in 2015 (p<0.001). There was a slight reduction in the proportion from 2014, where 187 (87.8) of 213 households had a rubbish pit, although this was not statistically significant (p=0.171).

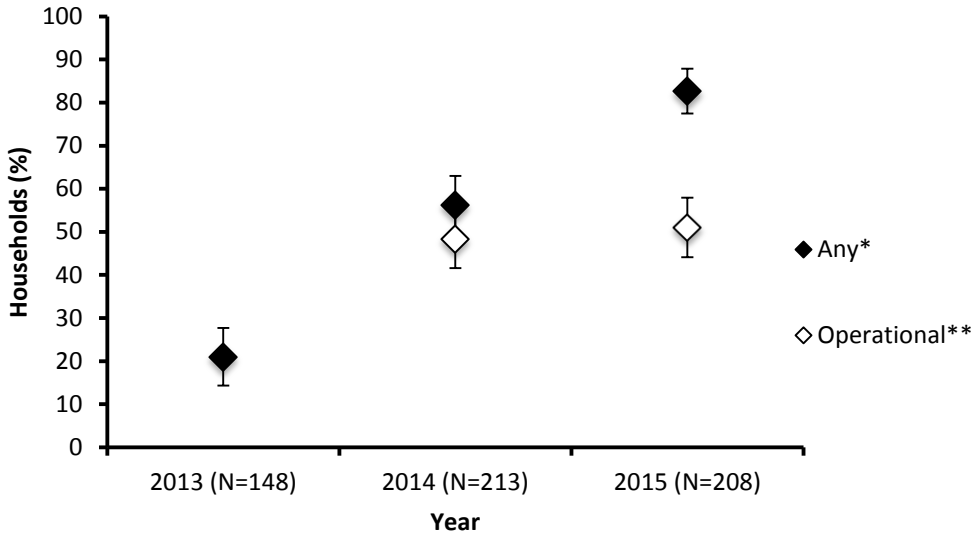
Figure 17: Proportion and 95% CI of households with a rubbish pit in Tanna, Vanuatu, 2013–2015



Differences in the proportion of households with a rubbish pit over the three years were investigated, giving a p-value of <0.001.

Figure 18 shows the proportion of households with handwashing facilities observed by year. There was a significant increase in the proportion of handwashing facilities from 31 (21.0%) of 148 in 2013 and 120 (56.3%) of 213 in 2014, to 172 (82.7%) of 208 in 2015 (p<0.001). In 2014 and 2015 the operational status of the handwashing facilities were also observed, shown in Figure 16. In 2014 103 (48.4%) of 213 households had an operational handwashing facility, compared to 106 (51.0%) of 208 in 2015, which was not a significantly different (p=0.794).

Figure 18: Proportion and 95% CI of households with a handwashing facility, any and operational, in Tanna, Vanuatu, 2013–2015



Differences in handwashing facilities over the three years were investigated. The operational status of handwashing facilities were not reported in 2013. Separate tests were carried out for all handwashing facilities, and operational facilities only, as indicated by the asterisks. *p<0.001 **p=0.794.

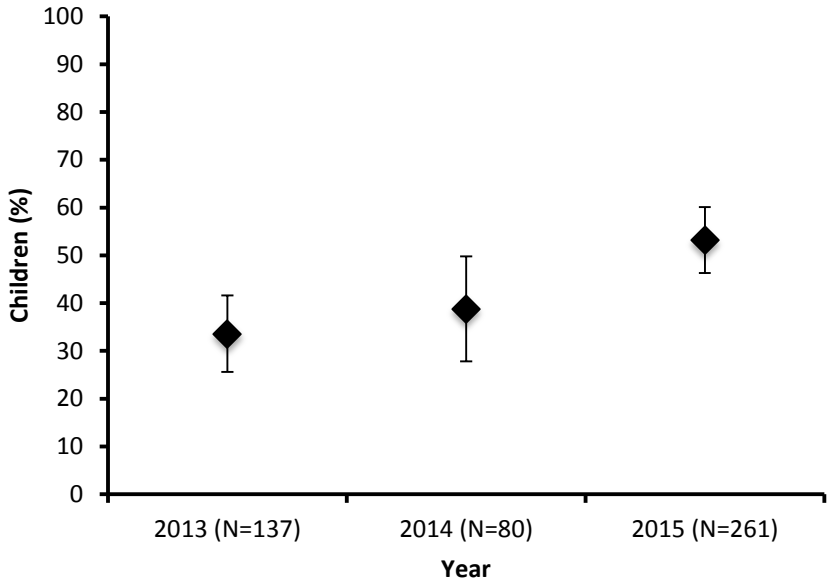
7.3 Health of children under five years of age

7.3.1 Dietary diversity

Figure 19 shows the proportion of children who had received minimum dietary diversity in 24 hours prior to the survey as defined by World Vision, food from each of the three main food groups: carbohydrates, protein, and fruit and vegetables. In 2013 and 2014 the question 'what did your children eat yesterday during the day and the night?' was asked at the household level. In 2015, the second year evaluation, the same question was asked of each child at the household. The data from 2013 and 2014 were still able to be compared to 2015 using World Vision dietary diversity definitions by treating households from the 2013 and 2014 analyses as a single children, and treating multiple children in a household in the 2015 analysis as multiple observations, clustering responses at the household level. However, dietary diversity was not comparable by WHO IYCF MDD definitions, as the age of each child is required. Additionally the 2014 dataset only recorded dietary diversity as a yes or no response instead of recording all food types consumed. Their was a significant increase in the number of children 6–59 months of age receiving foods from three of the main food

groups, from 46 (33.6%) of 137 in 2013 and 31 (38.8%) of 80 in 2014, to 136 (53.2%) of 261 in 2015 (p=0.001).

Figure 19: Proportion and 95% CI of children 6–59 months of age who consumed three food groups in the past 24 hours in Tanna, Vanuatu, 2013–2015

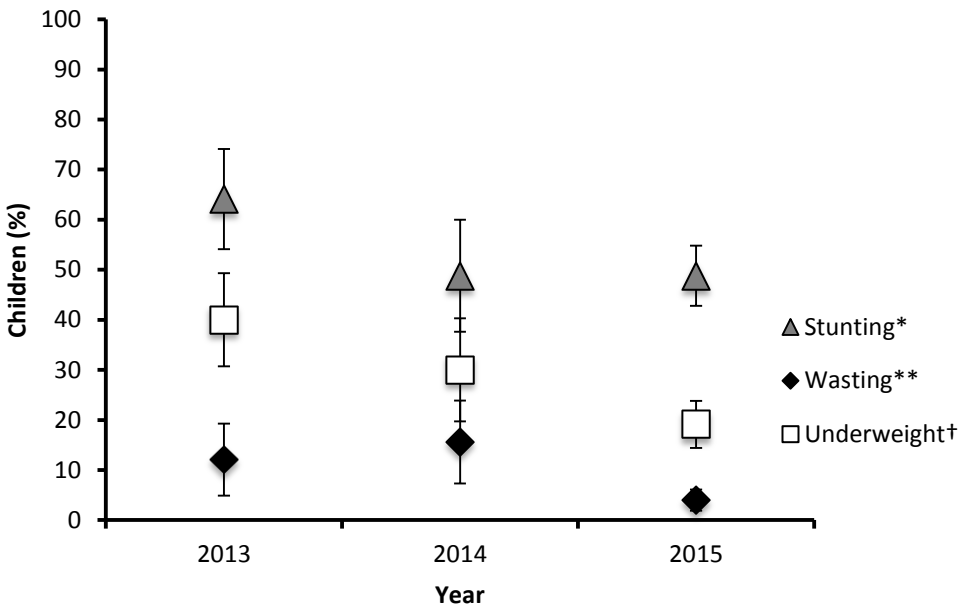


Differences in the proportion of under five year olds receiving World Vision defined dietary diversity (protein, carbohydrates, and fruits or vegetables) over the three years were investigated, giving a p-value of 0.001.

7.3.2 Undernutrition

Figure 20 shows the prevalence of stunted, wasted and underweight children, by Project year. Because of known inaccuracies in height measurements in baseline data, we excluded 2013 from statistical analyses of stunting and wasting trends. There was no significant change in stunting from 38 (48.8%) of 80 children in 2014 to 145 (48.8%) of 297 children in 2015 (p=0.991). There was a significant reduction in the prevalence of wasted children from 12 (15.6%) of 77 children in 2014, to 12 (4.0%) of 303 children in 2015 (p<0.001). There was a significant reduction in the prevalence of underweight children from 44 (40.0%) of 110 in 2013 and 24 (30.0%) of 80 in 2014, to 59 (19.1%) of 309 children in 2015 (p<0.001). However, as there are likely to be inaccuracies in 2014 results, as discussed later, apparent changes may not be meaningful.

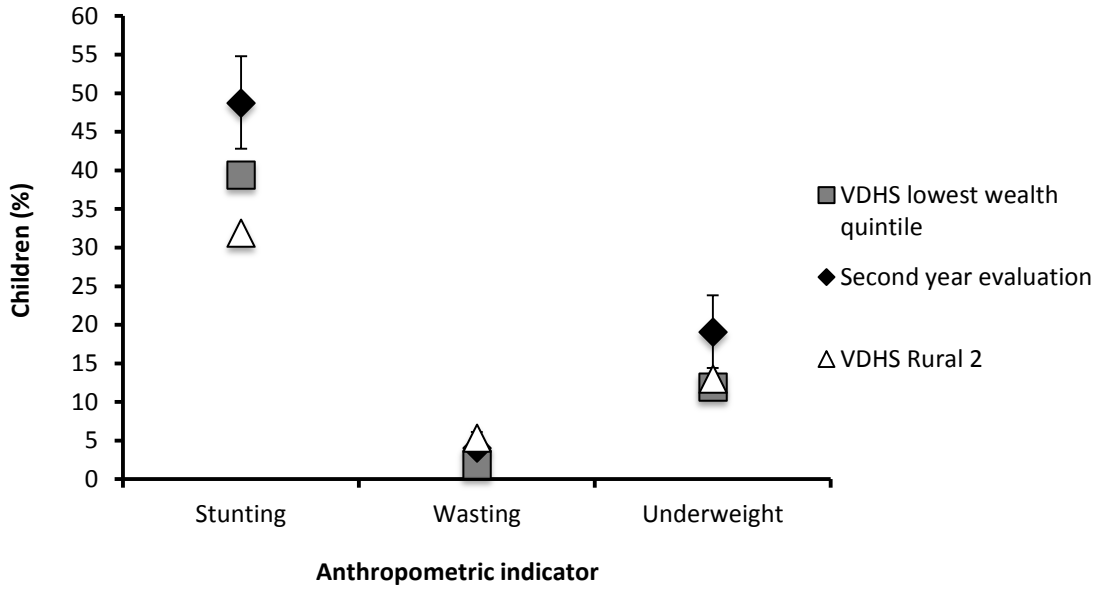
Figure 20: Proportion and 95% CI of stunted, wasted, and underweight children under five years of age in Tanna, Vanuatu, 2013–2015



Differences in undernutrition over the three years were investigated. Separate tests were carried out for each variable, as indicated by the asterisks. The 2013 stunting data point was excluded from the stunting and wasting statistical analysis due to known inaccuracies in height measurements. *p=0.991, **p<0.001, †p<0.001.

Anthropometric indicators assessed in the VDHS were the same as the second year evaluation, and similar methods were used. This allowed for a comparison, as shown in Figure 21 and Table 33. The population of south west Tanna had a two week period prevalence of diarrhoea of 145 (48.8%) of 297, compared to 31.9% in the VDHS 'rural 2' population, and 31.9% in the VDHS lowest wealth quintile population. Additionally, the prevalence of underweight children in our evaluation was 59 (19.1%) of 309, compared to 13.0% in the VDHS 'rural 2' population, and 11.9% in the VDHS lowest wealth quintile population. The population of south west Tanna and disaggregated VDHS populations had a higher prevalence of stunted and underweight children than national VDHS results, which were 28.5% and 10.7% respectively (Table 33).

Figure 21: Ecological comparison of anthropometry indicators for children under five years of age in the end of second year evaluation in Tanna 2015, to the Vanuatu Demographic and Health Survey (VDHS) 2013



Undernutrition indicators for the WASH Project displayed as proportions and 95% confidence intervals. Undernutrition indicators for VDHS displayed as proportions only, as exact numbers of children unknown.

Table 33: Ecological comparison of anthropometry indicators for children under five years of age in the end of second year evaluation in Tanna 2015, to Vanuatu Demographic and Health Survey (VDHS) 2013

Anthropometry indicator	Second year evaluation	VDHS		
		Total	Lowest wealth quintile	'Rural 2'
Stunting (<-2z)	48.8 (145/297)	28.5	39.4	31.9
Wasting (<-2z)	4.0 (12/303)	4.4	1.9	5.3
Underweight (<-2z)	19.1 (59/309)	10.7	11.9	13.0

Chapter eight – Water microbiology results (objective five)

8.1 Results of household water microbiological testing

We attempted drinking water sampling at 213 (98.8%) of the 220 available households with children under five years of age. Four (1.9%) of these houses did not have enough stored drinking water available for sampling, and a further eight (3.8%) samples that were collected were lost before data was recorded. Thus, of the 213 households where testing was attempted, 201 (94.4%) were completed. We present the results from the CBTs as levels of health risk classified by WHO (Table 7) (187).

Figure 22 and Table 34 shows the drinking water microbiological safety of households by WHO health risk category. Of the 201 households where water testing was completed, 145 (72.1%) had drinking water that was very high health risk, 34 (16.9%) had drinking water that was high risk, and 12 (6.0%) had drinking water that was intermediate risk. These three risk categories are not considered microbiologically safe by WHO (187). Therefore at the time of testing, only 10 households (5.0%) had microbiologically safe drinking water, and 191 (95.0%) households in our sample had microbiologically unsafe drinking water.

Figure 22: Household drinking water microbiological safety in Tanna, Vanuatu, 2015

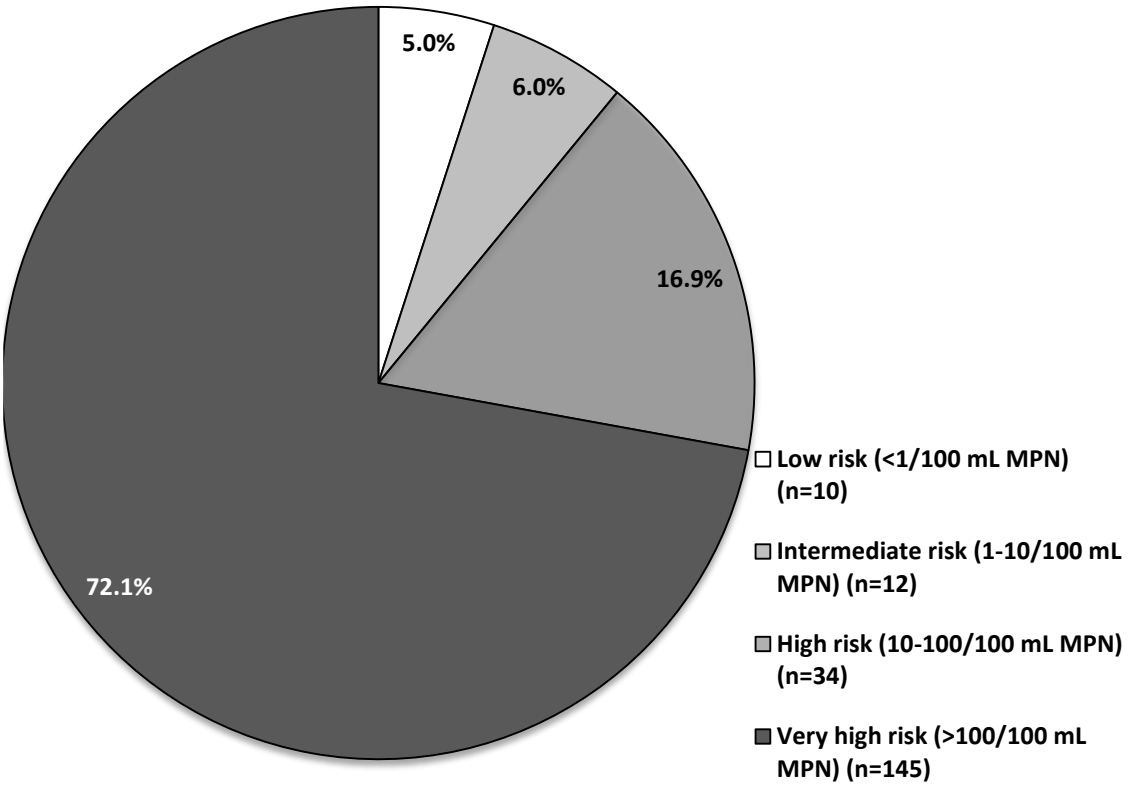


Table 34: Household drinking water microbiological safety in Tanna, Vanuatu, 2015

Health risk*	***E. coli* MPN/CFU per 100 mL**	**n**	**(%)**
Safe	<1	10	(5.0)
Intermediate risk	1-10	12	(6.0)
High risk	>10-100	34	(16.9)
Very high risk	>100	145	(72.1)
Total		**201**	**(100.0)**

* Health risk as per compartment bag test (Aquagenx, 2013) result and WHO risk classification (WHO, 2011): <1 MPN/100 mL = safe; 1–10 MPN/100 mL = intermediate risk; >10–100 MPN/100 mL = high risk; >100 MPN/100 mL = very high risk.

8.2 Water collection point microbiology testing

Overall, we sampled 19 drinking water collection points, which included the main sources of household drinking water for each community. There are likely many additional village water sources that we missed due to lack of survey time in each village, although the exact number is unknown. Of the 19 collection points tested, 14 (73.7%) were unprotected, and five (26.3%) were protected. Of the five protected sources, four (80.0%) were public standpipes and one (20.0%) was a rainwater catchment system. Table 35 summarises the water testing results for these collection points by unimproved or improved source type. Of the 19 collection points, 13 (68.4%) had water that was high or very high health risk, and 6 (31.6%) had water that tested safe or intermediate health risk. There was no difference in the health risk between improved and unimproved sources.

Table 35: Drinking water collection point microbiological safety in Tanna, Vanuatu, 2015

Health risk	Unimproved		Improved		Total tested	
	n	(%)	n	(%)	n	(%)
Safe	2	(14.3)	0	(0.0)	2	(10.5)
Intermediate risk	1	(7.1)	2	(40.0)	3	(15.8)
High risk	6	(42.9)	1	(20.0)	7	(36.8)
Very high risk	5	(35.7)	2	(40.0)	7	(36.8)
Total	**14**	**(100.0)**	**5**	**(100)**	**19**	**(100.0)**

World Health Organisation water health risk categories (187): safe = Most Probable Number (MPN) *Escherichia coli* >1/100 mL; intermediate risk = MPN *E. coli* 1–10/100 mL; high risk = MPN *E. coli* >10–100/100 mL; very high risk = MPN *E. coli* >100/100 mL.

Table 36 shows the microbiological health risk of these springs by community and spring name. At the time of this evaluation, a total of seven unprotected springs were planned, or in the process of being developed by World Vision, to become the water source for proposed gravity fed water systems. Spring development includes protecting the spring with a spring catchment box and establishing a gravity-fed system from the spring, as already described. Unprotected springs were being used as water collection points at the time of testing in this evaluation. Of the seven unprotected springs two (28.6%) had microbiologically safe drinking water, one (14.3%) had water that was intermediate risk,

three (42.9%) had water that was high risk, and one (14.3%) had water that was very high risk.

Table 36: Water microbiological safety of springs under development for gravity fed systems in Tanna Vanuatu, 2015

Community	Spring name	Health risk
Ienapkasu	Nu hagen	Intermediate
	Nu hauan	High
Ikakahak	Imairaving spring	High
	Nkuanentata	Very high
Ikulnala	Imrasukun spring	Safe
Karimasanga	Imraruk	Safe
Yekue	Nu Ibai	High

World Health Organisation water health risk categories (187): safe = Most Probable Number (MPN) *Escherichia coli* <1/100 mL; intermediate risk = MPN *E. coli* 1–10/100 mL; high risk = MPN *E. coli* >10–100/100 mL; very high risk = MPN *E. coli* >100/100 mL.

Chapter nine – Factors associated with household water contamination (objective six)

I analysed factors that could be associated with the level of household drinking water contamination by three separate analyses, as described in the methods section. Analysis one, households with safe water (MPN *E.coli* <1/100 mL) versus unsafe water (MPN *E.coli* >1/100 mL) (Table 37 and Table 38), would have revealed any factors that may be associated with lower or higher levels of unsafe water. However, there were only 10 households with safe water and therefore a multivariate analysis was inappropriate due to low numbers and just the univariate analysis is reported instead. Analysis two, safe to intermediate risk water (MPN *E.coli* 0–10/100 mL) versus high risk to very high risk water (MPN *E.coli* >10/100 mL) (Table 39, Table 40, and Table 41), was undertaken because the WHO drinking water health risk classification states that households with intermediate risk water are lower priority for action (187), and intermediate risk water may be tolerated in a development context (176). Analysis three, very high risk water (MPN *E.coli* >100/100 mL) versus all other households (MPN *E.coli* <100/100 mL) (Table 42, Table 43, Table 44, and Table 45), investigates factors that may be associated with lower or higher levels of high risk water. In this chapter I also investigate whether households with contaminated water have worse child health outcomes, such as diarrhoea, undernutrition, and respiratory illnesses.

All factors investigated for associations with water microbiology were included due to prior hypothesis. Univariate analyses were undertaken to narrow down the factors for inclusion into multivariate analyses. Plausible associations that met the criteria outlined in our methods were investigated in multivariate analyses. I investigated both WASH factors and child health outcomes for associations with water microbiology. Separate multivariate analyses were carried out for individual health outcomes because of the correlation between outcomes. An estimation of odds ratios rather than prevalence ratios was generated partly because of the small number of household with safe water, but also

because water safety could be more reasonably be used as an 'outcome' in the new model, described in the statistics methods.

9.1 Analysis 1: Safe versus unsafe

9.1.1 WASH factors

Table 37 shows WASH variables investigated for any association with unsafe drinking water. The odds of having unsafe water was 90% lower among households where the caregiver reported having any education (OR: 0.10, 95% CI: 0.01–0.97), which was statistically significant (p=0.047). Additionally the odds of having unsafe water was 78% lower among households where the caregiver reported having a secondary school education (OR: 0.22, 95% CI: 0.06–0.89), which was also statistically significant (p=0.034).

I did not find any statistically significant difference in caregiver perceived water safety between households with safe and unsafe drinking water (p=0.880). Of 186 caregivers from households with unsafe water, 112 (60.2%) perceived their drinking water as clean, compared to 6 (60.0%) of 10 caregivers from households with safe water.

The odds of having unsafe water was 85% lower among households with an improved water source compared to households with a unimproved source (OR: 0.15, 95% CI: 0.03–0.72), which was statistically significant (p=0.017). When this was disaggregated into improved source types, gravity fed systems and rainwater, we found that rainwater had a statistically significant association with safe water (p<0.001), whereas gravity fed systems was not significant (p=0.565). The odds of having unsafe water was 93% lower among households that used a rainwater source (OR: 0.07, 95% CI: 0.023–0.18).

There was no statistically significant relationship between caregivers who reported that they normally treat their water with an effective method such as boiling and household water being unsafe (p=0.941). The reported treatment methods were usually not currently being carried out on the tested sample. When interviewers took the sample of stored drinking water for treatment, the person at the household was asked if the sample water had been treated. Of the 201 samples taken, only 6 (3.0%) were reported to come from treated

samples. We also considered it unlikely that the stored water was yet to be treated, as most of the time the drinking water was already separated into a separate container from other water. None of the 10 households with safe drinking water had reported treating the current sample.

The odds of having unsafe water was 38% lower among households that reported adequate water storage compared to those who reported inadequate storage (OR: 0.62, 95% CI: 0.10–3.68), although this was not statistically significant (p=0.597). I did not see a statistically significant association between unsafe water and households where the water was reported to be stored in a container with a spigot (OR: 0.51, 95% CI: 0.09–3.01, p=0.455)

In the univariate analysis, households with a VIP latrine and handwashing facilities were associated with a higher odds of unsafe water (OR: 7.60, 95% CI: 2.21–26.14 and OR: 5.20, 1.21–22.34, respectively), which was statistically significant (p=0.001 and p=0.027). However, the confidence intervals of the ORs are very large and the direction of these associations are unlikely to be plausible in a causal sense. Caregiver reporting washing hands in the past 24 hours was also associated with a higher odds of unsafe water (OR: 2.24, 95% CI: 0.86–5.88), although this was not statistically significant (p=0.100), and the confidence interval for the OR is large. We did not find any evidence of an association between observed household cleanliness and having unsafe water (p=0.859).

Table 37: Univariate analysis of WASH factors associated with household microbiologically unsafe drinking water (MPN *E. coli* >1/100 mL) in Tanna, Vanuatu, 2015**

Household factors	Safe	Unsafe	OR (95% CI)	p-value
Education and training	**(N=10)** **n (%)**	**(N=179)** **n (%)**		
Any	9 (90.0)	83 46.4)	0.10 (0.01–0.97)	0.047*
Secondary and above	4 (40.0)	23 (12.9)	0.22 (0.06–0.89)	0.034*
World vision training (N=188)	5 (50.0)	136 (72.3)	3.24 (0.49–21.29)	0.221
Water perceptions	**(N=10)** **n (%)**	**(N=186)** **n (%)**		
Clean	6 (60.0)	112 (60.2)	1.13 (0.23–5.61)	0.880
Unclean	2 (20)	33 (17.7)		
Don't know	2 (20)	41 (22.0)		
Water source type	**(N=10)** **n (%)**	**(N=191)** **n (%)**		
Unimproved	2 (20.0)	119 (62.3)		
Improved (all)	8 (80.0)	72 (37.7)	0.15 (0.03–0.72)	0.017*
Gravity fed	2 (20.0)	55 (28.8)	1.16 (0.32–8.31)	0.565
Rainwater	6 (60)	17 (8.9)	0.07 (0.023–0.18)	<0.001*
Water treatment (self-reported)	**(N=10)** **n (%)**	**(N=178)** **n (%)**		
Boil	3 (30)	56 (31.5)	1.07 (0.18–6.54)	0.941
Don't boil	7 (70)	122 (68.5)		
Water sample treated	**(N=10)** **n (%)**	**(N=186)** **n (%)**		
Treated	0 (0.0)	4 (2.2)	Omitted	
Not treated	10 (100.0)	182 (97.9)		
Water storage (self-reported)	**(N=10)** **n (%)**	**(N=166)** **n (%)**		
Adequate	7 (70.0)	98 (59.0)	0.62 (0.10–3.68)	0.597
Inadequate	3 (30.0)	68 (41.0)		
Covered (all)	10 (100.0)	153 (92.2)	Omitted	
spigot	7 (70.0)	90 (54.2)	0.51 (0.09–3.01)	0.455
Latrine	**(N=10)** **n (%)**	**(N=186)** **n (%)**		
Improved	9 (90.0)	181 (97.3)	4.02 (0.78–20.80)	0.097
Unimproved/none	1 (10.0)	5 (2.7)		
VIP***	6 (60.0)	171 (91.9)	7.60 (2.21–26.14)	0.001*

Household factors	Safe	Unsafe	OR (95% CI)	p-value
Hygiene	**(N=10)** **n (%)**	**(N=186)** **n (%)**		
Handwashing facility	5 (50.0)	156 (83.9)	5.20 (1.21–22.34)	0.027*
No handwashing facility	5 (50.0)	30 (16.1)		
Operational facility	2 (20.0)	96 (51.6)	4.27 (0.73–25.06)	0.108
Caregiver washed hands in 24 hours	6 (60.0)	138/179 (74.2)	2.24 (0.86–5.88)	0.100
Household cleanliness	**(N=10)** **n (%)**	**(N=186)** **n (%)**		
Unclean	4 (40.0)	67 (36.0)	1.18 (0.19–7.60)	0.859
Clean	6 (60.0)	119 (63.9)		

World Health Organisation water health risk categories (187): safe = Most Probable Number (MPN) *Escherichia coli* <1/100 mL; unsafe = MPN *E. coli* >1/100 mL.
Extreme values of 0% or 100% were not able to be tested using our model and are labeled as omitted
* Statistical significant = p≤0.05
** WASH = water, sanitation, and hygiene
*** VIP = ventilated improved pit

9.1.2 Child health outcomes

Table 38 shows the univariate analysis of associations between child health outcomes and microbiological water safety. We found that no children from households with safe water were wasted, compared to 9 (3.5%) of 255 children in households with unsafe water. This difference was not able to be statistically tested in our model. There was no evidence of an association between stunted children and unsafe water (p=0.915), although the confidence interval for the OR was large. There was also no significant association between underweight children and safe water (p=0.580). However, no children from households with safe water were severely underweight, compared to 18 (6.9%) of 260 in households with unsafe water.

Households with children who had diarrhoea in the past two weeks had a lower odds of unsafe water (OR: 0.27, 95% CI: 0.09–0.83), which was statistically significant (p=0.027). However, the direction of the relationship was not plausible in a causual sense, and likely due to small numbers of children with diarrhoea and small numbers of safe water testing results.

Table 38: Univariate analysis of child health outcomes associated with microbiologically household drinking water unsafe (MPN *E. coli* <1/100 mL) in Tanna, Vanuatu, 2015

Child health outcomes	Safe	Unsafe	OR (95% CI)	p-value
Wasted	**(N=15) n (%)**	**(N=255) n (%)**		
WHZ** score [Median(range)]	0.0 (-1.9–0.96)	0.12 (-4.1–2.7)	1.21 (1.00–1.47)	0.047*
Wasted	0 (0.0)	9 (3.5)	Omitted	
Normal	15 (100.0)	244 (95.7)		
Severely wasted	0 (0.0)	2 (0.8)	Omitted	
Stunting	**(N=16) n (%)**	**(N=251) n (%)**		
HAZ** score [Median(range)]	-1.9 (-4.1–-0.3)	-2.0 (-4.9–4.5)	1.18 (0.78–1.77)	0.442
Stunted	8 (50.0)	123 (49.0)	1.10 (0.20–6.09)	0.915
Not stunted	7 (43.8)	128 (51.0)		
Severely stunted	2 (12.5)	47 (18.7)	1.50 (0.45–4.96)	0.508
Underweight	**(N=16) n (%)**	**(N=260) n (%)**		
WAZ** score [Median(range)]	-1.2 (-2.8–0.57)	-0.96 (-4.9–3.5)	1.15 (0.86–1.53)	0.346
Underweight	4 (25.0)	50 (19.2)	0.71 (0.22–2.35)	0.580
Normal weight	12 (75.0)	210 (84.6)		
Severely underweight	0 (0.0)	18 (6.9)	Omitted	
Diarrhoea	**(N=16) n (%)**	**(N=255) n (%)**		
Diarrhoea	5 (31.3)	28 (11.0)	0.27 (0.09–0.83)	0.022*
No diarrhoea	11 (68.8)	227 (89.0)		
Respiratory illness	**(N=16) n (%)**	**(N=253) n (%)**		
ARI†	2 (12.5)	18 (7.1)	0.54 (0.18–1.59)	0.262
URTI‡	8 (50.0)	125 (49.4)	0.98 (0.37–2.58)	0.962
ARI† or URTI‡	10 (62.5)	142 (56.1)	0.78 (0.22–2.75)	0.962

World Health Organisation water health risk categories (187): safe = Most Probable Number (MPN) *Escherichia coli* <1/100 mL; unsafe = MPN *E. coli* >1/100 mL. Extreme values of 0% or 100% were not able to be tested using our model and are labeled as omitted

* Statistically significant = p≤0.05

** WHZ = weight-for-height Z-score; WAZ = weight-for-age Z-score; HAZ = height-for-age Z-score

† ARI = acute respiratory infection

‡ URTI = upper respiratory tract infection

9.2 Analysis 2: Safe to intermediate risk versus high risk to very high risk

9.2.1 WASH factors

Univavriate analysis

Table 39 shows household variables investigated for any association with high risk to very high risk drinking water. Similar to the previous analysis, the odds of having high risk to very high risk water was almost 90% lower among households where the caregiver reported any education (OR: 0.18, 95% CI: 0.06–0.55), which was statistically significant (p=0.003). There was no evidence of an association between caregiver perception of water safety and having high to very high risk water (p=0.788).

The odds of having high risk to very high risk water was 93% lower among households using rainwater sources (OR: 0.07, 95% CI: 0.02–0.26), which was statistically significant (p<0.001). Additionally, the odds of having high to very high risk drinking water was 59% lower among households that reported they normally treated their water using adequate disinfection methods (OR: 0.41, 95% CI: 0.19–0.85), which was statistically significant (p=0.017). However, there was not a statistically significant relationship between those who reported the current sample of drinking water was treated and water microbiological quality (p=0.205).

In the univariate analysis, households with VIP latrines were associated with a higher odds of high to very high risk water (OR: 4.64, 95% CI: 1.96–10.98) which was statistically significant (p<0.001). Caregiver reporting washing hands in the past 24 hours was also associated with a higher odds of unsafe water (OR: 3.14, 95% CI: 0.90–10.99), although this was not statistically significant (p=0.073). However, the direction of these associations are unlikely to be plausible in a causal sense. We did not find any evidence of an association between observed household cleanliness and having unsafe water (p=0.722).

Table 39: WASH factors associated with high risk to very high risk household drinking water (MPN *E. coli* >10/100 mL) in Tanna, Vanuatu, 2015**

Household factors	Safe to intermediate risk	High to very high risk	OR (95% CI)	p-value
Education and training	**(N=22)**	**(N=167)**		
	n (%)	**n (%)**		
Any	18 (81.8)	74 (44.3)	0.18 (0.06–0.55)	0.003*
Secondary and above	8 (36.4)	19 (11.4)	0.23 (0.76–0.66)	0.007*
World vision training	14 (63.6)	127 (76.1)	1.86 (0.73–4.69)	0.188
Water perceptions	**(N=22)**	**(N=174)**		
	n (%)	**n (%)**		
Clean	12 (54.6)	106 (60.9)	1.14 (0.44–2.96)	0.788
Unclean	4 (18.2)	31 (17.8)		
Don't know	6 (27.3)	37 (21.3)		
Water source type	**(N=22)**	**(N=179)**		
	n (%)	**n (%)**		
Improved (all)	15 (68.2)	65 (36.3)	0.27 (0.05–1.33)	0.107
Unimproved	7 (31.8)	114 (63.7)		
Gravity fed	4 (26.7)	53 (82.8)	1.89 (0.72–4.96)	0.194
Rainwater	**11 (73.3)**	**12 (18.8)**	**0.07 (0.02–0.26)**	**<0.001***
Water treatment self report	**(N=22)**	**(N=166)**		
	n (%)	**n (%)**		
Boil	**11 (50.0)**	**48 (28.9)**	**0.41 (0.19–0.85)**	**0.017***
No or ineffective treatment	11 (50.0)	118 (71.1)		
Water sample treated self report	**(N=22)**	**(N=174)**		
	n (%)	**n (%)**		
Treated	1 (4.6)	3 (1.7)	0.37 (0.08–1.73)	0.205
Not treated	21 (95.5)	171 (98.3)		
Water storage self report	**(N=21)**	**(N=155)**		
	n (%)	**n (%)**		
Adequate	15 (71.4)	90 (58.1)	0.55 (0.19–1.64)	0.285
Inadequate	6 (28.6)	65 (41.9)		
Covered	21 (100.0)	142 (91.6)	Omitted	
Spigot	15 (71.4)	82 (52.9)	0.45 (0.16–1.25)	0.124
Latrine	**(N=22)**	**(N=174)**		
	n (%)	**n (%)**		
Improved	21 (95.5)	169 (97.1)	1.61 (0.45–5.71)	0.461
Unimproved/none	1 (4.6)	5 (2.9)		
VIP***	16 (72.7)	161 (92.5)	4.64 (1.96–10.98)	<0.001*

Household factors	Safe to intermediate risk	High to very high risk	OR (95% CI)	p-value
Hygiene	**(N=22)** **n (%)**	**(N=174)** **n (%)**		
Hand washing facility	16 (72.7)	145 (83.3)	1.88 (0.60–5.86)	0.279
No hand washing facility	6 (27.3)	29 (16.7)		
Operational facility	9 (40.9)	89 (51.1)	1.51 (0.49–4.67)	0.472
Caregiver washed hands in 24 hours	12 (54.6)	132/167 (79.0)	3.14 (0.90–10.99)	0.073
Household cleanliness	**(N=22)** **n (%)**	**(N=174)** **n (%)**		
Clean	15 (68.2)	110 (63.2)	0.80 (0.24–2.70)	0.722
Unclean	7 (31.8)	64 (36.8)		

World Health Organisation water health risk categories (187): safe to intermediate risk= Most Probable Number (MPN) *Escherichia coli* 0–10/100 mL; high to very high risk = MPN *E. coli* >10/100 mL. Bolded associations were included in the multivariate analysis.
* Statistical significant = p≤0.05
** WASH = water, sanitation, and hygiene
*** VIP = ventilated improved pit

Multivariate analysis

The final multivariate analysis is shown in Table 40. In our univariate analysis, variables that had statistically significant and biologically plausible associations with high risk to very high risk water included caregiver education, rainwater water sources, and adequate water treatment. Table 40 shows that the odds of having high risk to very high risk water was 90% lower among households using a rainwater source (OR: 0.12, 95% CI: 0.03–0.44), which was statistically significant (p=0.002). The associations between high to very high risk water and caregiver education and normal water treatment were no longer statistically significant in our multivariate analysis.

Table 40: Multivariate anlaysis of WASH factors associated with high to very high risk drinking water (MPN *E. coli* >10/100 mL) in Tanna Vanuatu, 2015**

Variable	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Any education	0.18 (0.06–0.55)	0.003	0.34 (0.01–1.16)	0.084
Rain water	0.07 (0.02–0.26)	<0.000	0.12 (0.03–0.44)	0.002*
Normal water treatment	0.41 (0.19–0.85)	0.017	0.65 (0.30–1.41)	0.278

World Health Organisation water health risk categories (187): safe to high risk = Most Probable Number (MPN) *Escherichia coli* 0–100/100 mL; very high risk = MPN *E. coli* >100/100 mL
*Statistically significant = p≤0.05
** WASH = water, sanitation, and hygiene

9.2.2 Child health outcomes

Table 41 shows the univariate analyses of child health outcomes associated with high to very high risk drinking water. No households with safe to intermediate risk water had wasted children. However we could not investigate the association between total wasting and high to very high risk water in our model. Households with stunted children had a higher odds of high to very high risk water (OR: 1.43, 95% CI: 0.46–4.46), although this was not significant (p=0.539). Households with underweight children also had a higher odds of high to very high risk water (OR: 1.30, 95% CI: 0.58–2.91), which also was not significant (p=0.526). There was no evidence of an association between households with high to very high risk water and children with diarrhoea (p=0.164). Nor was there evidence of an association between households with high to very high risk water and child respiratory illnesses, including ARI (p=0.375).

Table 41: Child health outcomes associated with high risk to very high risk household drinking water (MPN *E. coli* >10/100 mL) in Tanna, Vanuatu, 2015

Child health outcomes	Safe to intermediate risk	High to very high risk	OR (95% CI)	p-value
Stunting	**(N=34)** **n (%)**	**(N=232)** **n (%)**		
HAZ score	-1.7 (-4.2–4.5)	-2.0 (-4.9–2.5)	0.91 (0.72–1.15)	0.428
Stunted	14 (41.2)	116 (50.0)	1.43 (0.46–4.46)	0.539
Not stunted	20 (58.8)	116 (50.0)		
Severely stunted	5 (14.7)	44 (19.0)	1.36 (0.45–15.99)	0.586

Child health outcomes	Safe to intermediate risk	High to very high risk	OR (95% CI)	p-value
Underweight	**(N=37)** **n (%)**	**(N=239)** **n (%)**		
WAZ score [median(range)]	-1.2 (-2.8–3.5)	-0.9 (-4.9–3.8)	0.94 (0.75–1.17)	0.574
Underweight	6 (9.8)	48 (23.7)	1.30 (0.58–2.91)	0.526
Normal weight	31 (90.2)	191 (76.3)		
Severely underweight	0 (0.0)	18 (9.3)	Omitted	
Wasted	**(N=35)** **n (%)**	**(N=235)** **n (%)**		
WHZ score [median(range)]	0.2 (-1.9–1.4)	0.3 (-4.1–2.7)	1.08 (1.81–1.44)	0.623
Wasted	0 (0.0)	11 (4.3)	Omitted	
Normal	35 (100.0)	224 (70.2)		
Wasted	**(N=35)** **n (%)**	**(N=235)** **n (%)**		
Severely wasted	0 (0.0)	2 (0.8)	Omitted	
Diarrhoea	**(N=37)** **n (%)**	**(N=234)** **n (%)**		
Diarrhoea	7 (18.9)	26 (11.1)	0.54 (0.22–1.29)	0.164
No diarrhoea	30 (81.1)	208 (88.9)		
Respiratory illness	**(N=37)** **n (%)**	**(N=232)** **n (%)**		
ARI	4 (10.8)	16 (6.9)	0.61 (0.21–1.8)	0.375
URTI	16 (43.2)	117 (50.4)	1.34 (0.82–2.18)	0.248
ARI or URTI	20 (54.1)	132 (56.9)	1.13 (0.59–2.19)	0.709

World Health Organisation water health risk categories (187): safe = Most Probable Number (MPN) *Escherichia coli* <1/100 mL; unsafe = MPN *E. coli* >1/100 mL. Extreme values of 0% or 100% were not able to be tested using our model and are labeled as omitted.

* Statistically significant = p≤0.05

** WHZ = weight-for-height Z-score; WAZ = weight-for-age Z-score; HAZ = height-for-age Z-score

† ARI = acute respiratory infection

‡ URTI = upper respiratory tract infection

9.3 Analysis 3: Very high risk water versus other

9.3.1 WASH factors

Univariate analysis

Table 42 shows household variables investigated for any association with very high risk drinking water. Similar to analysis one and analysis two, the odds of having very high risk drinking water was 60% lower among households where the caregiver reported any education (OR: 0.40, 95% CI: 0.16–0.98), which was statistically significant (p=0.045). There was no evidence of an association between caregiver perception of water safety and having high to very high risk water (p=0.793).

The odds of having very high risk drinking water was 84% lower among households using rainwater sources (OR: 0.16, 95% CI: 0.04–0.65), which was statistically significant (p=0.010). There was no evidence of an association between self-reported water treatment and very high risk drinking water (normal: p=0.989 and current: p=0.485), although confidence intervals for the odds ratios were wide and we can not rule out a difference.

The odds of having water that was very high risk was 53% lower among households reporting adequate water storage (OR: 0.47, 95% CI: 0.22–1.00), which was statistically significant (p=0.050). Additionally, the odds of having very high risk water was 53% lower if the storage container was reported to have a spigot (OR: 0.47, 95% CI: 0.22–0.97), which was statistically significant (p=0.041).

Households having a VIP latrine, and caregivers reporting washing their hands in the past 24 hours were associated with a higher odds of very high risk water (OR: 4.03, 95% CI: 1.67–9.76 and OR: 2.94, 95% CI: 1.11–7.81), which were statistically significant (p=0.002 and p=0.030). However the confidence intervals for the ORs were wide, and the direction of the associations were not plausible in a causal sense. Therefore, we did not investigate them any further. There was no evidence of an association between high to very high risk water and observation of household cleanliness (p=0.469).

Table 42: WASH factors associated with very high risk household drinking water (MPN *E. coli* >100/100 mL) in Tanna, Vanuatu, 2015**

Household factors	Safe–high risk	Very high risk	OR (95% CI)	p-value
Education and training	**(N=54) n (%)**	**(N=135) n (%)**		
Any	**35 (64.8)**	**57 (42.2)**	**0.40 (0.16–0.98)**	**0.045***
Secondary and above	14 (25.9)	13 (9.6)	0.31 (0.082–1.13)	0.075
World vision training	38 (70.4)	103 (76.3)	1.39 (0.58–3.35)	0.452
Water perceptions	**(N=56) n (%)**	**(N=140) n (%)**		
Clean	31 (55.4)	87 (62.1)	1.12 (0.47–2.67)	0.793
Unclean	10 (17.9)	25 (17.9)		
Don't know	15 (26.8)	28 (20.0)		
Water source type	**(N=56) n (%)**	**(N=145) n (%)**		
Improved (all)	36 (64.3)	44 (30.3)	0.24 (0.09–0.67)	0.006*
Unimproved	20 (35.7)	101 (69.7)		
Gravity fed	21 (37.5)	36 (24.8)	0.55 (0.21–1.45)	0.226
Rainwater	**15 (26.8)**	**8 (5.5)**	**0.16 (0.04–0.65)**	**0.010***
Household factors	**Safe–high risk**	**Very high risk**	**OR (95% CI)**	**p-value**
Water treatment: self report	**(N=54) n (%)**	**(N=134) n (%)**		
Boil	17 (31.5)	42 (31.3)	0.99 (0.39–2.52)	0.989
Don't boil	37 (68.5)	92 (68.7)		
Water sample treated: self report	**(N=56) n (%)**	**(N=140) n (%)**		
Treated	2 (3.6)	2 (1.4)	0.39 (0.03–5.44)	0.485
Not treated	54 (96.4)	138 (98.6)		
Water storage: self-report	**(N=50) n (%)**	**(N=126) n (%)**		
Adequate	36 (72.0)	69 (54.8)	0.47 (0.22–1.00)	0.050
Inadequate	14 (28.0)	57 (45.2)		
Covered	48 (96.0)	115 (91.3)	0.37 (0.08–2.34)	0.332
Spigot	**34 (68.0)**	**63 (50.0)**	**0.47 (0.22–0.97)**	**0.041***
Latrine	**(N=56) n (%)**	**(N=140) n (%)**		
Improved	53 (94.6)	137 (97.9)	2.59 (0.64–10.45)	0.183
Unimproved/none	3 (5.4)	3 (2.1)		
VIP	45 (80.4)	132 (94.3)	4.03 (1.67–9.76)	0.002*
Hygiene	**(N=56) n (%)**	**(N=140) n (%)**		
Handwashing facility	45 (80.4)	116 (82.9)	1.18 (0.56–2.52)	0.665
No handwashing facility	11 (19.6)	24 (17.1)		
Operational facility	31 (55.4)	67 (47.9)	0.74 (0.36–1.54)	0.421
Caregiver washed hands in 24 hours	33 (61.1)	111/135 (82.2)	2.94 (1.11–7.81)	0.030*
Household cleanliness	**(N=56) n (%)**	**(N=140) n (%)**		
Unclean	23 (41.1)	48 (34.3)		

Clean	33 (58.9)	92 (65.7)	1.34 (0.61–2.93)	0.469

World Health Organisation water health risk categories (187): safe to high risk = Most Probable Number (MPN) *Escherichia coli* 0–100/100 mL; very high risk = MPN *E. coli* >100/100 mL. Bolded associations were included in the multivariate analysis.
* Statistical significant = p≤0.05
** WASH = water, sanitation, and hygiene
*** VIP = ventilated improved pit

Multivariate analysis

Our final multivariate analyses is shown on Table 43. In our univariate analysis variables that met criteria for investigation by multivariate analysis included: caregiver education; rainwater water sources; and having a container with a spigot. In our multivariate analysis on the odds of having very high risk water was 81% lower if rainwater was the source (OR: 0.19, 95% CI: 0.04–0.91), which was statistically significant (p=0.037). The odds of having very high risk water was 66% lower if the storage container was reported to have a spigot (OR: 0.34, 95% CI: 0.15–0.77), which was statistically significant (p=0.010). The associations between very high risk water and caregiver education was no longer statistically significant in our multivariate analysis (Table 43).

Table 43: Multivariate analysis of WASH factors associated with very high risk household drinking water (MPN *E. coli* >100/100 mL) in Tanna Vanuatu, 2015**

Variable	Univariate analysis		Multivariate analysis*	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Any education	0.40 (0.16–0.98)	0.045	0.61 (0.27–1.37)	0.229
Rain water	0.16 (0.04–0.65)	0.010	0.19 (0.04–0.91)	0.037*
Spigot	0.47 (0.22–0.97)	0.041	0.34 (0.15–0.77)	0.010*

World Health Organisation water health risk categories (187): safe to high risk = Most Probable Number (MPN) *Escherichia coli* 0–100/100 mL; very high risk = MPN *E. coli* >100/100 mL
*Statistically significant = p≤0.05
** WASH = water, sanitation, and hygiene

9.3.2 Child health outcomes

Univariate analysis

Table 44 shows the univariate analysis of child health outcomes associated with very high risk drinking water. All of the 11 children that were wasted were from households with very high risk water drinking water. However, I could not investigate the association between

total wasting and very high risk water in our model. Households with severely stunted children had over twice the odds of having very high risk drinking water (OR: 2.44, 95% CI: 1.08–5.53), which was statistically significant (p=0.032). Additionally, households with underweight children had almost three times the odds of having high to very high risk drinking water (OR: 2.88, 95% CI: 1.23–6.75), which was statistically significant (p=0.015).

Households with children who reported an URTI in the past two weeks had twice the odds of having high to very high risk drinking water than households without (OR: 2.04, 95% CI: 1.28–3.23), which was statistically significant (p=0.003). This relationship remained when children with URTIs and ARIs were investigated together (OR: 1.90, 95% CI: 1.23–2.94, p=0.004). However, when ARI was considered on its own, there was no evidence of an association between children with ARIs and very high risk drinking water (OR: 0.82, 95% CI: 0.31–2.17, p=0.683).

Table 44: Child health outcomes associated with very high risk household drinking water (MPN *E. coli* >100/100 mL) in Tanna, Vanuatu, 2015

Child health outcomes	Safe–high risk	Very high risk	OR (95% CI)	p-value
Stunting	**(N=78) n (%)**	**(N=188) n (%)**		
HAZ score [Median(range)]	-1.9 (-4.2–4.5)	-2.1 (-4.9– -1.9)	0.84 (0.69–1.03)	0.087
Stunted	34 (43.6)	96 (51.1)	1.35 (0.68–2.67)	0.387
Not stunted	44 (56.4)	92 (48.9)		
Severely stunted	8 (10.3)	41 (21.8)	2.44 (1.08–5.53)	0.032*
Underweight	**(N=82) n (%)**	**(N=194) n (%)**		
WAZ score [Median(range)]	-0.97 (-2.8–3.5)	-0.96 (-4.9–2.8)	0.81 (0.67–0.99)	0.044*
Underweight	8 (9.8)	46 (23.7)	2.88 (1.23–6.75)	0.015*
Not underweight	74 (90.2)	148 (76.3)		
Severely underweight	0 (0.0)	18 (9.3)	Omitted	
Wasted	**(N=80) n (%)**	**(N=192) n (%)**		
WHZ score [Median(range)]	0.2 (-1.9–2.1)	0.1 (-4.1–2.7)	0.93 (0.77–1.13)	0.476
Wasted	0 (0.0)	11 (5.7)	Omitted	
Normal	80 (100.0)	179 (93.3)		
Severely wasted	0 (0.0)	2 (1.0)	Omitted	
Diarrhoea	**(N=82) n (%)**	**(N=189) n (%)**		
Diarrhoea	13 (15.9)	20 (10.6)	0.63 (0.28–1.42)	0.263
No diarrhoea	69 (84.2)	169 (89.4)		
Respiratory illness	**(N=83) n (%)**	**(N=186) n (%)**		
ARI	7 (8.4)	13 (7.0)	0.82 (0.31–2.17)	0.683
URTI	31 (37.3)	102 (54.8)	2.04 (1.28–3.23)	0.003
ARI or URTI	38 (45.8)	114 (61.3)	1.90 (1.23–2.94)	0.004

World Health Organisation water health risk categories (187): safe = Most Probable Number (MPN) *Escherichia coli* <1/100 mL; unsafe = MPN *E. coli* >1/100 mL. Extreme values of 0% or 100% were not able to be tested using our model and are labeled as omitted.

* Statistically significant = p≤0.05

** WHZ = weight-for-height Z-score; WAZ = weight-for-age Z-score; HAZ = height-for-age Z-score

† ARI = acute respiratory infection

‡ URTI = upper respiratory tract infection

Multivariate analyses

Table 45 shows the multivariate analyses of associations between child health outcomes and very high risk water that met our inclusion criteria in the univariate analysis. Underweight outcomes were adjusted for child gender and age in six month groups, maternal height, and

caregiver education, as well as using rainwater, and water storage method. Respiratory outcomes were adjusted for child age in six month age groups as well as using rainwater and water storage method. The results of this adjustment are shown on Table 45. Households with severely stunted children had three times the odds of having very high risk drinking water when adjusted for other factors (OR: 3.02, 95% CI: 1.13–8.03), which remained significant (p=0.027). Households with underweight children had over twice the odds of having very high risk water (OR: 2.52, 95% CI: 1.02–6.19), which also remained significant. The association between very high risk water and respiratory infections was not significant when other factors were adjusted for.

Table 45: Multivariate analysis of child health outcomes associated with very high risk water (MPN *E. coli* >100/100 mL) in Tanna Vanuatu, 2015

Child health outcomes	Unadjusted OR		Adjusted OR**	
	OR (95% CI)	p-value	OR (95% CI)	p-value
WAZ*** score	0.81 (0.67–0.99)	0.044	0.90 (0.72–1.11)	0.326
Total underweight	2.88 (1.23–6.75)	0.015	2.51 (1.02–6.19)	0.045*
Severely stunted	2.44 (1.08–5.53)	0.032	3.02 (1.13–8.03)	0.027*
URTI‡	2.04 (1.28–3.23)	0.003	1.66 (0.93–2.95)	0.086
ARI† or URTI‡	1.90 (1.23–2.94)	0.004	1.56 (0.92–2.65)	0.103

*Significant p-value (p≤0.05)

**Undernutrition outcomes adjusted for child gender and age in six months age groups, maternal height, caregiver education, using rainwater as source water, and storage method. Respiratory variables were adjusted for age of the child in six month age group, using rainwater as source water, and storage method.

*** WAZ = Weight-for-Age Z-score

†ARI = acute respiratory infection

‡ URTI = upper respiratory tract infection

Chapter ten – Discussion

Our evaluation showed that WASH infrastructure, knowledge, and practices have improved over the course of Project implementation. There was significant increase in the proportion of households with access to improved latrines (shared or not shared), from 39 (26.2%) of 148 at baseline to 202 (97.1%) of 208 in 2015 ($p<0.001$). There was also a significant increase in the proportion of caregivers who had handwashing knowledge, from two (1.4%) of 148 at baseline to 190 (91.8%) of 208 in 2015. Despite these improvements our evaluation revealed that undernutrition remains an important health concern in the Project population of south west Tanna, with 145 (48.8%) of 297 children stunted and 59 (19.1%) of 309 children underweight.

Furthermore our evaluation found a lack of safe drinking water and adequate water treatment practices. Of the 201 households where drinking water samples were tested, 10 (5.0%) were microbiologically safe, whereas 145 (72.1%) were classified as very high health risk. Of 207 households, 75 (36.2%) reported adequate normal drinking water treatment methods. In our multivariate analyses households using rainwater sources had lower odds of very high risk water than other sources (OR: 0.10, 0.02–0.57, p=0.009). Households where caregivers reported using a water storage container with a spigot also had lower odds of very high risk water (OR: 0.34, 0.15–0.77, p=0.010). Households with severely stunted and underweight children had higher odds of very high risk drinking water (severely stunted: OR: 3.01, 95% CI: 1.13–8.04, p=0.027, underweight: OR: 2.63, 95% CI: 1.11–6.35, p=0.029).

10.1 Strengths and limitations of the evaluation

The following sections will discuss a number of strengths and limitations of our evaluation and previous Project surveys, which should be considered in the interpretation of our results.

10.1.1 Evaluation design and methods

Cross-sectional design

The cross-sectional nature and complete enumeration are a strength of the study for describing the measures in our objectives. However, our cross-sectional design could not establish temporality between child health outcomes and exposures in our multivariate analyses. We were also unable to recruit control villages that were not involved in the Project, so comparisons to baseline and end of year one were limited to the Project population.

Village members who were not present at the time of data collection were missed. Community chiefs were informed of the date of our planned visit, so that they could encourage community members to be present. Common reasons for caregivers being absent included taking someone to the hospital or visiting family or friends at the hospital, so might have biased our sample towards a healthier subgroup of the population. At one village our date of intended data collection was brought forward by one day and coincided with a whole village meeting. Therefore the village could not take part in the survey and was excluded. This exclusion is unrelated to the health or health practices of the villagers, so is less likely to have caused bias.

Our study was conducted during a brief period 19th–29th January 2015 and as such may not reflect seasonal fluctuations in diseases and diet. For example, respiratory infections were thought by World Vision staff to be more common during Vanuatu's hot, wet season from November to April (World Vision Tanna, personal communication, January 2015). Dietary diversity and nutritional status can also be affected by seasonality due to variations in crop availability and crop success. Although we used stunting as in indicator of chronic undernutrition, we used a 24-hour recall for dietary questions. Thus our dietary questions do not differentiate between those with an inadequate diet for a long period of time, and those who have only experienced short-term deprivation.

Smartphone data collection

Our study used a smartphone application developed by Smap Consulting into which questionnaires were uploaded and interviewers directly recorded answers into the 'phone.

The benefits of using smartphone platforms for field data collection in challenging environments have been described by DeRenzi et al (188). These included allowing capturing of rich forms of data, such as geopositional information, audio, and photos; reducing the errors from manually inputting data; quicker access to data after survey completion; the ability to use automatic answer constraints and complex question branching; and reduced survey cost in the long term (188). However, there are also challenges to using these platforms including situations where internet connectivity is absent; concerns about wireless privacy and theft of devices; and the necessity to charge batteries in field situations (188).

In the evaluation using a smartphone data collection platform saved time, limited human error by avoiding post-collection data entry, and interviewers reported that it was easy to use. However, there were limitations with using the Smap application. First, smartphones, originating from the World Vision office in Port Vila, were delivered late due to weather conditions. It was therefore necessary to conduct Smap application training before the smartphones arrived, using the paper-based manual provided in Appendix 7. By the time smartphones arrived and were uploaded with the evaluation questionnaires there was little time for interviewers to practice working the questionnaires on the smartphones prior to commencing data collection. Consequently, field testing with the smartphone application was not performed as planned. The lack of practice had some effects on the quality of data collection early in the evaluation, resulting in the loss of 12 child surveys due to interviewers selecting the wrong option when prompted whether they would like to carry out a child survey.

Lack of field testing led to one question that was incorrectly programmed not being exposed, and also led to the misinterpretation of one question by the interviewers. These were both discovered within two days of data collection and were partially corrected at the time, and fully corrected at the end of the first week of data collection once internet access was available. However, this incorrect programming resulted in 37 missing measles vaccination answers and may have resulted in an underestimation of the proportion of children ever breastfed.

Lack of internet access in the field meant that we could not utilize features of the Smap application that allow for rapid collation and monitoring of data. Monitoring instead took

place by checking individual surveys on smartphones every night after data collection. This was time consuming and less reliable and efficient than would have been possible with the Smap application and internet access. Nonetheless, manual checking provided robust quality control when internet was not available. A further method of quality control was having meetings with all World Vision team members after data collection had been completed for the day. During these meetings questions and problems from the day of data collection were discussed and were able to be promptly addressed.

Bias in self-report and observations

Self-reported results are subject to bias that is difficult to control for. The common bias in self-reported data is social desirability bias, where participants choose responses that will portray themselves or their family in a good light (189, 190). In our evaluation social desirability bias would lead to the over-reporting of perceived 'good' behaviours, such as handwashing and using the latrine. As caregivers had received more training by the second year evaluation compared to earlier evaluations, they may have been more aware of favorable behaviours. Thus social desirability bias may result in the reported behaviour of the population appearing to improve more than it actually had. Further examples of bias in self reported studies include courtesy bias, where participants may underestimate their problems so as not to offend the interviewer or organization and recall issues leading participants to give incorrect results accidently (190).

To counter potential self-report bias we also conducted observations to gain more objective measurements. Although these measures may be more objective than self-report, they were also subject to bias because participants knew when the evaluation was being conducted and may have specifically prepared. Some households may have made a special effort to clean their latrine, and fill the water bottle at their hand washing facility. By comparing our observed results to self-reported results we note that social desirability bias has likely been a factor in our results. For example, handwashing facilities were reported by caregivers to be present at 193 (92.8%) of 208 households, whereas they were observed at 172 (82.7%) of 208 households. Furthermore, 155 (74.5%) of 208 caregivers reported that they had washed their hands in the last 24 hours, although fewer households than this, 106 (51%) of 208 households, had operational handwashing facilities. Despite studies showing self-reported

hand washing frequently overestimates behaviour (114), self-reported results were used because a less costly and time intensive method was required.

Anthropometry

Anthropometry techniques were taught to the World Vision staff by Assoc. Prof. Lisa Houghton. Assoc. Prof. Houghton has extensive experience in both teaching and conducting anthropometry fieldwork in LMIC. The training included field practice of the anthropometric techniques on children in a nearby village. This training and practice led to improved measuring techniques and more accurate measures of anthropometric outcomes.

However, there were limitations with some anthropometric measurement data during the first three days of data collection. Children under two years of age should be measured by recumbent length on a length board and over two years of age measured standing upright with a stadiometer. This protocol was not strictly adhered to during the first three of days of data collection. There was a tendency to measure small children on the length board if they refused to stand on the stadiometer. This may lead to a minor underestimation of stunting and overestimation of wasting, as standing height is 0.7 cm less than recumbent height (172).

Many children resisted being measured, which may be due to prior negative experiences with health workers. Including mothers in the measurement process, showing older children and adults being measured, and giving out balloons were usually successful means of calming resistant children. If children could not be calmed, measurements were not taken. This only occurred on two occasions.

Water testing

Aquagenx CBT, was selected based on its portability, low cost, ease of use, and ability to produce results similar to conventional standard water testing approaches, including membrane filtration as well as Colisure/Colilert-Quantitray (174). In addition, because the Aquagenx CBT allowed ambient air incubation, testing could be done in places without electricity. The CBT method is a relatively new approach, developed in 2013, with few published field results at the time of our evaluation. In field conditions similar to south west

Tanna the hyrodgen suphide (H_2S) test is frequently used, although it is criticized for lacking quantitation. Newer testing kits, such as DelAgua Single Incubator (DelAgua Water Testing Ltd., Wiltshire, United Kingdom) can carry out multiple basic tests in field conditions, including microbiological quality, turbidity, chlorine, pH, and temperature (191). However, chlorination was not practiced in Tanna, the DelAgua kit was more expensive and complex to use than CBT, and the DelAgua kit lacked the throughput capabilities needed for our study. Thus CBT was selected for the particular context of the Tanna evaluation. In other field situations where more detailed water sampling is required, kits like the DelAgua kit are advantageous (191).

In our evaluation an MPN of *E. coli* was used to indicate faecal contamination. However, solely testing water for *E. coli* has drawbacks. Our evaluation initially intended to include both CBT and pH testing for every sample. However, due to inadequate preparation it became apparent there were insufficient litmus tests to support full pH testing. This was a limitation of the water testing component of the evaluation as pH is known to affect the rate of growth of micro-organisms, and can also impact on the function of *β*-D-glucuronidase (GUS) (192). Of the 13 water samples where litmus tests were undertaken in the first week of the evaluation, all samples had a pH of 6.0. This was a lower pH than is optimum for GUS activity, which for commercially produced GUS is 8.0 to 8.5 (192). However, GUS in stagnant water has been found to have optimal activity over a far broader range, between pH 5.0 and 9.0. It is probable that any inhibitory effects on GUS had negligible effects on our results due to the large proportion of positive samples.

Another consideration when using GUS to estimate *E. coli* concentration is that other micro-organisms can also produce GUS, including other strains belonging to the *Enterocacteriaceae* family, such as some S*higella* and *Salmonella* strains; *Bacillus* spp.; and *Aerococcus viridans* (193). Thus the presence of such microbes could lead to false positive results (193). However, the prevalence of false positive results for the CBT test in naturally contaminated water has been reported to be 3.4% which is similar to membrane filtration at 4.3% (194). The occurrence of false negative results has been reported to be higher at 5.1% (194). False negative results can occur when *E. coli* does not produce GUS.

Water quality can vary substantially at different points in time as bacterial communities change and fluctuate in response to turbidity and seasonal changes, such as volcanic ash and flooding (187). Thus sampling at one point in time may not reflect the normal water quality (187). Reviews have also reported that some *E. coli* can persist in the environment for long periods of time, and even multiply when environments have narrow fluctuations in temperature, adequate nutrients, and where the *E. coli* strain exhibits a high level of catabolic flexibility (195). However, most environments fluctuate in nutrients and temperatures, and in most cases the growth rate of micro-organisms is exceeded by the death rate (195).

10.1.2 Comparisons to baseline and end of year one

In our analysis, we compared our results to baseline and end of first year project data. However, there were a number of limitations with these comparisons due to flaws in the design and collection of the baseline and end of first year data. These flaws were specifically related to sampling, anthropometric techniques, and non-optimal recall periods in questionnaires.

Baseline, April 2013

For the baseline survey sample size calculations were carried out to generate a sample size that could be representative of the population, and this was amended when better estimations of the total population became apparent during data collection (11). However, the sample size was based on the number of adults, not children and the selection of participants was based on convenience, not a random sample. The sample also included households without children under five years of age.

Questions investigating child diarrhoea at baseline asked for a one-month recall of diarrhoea (11). One month is regarded as too long for accurate caregiver recall, with one week or two weeks recommended (196). Studies have shown that recall bias increases as the recall period increases, with recall periods longer than two or three days tending to underestimate diarrhoea period prevalence (197-201). Even a two-week recall period has been reported to underestimate disease period prevalence (198). However we chose the two-week recall in our survey to enable comparison to national data collected for the VDHS, 2013.

Child anthropometric measurement techniques at baseline were reported to have substantial flaws. Firstly, a flexible measuring tape was reported to have been used for measuring children who were frightened of the length board (11). Some children were therefore not measured to their full length (11). This would result in overestimation of stunting. Hanging scales were also used for children under two years of age. Hanging scales have been reported to give inaccurate results due to unsettled infants causing fluctuations in the weight (202).

Unlike our study, in the baseline evaluation immunisation cards were not used to establish the age of the children. Mothers often could not remember which month their child was born. At baseline, interviewers frequently reported the age of the child in years, and data were analysed as the year reported, plus six months (11). World Vision stated in the baseline report that the age assumption did not have much of an influence on the proportion of children that were underweight or stunted (11). In our evaluation we generated calendar of local events that were used during data collection when the child did not have an immunisation card and caregivers did not know their children's month of birth to allow more accurate estimates of the date of birth.

End of year one, January 2014

As the results from the end of first year survey were generated for monitoring purposes and not formally reported, we cannot be sure of the sampling framework used. Accounts from World Vision team members present at the end of year one survey suggest that convenience sampling was used, and that the survey included households without children under five years of age (World Vision Tanna, personal communication, January 2015). Some households surveyed at the end of the first year had also been exposed to a previous World Vision project that focused on maternal, child health, and nutrition, which may have influenced the results (24).

Furthermore, because the survey was primarily addressing monitoring outputs of the Project in Table 2, it did not include many questions that were asked at baseline or in our second year evaluation. Therefore, many comparisons from our evaluation could be made to baseline data only. The diarrhoea question had the same flaws as the baseline survey, further limiting comparisons (24). Anthropometric flaws in the end of year one survey were

similar to baseline, including using hanging scales, not taking duplicate measurements, and not using immunsation cards for child age (World Vision Tanna, personal communication, January 2015).

Despite the above limitations, findings from our evaluation were sufficient to address the key objectives of the evaluation. The findings, in relation to the objectives and existing literature are discussed below

10.2 WASH infrastructure, knowledge, and practices (Objective one and three)

10.2.1 Caregiver WASH knowledge has improved over the course of the project despite low World Vision training recall

World Vision's PHAST education with added nutrition modules was designed to improve caregiver knowledge regarding WASH, child nutrition, and disease prevention methods. The PHAST approach is based on the understanding that regardless of education, everyone can be taught to understand the faecal-oral route of disease transmission, and that knowing this will allow them to collectively come to the conclusion that hygiene and sanitation solutions are beneficial to their families (203). We found that the proportion of caregivers with an education was low in the Project population, with over half, 107 (54.1%) of 208, reporting they had not received any schooling. This was much higher than the national prevalence of no education reported by the VDHS, which ranged from 1.9% in adults 15–19 years of age, to 34.2% in adults aged 65 years and older (18).

To evaluate whether PHAST training had improved caregiver knowledge of diarrhoea and hygiene a number of knowledge questions were asked. We found the proportion of caregivers who could answer these questions correctly had improved from baseline and end of year one. In the evaluation, over half the caregivers could identify three or more correct causes of diarrhoea, 112 (53.9%) of 208, compared to only 1 (0.7%) of 148 of caregivers at baseline. Additionally, in 2015 179 (86.1%) of 208 caregivers could identify one or more correct treatments for diarrhoea.

Knowledge of hand washing had also increased from baseline, with 190 (91.8%) of 208 caregivers able to identify when to wash their own hands compared to 2 (1.4%) of 148 caregivers at baseline. However, self-reported handwashing practices were lagging behind knowledge, with 155 (74.5%) of 208 caregivers reporting washing hands in the past 24 hours. Furthermore, the estimate of the proportion of people washing their hands was likely to be subject to social desirability and courtesy bias (204).

An evaluation of the PHAST tool in Kenya by UNICEF in 2009 found that this participatory approach can bring about changes in hygiene practices, empower communities to participate and collaborate with stakeholders, and can be used alongside other participatory approaches, such as CTLS (205). However, they also found PHAST methodology time consuming, and trainers needed to be taught well for successful PHAST implementation (205). World Vision Vanuatu has been developing its WASH community engagement approach since 2004. In the initial project, Wota Loef Blong Yumi (water is our life) on the island of Santo in the Sanma province in 2004, key lessons were learned in PHAST implementation (206).

In the Wota Loef Blong Yumi project, considerable deviations from the PHAST community driven approach were reported to occur in the field. Community representatives were trained, and expected to disseminate information to their communities (206). Training was reported to be health education sessions instead of participatory training that encouraged discussion, and many decisions were made by World Vision rather than by communities. In addition gender was not addressed in the project sufficiently, and women in the communities reported feeling left out of the process (206). Although the project improved potable water with gravity fed systems, and improved sanitation, with VIP latrines, these technologies were predetermined by World Vision, and there was no perceivable change in handwashing facilities or hygiene practices (206).

The failures of the Wota Loef Blong Yumi project were reported to stem from inadequate training of World Vision implementers resulting in misinterpretation of PHAST tools (206). After the project evaluation, World Vision Vanuatu's PHAST approach was redesigned to emphasise community development rather than WASH infrastructure and targets. Ongoing support for implementation teams, and increasing roles for women were identified as two

important factors for the success of future projects (206). Comments from WMC members during our evaluation, which included women, gave mostly positive feedback on the Project as a whole, and demonstrated that communities were identifying problems that they want to address (Appendix 5).

Hygiene and sanitation infrastructure has improved over the course of the Project

Our evaluation found that household access to improved sanitation facilities had increased from baseline. Of the 208 households, 202 (97.1%) had access to an improved pit latrine or VIP latrine, compared to 39 (26.2%) of 148 in 2013. Many caregivers still reported sharing their latrine with other households. During latrine observations only three households were observed to not have a latrine. However, the latrines were often up to 50 metres from the household and interviewers often asked a member of the household to take them to the latrine that they had access to, not specifying sole ownership. Therefore, 116 (59.2%) of 196 households in the population had a latrine that met the criteria of the JMP improved latrine, VIP or pit with a slab that was not shared. By contrast 23 (15.5%) of 148 households had access to an improved latrine at baseline.

The proportion of households with sanitation facilities in south west Tanna was higher than the national level reported by the VDHS in 2013, where the 50.7% of households in the total population had an improved latrine that was not shared (18). The VDHS 'rural 2' population had slightly higher proportion of persons with access compared with the total population, 52.6%, because of a higher proportion of pit latrines with slabs (18). The JMP report from Vanuatu reported higher improved sanitation access than the VDHS, with 58% in total, and 55% in rural areas (2).

The MDG target for 'basic sanitation' included 'the lowest-cost option for securing sustainable access to safe, hygienic, and convenient facilities' (207), which was deemed to be context specific. However, the JMP excluded shared facilities from their improved sanitation definition. Shared facilities, defined as two or more households using the latrine, were excluded because of concerns regarding whether they are clean, and accessible during periods of high demand (2). However, a large proportion of sanitation facilities available to households in LMIC are shared (2). Shared latrines are often used because of crowding in urban areas and cost sharing in rural areas (208).

Due to the clear advantages of shared latrine facilities over open defecation, the JMP has proposed alterations to its improved sanitation definition for post-2015 monitoring, to include some shared facilities, renaming the indicator 'adequate sanitation' (209). Adequate sanitation at the home includes improved facilities shared by no more than five families or 30 individuals; whichever is fewer (2). JMP also proposed more indicators for settings beyond the household, including schools and health centres (2). We did not measure the number of households that were sharing each latrine. However, it was unlikely that more than five families or 30 individuals were sharing any of the latrine facilities in our study because of small village populations and lack of crowding. We surmise that 202 (97.1%) of 208 households in south west Tanna had access to the post-2015 definition of adequate sanitation. However, the World Vision team observed that schools had a lack of improved latrines or handwashing facilities in the Project area. Furthermore, open defecation and lack of handwashing are also likely in agricultural fields where adults may spend the majority of their day.

Interventions that improve latrine infrastructure do not often eliminate open defecation. Barnard et al (210) conducted a cross sectional study assessing latrine coverage and use three years after the Total Sanitation Campaign in Orissa, India. They reported that 39% of latrines were not being used by any member of the household, and only 47% of household members with latrines reported using the latrine for all defecation events (210). In our household questionnaire we included a latrine use question to assess whether a similar situation may have occurred. We did not see a similar situation in our population, where 206 (99.0%) of 208 of the caregivers responded they used their available latrine. Additionally this result was unlikely to be due to courtesy bias, as observations of latrines found a similarly high proportion that appeared to be in use.

The high use of latrines seen in the Tanna population may be due to PHAST training and WMC member attempts to change social norms (211). We cannot also rule out that latrine use may be overestimated, because 205 (98.6%) of 208 caregivers asked were women. Women may be more likely to use latrines because of the safety and privacy concerns associated with open defecation (211).

Of the 208 households where observations took place, 172 (82.7%) had a hand washing facility such as tippy-taps. This was a significant increase from previous years, where only 31 (21.0%) of 148 had a hand washing facility at baseline and 120 (56.3%) of 213 at the end of year one in 2014. However, when the operational status of the hand washing facilities was considered, only 106 (51.0%) of 208 of the households had an operational hand washing facility, with no significant improvement from 2014. The difference between operational and non-operational status was usually whether there was water present. Thus a lack of water availability was likely a barrier to having operational hand washing facilities.

Nutrition practices were similar to national levels, with room for improvement

In our study a limited number of WHO IYCF indicator questions were investigated, and were usually only asked in relation to the youngest child of the household. Of the WHO IYCF questions that were asked, most of the indicators were consistent with national findings reported in the 2013 VDHS. As the IYCF indicator questions were not asked in previous surveys, we could not investigate whether these practices have increased over the course of the Project.

Of the 205 youngest children in our study, 188 (91.7%) were reported to have been ever breastfed. This was likely to be an underestimation because of the misinterpretation of the breastfeeding question, as already discussed in the limitations, and was probably similar to the national level reported by the VDHS of 94.9% (18). Of 196 children, early breastfeeding initiation was reported to have been practiced for 151 (81.2%), somewhat less than the national proportion of 85.4% (18). Additionally, 29 (70.7%) of 41 children under six months of age were reported to only receiving breast milk in the 24 hours prior to the survey, interpreted as exclusive breastfeeding. This was slightly less than national level of 72.6% reported by the VDHS (18).

Of concern, were the six children under six months of age, including two under two months of age, that caregivers reported not to have had any breast milk in the past 24 hours. This was especially concerning as these communities were not known to use any milk formula, and the consumption of dairy products was found to be lacking in our survey. In one notable case, a child whose mother had died was being fed coconut water as an alternative to breast

milk, which is insufficient for the needs of infants and young children. This child was noted to be severely wasted, stunted and underweight.

The WHO IYCF indicator with the greatest room for improvement among Project area children was minimum dietary diversity (MDD), where only 59 (57.8%) of 102 children 6–23 months of age had received four or more of the IYCF food groups the 24 hours prior to the survey. The VDHS 2013 reported that 71.2% of children were receiving minimum dietary diversity, which is substantially more than we found in south west Tanna. We could not investigate the proportion of children receiving a minimum acceptable diet in our evaluation because we did not ask about the number of milk feeds for children. However, we did investigate minimum meal frequency (MMF). Of the 79 children 6–23 months of age, 63 (79.8%) had MMF in the 24 hours prior to the evaluation. This was higher than the MMF reported by the VDHS, of 40.6% (18).

Access to improved water facilities was poor and has reduced over the course of the Project

At the time of our evaluation the majority of households were collecting water from unimproved sources. In the questionnaire, 62 (29.8%) of the 208 households reported their primary source of water was improved. Furthermore, of the 208 households, only 8 (3.9%) reported they had improved water that was available all year round. This was a statistically significant reduction from what was reported in previous years, from 79 (53.4%) of 148 households in 2013 and 140 (65.7%) of households in 2014. This was likely due to failure to undertake periodic maintenance of gravity fed systems and less annual rainfall for filling rain catchment systems (212). Although there are no records of average rainfall in Tanna, World Vision staff reported there was a concern among community members that if they did not get more rain around the time of the evaluation in January, water sources could dry up during the dry season from May to October (World Vision Tanna, personal communication, January 2015).

Approximately 30% of our evaluation population had access to improved water, substantially lower than Vanuatu national levels outlined in the 2014 JMP drinking water and sanitation report (2). The JMP report stated 91% of the Vanuatu population and 88% of those living in rural areas had access to improved water (2).

10.3 Health outcomes of children under five years of age and associated factors (Objective two, three, and four)

Diarrhoea

In the evaluation 35 (11.6%) of 303 children had diarrhoea. As discussed, different recall periods were used for diarrhoea in earlier study years, and therefore comparisons to baseline, where 15% reported diarrhoea in the past month (11), and end of year one, where 33% reported diarrhoea in the past month (24), were inappropriate. The VDHS reported that the period prevalence of diarrhoea in children under five years was 11.8% nationally and 11.1% in the 'rural 2' population. Thus, the prevalence of diarrhoea in our population, 11.6%, at the second year evaluation was similar to national levels.

I explored associations between child diarrhoea and child, caregiver, and WASH factors using multivariate analyses. After controlling for the age of the child in a multivariate regression, the only factor significantly associated with diarrhoea was the age of the caregiver, where the period prevalence of diarrhoea in the two weeks prior to the evaluation was 8% lower for every one year increase in caregiver age (PR: 0.92, 95% CI: 0.86–0.98, p=0.015). This relationship may be due to caregiver knowledge and understanding of WASH and health increasing with age. A young maternal age at birth has been associated with poorer health outcomes, including diarrhoea and undernutrition, in children in LMIC (213).

I also assessed the risk of possible future outcomes, based on previous illness. Children who had diarrhoea were more likely to be severely wasted (PR: 8.14, 95% CI: 4.15–15.96, p<0.001) and underweight (PR: 2.34, 95% CI: 1.55-3.54, p<0.001); consistent with other studies. Diarrhoea and undernutrition have been described to have a 'bi-directional' relationship, where diarrhoea episodes can cause rapid weight loss via reduced nutrient absorption, with an immediate impact on the WHZ score (214). Severe undernutrition can alter immune system defenses causing children to be more vulnerable to infections (215). Researchers have estimated that 5.3% of diarrhoea could be attributable to a WAZ score of under -2 (49). In 2008, Black et al. used datasets from eight LMICs to investigate disease mortality associated with childhood undernutrition (50). Black et al found that the risk a death from diarrhoeal diseases increased with descending Z-score. This relationship was

particularly strong for wasting (OR: 2.9, 95% CI: 1.8–4.5), severe wasting (OR: 6.3, 95% CI: 2.7–14.7), underweight (OR: 3.4, 95% CI: 2.7–4.4), and severely underweight (OR: 9.5, 95% CI: 5.5–16.5) (50).

I did not see a similar relationship between stunting and diarrhoea in our evaluation. This was not surprising as a two-week period prevalence of diarrhoea was used and stunting indicates long-term inadequate nutrition (57). Stunting develops over a prolonged period of inadequate nutrition that may be caused by insufficient dietary intake, persistent diarrhoeal disease, and EED (216). Our two-week period prevalence indicator for diarrhoea may not represent the health status of children in the long term, and stunting may also be primarily cause by factors other than diarrhoeal diseases, such as EED, in this population.

Acute Respiratory Infection (ARI)

The number of children who had symptoms consistent with an ARI in the two weeks prior to the survey was 22 (7.3%) of 300 (section 5.3). This ARI period prevalence was higher than levels reported by the VDHS, of 3.0% nationally and 2.6% in 'rural 2' areas. As the VDHS was conducted from 1st September to 6th December 2013, and our evaluation was in January 2015, it is possibly that seasonality was having an effect on our ARI period prevalence, as the peak influenza season occurs in the rainy season, November to April, coincides with peak influenza cases (World Vision Tanna, personal communication, January 2015).

There were not sufficient children with ARIs to investigate associations with household, caregiver, and child factors. However, ARI was investigated for associations with other health outcomes. Diarrhoea was associated with ARI, with the period prevalence of diarrhoea over 3.5 times higher in children who had an ARI (PR: 3.63, 95% CI: 1.87–7.04, p<0.001). Additionally children with ARIs were more frequently underweight (PR: 2.18, 95% CI: 1.10–4.33, p=0.026). Other respiratory complaints that were not consistent with ARI symptoms did not have significant associations with diarrhoea or undernutrition in our adjusted regression analyses.

Studies have reported that diarrhoea episodes increase the risk of pneumonia in children (217, 218), and that this relationship is stronger as disease severity increases (218, 219). One proposed biological mechanism of the relationship includes immune suppression caused by

reduced nutrient intake, such as zinc, during diarrhoea episodes (218). Other contributors to the relationship include comorbidity from conditions of poverty, including poor housing, and limited access to health care or preventive interventions (218).

Undernutrition increases the risk of many childhood illnesses, including pneumonia via immune deficiencies (220, 221). Studies investigating the relationship between undernutrition and respiratory illness estimate that 16.5% of pneumonia episodes could be attributable to a WAZ-score of less than -2 (49). As well as increasing the frequency of pneumonia episodes, undernutrition also increases pneumonia severity (50, 221). Severe wasting has been reported to increase the risk of pneumonia mortality 15-fold (222).

Wasting

In our evaluation 12 (4.0%) of 303 children were wasted, similar to the 2013 national prevalence reported by the VDHS of 4.4% (18). According to the WHO classification for severity of undernutrtion, Table 4, this level of wasting prevalence was of low public health concern. However, the WHO categorization of undernutrition severity is reflective of statistical groupings of worldwide prevalence, and WHO warns that low levels should not be interpreted as grounds for complacency (58). Wasting is a measure of short-term inadequate nutrition caused by illness or poor dietary intake. Therefore, any short-term positive effects of interventions of child nutrition may be apparent by assessing the prevalence of wasting. We were not able to evaluate whether or not there had been changes in wasting since the start of the Project due to unreliable height and possibly weight measurements in previous years. Additionally the wasting indicator can vary seasonally and yearly, depending on food availability and infectious disease rates (18).

There were not enough children categorized as wasted to undertake a multivariate analysis of the factors associated with wasting. However, we did find significant associations between severe wasting and diarrhoea, as already described. Although wasting, underweight, and stunting are viewed separately, they share similar risk factors, such as dietary deficiencies, illnesses, and insanitary environments (216). Therefore factors associated with other nutrition indicators may also be relevant to children who were wasted, especially underweight factors, as underweight is a composite indicator.

Stunting

In our evaluation, 145 (48.8%) of 297 children were stunted, greater than national levels recorded by the VDHS of 28% in total, 34.9% in the 'rural 2' population, and 31.9% in the lowest wealth quintile. According to WHO categorization south west Tanna was in the very high severity range for levels of stunting. Stunting represents long-term inadequate nutrition, and has been reported to take longer than the two-year time span of this Project to date to see clear changes in stunting among children exposed to interventions aimed at reducing stunting (171). Yet, although a lack of observable reduction is not surprising, the prevalence of stunting in this population was of very high public health concern.

In our multivariate analysis, we found that maternal height was negatively associated with stunted children (PR: 0.95, 95% CI: 0.92–0.98, p=0.001). Maternal height has been reported to be associated with both the size of children at birth and with postnatal stunting (223-225). A longitudinal study by Addo et al showed that maternal height was associated with child height in all age groups, with a 1 cm increase in maternal height predicting a 0.04 standard deviation increase in child height at 2 years (223). A lower maternal height increased the likelihood of short statue of offspring in adulthood, thus stunting has been described to have an 'intergeneration' effect (216). Maternal height was controlled in all our multivariate analyses investigating undernutrition indices in order to illuminate this confounding and explore environmental factors.

The prevalence of stunting was 34% lower in households that were collecting drinking water from an improved source (PR: 0.66, 95% CI: 0.53–0.82, p=0.001). When improved sources were divided into gravity fed systems or rainwater, both gravity fed systems and rainwater had negative associations with stunting. However, this association with stunting was only significant for gravity fed systems (unadjusted PR: 0.55, 95% CI:0.42–0.73, p<0.001). Gravity fed systems can benefit health via increasing the amount of water available at the households and thus increasing opportunity for hygiene practices and reduced water washed diseases (33). However, increased water supply and reductions in stunting has not been demonstrated.

Underweight

Underweight is a composite indicator of stunting and wasting, thus reflects both acute and chronic undernutrition (170). The prevalence of underweight children in our evaluation, 59 (19.1%) of 309, was much higher than prevalences reported by the VDHS, 2013, of 10.7% in total, 13.0% in the 'rural 2' population, and 11.9% in the lowest wealth quintile (18). The prevalence of underweight places south west Tanna in the upper medium severity range for levels of underweight (Table 4).

In settings where stunting is high and wasting is low, underweight can underestimate the burden of undernutrition, as it does not distinguish between stunting and wasting (216). This is especially apparent in regions where there is also a high prevalence of overweight children (216). Because of this, international indicators are moving away from using underweight as a global indicator (216). However, underweight is still an important indicator in terms of the health risk of individual children. Black et al reported the odds of overall mortality is 9.7 times higher (OR: 9.7, 95% CI:5.2–17.9) for children who were severely underweight and 2.5 times higher (OR: 2.5, 95% CI:1.22.7) for children that were moderately underweight (50). Additionally, mortality risk compounds in children that have more than one indicator, for example underweight and stunting (216).

Similar to our stunting analysis, we found that having an improved drinking water source was negatively associated with underweight (PR: 0.45, 0.27–0.74, p=0.002). When improved sources were disaggregated into type, both rainwater and gravity fed systems had a negative association with underweight. However, this was only significant for rainwater (unadjusted PR: 0.44, 0.21-0.93, p=0.031).

Beyond project interventions – vitamin A supplementation, immunisations, and deworming

Factors other than Project interventions that could have contributed to the health of children in south west Tanna include immunisation, vitamin A supplementation, and deworming programmes. In our evaluation 39 (66.4%) of 57 children 12–23 months of age had received three doses of the DTP vaccination, and 19 (43.2%) of 44 had received a measles vaccination. This was comparable to national levels of DTP and measles vaccination of 55.1% and 52.6% respectively (18). The number of children who had a vitamin A dose and de-worming medication in the last six months was 170 (71.7%) of 237 children ages 6–59 months of age and 152 (76.4%) of 199 children aged 12–59 months of age respectively. This

was higher than 2013 VDHS national levels, 24.8% for vitamin A and 49% for deworming (18).

Our evaluation also found that the prevalence of stunting was 20% lower in children who had been dewormed in the last six months (unadjusted PR: 0.80, 95% CI: 0.61–0.92, 0.007). This association remained significant when we adjusted for child and caregiver characteristics related to stunting, collecting water from an improved water source, and microbiological quality of drinking water. However, when vitamin A dose and immunisations were controlled for, the relationship was no longer significant (PR: 0.69, 95% CI: 0.45–1.06, p=0.092). As deworming occurs with vitamin A doses and immunisations in Tanna it was possible they were confounders of the relationship between deworming and stunting.

Vitamin A supplementation and immunisation can reduce all cause mortality and disease specific mortality in children in LMIC (226-228). The case for mass deworming is less clear. As already discussed in chapter two, STHs are very common agents of infection, especially ascariasis, tricharis, and hookworm. Infection with STHs long term has been associated with constrained growth (229), anaemia (230), poor physical fitness (231), and poor cognitive development (232). In response to these consequences there has been emphasis on mass deworming campaigns.

Mass deworming was originally recommended only to school aged children, 5–14 years of age, due to unknown safety of anthelmintics and a perceived lower burden of STHs in younger age group. In 2002 WHO changed their recommendation to include pre-school aged children, over 1 year of age (233). This change was due to toxicity studies demonstrating the safety of the anthelmintics, albendazole and mebendazole (234). Further justification for deworming at younger age groups was from studies showing that to prevent stunting and underweight, preventive interventions should occur before 24 months of age (235). Whereas deworming for school aged children occurs in schools, for pre-school children it is often tagged onto immunisation or supplementation campaigns. Therefore deworming in pre-school aged children is lagging behind school-aged children (236).

There is an ongoing debate about the effect of mass deworming campaigns in endemic regions (237). Supporters of deworming encourage mass deworming campaigns as a government priority, as it has been reported to be cost-effective (238, 239); can increase

school participation (240); and has been shown to have positive effects on individuals in terms of school attendance, cognition, haemaglobin levels, and nutrition status (160). However, others emphasize that even though there may be possible benefits for individual children, there is no good quality evidence that mass deworming improves cognition, school attendance, nutrition status, or haemaglobin levels, on a population basis (241).

In July 2015 a Cochrane review article was published that did not find any benefit from mass deworming (241). However, many have criticized this review as, even though the quality of evidence included in the meta-analyses was rated poor to moderate, they stated there was 'substantial' evidence that mass deworming does not improve nutritional status, haemoglobin levels, school performance, cognition or mortality (241). It has also been criticized for its strict adherence to RCTs and admission of papers when there is little RCT evidence, especially in children 15 years of age (237).

A recent RCT investigating mass deworming in pre-school aged children did not find any difference between growth in the control and intervention groups at one year (242). However, the study noted that there were likely to be high reinfection rates, and that the control group also had easy access to anthelmintics (242). Suggested reasons for heterogeneity between studies include the prevalence of infection at baseline, re-infection after treatment with a single dose, spill-over effects into control groups, frequency of dosing, and differing levels of hygiene and sanitation contributing to re-infection rates (243). It is possible that deworming occurring concurrently with WASH programmes could reduce vectors to re-infection, and thus may have greater impacts than deworming alone (243, 244).

10.4 Microbiological safety of drinking water: (Objective five and six)

Almost all drinking water at the household and water collection points was unsafe for consumption.

Our evaluation found that the vast majority of households, 179 (95.0%) of 201, had drinking water contamination beyond the WHO recommended safe drinking water levels, MPN *E. coli*

>1/100 mL. Furthermore, 145 (72.1%) of 201 households had drinking water that was classified as very high health risk, MPN *E.coli* >100/100 mL. As the water component of the Project had not yet been implemented, some contamination of water was anticipated. However, the contamination we report was beyond expected levels and was likely to be a major contributing factor to ill health in this population.

World Vision recommended boiling water as an interim measure before the new gravity fed systems were built. However, although 75 (36.2%) of 207 caregivers reported they usually treated their water with effective disinfection methods, only 4 (2.0%) of 196 households reported that the currently stored water had been treated. As the person at the household who answered this question was often different to the caregiver who was being interviewed, it was possible that the person at the household knew less about the treatment of the water than the caregiver, who was usually the mother, and the person most often responsible for collecting water and cooking. It is also possible that more water samples may have been treated before drinking. However this was deemed unlikely, as the drinking water tested at the majority of households had already been poured into small water bottles specifically for drinking water, as observed by the interviewer.

Because of uncertainties in which reported treatment - current sample, or self-reported usual treatment, was the most accurate, both were investigated for associations with safe water. We found that there was no association between current reported treatment and safe water, as no households that reported treatment, had safe levels of drinking water. In our univariate analysis there was an association between households with safe to intermediate risk water and usual adequate treatment (unadjusted OR: 0.41, 95% CI: 0.19-0.85, p=0.017). However this association was no longer significant when rain being the source water was controlled for.

From the high magnitude of unsafe water it is unlikely that adequate water treatment was occurring at the households, and when it did, re-contamination post treatment was likely. It is possible that self-reported usual treatment only occurred when water was visually contaminated, such as after flooding. Furthermore, caregivers did not have an accurate perception of whether the water was safe or unsafe, with 118 (60.2%) of 196 caregivers believing water to be safe for drinking.

In our study we tested water from all of the seven proposed spring catchment sites for the World Vision gravity fed systems. Only two (28.6%) of the seven springs had microbiologically safe water, one (14.3%) had intermediate levels, with the remaining four (57.1%) having high or very high levels of contamination. World Vision's gravity fed systems do not include a community water treatment step as Project designers thought that the spring catchment boxes would sufficiently protect water. At the time of sampling, the springs were still open to external contamination, so it is possible that spring boxes may protect the water source. However, as there are currently high levels of contamination, safety should not be assumed even with protection.

Improved household water and water containers with spigots were associated with a lower odds of very high risk drinking water

Of the 10 households that had safe water, 6 (60.0%) were from rainwater catchments, and 2 (20.0%) were from gravity fed systems. In our univariate analysis the odds of having unsafe water was 93% lower if the water source was rainwater (unadjusted OR: 0.07, 95% CI: 0.02-0.18, p<0.001), although this analysis was not controlled for other factors by multivariate regression because numbers were too low. When multivariate analyses was carried out, rainwater was associated with 90% reduction in the odds of having high risk or very high risk water (OR: 0.10, 95% CI: 0.02-0.57, 0.009), and a 81% reduction in the odds of having very high risk water (OR: 0.19, 95% CI:0.04–0.91, p=0.037).

Rainwater is relatively free from contaminants and impurities (245). However, rainwater can be contaminated during the rainwater harvesting process by dirt, leaves, and animal and bird excreta (245). Hygienic storing of the rainwater at the harvesting point and at the point of use is also a concern. Although rainwater was more likely to have lower levels of contamination, 8 (34.8%) of the 23 rainwater samples had high levels of contamination. In the Project population, rainwater collection methods varied, from polyvinyl chloride tank storage, to thatch-roof collection into buckets open to contamination. The different rainwater collection methods and cleanliness of roofs, storage tanks, and buckets were likely contributing to differences in microbiological safety.

Gravity fed systems are considered improved by the definitions of the JMP, even if the source water is known to be contaminated. We found that there was no association

between microbiologically safer water and gravity fed systems in our evaluation. This finding is similar to results found by other studies (246-248) and reflects that the only gravity fed system in place at the time of the second year evaluation originated from an unprotected water source. Additionally, we found that when two source points of two separate gravity fed systems were tested, contamination either remained for the source that already had very high levels of contamination, or increased for the source that had safe levels once it was stored at the household.

A recent assessment of household drinking water in Peru, by Heitzinger et al, also used CBTs as a measure of *E. coli* contamination and WHO health risk categories as the measure of importance (247). They found that of the households that had an improved water source, 55% were contaminated (247). Due to evidence that the improved water indicator does not equate to water microbiological safety (246-248), the JMP have proposed changes to this indicator for post-2015 monitoring. Post-2015, the definition of improved water is redefined as a 'basic' drinking water service, which is identical to the previous indicator but adds that collection time should take no longer than 30 minutes (249). Importantly, another water service level has been defined called 'safely managed.' Safely managed water is an improved source type that is compliant with WHO faecal and chemical contamination standards, located on premises, and available when needed (249)

Adequate protection for the proposed source water for the new World Vision gravity systems will be an important determinant in whether this intervention can deliver safe water to the household and meet the post-2015 JMP safely managed water definition. Delivery of safe water to the households would eliminate the most important point of contact with feacal matter in the Project population, and is likely to have flow on effects reducing the contamination of the living environment in general, and improving child health outcomes. Although we found that rainwater was more likely to be safe compared to gravity fed systems, rainwater sources were reported to lack year-round availability. Therefore rainwater was not a viable alternative to gravity fed systems in the population.

Caregivers who reported their storage container had a spigot were less likely to have very high risk drinking water (OR: 0.34, 95% CI: 0.15–0.77, p=0.010). This was similar to the finding by Heitzinger et al, where the prevalence of *E. coli* contamination was 42% lower in

households that were using a spigot to dispense drinking water (PR: 0.58, 95% CI: 0.42–0.80) (247). Water containers with spigots and narrow mouths can reduce the contamination of stored water at the household by avoiding the use of foreign objects or hands for water for extraction.

Households with stunted and underweight children had a higher odds of having very high risk water

We investigated associations between water microbiological safety and child health outcomes: diarrhoea; ARI; URTI; and the undernutirition indicators, wasting, stunting, and underweight. Surprisingly we did not see a positive association between diarrhoea and unsafe water in our evaluation. The ingestion of unsafe water is the major vehicle for the transmission of disease causing microorganisms (42). Any true association between water microbiological safety and diarrhoea may be difficult to observe in our population because nearly all drinking water was contaminated. The high level of water contamination suggests that living environments may have high faecal contamination, and therefore other routes of diarrhoeal pathogen transmission were likely, including person-to-person mediated through poor hygiene.

On the other hand, underweight outcomes appeared to be associated with very high health risk water. Of the nine children that were wasted and had their drinking water tested, all had water that was very high health risk, although the statistical significance of this finding could not be tested using our model. We did find an association between stunting and microbiological water quality. In households with severely stunted children, the odds of having very high risk drinking water was three times higher than in households without (OR: 3.02, 95% CI: 1.13–8.03, p=0.027). Additionally, in households with underweight children, the odds of having very high risk drinking water were over twice as high than in households without (OR: 2.51, 95% CI:1.02–6.19, p=0.045).

The associations between water microbiological quality and underweight outcomes support our earlier findings where improved water sources were associated with lower levels of stunting and underweight outcomes. For the underweight outcome, the negative association with rainwater we found is probably mediated through microbiologically safer water, also apparent evaluation. Although we did not see any evidence of gravity fed systems having

microbiologically safer water, the negative association between stunting and gravity fed systems may still be true, as stunting takes time to develop, and our water testing results are only relevant to the point in time when they were tested. Gravity fed systems also have other benefits to health, as already discussed.

The association between stunting and microbiologic water quality is important for this evaluation, as it is showing that environmental contamination may be contributing to the very high prevalence of stunting, 48.8% in our population. This is especially important as we found no evidence of differences in IYCF practices between children who were and were not stunted. Although poor IYCF practices, especially a lack of animal food, are likely major contributors to undernutrition, ingesting large amounts of faecal bacteria would exacerbate the problem. The likely mechanism for this action is discussed in the next section.

10.5 Environmental Enteric Disorder (EED)

Additional health outcomes not measured in our evaluation that are known to be affected by WASH interventions include EED (61), STH (112), and trachoma (89), as described in earlier sections. An assessment of these health outcomes in our study population was not feasible in the limited time that we had to undertake data collection in each village. The WASH interventions in the Project aim to introduce barriers between faeces and human contact, thus could have plausible benefits by preventing diseases beyond diarrhoea and undernutrition. As EED, STHs, and trachoma are caused by contact with faeces, barriers in these transmission routes established during the WASH Project could have positive effects on these disease outcomes. However, these benefits would be unlikely to occur in concurrence with the levels of drinking water contamination described in our evaluation. We could not take an EED investigation due to the lack of laboratory facilities or equipment to freeze stool or urine samples, and insufficient time at each village. However, EED has been described as ubiquitous in conditions of poverty (69), and therefore its relevance to our population can be assumed.

EED has been postulated as the missing link between poor WASH and undernutrition, specifically linear growth. EED is thought to be caused by the ingestion of large amounts of

faecal micro-organisms (60). In our evaluation we found that there was a combination of high environmental contamination, shown by the high levels of contaminated water, and a high prevalence of stunting in the absence of high diarrhoea period prevalence. Also, households with drinking water contamination defined as very high health risk, were more likely to have severely stunted children. Therefore, it is likely that EED was an important driver of stunting in our evaluation (66). The attributable fraction of EED to stunting has not been elucidated because of difficulties in studying the EED, including no widely accepted case definitions or gold standard biomarkers (69). However, an early study published in 1991 by Lunn et al found that the L:M ratio explained 43% of linear growth in Gambian children two to fifteen months of age. Furthermore, they did not find a similar association between diarrhoea and growth failure (68, 75).

The association between undernutriton and EED is likely via a combination of local and systemic inflammation. Local inflammation from immune responses to faecal bacteria in the gut can change the structure of the gut lumen, causing blunting of villi, reducing absorptive capacity, and also causes increased permeability for faecal antigens to move from the lumen and cause systemic responses. Chronic systemic responses have been postulated to lead to growth hormone resistance in children (69).

Studies currently being undertaken in LMIC should better elucidate the relationship between EED and stunting. Three of these studies are: the Etiology, Risk Factors, and Interactions of Enteric Infections and Malnutrition, and the Consequences for Child Health and Development (MAL-ED) study, a birth cohort of eight LMIC (67); the Sanitation, Hygiene, Infant Nutrition Efficacy (SHINE) Project, Zimbabwe (69); and the WASH benefits study in Bangladesh and Kenya (146). Preliminary investigations in the WASH benefits study have found that children within more hygienic environments had lower L:M ratios, better linear growth, and less immune stimulation (76). The SHINE project hypothesizes that that EED will be a major cause of stunting in their study (69).

10.6 Project recommendations

Water recommendations:

As the majority of household drinking water and water from village collection points tested unsafe for human consumption, the lack of safe drinking water was an important limitation in the Project's ability to improve the health of communities. Despite VIP toilets encouraging safe disposal of human faecal matter, water is highly contaminated. The third year of the Project has a focus on establishing piped water to villages via gravity fed systems from protected spring boxes. The Project previously promoted boiling as an interim measure for water. However, there appears to be a wide gap between knowledge and actual practices of caregivers regarding boiling water, as shown by differences between self-reported normal treatment and treatment of the currently stored water at households. This is also shown by the lack of safe water.

Our water recommendations for the future of the project were as follows:

1) *Continuation of gravity fed water system plans from protected sources with the addition of drinking water quality monitoring through microbiological testing.*

Gravity fed systems have many advantages, and were deemed important by communities. The primary focus of the third year of Project implementation was on delivering piped water to villages through gravity fed systems from protected water sources. Protecting the source water from external contamination is important for water quality, and community maintenance will need to be ongoing. The selection of microbiologically safe drinking water sources will also contribute to how effective the gravity fed systems are in delivering potable water and reducing disease. In our evaluation, only two of the seven proposed sources had safe water. Therefore microbiological testing of these sources should be carried out to ensure that protecting them from external contamination by the spring catchments boxes, actually results in safe water.

Microbiological testing should also occur after systems have been established, to determine whether the gravity fed system has improved the water quality. This could be done using the CBT method, as it has proven to be a relatively inexpensive and easy to in the Project area. In

the long term, even simpler and cheaper methods, such as hydrogen sulfide (H_2S) test strips could be used. Although H_2S test strips do not give a concentration of *E. coli*, just a positive or negative reading, they have the advantage of not requiring as much equipment and are easy to perform (250). Regular testing using H_2S could be carried out by WMC committee members, allowing self-management of drinking water sources. Regular testing in the long term is important, as a single result can lead to false assurance of water safety (187). Regular testing aligns with the Vanuatu Draft National Water Drinking Standards, where testing using H_2S test strips are recommended for rural areas once a week (251). If water quality has not improved, further interventions will be necessary, as per the following recommendation.

2) *If gravity fed water systems do not deliver microbiologically safe drinking water, household treatment methods should be promoted as a long-term strategy*

Although boiling water was previously promoted by World Vision in this area, I did not recommended promoting boiling water going forward in the Project as a long-term solution to unsafe water, because of adherence issues and dangers to health through indoor air pollution. Instead, an appropriate alternative form of disinfection was recommended. No one treatment is ideal for all situations, and therefore a strategy for a long-term treatment method would need to be established with south west Tanna contextual elements in mind and in consultation with communities to increase adherence.

One concern may be turbidity in the rainy season or after major volcanic eruptions. Turbidity not only increases microbial load but can render water treatments such as filtration and chlorination inefficient. If turbidity is a problem turbidity mitigation methods like flocculation or sedimentation should be carried out prior to disinfection. Ceramic and biosand filters are an example of disinfecton method that has the potential to reduce microbial contaminants and reduce water-related diseases. However, ceramic and biosand filters do not reduce heavy metals. Heavy metals in drinking water is another consideration as they may be higher than normal if water sources are exposed to volcanic ash or groundwater is exposed to ash leachate (252). As the levels of trace of heavy metals was unknown at the time of our evaluation, testing would be required to assess the need for specific treatment, such as deflouridation by specialized filtration media (253).

Nutrition recommendations

The consequences of undernutrition include an increased risk of morbidity and mortality, lower adult size, lower intellectual ability, and worse health in general (254). The most effective interventions aimed at decreasing stunting prevalence involve multiple components, such as WASH interventions, maternal nutrition, education on infant and young child feeding practices including exclusive breastfeeding, complementary feeding with a diverse diet, and supplementation or fortification (160, 170). In 2015 WHO updated its nutrition recommendations to integrate one or more WASH interventions into programmes aimed at reducing undernutrition (170). This revision was to address the proportion of undernutrition caused by diseases, including diarrhoea, EED, and STHs. As the Project already addresses WASH, a focus on WHO IYCF recommendations could help to achieve reductions in undernutrition.

Our nutrition recommendation for the third year of the project was as follows:

1) *Caregiver nutrition education focusing on improved complementary feeding to increase the consumption of animal source foods should continue into the third year of the Project.*

A high maternal nutrition knowledge has been shown to partially compensate for a lack of schooling (255). Education sessions should continue into the third year of the Project, focusing on the following topics: improving early initiation and exclusive breastfeeding up to the age of six months, with continuation of breastfeeding beyond two years of age; appropriate complementary feeding practices for children 6–23 months of age; adequate nutrition for pregnant and lactating women; and diversifying diets – especially with animal source foods. IYCF education should be targeted to caregivers of children under two years of age and pregnant women, as this is where interventions can make the most difference to child growth (159). The community nutrition officers, part of the WMC committee, could provide a supportive and promotional role in addition to training.

10.7 Conclusions

The proportion of sanitation and hygiene facilities in households in the Project area increased over the course of the Project; knowledge of hygiene and diarrhoea indicators improved; and child nutrition practices were largely similar to national levels. Although reported hygiene practices had increased, there was likely substantial social desirability bias in this indicator. Taken together, our evaluation findings indicate that the Project was largely achieving its short-term outcomes and medium-term outcomes, with the notable exception of delivering clean water to households. Progress of the long-term indicator of healthier children and families was harder to assess because of flaws in baseline and first year anthropometry, and differing diarrhoea recall periods. However, the prevalence of undernutrition was high in the population, especially stunting. The majority of household water had very high levels of faecal contamination. Improvements in child health may not be evident until they have safe drinking water. Further research post water intervention would be beneficial to assess the uptake of water interventions and whether they are improving child health. It would also be valuable to undertake research into EED in this population and wider Vanuatu, as it is it may be contributing to the results shown in this evaluation, and limiting health effects from nutrition interventions.

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Appendices

Appendix one – household questionnaire

This survey was programmed into the smap app. Below is a list of questions, but not how they looked once in the app.

No.	Question	Hint	Answer
1.	Today's date		
2.	Interviewer name:		
3.	Community name:		1. Ikakahak 2. Ikulnala 3. Ienapkasu 4. Karimasanga 5. Yekue 6. Imapul
4.	Village name:		
5.	Household identifier:		
6.	Gender:		0. Male 1. Female
7.	Do you know how old you are?		0. Male 1. Female
8.	How old are you in years?		
9.	Relationship to the child/children in this household:		1. Mother 2. Father 3. Grandmother 4. Grandfather 88. Other – Specify:
10.	Are you the primary caregiver of the children?		0. No 1. Yes
11.	What is the highest level of education you (the primary caregiver) attended?		1. Preschool 2. Primary 3. Secondary 4. Tertiary 5. Vocational 6. None 88. Other

12.	No. of people in household:		
13.	No. of adult females (over 15 years):		
14.	No. of adult males (over 15 years):		
15.	No. of children female (0-14 years):		
16.	No. of children male (0-14 years):		
17.	How many children in the household are under 5 years old (0-4 years)?		
18.	Does your family have access to a toilet?		0. No 1. Yes
19.	What type of toilet is it?		2. VIP 3. Bush toilet 4. Open defaction 88. Other - Speficy
20.			
21.	Do you use the toilet?		0. No 1. Yes
22.	Do you share this facility with others who are not members of this household?		0. No 1. Yes
23.	Do you have facilities to wash hands after going to the toilet?		0. No 1. Yes
24.	Have you used soap for washing your hands today or yesterday?		0. No 1. Yes
25.	When do you wash your hands?	Do **not** prompt - select all mentioned.	1. After going to the toilet 2. Before eating 3. Before preparing food 4. After cleaning babies bottoms 5. After gardening 88. Other – Specfity 99. Don't Know
26.	When do you wash your children's hands?		1. After they go to the toilet 2. Before eating 99. Don't know
27.	Does your household have any of the following items?	Read out list.	1. A rubbish pit or disposal unit for waste 2. Dish drying rack 3. Soap/ash for hand-washing 4. Clean/covered/sealed water storage facility 5. None of these items
28.	What is the main source of drinking water for members of your household?	Select one.	1. Open river 2. Protected spring 3. Unprotected spring 4. 4. Gravity fed systems 5. Rainwater catchment 6. Protected dug well 7. Unprotected dug well 8. Bottled water 88. Other - Specify

29.	If gravity fed, name the source of the water		
30.	Is this main water source available to you all year round?		0. No 1. Yes 99. Don't know
31.	What times of the year do you not have access to this water supply?		2. Dry season 3. Wet season 4. January 5. Febuary 6. March 7. April 8. May 9. June 10. July 11. August 12. September 13. October 14. November 15. December
32.	What secondary sources of drinking water are used?	Select all mentioned.	0. Open river 1. Protected spring 2. Unprotected spring 3. 4. Gravity fed systems 4. Rainwater catchment 5. Protected dug well 6. Unprotected dug well 7. Bottled water 88. Other - Specify
33.	If gravity fed, name the source of the water		
34.	How long does it take to go there, get your drinking water, and come back? (in minutes)		
35.	How many times a day is water collected for your household?		
36.	Who usually goes to the main source to fetch drinking water?		1. Adult women 2. Adult man 3. Female child (<15 years) 4. Male child (<15 years)
37.	Do you do anything that makes the water safer to drink?		0. No 1. Yes 99. Don't know
38.	What do you do to treat your water?	Do **not** prompt - select all mentioned.	1. Boil 2. Strain through a cloth 3. Use a water filter (ceramic/sand/composite) 4. Solar disinfection 5. Let it stand and settle 6. Container with a lid and cap 7. Add bleach and chlorine 88. Other specify
39.	Do you store your water for drinking?		0. No 1. Yes
40.	Do you store your drinking water		0. No

	in a container only used for storing drinking water?		1. Yes 99. Don't know
41.	How do you store water for drinking?		1. Uncovered container 2. Covered container (wide open with cover) 3. Bottle necked container with lid/jerry cans 4. Container with lid and tap/spigot 99. Don't know
42.	What is the main source used by your household for purposes such as cooking and hand-washing?	Select all mentioned.	0. Protected spring 1. Unprotected spring 2. 4. Gravity fed systems 3. Rainwater catchment 4. Protected dug well 5. Unprotected dug well 6. Bottled water 88. Other - Specify
43.	If gravity fed, name the source of the water		
44.	Has any family member visited a health clinic / aid post / hospital in the past month?		0. No 1. Yes 99. Don't know
45.	Have any adults (over 15 years) in your household visited a health clinic / aid post / hospital in the past month?		0. No 1. Yes
46.	What is the number of adult health visits?		
47.	Have any children, over 5 years (less than 15 years), in your household visited a health clinic / aid post / hospital in the past month?		0. No 1. Yes
48.	What is the number of child, over 5 years, health visits?		
49.	Have any children, under 5 years, in your household visited a health clinic / aid post / hospital in the past month?		0. No 1. Yes
50.	What is the number of child, under 5 years, health visits?		
51.	What do you think causes diarrhoea?	Do **not** prompt - select all mentioned (scroll down for full list).	1. Dirty hands 2. Flies 3. Drining dirty water 4. Open defecation 5. Faeces from free ranging animals 6. Food not properly washed 7. Mother has hot breast milk 8. Mother works too hard 9. Dirty kitchen 10. Weather 11. Dirty in general 12. Food not good 13. Not breastfeeding 14. Not eating proper food

			15. Working in the hot sun 16. Greasy food 17. Too much meat 18. Too much fruit 19. Food in the hot sun 20. Mother not happy 21. Not washing the baby 22. Not washing hands after food 88. Other – Specify: 99. Don't know
52.	Can you list what you think are the best ways to treat diarrhoea?	Do **not** prompt - select all mentioned (scroll down for full list).	1. Go to the aid post 2. Treat at home with bush medicine 3. Give lots of water and fluids 4. ORS 5. Green coconut 6. Sugar cane 7. Boil water 8. Dry coconut 9. Massage foot gently 10. Water with salt 11. Meat 12. Give antibiotics 88. Other Specify: 99. Don't know
53.	Have you, or anyone in your household, participated in any training provided by World Vision or your WASH officers?		0. No 1. Yes 99. Don't know
54.	What subjects were you trained on?	Do **not** prompt - select all mentioned.	1. Hand washing 2. Environmental hygiene (animals) 3. Home hygiene and waste disposal 4. Diarrhoea prevention and treatment 5. Safe drinking water storage 6. Nutrition for children 7. Breast feeding 8. Immunisations 1. Other – Specify:
55.	Was there anything special about yesterday? E.g. a wedding, ceremony or special occasion held in the village which would impact on diet?		0. No 1. Yes 99. Don't know
56.	Would you consider this time of year a good time in regards to the abundance of food, or a hungry season?		1. Good 2. Average 3. Hungry

Appendix two – child questionnaire

This survey was programmed into the smap app. Below is a list of questions, but not how they looked once in the app.

No.	Question	Hint	Answer
57.	What is the child's name?		
58. 1	What is the child's number	This must be the same as their anthropometry number	
59. 2	What gender is the child?	Do not assume this - always ask	2. Male 3. Female
60. 3	Does the child have an immunisation or health card available for us to look at?	Prompt with description of card such as 'blue card that has child's information about when they see the doctor for injections'	0. No 1. Yes
61. 4	Record child's date of birth as reported on card	Check it is the right card for the child and not a sibling (same name)	
62. 5			
63. 6	Child's age is: ${age_months_calc} months	The child must be under 60 months - if 60 months or more discontinue collecting information from the child	
64. If Q4=1	If the mother does not know the child's date of birth, we will try to estimate using an events calendar	This may have already been done for anthropometry. Use the 5 year events calendar to find out the child's year and month of birth	
65.	Child's age is ${age_months_est_c} months		
66.	Has ${child1_name} had diarrhoea in the past 2 weeks? (3 loose stools over 24 hours)		0. No 1. Yes 99. Don't know
67. If Q10=1	Was there any blood in the stools?		0. No 1. Yes 99. Don't know
68. If Q10=1	Did you seek advice from any of the following?		1. Aid post 2. Traditional practitioner 3. No advice sought 88. Other – Specify:
69. If Q10=1	Did ${child1_name} receive any of the following treatments?		1. ORS 2. A government recommended home-

			made remedy 3. Herbal or traditional medicine 4. Antibiotics 5. Drinking extra water 6. None of the above
70.	Has ${child1_name} had an illness with a cough in the last two weeks?		0. No 1. Yes 99. Don't know
71.	When ${child1_name} had an illness with a cough, did he/she breath faster than usual with short, rapid breaths, or have difficulty breathing?		0. No 1. Yes 99. Don't know
72.	When ${child1_name} had this illness, did he/she have a problem in the chest, or a blocked or runny nose?		1. Chest only 2. Nose only 3. Both 88. Other – specify: 99. Don't know
73.	Has this child been immunised?	Prompt with description of immunisation – eg injection in arm or thigh and droplets in the mouth	0. No 1. Yes 99. Don't know
74.	Do you have an immunisation card for this child that we can look at so see whether they are fully immunised?	Prompt with description of card such as 'blue card that has child's information about when they see the doctor for injections'	9. No 10. Yes
	Answer the next two questions from the information recorded in the immunisation cards		
75.	Record whether this child has had their 3rd DTP (pentavalent) vaccine:		3. No 4. Yes
76.	Record whether this child has received a Measles/Rougeole vaccine:		6. No 7. Yes
77.	Has this child had 3 injections in their thigh or arm over 3 months for protection against Hepatitis B, Type B Influenza, Whooping cough, Tetanus and Diptheria?		0. No 1. Yes 99. Don't Know
78.	Has this child had a vaccine in their thigh or arm at one year of age to protect against Measles?		0. No 1. Yes 99. Don't Know
1.	Has ${child1_name} ever received a Vitamin A dose? This would have been a capsule with red liquid in it that was cut open and fed to the child.		0. No 1. Yes 99. Don't Know
2.	Did ${child1_name} receive a vitamin A dose within the last six months?		0. No 1. Yes 99. Don't Know

3.	Has ${child1_name} received a dose to get rid of intestinal worms in the last 6 months? This would have been a tablet that they chew.		16. No 17. Yes 99. Don't know
	Now I would like to ask you about foods your child ate over the last 24 hours including the day and night. I am interested in whether your child had the item even if it was combined with other foods. Yesterday did your child eat:	This is only for children that are **eating solid food** (not exclusive breast feeding)	
4.	Any food from grains like rice, noodles, macaroni, biscuits, or any other foods made from rice, or other local grains?	Last 24 hours	0. No 1. Yes 99. Don't know
5.	Any potatoes yams, kumara, manioc, taro or any other foods made from roots or tubers?	Last 24 hours	0. No 1. Yes 99. Don't know
6.	Any food made from beans, peas, peanuts or nuts	Last 24 hours	0. No 1. Yes 99. Don't know
7.	Any beef, pork, lamb, goat, wild game, chicken or other birds, liver, kidney?	Last 24 hours	0. No 1. Yes 99. Don't know
8.	Any fresh or dried fish or shellfish?	Last 24 hours	2. No 3. Yes 99. Don't know
9.	Any eggs?	Last 24 hours	0. No 1. Yes 99. Don't know
10.	Any cheese, yoghurt, milk (tinned or fresh or breast milk) or other milk products like baby formula?	Last 24 hours	0. No 1. Yes 99. Don't know
11.	Any dark-green leafy vegetables? e.g island cabbage	Last 24 hours	2. No 3. Yes 99. Don't know
12.	Any yellow/red/orange vegetables and fruit? - yams, sweet potato, pumpkin, pawpaw, carrots, mango, passionfruit	Last 24 hours. Not this **does not** include corn, tomatoes, pineapple or capsicum	2. No 3. Yes 99. Don't know
13.	Any other fruit and vegetables e.g. corn, tomato, cucumber,melon, capsicum	Last 24 hours	0. No 1. Yes 99. Don't know
14.	Any other foods? (read through list)	Last 24 hours	1. Oil, fats 2. Condiments e.g soy sauce 3. Flavourings (spices, herbs, chilli, garlic, local curry dry ginger) 4. Sugary foods (chocolates, sweets) 5. Sugar cane 6. Sweet beverage 7. Tea or coffee 8. Sugar or honey 88. Other 99. None
1.	How many meals (excluding snacks) did you feed ${child1_name} yesterday?	Last 24 hours	0. 0 1. 1 2. 2

			3. 3 4. 4 5. 5 6. 6 99. Don't'know
2.	How many snacks did you feed ${child1_name} yesterday	Last 24 hours	0. 0 1. 1 2. 2 3. 3 4. 4 5. 5 6. 6 99. Don't know
3.	Now I would like to ask you some questions about your most recent breastfeeding experience. These questions only concern your youngest child		
4.	Was your youngest child ever breastfed by anyone?		2. No 3. Yes
5.	How long after birth did you put this child to the breast?		1. Immediately (<1 hour) 2. More than one hour, less than one day 3. One day or more
4.	How many hours after birth was this child put to the breast?		2.
5.	How many days after birth was this child put to the breast?		
6.	In the first three days after birth, was this child given anything other than breast milk to drink?		0. No 1. Yes
7.	What was the child given to drink?		1. Milk (other than breast milk) 2. Plain water 3. Sugar or glucose water 4. Gripe water 5. Sugar-salt-water solution 6. Fruit Juice 7. Infant formula 8. Tea/infusions 9. Honey 10. Green coconut milk 88. Other
1.	What age was the child when you first introduced solid food? In months		9. Hand washing 10. Environmental hygiene (animals) 11. Home hygiene and waste disposal 12. Diarrhoea prevention and treatment 13. Safe drinking water storage 14. Nutrition for children 15. Breast feeding 16. Immunisations 88. Other – Specify:
2.	Are you still breastfeeding this child?		2. No 3. Yes
3.	For how many months did you		

	breastfeed this child?		
4.	For how many months did you breastfeed this child?		
5.	Yesterday, during the day or at night, did the child drink or eat any of the following?		1. Plain water 2. Commercially produced infant formula 3. Baby cereal 4. Any other porridge or gruel? 99. None of the above

Appendix three – observation questionnaire

This survey was programmed into the smap app. Below is a list of questions, but not how they looked once in the app.

No.	Question	Hint	Answer
1.	Interviewer name:		
2.	Community name:		7. Ikakahak 8. Ikulnala 9. Ienapkasu 10. Karimasanga 11. Yekue 12. Imapul
3.	Village name:		
4.	Household identifier:		
5.	Is there a container for drinking water separate from cooking water?		4. No 5. Yes
6.	Observation of drinking water treatment method	Ask to see drinking water and treatment methods, tick which boxes apply	2. Observe chlorine (bottles or tablets) 3. Observe filter cloth (in tact) 4. Obsevre settling containers and/or sediment 5. Fuel source for boiling water/equipment
7.	Observation of safely stored drinking water	Ask to see stored drinking water, and tick which boxes apply	1. Completely covered with lid 2. Completed covered with leaf lid 3. Open, uncovered 4. Narrow opening 5. Spigot 6. Beyond reach of animals 7. Clean (free of dirt, debris, garbage) 8. Dirty 88. Other – Specify:
8.	Is the drinking water clean?		0. No 1. Yes
9.	Is there a toilet or latrine?		1. No latine 2. Pit, unimproved 3. Pit, improved 4. VIP
5.	If there is a latrine, are there hand washing facilities outside it?		4. No 5. Yes
6.	Are there handwashing facilities close to the house or outside the house?		0. No 1. Yes
7.	Is there a rubbsih pit more than just under a tree?		0. No 1. Yes
8.	Observe and score the general household cleanliness		1. Very unclean 2. Unclean 3. Clean 4. Very Clean

No.	Question	Hint	Answer
9.	Is the drinking water being sampled for testing improved or unimproved?		0. Unimproved 1. Improved
10.	Has the drinking water sample been 'treated'?		0. Untreated 1. Treated
11.	Aqugenx™ CBT result		
12.	pH test strip result		

Appendix four – key informant interview

Key Informant Interview: January-February 2015			
#No	**Question**	**Coding Variable**	**Skip**
	Interviewer Name:		
	Interviewer number:		
	Village Name:		
	Number of village members:		
	Gender	0 Male 1 Female	
	Interviewee name:		
	Date of Survey	--/--/----	
1.	Is there a village level committee that makes decisions around WASH?	0 = No 1 = Yes 88 = Don't know	
2.	How often does the WASH committee meet?	1= Monthly 2= Quarterly 3= Bi-annually 4= Never	
3.	List the different roles that the members of the WASH community play?	1= Youth representative 2= Women/girls representative 3= Boys representative 4= Chairperson 5= Secretary 6= Treasurer 7= Constructing and maintenance team 8= Hygiene team 9= Nutrition and health 10= Not involved in committee 11= Interested, but no committee exists	
4. 4a	What **types** of toilet/sanitation facilities are there in the community	Types =	
4b	How many toilet/sanitation facilities are there in **total**?	Number=	
4c	How many toilet/sanitation facilities are **VIP latrines?**	VIP =	
5. 5a	What are the different types of sources of drinking water in your village?	List types _____	
5b	How many sources are there for drinking water in your village?	□□	

6.	Of the operational water sources in (name of village), how many meet Vanuatu National Standards?	□□	
7.	How often are the sanitation facilities maintained? (including both general maintenance and upgrades)	1 = Every day 2 = At least once per week 3 = Once a month 4 = once a year 5 = Never	
8.	How often are the village water supplies upgraded or maintained?	1 = Every day 2 = At least once per weel 3 = Once a month 4 = Once a year 5 = Never	
9.	Does your community have a Community Action Plan?	0 = No 1 = Yes 88 = Don't know	
10.	How often is the Community Action Plan updated for the community?	1 = Once a month 2 = Once a year 3 = Never	

Any other comments:

Appendix five - key Results from key informant interview

Interviews were carried out with at least one, and up to three, members of each WASH Management Committee (WMC). These interviews were primarily to allow the Tanna World Vision staff to gain insights about the main concerns of people in the communities going forward and how they think the project is going. Questions were also asked to find out about WMC activities

11.1 Key Comments

The majority of comments were overwhelmingly positive, with most WMC members commenting on the differences they have seen in the communities from baseline until now. Some of these positive comments are below:

"Since the WASH project came in, all community members have moved to live separately from animals. It is really good. Sickness has been reduced and children can play in a safe place. Women don't have to chase the pigs each time they prepare food. Children are much healthier."

"There's a big change in our community with people using VIP toilets. Reduce transmission of sickness."

"Thanks to World Vision for helping to give the trainings on hygiene and nutrition – it has made a lot of change in out community. Children are healthier and we have good toilets."

In my community the people they don't go to school and we find it very hard living. But we thank World Vision that they came and opened our eyes and now we can see where to go for a better future for out community."

"Community always comes together for planning or when Chairperson [of WMC] calls a meeting. They always turn up and work to implement action plan."

"This project has helped to improved the health status in the community. We used to go to hospital a lot of the time, now we don't usually go to hospital. "

"The youth are very active and supportive of the project in the community"

"I'm really happy to see that whenever we did as we were taught – clean village/home, wash hands after toilet and before eating – it really helped to keep my family healthy. I want to keep practicing these good practices"

From the WMC comments, it seems that the lack of education in the communities was a barrier to implementation:

"In my community it is very hard because the level of education is too low. We find it very hard to tell people to move forward. People are always gardening and custom ceremonies and they don't listen to what world vision had told us to do. But slowly we are trying to put into practice everything we have learnt in World Vision trainings."

"Our education level is too low but we are trying very hard to work with World Vision so that we can change our community."

The largest concern going into the final year of the project was setting up the water systems:

"It has been a long time that we have been struggling to build our water supply to pipe water to the villages. We are still wondering when we will complete building the system. I want to see that our water supply be built by this year – 2015."

"We are looking forward to World Vision to build the water supply system that will reduce the load of work fetching water and washing hands after toilet."

"If we have a water supply it would be best and make life much easier. Sometimes we don't swim [wash] after coming back from the garden when we are too tired."

"The community members really want to see a good water supply be built for them"

A level of skepticism about the water system was also expressed:

"Some community members did not believe that World Vision would do the water supply until they saw the storage tank. Some elderly men were discouraged and downhearted when they heard from the chairman that World Vision could take back the storage tank if the community does not work. The community members really want to see a good water supply be built for them."

Other comments included the WMC members looking forward to the next project and a request for more training.

WASH Management Committee Activities

Table 8: Wash Management Committee (WMC) Activities in South West Tanna, January 2015

WASH Management Committee (WMC)	Meetings	Types of toilets operational	Number of VIP toilets	How often are sanitation facilities maintained*
Ienapkasu 1	every 2 months	VIP	30	3 times a year
Ienapkasu 2	quarterly	VIP, bush toilet	54	biannually
Ikakahak	monthly	VIP, local pit toilet	57	once a week
Imapul	monthly	VIP	32	once a month
Ekyo	weekly	VIP, local pit toilet	15	once a week
Ikunala	quarterly	VIP, local pit toilet	19	once a week
Karimasanga	monthly/quarterly	VIP, local pit toilet	64	once a week
Yekue 2	twice a year	VIP	30	once a year
Yekue 3	twice a month	VIP	53	once a month
Total			354	

WASH Management Committee (WMC)	Types of drinking water sources	How often is the water supply upgraded/maintained*	Is there a Community Action Plan (CAP) in operation	How often is CAP updated***
Ienapkasu 1	River, Rain catchment	every 3 months	Yes	every 3 month
Ienapkasu 2	Rain catchment, spring water	3-4 times a year	Yes	every 3 month
Ikakahak	Creek, Rain catchment, gravity fed system from spring	3-6 times a year	Yes	once a week
Imapul	Open river	missing	missing	missing
Ekyo	Open spring, rainwater catchment, spring water	never	Yes	once a week
Ikunala	River, Gravity fed system from spring	once a month	Yes	every 3 month
Karimasanga	Rain catchment, creek, gravity fed system	once a year	Yes	once a week
Yekue 2	Spring, river	3 times a year	Yes	every 3 month
Yekue 3	Open spring, rain catchment, river	missing	missing	missing

Total	7 CAPs (2 results missing)	*Maintenance of sanitation clearly defined, and resulted

informants reporting on how often the toilet is cleaned, and others reporting on how often the structure of the toilet is updated.
**For communities without gravity fed systems this maintenance includes cleaning of rainwater catchment systems, or cleaning debris from streams/fixing stream bamboo catchments and temporary spring boxes af
***As most community elders do not read or write, this includes meetings where they plan WASH actions for future weeks/months

World Vision

Nutrition Toolkit



MEASURING CHILD GROWTH FOR SURVEYS

Part 1: Training for Measuring Weight, Height and Mid-Upper Arm Circumference

Participant's Workbook

Version 1, December 2011

Global Health and WASH

Nutrition Centre of Expertise

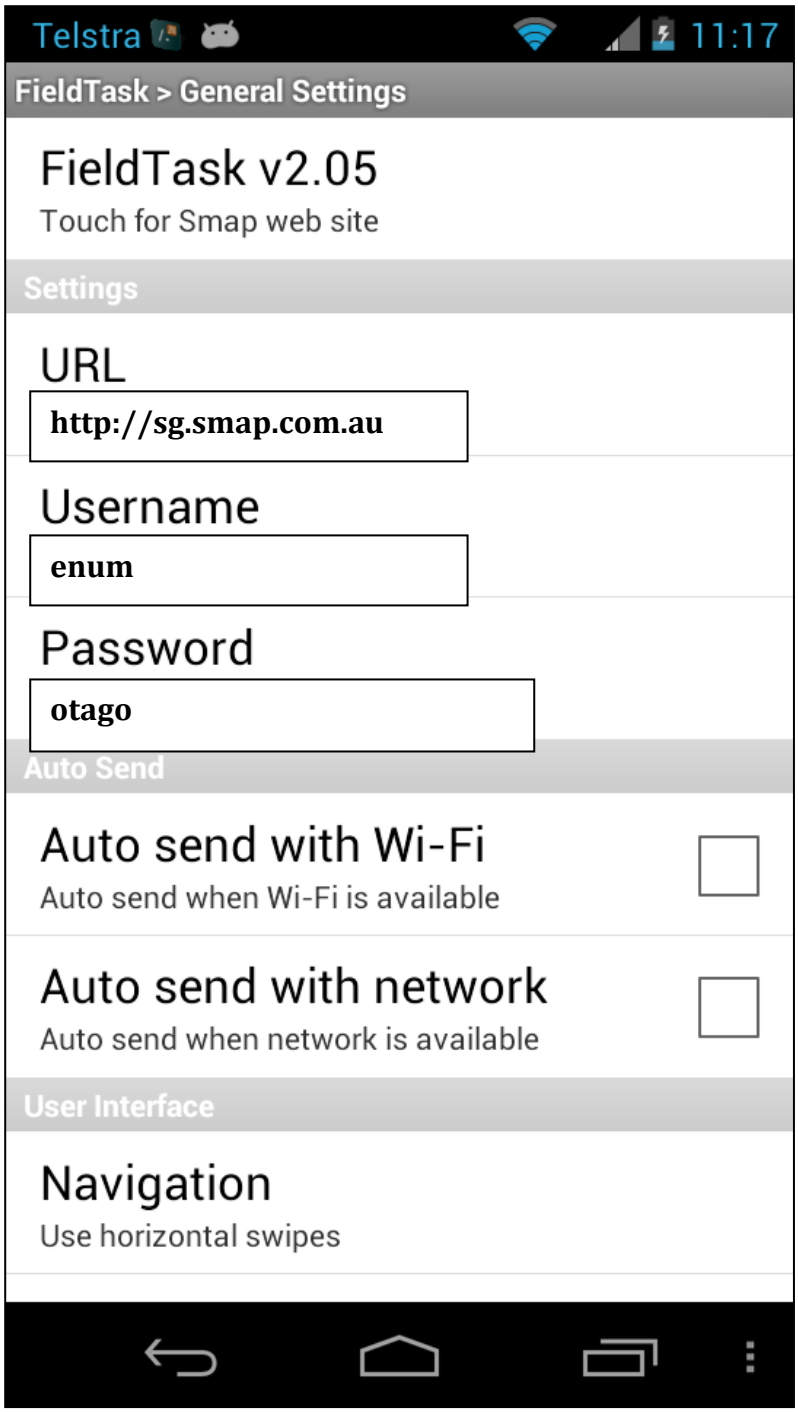
Appendix seven – smap training manual

SMAP FIELDTASK APP & HOUSEHOLD SURVEY

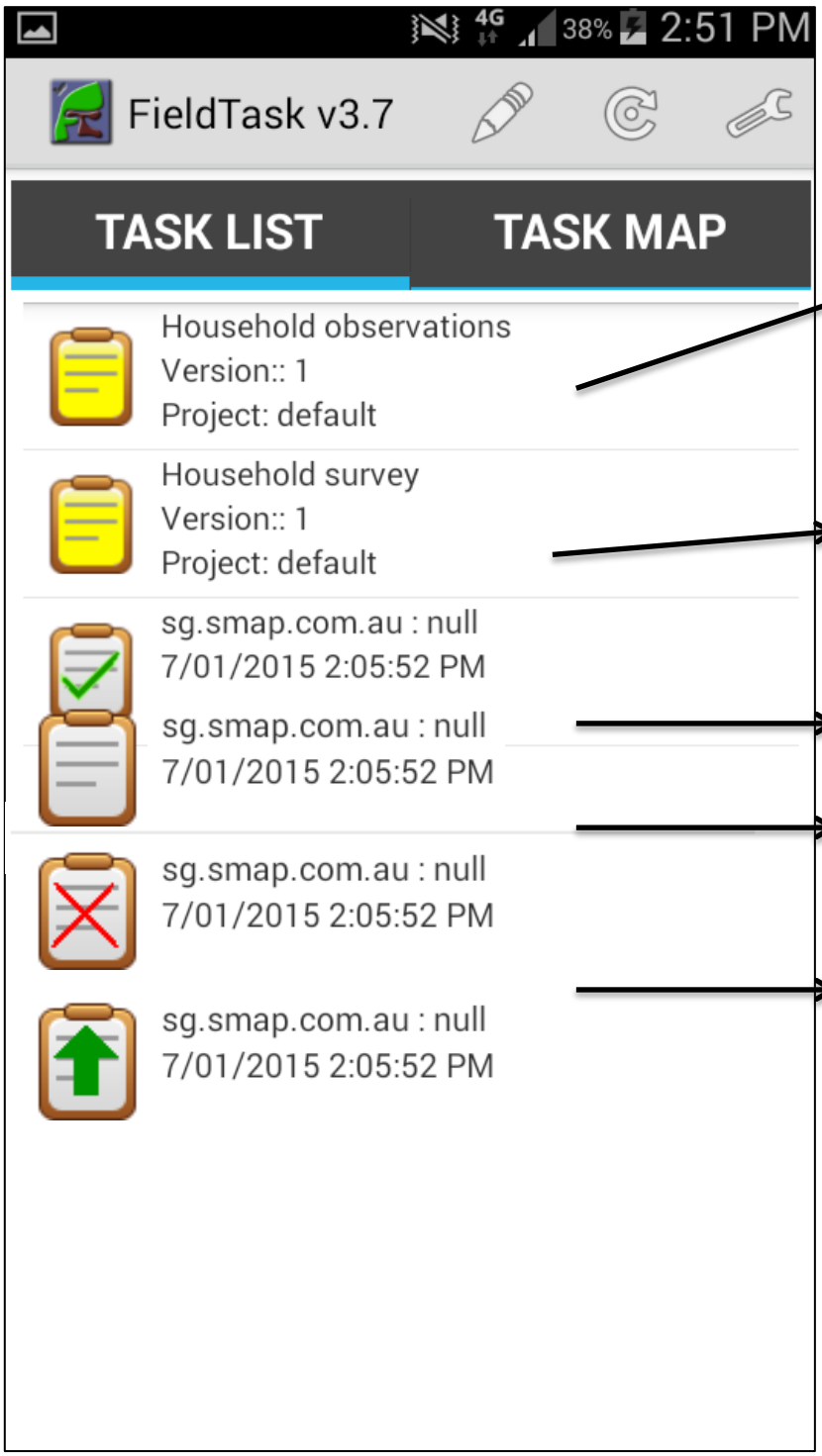
INFORMATION BOOKLET



Setting up smart phones with otago server
(This should already have been done for you)



Understanding the labels



Household observations: This is the section for those carrying out water testing and observations.

Household survey: this is the survey that will be conducted at each household with the primary caregiver of the children.

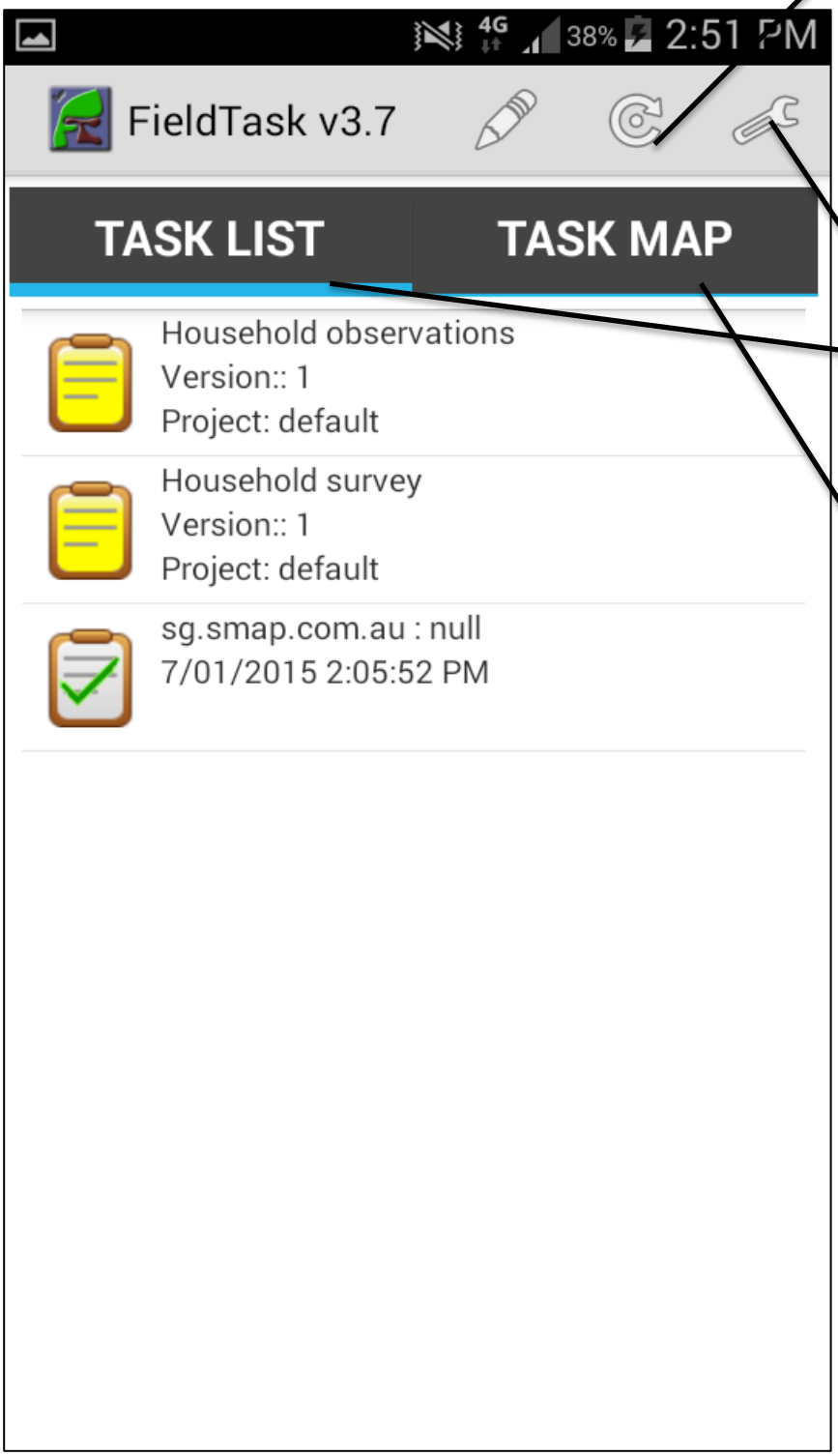
Survey uploaded to server successfully.

progress.

Task/ survey rejected – refresh or try again while in internet.

Survey completed, you can now upload this.

Understanding the labels



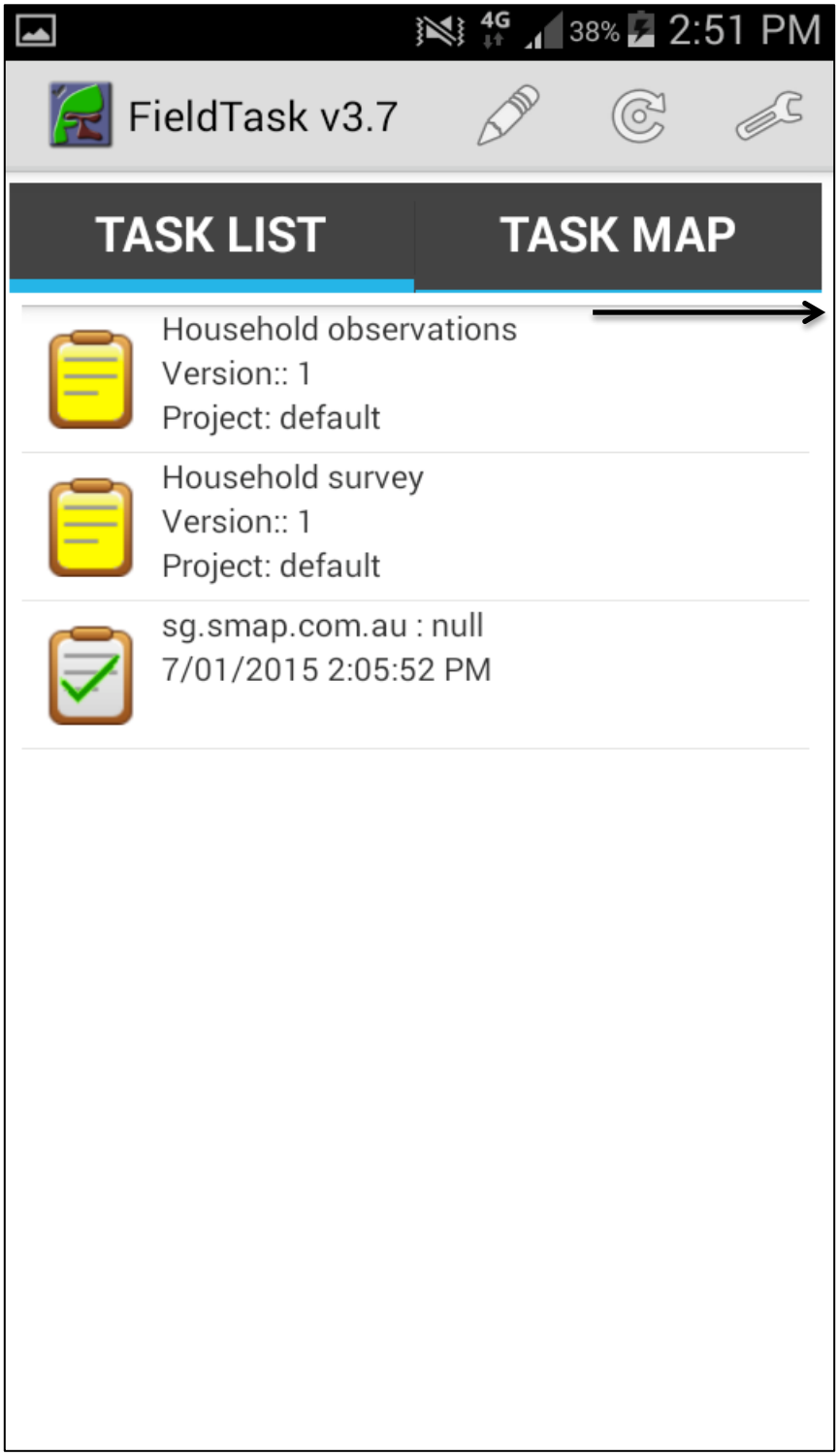
Refresh will upload completed/saved surveys and also delete surveys that aren't completed and surveys already uploaded. This can only be done when internet is available

General settings

Task list: Shows list of surveys on server:
yellow = blank surveys

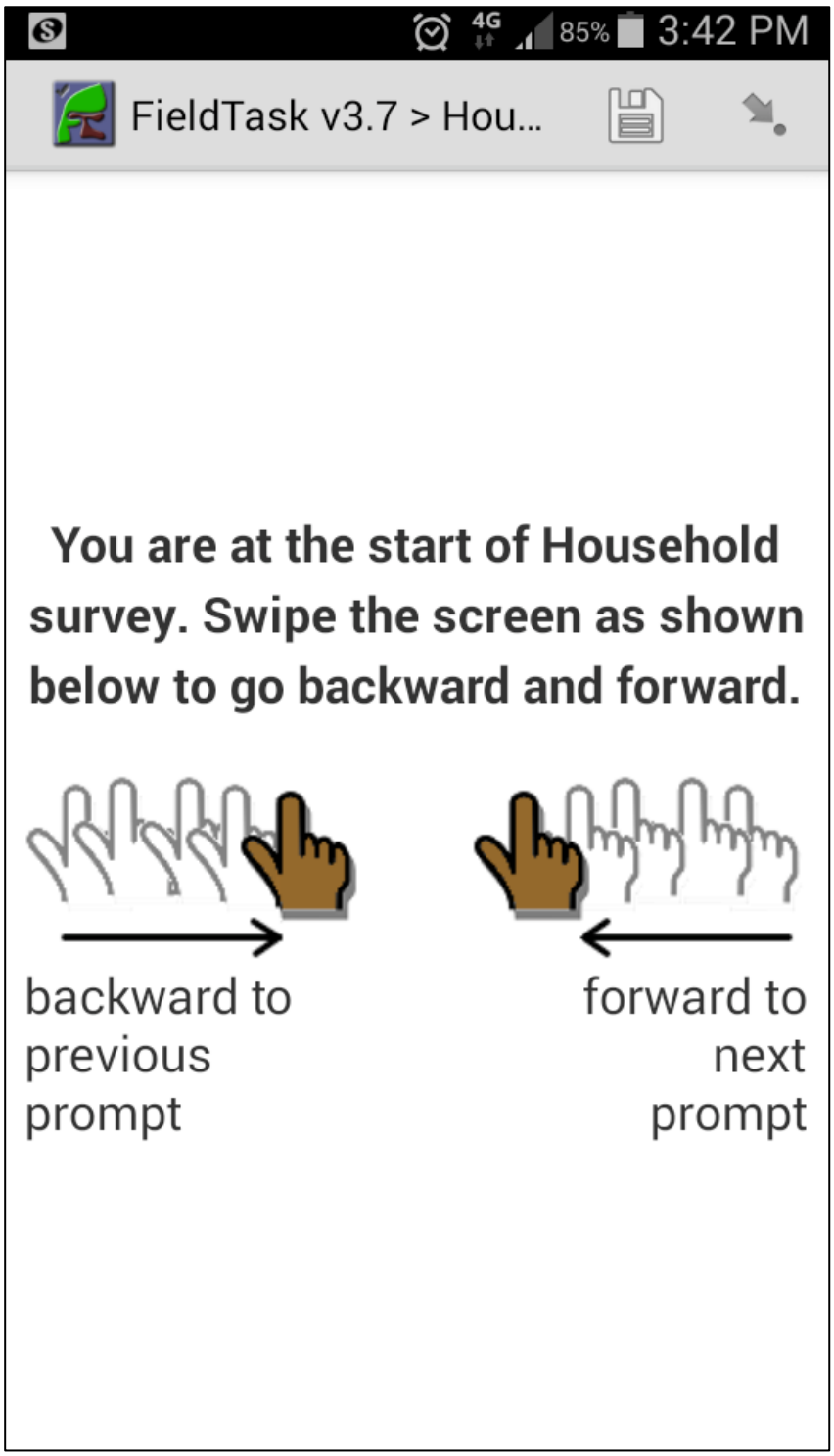
Task map: this will not be used for this survey

Beginning a new household survey



Starting a new survey: select the survey named 'Household survey'. Ignore 'Household observations'.

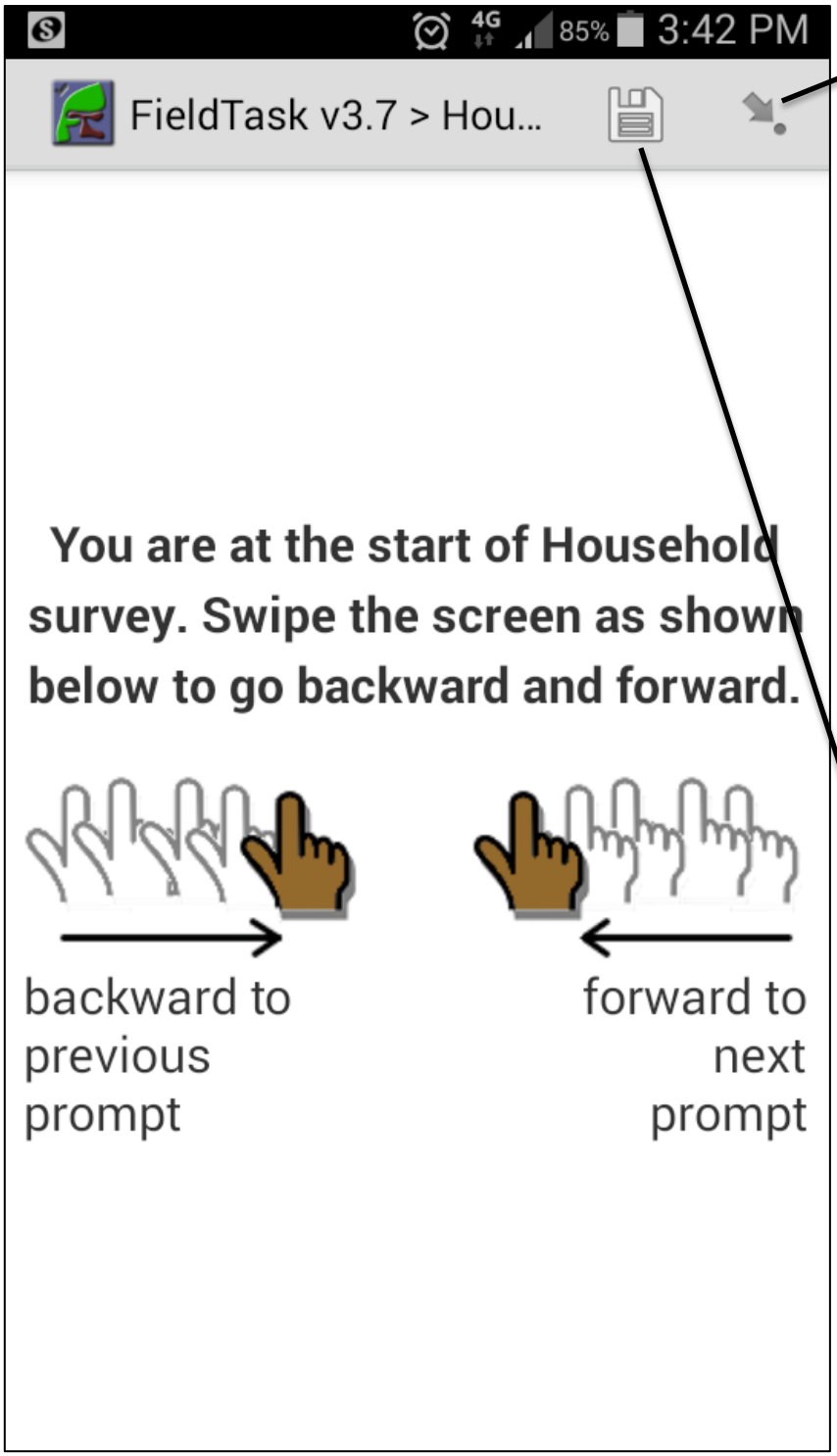
Conducting a household survey



Next question: swipe right as shown.

Previous question: swipe left as shown.

Conducting a household survey

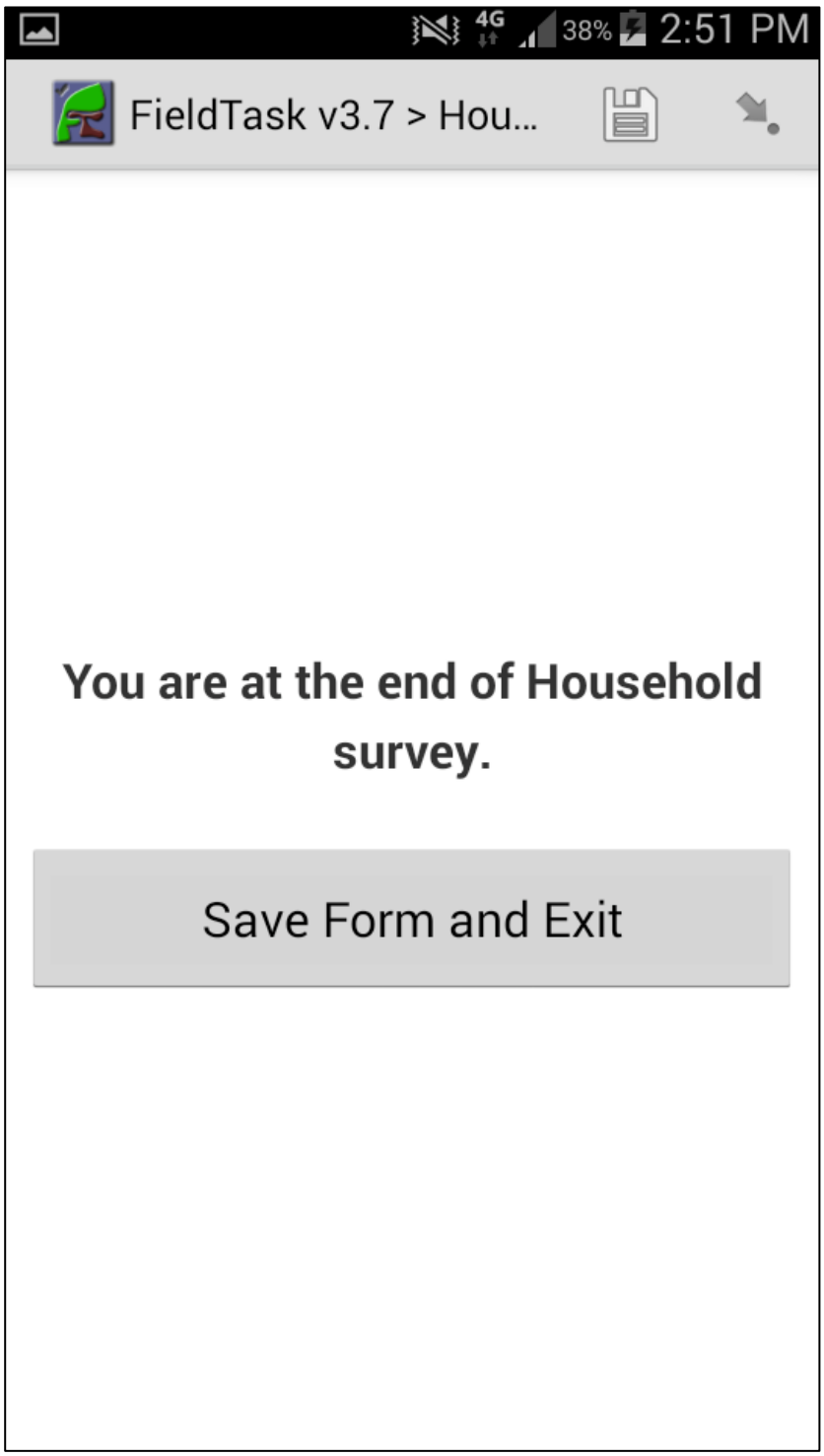


Jump to questions: If you want to answer some questions before others, you can use this button to view all questions and select which question you want to answer. This may be useful if you want to carry out the child anthropometry earlier in the survey if they want to leave.

However, when possible, conduct survey in the order given.

Save while you go. If you want to save the information you have recorded you may select this button any time. You will still be asked to save the final version at the end.

Saving completed survey



When you have answered all the survey questions, click **'save form and exit'** – if you don't click this, the survey results will not be able to be uploaded.

Uploading completed surveys

At the end of the day, when you are back at World Vision, turn on the wifi (internet) on the phone and upload completed surveys. This is important, as it allows results to be collected from the phone to the server, so we can monitor the data and collate results.



Completed surveys that look like this can be uploaded.

After the survey has been uploaded it will look like this.

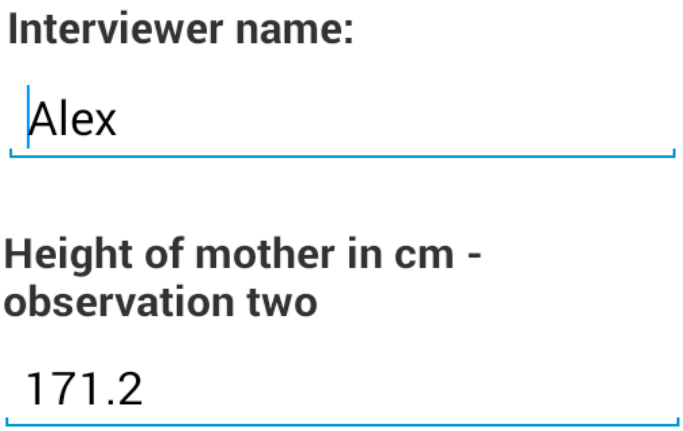
To upload: select 'menu' and select 'send finished data'. The Menu button is on the black section of the phone, on the opposite side from the back key (this will be different for different types of phone).
This can only be done when internet is available.

Pressing the **Refresh** button when in internet will also upload completed surveys and clear any partly completed or failed surveys from the task list.

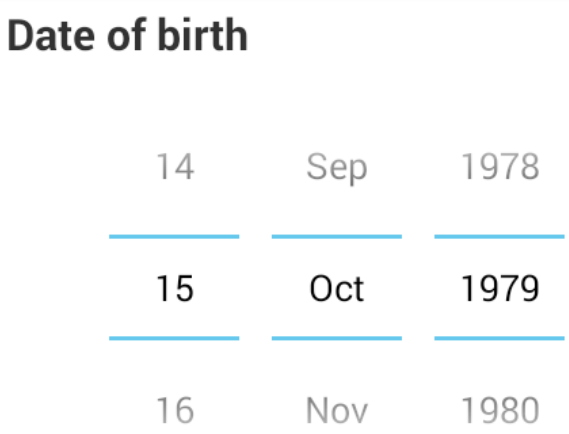
Types of questions

The types of questions that will be asked in the survey include:

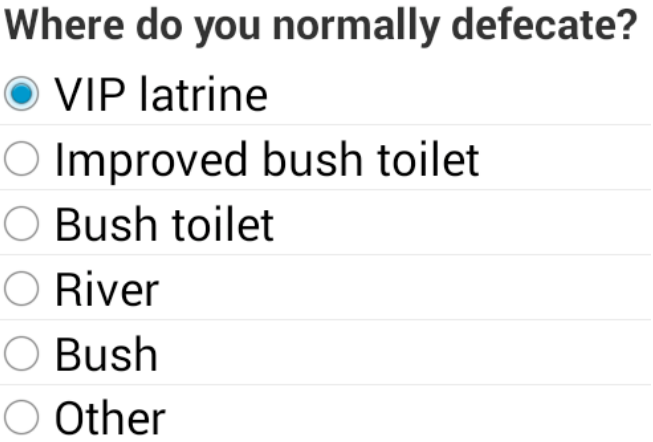
1) Questions where you need to type in an answer



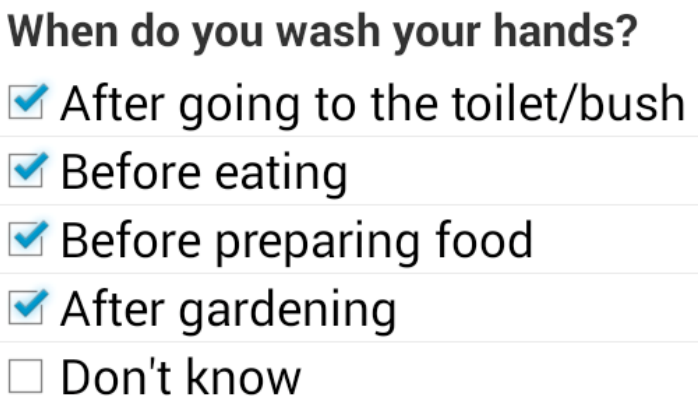
2) Questions where you need to insert a date



3) Questions where you must select only one answer

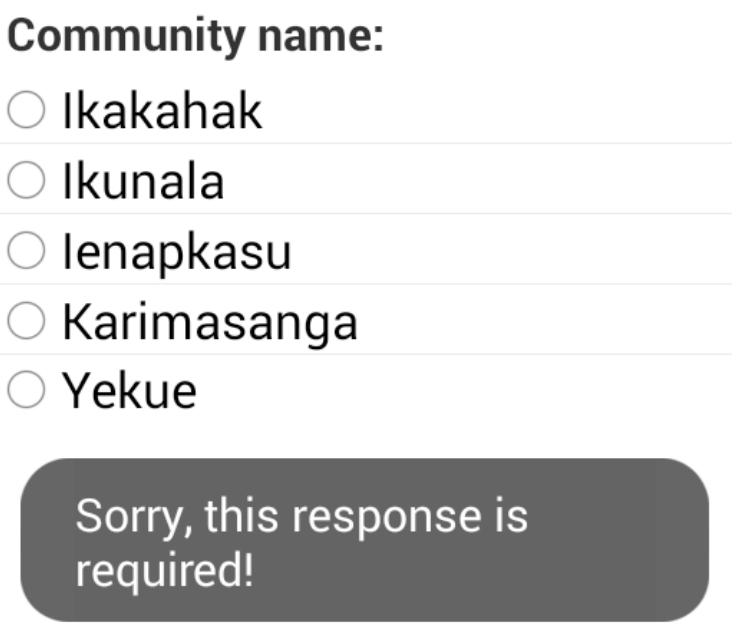


4) Questions where you may select more than one answer



Please ask and report every question in the survey.
This will allow the most accurate results to be obtained.

Some questions will not allow you to move to the next question without answering:



Appendix eight – CBT standardisation

Most Probable Number Table

The MPN Table represents World Health Organization "Guidelines for Drinking Water Quality," 4th Edition. Table 5.4 in the Guidelines has risk categories of drinking water based on *E. coli* levels as ranges: 0/100 mL = Safe; 1-10/100 mL = Intermediate Risk; 11-100/100 mL = High Risk; and >100/100 ml = Very High Risk.

The general consensus is drinking water should contain no *E. coli*, but in some countries *E. coli* numbers of up to 10/100 mL may be tolerated as being of intermediate risk.

Match your compartment bag volumes to one of these 32 possible outcomes:

Compartment #					MPN/100mL	Upper 95% Confidence Interval/100mL	Health Risk Category Based on MPN and Confidence Interval
1	2	3	4	5			
10mL	30mL	56mL	3mL	1mL			
					0.0	2.87	Low Risk/Safe
					1.0	5.14	Intermediate Risk/ Probably Safe
					1.0	4.74	
					1.1	5.16	
					1.2	5.64	
					1.5	7.81	
					2.0	6.32	
					2.1	6.85	
					2.1	6.64	
					2.4	7.81	
					2.4	8.12	
					2.6	8.51	
					3.2	8.38	
					3.7	9.70	
					3.1	11.36	Intermediate Risk/ Possibly Safe
					3.2	11.82	
					3.4	12.53	
					3.9	10.43	
					4.0	10.94	
					4.7	22.75	
					5.2	14.73	
					5.4	12.93	
					5.6	17.14	
					5.8	16.87	
					8.4	21.19	
					9.1	37.04	
					9.6	37.68	
					13.6	83.06	High Risk/Possibly Unsafe
					17.1	56.35	
					32.6	145.55	High Risk/Probably Unsafe
					48.3	351.91	
					>100	9435.10	Unsafe

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Appendix nine – Vanuatu Ministry of health ethics

GOUVERNEMENT
DE LA
REPUBLIQUE DE VANUATU
MINISTERE DE LA SANTE

GOVERNMENT
OF THE
REPUBLIC OF VANUATU
MINISTRY OF HEALTH

Director General

Ref: MOH/DG 15/19-GT/mc

12th January 2015

Ms Emma Dunlop-Bennett
Director
World Vision
Port Vila
Vanuatu

Dear Ms Dunlop-Bennett,

Re: Tanna Integrated WASH Project Year 2 Evaluation

We are pleased to hear that you will be collaborating with the University of Otago to enhance the annual review component of the established World Vision Tanna Integrated WASH Project.

We understand that the concept for the Tanna Integrated WASH Project was developed in 2012, with funding granted from the New Zealand Aid Programme on 20 December 2012. The project began on 1 February 2013 and will run to 31 January 2016. As part of the project, a baseline evaluation was conducted at the beginning of the project; an annual review is required to be undertaken at the end of project years 1 and 2; and a final evaluation to be done at the end of the project in January 2016. We acknowledge that World Vision Vanuatu work closely with government authorities in both Port Vila and Tanna (Lenakel), involving them in project planning and implementation whenever possible.

We acknowledge that the University of Otago has granted ethical approval for the Year 2 evaluation review of the Tanna Integrated WASH Project. We are satisfied that this evaluation will be conducted to the highest standards and are pleased to grant ethical approval for this evaluation on behalf of the Ministry of Health, Vanuatu.

Yours sincerely,

REPUBLIC OF VANUATU
ACTING DG OF HEALTH
DG INTERIM DE LA SANTÉ

Mr George Taleo
Acting Director General

Cc: Hon. Minister of Health
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Appendix ten – information sheet – main evaluation

WASH 2015 INFORMATION SHEET

QUESTIONNAIRE, ANTRHOPOMETRY, WATER TESTING

[Reference Number: *as allocated upon approval by the Human Ethics Committee*]

TANNA WATER AND SANITATION PROJECT
INFORMATION SHEET FOR PARTICIPANTS AND GUARDIANS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

Aims of the Project:

This project aims to assess World Vision's water and sanitation programme that is being carried out in your area. We will look at the number and type of toilets, hand washing facilities, water cleanliness, child diarrhoea and nutrition status of children and mothers. This will help inform World Vision Vanuatu in the final years of project implementation on what is working and what still needs to be done. This project is also contributing to Alex Morrison's Masters in Public Health through the University of Otago.

Participants Sought:

Participants are being recruited via random selection of households in South West Tanna. Households that have children under 5 will be able to participate, and the respondent will be the caregiver of the children. Overall, 250-300 households from South West Tanna will be involved in the survey, with an aim of collecting diarrhoea and nutritional information on 400 children under 5 years of age. This sample will help us to understand the communities as a whole.

What will Participants be Asked to Do?

Should you agree to take part in this project, you will be asked to

- Answer questions asked by an interviewer about your drinking water, toilets, what your children eat and their health.
- Allow interviewers to collect a small sample of your household drinking water for testing.
- Allow researchers to collect information on the height and weight of children under 5 in the household and of mothers in the household.

This will take approximately 40 minutes. Please be aware that you may decide not to take part in the project without any disadvantage to yourself of any kind.

Information that will be Collected:

- Your age, sex and occupation.
- The number of people in your household and their ages.
- Information about your drinking water and toilets.
- Health information about your children under 5 and what they eat.
- Height and weight of mothers and children under 5.
- A sample of your drinking water will be collected for testing.

The following people will have access to the data:

- The following researchers from University of Otago's Centre for International Health. This includes Professor John Crump, Associate Professor Katrina Sharples, and student researchers Alex Morrison and Hanneke Leuthwaite.
- World Vision Vanuatu.

The data collected will be securely stored in such a way that only those mentioned above will be able to gain access to it. Data obtained as a result of the research will be retained for **at least 5 years** in secure storage. Any personal

information held on the participants may be destroyed at the completion of the research even though the data derived from the research will, in most cases, be kept for much longer or possibly indefinitely.

You or anyone in your household will not be identified in the data or in any published documents that are based on the data. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve your anonymity.

Withdrawing from the project: Your/your child's participation is appreciated, but there will be no disadvantage to you or your household if you decide not to take part. You are also allowed to stop the interview at any time or say no to answering any question you do not want to answer.

We are unable to give you the safety results about your household drinking water, or other individual results from the study. However you are welcome to ask for copies of the evaluation when published data becomes available.

If you have any questions about our project, either now or in the future, please feel free to contact either:

Otago University Researchers:

Student researcher Alex Morrison
Department of Preventive and Social Medicine
University Telephone Number: 64 3 470 3584
Email Address: moral870@student.otago.ac.nz

and

Professor John Crump
Department of Preventive and Social Medicine
University Telephone Number: 64 3 470 3584
Email Addres: john.crump@otago.ac.nz

Or

World Vision Vanuatu:
Rue Artoi M/S
P.O Box 247
Port Vila, Vanuatu
Phone: 678-22161

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Appendix eleven – information sheet for key informant interview

WASH 2015 INFORMATION SHEET

KEY INFORMANT INTERVIEW

[Reference Number: *as allocated upon approval by the Human Ethics Committee*]

TANNA WATER AND SANITATION PROJECT
INFORMATION SHEET FOR KEY INFORMANT INTERVIEWS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

Aims of the Project/Interview:

This project aims to assess World Vision's water and sanitation programme that is being carried out in your area. We will look at the number and type of toilets, hand washing facilities, water cleanliness, child diarrhoea and nutrition status of children and mothers. This key informant interview aims to answer important questions about how World Vision's water and sanitation project has helped your community this far and let World Vision know what still needs to be done. In this interview we will ask broad questions on drinking water and toilets in your village. This project is also contributing to Alex Morrison's Masters in Public Health through the University of Otago.

Participants Sought:

Participants sought for this interview are those that have superior knowledge of drinking water and toilets in your village.

What Participants will be Asked to Do:

Should you agree to take part in this interview, you will be asked to:

- Answer questions asked by an interviewer about any water and toilet committees that your village has and details of meetings and roles of members.
- Answer questions about the toilets and water sources your village may use.
- You may have other comments about drinking water and toilets in your villages that you may wish to share with us during this interview.

This will take approximately 30 minutes. Please be aware that you may decide not to take part in the interview without any disadvantage to yourself of any kind.

Information that will be Collected:

- Information about any water and toilet committees and action plans your village has that you know about.
- The drinking water sources your village uses.
- The number of toilets in the village and what they are like.
- Information about any maintenance that occurs of the toilets or water supplies.

The following people will have access to the data:

- The following researchers from University of Otago's Centre for International Health. This includes Professor John Crump, Associate Professor Katrina Sharples, and student researchers Alex Morrison and Hanneke Leuthwaite.
- World Vision Vanuatu.

The data collected will be securely stored in such a way that only those mentioned above will be able to gain access to it. Data obtained as a result of the research will be retained for **at least 5 years** in secure storage. Any personal information held on the participants may be destroyed at the completion of the research even though the data derived from the research will, in most cases, be kept for much longer or possibly indefinitely.

You or anyone in your household will not be identified in the data or in any published documents that are based on the data. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve your anonymity.

Withdrawing from the project: Your participation is appreciated, but there will be no disadvantage to you if you decide not to take part. You are also allowed to stop the interview at any time or say no to answering any question you do not want to answer.

You are welcome to ask for copies of the evaluation when published data becomes available.

If you have any questions about our project, either now or in the future, please feel free to contact either:

Otago University Researchers:

Student researcher Alex Morrison
Department of Preventive and Social Medicine
University Telephone Number: 64 3 470 3584
Email Address: moral870@student.otago.ac.nz

and

Professor John Crump
Department of Preventive and Social Medicine
University Telephone Number: 64 3 470 3584
Email Addres: john.crump@otago.ac.nz

Or

World Vision Vanuatu:
Rue Artoi M/S
P.O Box 247
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This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Appendix twelve – consent forms

WASH 2015 INFORMED CONSENT

QUESTIONNAIRE, ANTRHOPOMETRY, WATER TESTING

My name is _____ and I am a part of the World Vision WASH team, here today to conduct household interviews with some of your community households.

The information we are collecting is to help the project staff understand different aspects of the Water, Sanitation and Hygiene practices and understandings in this community. You are probably already aware that World Vision Vanuatu has been partnering with the community here over the past 2 years. We would like to better understand how the programme is working or needs improvement, and some of the questions we ask you would be used to help answer these questions. We will use the information to strengthen the project in the future.

The information we would like to collect is in three parts:

1) **Weighing and measuring height of the children under 5 years old in this household, and their caregiver**
2) **Questions about the people in your household, your drinking water, diet and toilets**
3) **Allowing us to take a sample of your drinking water supply to test for water safety**

Your/your child's participation is appreciated, but there will be no disadvantage to you or your household if you decide not to take part. You are also allowed to stop the interview at any time or say no to answering any question you do not want to answer.

All of your answers will remain confidential to the World Vision team, and your name will not be associated with any of the data we are collecting. The data collected will be stored with World Vision and Otago University (New Zealand), and destroyed after 5 years.

We just need a sample of households in the community to help understand the whole community, which is why not all houses in this village will be taking part.

Please note: We are unable to give you the safety results about your household drinking water, or other individual results from the study, however you are welcome to ask for copies of the evaluation when published data becomes available.

Please answer as truthfully as you can, there are no right or wrong answers, just what is true for you at this time.

Thank you for your time

If you agree for you and your children under 5 years old to take part in this evaluation, please sign your name for consent below:

Full name of caregiver: _____

Signature of caregiver: _____

Name of child/children:_____

Date: _____

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

WASH 2015 INFORMED CONSENT

KEY INFORMANT INTERVIEW

My name is _____ and I am a part of the World Vision WASH Evaluation team, here today to conduct household interviews with some of your community households.

The information we are collecting is to help the project staff understand different aspects of the Water, Sanitation and Hygiene practices and understandings in this community. You are probably already aware that World Vision Vanuatu has been partnering with the community here over the past 2 years. We would like to better understand how the programme is working or needs improvement, and some of the questions we ask you would be used to help answer these questions. We will use the information to strengthen the project in the future.

The information we would like to collect as part of this key informant interview is around:

a) Any water and toilet committees that exist in your village
b) The number of drinking water sources and toilets that your village has and what they are like

Please refer to the information sheet for more information about the types of questions you will be asked.

Your participation is appreciated, but there will be no disadvantage to you if you decide not to take part. You are also allowed to stop the interview at any time or say no to answering any question you do not want to answer.

Your name will not be associated with any of the answers or comments you provide. The data collected will be stored with World Vision and Otago University (New Zealand), and destroyed after 5 years.

You are welcome to ask for copies of the evaluation when published data becomes available.

Please answer as truthfully as you can, there are no right or wrong answers, just what is true for you at this time.

Thank you for your time

If you to take part in this interview, please sign your name for consent below:

Full name of participant: _____

Signature of participant: _____

Date: _____

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Appendix 13 - Supplementary tables

Supplementary Table 1: Population of south west Tanna with children under five years of age included in the household survey component of the second year World Vision WASH evaluation

Community/Village	Households	Females ≥15	Males ≥15	Females <14	Males <14	Children <5	Total
Ienapkasu	**59**	**68**	**61**	**97**	**102**	**83**	**333**
Enumnawa	7	9	6	12	12	11	39
Etafum	7	9	8	15	11	10	43
Betany	10	12	10	22	15	13	59
Ienkuanenimava	1	1	1	1	0	1	3
Yetamalan*	23	25	24	28	42	32	124
Etau*	2	2	2	5	3	4	12
Yetukwas*	9	10	10	14	19	12	53
Ikakahak	**34**	**45**	**45**	**70**	**65**	**67**	**225**
Imairaving	5	6	5	10	7	7	28
Ikakahak Central	16	19	22	28	41	31	110
Nukuanentata	1	4	3	1	0	1	8
Green Point/Erasiau	7	11	9	17	12	21	49
Ienawen	5	5	6	14	5	7	30
Ikulnala	**19**	**22**	**20**	**30**	**30**	**29**	**102**
Ienanu	7	9	10	12	11	12	42
Tanakwakwa	12	13	10	18	19	17	60
Karimasanga	**29**	**41**	**36**	**42**	**50**	**43**	**169**
Imatanik	4	7	8	7	8	6	30
Yenkuenai	9	15	14	9	13	11	51
Imatukua	6	9	4	12	14	11	39
Iatukun	4	4	5	4	8	7	21
Ianamar	1	1	0	3	0	1	4
Isasia	5	5	5	7	7	7	24
Yekue	**42**	**53**	**51**	**79**	**70**	**60**	**252**
Imakal	6	7	6	12	9	8	34
Yelkis*	7	7	7	14	11	11	39
Yapnamal*	7	10	8	12	13	9	43
Kunekamiakis	7	10	9	14	15	10	48
Ikunakut	10	13	14	18	13	14	57
Yebnavitaleng	5	6	7	9	9	8	31
Imapul	**25**	**39**	**22**	**36**	**38**	**36**	**135**
Imapul	14	21	12	22	19	22	74
Ekyo	11	18	10	14	19	14	61
Total	**208**	**268**	**235**	**354**	**355**	**318**	**1,216**

Supplementary Table 2: Training topics recalled by caregivers in Tanna, January 2015

Training topic	Total (N=207) n (%)
WASH:	
Environmental hygiene	136 (86.6)
Home hygiene and waste disposal	129 (82.2)
Handwashing	127 (80.9)
Safe drinking water storage and treatment	56 (35.7)
Diarrhoea prevention and treatment	26 (16.6)
Nutrition	
Nutrition for children	141 (89.8)
Breastfeeding	23 (14.7)
Immunisations	14 (8.9)

Caregivers could give more than one answer

Supplementary Table 3: Common caregiver identified causes of diarrhoea in Tanna Vanuatu, January 2015

Caregiver responses: diarrhoea causes	Total (N=208) n (%)
Most common correct responses:	
Dirty hands	166 (79.8)
Dirty drinking water	103 (49.5)
General dirtiness	65 (31.3)
Flies	61 (29.3)
Dirty kitchen	48 (23.1)
Other biologically plausible causes:	
Animal faeces	16 (7.7)
Open defecation	8 (3.9)
Not breastfeeding	8 (3.9)
Most common incorrect responses:	
Mother works too hard	67 (32.2)
Hot breast milk	62 (29.8)
Not washing hands after food	55 (26.4)
Working in hot sun	32 (15.4)
Not eating proper food	32 (15.4)

Supplementary Table 4: Common caregiver identified diarrhoea treatments, Tanna, 2015

Caregiver responses: diarrhoea treatment	Total (N=208) n (%)
Most common correct responses:	
Go to the aid post	109 (52.4)
Give ORS*	69 (33.2)
Give lots of water or fluids	31 (14.9)
Green coconut water	65 (31.3)
Boiled water	78 (37.5)
Most common incorrect responses:	
Bush medicine	84 (40.4)
Sugar cane	22 (10.6)
Water with salt	7 (3.4)

*ORS = Oral Rehydration Salts

Supplementary Table 5: Commonly reported situations caregivers reported washing hands was necessary in Tanna, 2015

Caregiver responses: washing hands	(N=208) n (%)
After they go to the toilet	199 (95.7
Before preparing food	192 (92.3)
Before eating	167 (80.3)
After gardening	154 (74.0)
Before feeding children	70 (33.7)
After cleaning babies bottoms	18 (8.7)

Supplementary Table 6: Multivariate analysis of immunization status and diarrhoea in children under five years of age, Tanna Vanuatu, 2015

Caregiver and household variables	Univariate analysis		Multivariate analysis**	
	PR (95% CI)	p-value	PR (95% CI)	p-value
Child fully immunised	0.39 (0.15–1.02)	0.054	0.45 (0.16–1.25)	0.126

*Significant p-value = p≤0.05.

** Adjusted for age of the child in six months age groups and caregiver age

Supplementary Table 7: Multivariate analyses of upper respitatory tract infection (UTRI) status and stunting in children under five years of age, Tanna Vanuatu, 2015

Child health outcome	Unadjusted PR		Adjusted PR**	
	PR (95% CI)	p-value	PR (95% CI)	p-value
URTI	**1.26 (0.98–1.62)**	0.075	1.11 (0.93–1.32)	0.241*

*Significant p-value = p≤0.05.

** Adjusted for age of the child in six months age groups, child gender, maternal height, maternal education, and using an improved water source