Prevalence of Soil-Transmitted Helminthiasis in Central Eastern Division, Fiji Islands

By

Anish Praneel Singh

A thesis submitted to Auckland University of Technology
in partial fulfilment of the requirements for the degree of
Master of Medical Laboratory Science (MMLSc)

2018

Abstract

Soil-transmitted Helminthiasis (STH) affects approximately 1.5 billion people annually, 450 million of whom become ill as a result of infection. The World Health Organisation has labelled STH as a major neglected tropical disease (NTD). STH infections are caused by roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichiura*), hookworms (*Ancylostoma duodenale* and *Necator americanus*) and threadworm (*Strongyloides stercoralis*) which are transmitted to humans by ingestion of infective eggs or contact with larvae. Fiji has inadequate data on the health status of STH. Insensitive laboratory diagnostic techniques suggest limitation exists in positive detection and cases maybe under-reported. There is no published data on STH infection and its association with NTDs, which limits information on trends relating to morbidity and efficacy of helminth control programmes.

The purpose of this research was to determine if the reference diagnostic laboratory at Colonial War Memorial Hospital (CWMH) in Suva, Fiji was using a sensitive and accurate STH examination technique. The major objectives of the research were to: (1) determine the prevalence of the soil-transmitted helminths diagnosed at CWMH in Central Eastern Division from January 2008 to December 2016 according to data retrieved from the laboratory register; (2) identify the current laboratory techniques used in diagnosing STH in Fiji and compare these with current recommended methods; and (3) provide recommendations to medical laboratories and the Fiji Ministry of Health to improve STH diagnosis.

Results from data analysis showed that from the total of 12,020 stool sample results retrieved 2.2% (n=261; 95% CI: 1.4-2.9) were positive for at least one STH parasite. *A. lumbricoides* contributed to most STH infections (68.7%), followed by hookworm (22.2%), *S. stercoralis* (8.0%) and *T. trichiura* (1.1%). The highest prevalence of STH was found in the < 5 year age group (33%). More samples from male patients had STH positive results (61%) compared to females at 101/261 (39%). In regards to ethnic groups, a higher proportion of i-Taukei population had helminth infections (93%) compared to Indo-Fijians (6%) and other races (1%). According to gender distribution, male i-Taukei individuals are mostly infected (48.4%), followed by

female i-Taukei (33.5%), the Indo-Fijian females (4.7%) and Indo-Fijian males (2.2%), while other races were the least infected (0.4%).

Fiji still depends on direct microscopy and is lacking behind in STH diagnosis according to the updated WHO helminth testing standards. For STH diagnosis, the Kato-Katz (K-K) technique has been recommended by WHO as the gold-standard. The qPCR technique is an emerging molecular diagnostic technology and is considered superior to the K-K technique, due to its increased sensitivity and specificity. However, the higher costs involved in processing samples and the need for specialist technical staff could affect its implementation.

The prevalence study provides important epidemiological data of the STH parasites in the Central Eastern Division in Fiji. Socioeconomic factors, improper hygiene practices, climate change, rural-urban migration and remoteness could contribute towards STH infections. The K-K technique has been recommended by the WHO as the -gold-standard- for STH diagnosis in medical laboratories and should be implemented to diagnose STH in Central Eastern Division in Fiji. For future potential investigations of helminth infections, sustainable evaluation of parasite characteristics should be investigated for effectiveness of control factors.

Contents

List of Figures

List of Tables

Acknowledgements

Firstly, I would like to thank Dr Fabrice Merien and Dr Miomir Vidicki, my supervisors from Auckland University of Technology (AUT) for their support, encouragement and constant motivation and wisdom.

I convey my sincere appreciation to the Ministry of Foreign Affairs and Trade (MFAT) and New Zealand Aid (NZAID), together with the scholarship team at AUT for providing the Pacific-Scholarship and funding for this Masters research.

Manny thanks to Dr Devina Nand, Mr Shivnay Naidu and Ms Rosimina Tubuitamana, from Fiji National Health Research and Ethics Review Committee (FNHREC), based at the Ministry of Health and Medical Services in Fiji, for providing ethic approval details.

Thank you to Dr Nick Garrett, biostatistician from AUT, for providing support and guidance in data analysis.

I would also like to thank Ms Susan Smith, Head of Section, and Mrs Kiran Mistry, Senior Microbiology Technologist, both from Labtests, Auckland Regional District Health Board (ARDHB) Mt Wellington, for allowing me to meet and discuss diagnostic protocols and techniques.

On the same note, I would also like to convey my appreciation to Ms Mary Bilkey, Technical Head of Microbiology, and Ms Terri Swager, Senior Medical Laboratory Technologist in the microbiology department, both from LabPlus, Auckland District Health (ADHB), at Auckland City Hospital, Grafton, for allowing me to compare diagnostic procedures and gain current knowledge.

I would like to thank all Medical Laboratory Science lecturers and tutors, the staff from the School of Science, Faculty of Health and Environment Sciences, at AUT.

Finally, I would like to thank my parents, my wife and my daughter for giving me support and encouragement.

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree of diploma of a university or other institution of higher learning.

Signature: *Date: 02/06/18*

Abbreviations

^{0}C	Degree Celsius
%	Percent
p	Probability value
R^2	Coefficient of determination
R_0	Basic reproduction number
X^2	Chi square
ACP	African, Caribbean and Pacific
ADHB	Auckland District Health Board
ANOVA	Analysis on variance
ASID	Australian Society for Infectious Diseases
AUT	Auckland University of Technology
AUTEC	AUT ethics committee
AVI	Acute viral illness
BMLS	Bachelor of Medical laboratory science
C 10 and D3	Complement factor 3 and factor D3
CI	Confidence interval
CWMH	Colonial War Memorial hospital
DALYs	Disability adjusted life years
DNA	Deoxyribonucleic acid
dPCR	Digital polymerase chain reaction
EPG	Eggs per gram
ELISA	Enzyme linked immunosorbent assay
EQA	External quality assurance programmes
FEC	Formol ether concentration
FIMLS	Fiji Institute of Medical laboratory science
FNRERC	Fiji National Research Ethics Review Committee
G7	Group of seven nations
GDP	Gross domestic product
GI	Gastrointestinal
GIS	Geographical information system
GP's	General practitioners
Hib	*Haemophilus influenza* type b
HIV	Human immunodeficiency virus
HRMS	High resolution mass spectrometry
HTLV	1 Human T cell lymphotropic virus type 1
IANZ	International Accreditation New Zealand
IFAT	Indirect immunofluorescent antibody test

IFN	Interferon
IHA	Indirect haemagglutination assay
IL	Interleukin
IPI	Intestinal parasitic infection
K K	Kato Katz
LF	lymphatic filariasis
LIPS	Luciferase immunoprecipitation system
LIS	Laboratory information system
LQMS	Laboratory quality management system
LST	Land surface temperature
MDA	Massive drug administration
MDGs	Millennium Development Goals
MOE	Ministry of Education
MOH	Ministry of Health
MOHMS	Ministry of Health and Medical Services
NaCl	Sodium chloride
NSW	New South Wales
NTD(s)	Neglected Tropical Disease(s)
NT	Northern Territory, Australia
OR	Odds ratio
PATIS	Patient information system
PNG	Papua New Guinea
PPTC	Pacific Paramedical training Centre
PRISMA	Preferred reporting items for systemic review and meta-analysis
qPCR	Quantitative polymerase chain reaction
RCPA	Royal College of Pathologists of Australasia
RDTs	Rapid diagnostic tests
RS	Remote sensing
SDGs	Sustainable Development Goals
SEA	South East Asia
SIR	Susceptible Infectious Recovered
SOP	Standard operating procedure
SPSS	Statistical package for the social sciences
STATA	Data analysis and statistical software
STH	Soil transmitted Helminthiasis
TAS	Transmission assessment survey
TB	Tuberculosis
TC	Tropical Cyclone
UK	United Kingdom
USA	United States of America

WA	Western Australia
WASH	water, sanitation and hygiene
WHO	World Health Organization

Chapter 1 Background/Literature Review

1.1 Soil-transmitted helminthiasis

Soil-transmitted helminthiasis (STH) is a group of parasitic infections affecting humans caused by nematode worms transmitted by faecal-contaminated soil (Bopda et al., 2016; Pabalan et al., 2018). The worms that cause STH are roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichiura*), hookworms (*Ancylostoma duodenale* and *Necator americanus*) and threadworm (*Strongyloides stercoralis*) which are transmitted to humans by ingestion of infective eggs or contact with larvae. STH affects approximately 1.5 billion people annually, 450 million of whom become unwell as a result of infection, and is endemic in developing countries with lower socioeconomic status as well as in areas with poor hygiene standards (Hsieh et al., 2011; Weatherhead, Mejia, & Hotez, 2017; Zender & Plate, 2015).

In epidemiological studies, *endemic* characterises the presence of a disease and/or its conditions which is commonly found in a certain geographical area or amongst particular individuals (Madinga et al., 2017; Supali et al., 2010). It has been suggested that *A. lumbricoides* accounts for the highest infection numbers (820 million) by STH nematodes, followed by *T. trichiura* (470 million) and hookworm (420 million) (Moser, Labhardt, Cheleboi, Muhairwe, & Keiser, 2017). According to Global Burden of Disease Study 2015, it was estimated that more than 6 million disability-adjusted life-years (DALYs), which quantify mortality and morbidity of disease burden, relate to other known paediatric infections inflicted by STH (Weatherhead et al., 2017). This matches similar DALYs caused by measles and meningitis caused by *Haemophilus influenza* type b (Hib). *Morbidity* relates to an individual's state of being unhealthy, whereas *mortality* is used to refer to the number of deaths in a population (Martins-Melo, Ramos Ramos, Alencar, Lima, & Heukelbach, 2017).

Recent studies have shown that *S. stercoralis* is the most neglected STH. The presence of the parasite maybe underestimated or omitted in diagnostic procedures for faecal examinations, which is the base-line technique used to detect and identify human helminths (Nutman, 2017; Rego Silva et al., 2018). Lack of prevalence data was highlighted in the 3rd Global Meeting of the Partners for Parasite Control 2004. Prevalence outlines the proportion of individuals having a disease and/or its

characteristics in a population (Ntonifor, Sumbele, & Ebot, 2016). Informational gaps in prevalence data have been attributed to common STH diagnostic techniques (e.g., Kato-Katz, direct smear, formol-ether concentration) having lesser sensitivity to detect *S. stercoralis* larvae, which are the infective form (Ketzis & Conan, 2017; Schär et al., 2016). In contrast, the common diagnostic tests have shown higher sensitivity and success in detection rates of eggs of hookworm, *A. lumbricoides* and *T. trichiura* (Ketzis, 2017).

According to WHO, STH are noted as one the major Neglected Tropical Diseases (NTDs). The NTDs are a group of communicable diseases affecting most poor, rural communities of subtropical and tropical regions in 149 countries (Moser et al., 2017; WHO, 2018). WHO also focuses on the importance of diagnosis and control of helminthic infections, highlighting that they are the most prevalent of the NTDs (Kline, McCarthy, Pearson, Loukas, & Hotez, 2013).

1.2 Transmission from soil to humans

The most common infections from STH transmission are due to oral ingestion of roundworm and whipworm embryonated eggs. Hookworm and threadworm transmission occurs by direct entry through the skin (percutaneous invasion) of larvae by the parasites (Figure 1.0) (Bethony et al., 2006).

	Disease
Major worldwide pathogens	
Ascaris lumbricoides	Common roundworm infection
Trichuris trichiura	Whipworm infection
Necator americanus and *Ancylostoma duodenale*	Hookworm infection
Strongyloides stercoralis	Threadworm infection

Figure 1. STH infections of human beings.Bethony, J., Brooker, S., Albonico, M., Geiger, S. M., Loukas, A., Diemert, D., & Hotez, P. J. (2006). Soil-transmitted helminth infections: ascariasis, trichuriasis, and hookworm. Lancet, 367(9521), 1521-1532. Doi: 10.1016/S0140-6736(06)68653-4

STH are most commonly transmitted by ingestion of eggs (ova) that are passed in faeces of infected people. The adult worms then live in the human intestine and produce thousands of eggs, which when defecated can contaminate the soil due to

inadequate sanitation, the water source, as well as undercooked vegetables that are not washed properly (Kaminsky, Ault, Castillo, Serrano, & Troya, 2014).

1.2.1 Dynamics of transmission in STH

Dynamics is the use of mathematical models to study the structure and evolution of infectious disease. This may provide better understanding of host-parasite interrelation in terms of transmission, prediction of distribution, and even prevention of infection outbreaks (Betson, Nejsum, Bendall, Deb, & Stothard, 2014; Lisovski et al., 2018).

Transmission models are either deterministic or probabilistic. The basic reproduction number, also called basic reproductive rate, is denoted as R_0, which is used in mathematical modelling for transmission dynamics. R_0 shows the average of new infections that have been caused by one infected individual. In terms of STH, *A. lumbricoides* had the highest R_0 and hookworm had the lowest, which were (4-6) and (2-3) respectively. Susceptible-Infectious-Recovered (SIR) is a mathematical model of transmission dynamics- developed in 1927 by W. O. Kermack, a biochemist and A. G. McKendrick, a physician and epidemiologist in Scotland (Nikolay et al., 2015).

For STH, the foremost determinant of transmission dynamics and morbidity is the clumping and/or aggregation of worm in susceptible humans and different age groups. In most infected cases, helminth do not have a uniform distribution within human body; few have high worm burden while many individuals have very few worms to none (Awasthi et al., 2008). Bethony et al. (2006), informs that *A. lumbricoides* and *T. trichiura* infections are commonly associated with children with pre-school age progressing to highest intensity of worm amongst 10-15 years old. For hookworm infections, peak intensity of worm burden is observed at 20-25 years.

(Ortu et al., 2016), suggests that the sustainable Mass Drug Administration (MDA) programmes has been able to interrupt the transmission dynamics, which led to a decrease in STH prevalence in Burundi. The use of mathematical modelling and cartography (maps) of helminth infection enables better prediction global disease burden of STH (Martin, Pullan, Smith, Brooker, & Jasrasaria, 2014).

Environmental conditions and climate influences affect the dynamics of parasitic transmission. Warmer temperature, higher moisture and humidity enhance the development of *A. lumbricoides* and *T. trichiura* eggs, whereas in low temperatures their ova may not form embryos. High humidity supports hookworm larvae to increase in numbers. Land surface temperature (LST), altitude and aridity (extreme dryness) are environmental factors that influence the survival and transmission of STH (Mascarini-Serra, 2011).

1.3 Symptoms, morbidity and intensity of infection

The symptoms of STH include diarrhoea, loss of appetite, abdominal pain, weakness and iron deficiency anaemia (due to intestinal bleeding). In severe case of ascariasis, infection can lead to pneumonia as the larvae invade the lungs (Murray, 2016). Hookworm infections can cause skin rash and dermatitis as well. Hookworm infection has been found to be a leading cause of iron-deficiency anaemia, as the worm has the ability to extract blood from the intestinal submucosa and mucosa of human host (Hotez et al., 2016). Helminths have the capacity to cause unbearable chronic infections in hosts and yet show nonspecific clinical symptoms (Chen, 2016). While most *S. stercoralis* infections are asymptomatic, abdominal pain and diarrhoea maybe present in the early stages of infection. Dermatological symptoms, which relate to the skin and its diseases such as rash and itching, are common in chronic *S. stercoralis* infection (Hossain, 2016).

The number of parasitic worms within an infected person reflects the morbidity, which describes an individual's feeling of ill health. According to the WHO guidelines, the number of worms determines the intensity of infection (Cepon-Robins et al., 2014). From the STH group, *S. stercoralis* is the only helminth capable of causing auto-infection, which may lead to a high intensity of worms in immmunocompromised people. Auto-infection is due to reinfection by a parasite already present in the body (Hossain, 2016).

The intensity of STH infection is based on Markov nomenclature. This model was named after Andrei Markov, a Russian mathematician- born in 1856. The Markov model is used by the WHO to differentiate the class of intensity and to predict changes in prevalence of STH parasites (Figure 2.0) (Montresor, Deol, à Porta, Le Thanh, &

Jankovic, 2016). High-intensity STH infections are the major cause of morbidity in intestinal helminth infections (Yanola et al., 2018).

STH species	Zero eggs (epg)	Infections of light intensity (epg)	Infections of moderate intensity (epg)	Infections of heavy intensity (epg)
A. lumbricoides	0	1–4999	5000–49 999	> 50 000
T. trichiura	0	1–999	1000–9999	> 10 000
Hookworms	0	1–1999	2000–3999	> 4000

epg = eggs per gram of faeces.

Figure 2. WHO classification of STH infection intensity using Markov nomenclature
Montresor, A., Deol, A., à Porta, N., Le Thanh, N., & Jankovic, D. (2016). Markov Model Predicts Changes in STH Prevalence during Control Activities Even with a Reduced Amount of Baseline Information (Vol. 10). doi:10.1371/journal.pntd.0004371.

1.3.1 Co-infection risk associated with STH

Co-infections, where one person is infected by two or more disease-causing organisms (pathogens), are a common occurrence of NTDs. Studies have shown that polyparasitism, where multiple parasites infect the same host, may deteriorate the STH patient's conditions (Martins-Melo et al., 2017). Co-infections are quite prevalent in children. In a study done in Thailand to find the prevalence of intestinal parasites in children, 18.4% of the children were found to have polyparasitism (*with A. lumbricoides and T. trichiura*) when their stool samples were analysed. Single infections had a prevalence of 29.3% (Yanola et al., 2018). In Laos, a strong association was seen between morbidity, malnutrition and anaemia in children due to intestinal parasites (single and multiple species) (Sayasone, Utzinger, Akkhavong, & Odermatt, 2015a).

In Cambodia, hookworm and *S. stercoralis* co-infections had almost a 50% prevalence rate. Higher public health risks associated with polyparasitism increases the worm burden in endemic geographical areas (Forrer et al., 2018). Polyparasitism was observed in 31.4% of patients of a retrospective observational study in Northern Territory (NT) government health facilities in Australia (Mayer-Coverdale, Crowe, Smith, & Baird, 2017).

Interestingly, Immunocompromised patients' (individuals who have weakened immune system to fight infections) have a high risk of developing co-infection with at least two intestinal parasites. Cytokines are cell signalling molecules that regulate the body's immune response to infection and inflammation- mechanisms like interleukin (IL) and interferon (IFN) act as markers of immunosuppression with cytokines to boost

the immune system. Patients' with human immunodeficiency virus–1 (HIV-1) receiving anti-retroviral therapy and having co-infection with STH infection- show a decreased response of Th1 cytokine (IL- 2, IL- 12, and IFN- γ) in-vitro (Storey et al., 2017).

1.4 Laboratory diagnosis and treatment

Laboratory diagnosis of STH, according to the WHO, is by microscopic visualisation of stool samples to identify the parasites and determine the number of STH eggs present. The techniques involved are direct smear microscopy, formol- ether concentration (FEC), Kato-Katz method, McMaster and the FLOTAC method (Nikolay, Brooker, & Pullan, 2014). However, there may be intra-and inter- sample variation. Furthermore, microscopy based techniques may have varying sensitivities, especially in low-transmission settings with lesser intensity of infection (Nikolay et al., 2014).

STH treatment includes periodic deworming with Albendazole and Mebendazole, or the use of preventative anthelminthic (antiparasitic) - chemotherapy (Tchuem Tchuenté, 2011). Studies have shown that both drugs may have less effectiveness if only a single-dose treatment is administered (Cowan, Vargas, & Keiser, 2016). Ivermectin, which is a derivative drug of Avermectin, may also be used to treat Strongyloides infection (Chen, 2016; Rego Silva et al., 2018). Even though the infection can be treated, the eradication poses a challenge. This is due to the transmission pattern, either by faecal-oral and/or penetration-via-skin, which increases the probability of reinfections in STH-affected areas (Salam & Azam, 2017). It has been suggested that the development of effective drugs would be a milestone in the treatment of STH-endemic populations. The target areas for drug efficacy could lead to health improvements in communities with higher poverty and lower sanitation standards (Chen, 2016).

Preventive anthelminthic chemotherapy provides long-term prevention and control against STH infection. Single or combination of antiparasitic drugs, also called MDA is used to treat at-risk populations. WHO suggests MDA acts as a public health tool to control morbidity caused by helminth disease (WHO, 2018). Current literature informs us that MDA programmes in many countries rely on microscopic-based investigation for the presence of helminth eggs which is not a sensitive method in a population

undergoing deworming control (Hawkins, Cantera, Storey, Leader, & de los Santos, 2016).

1.4.1 Initial and post-treatment underperformance related to STH

Regular treatment for STH in at-risk populations is important, especially children and women of childbearing age. This may control higher intensity of worm and its impact on morbidity in patients. However, retreatment may be necessary if individuals are re-exposed to contaminated areas and unhygienic practices. Hookworm has the capability of causing reinfections, which could be almost 60% post-treatment if follow-up on cure is lacking. High poverty has been observed to cause co-infections with *S. stercoralis*. The high cost of Ivermectin, which could be almost $40 USD per treatment, may have limitations in drug-accessibility for *S. stercoralis* infected individuals (Forrer et al., 2018; Getachew, Tafess, Zeynudin, & Yewhalaw, 2013).

In a study in China, authors found that initial treatment with a single dose of Albendazole or Mebendazole has a high cure rate for *A. lumbricoides* infections compared to hookworm. *T. trichiura* has low cure rates with initial treatment and reinfections are probable (Yap et al., 2013).

This suggests a need for pre- and post- treatment faecal analysis requests by physicians to monitor the success of treatment and reduce the risk of reinfections.

1.5 Global distribution and prevalence of STH

According to WHO, it is estimated that STH affects almost 1.5 billion people worldwide, which accounts for 24% of the world's population. STH is more widespread in tropical and subtropical countries; however, China and East Asia, the Americas, and sub-Saharan Africa have the highest rates of infection (Figure 3.0).

WHO further reports that more than 260 million preschool-aged children and more than 560 million school-aged children require treatment and intervention controls to prevent the spread of STH, as these children are more prone to infection due to living in these at- risk areas (WHO, 2015b).

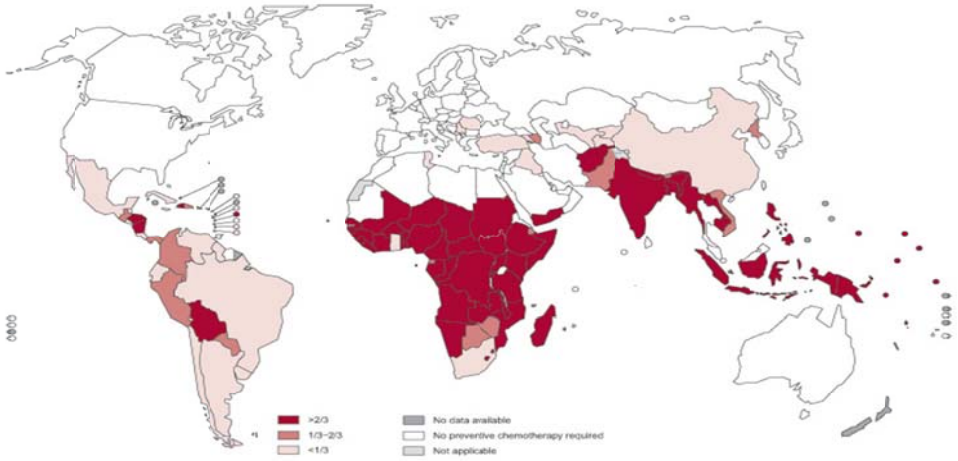

Figure 3. Global distribution of STH
http://www.who.int/intestinal_worms/epidemiology/Soil_transmitted_helminthiases_2011.jpgua=1

According to findings of Weatherhead et al. (2017), STH accounts for the most common infections found in children worldwide (Figure 4.0).

	Major Human Species	Estimated Prevalence (Cases)	DALYs (Millions)	Deaths
Roundworm (Ascariasis)	*Ascaris lumbricoides*	761.9 million	1.075	2700
Whipworm (Trichuriasis)	*T trichiura*	463.7 million	0.653	None specified
Hookworm	*N americanus* and *Ancylostoma* sp	428.2 million	1.758	None specified

Figure 4. Global prevalence and DALYs of STH
Weatherhead, J. E., Mejia, R., & Hotez, P. J. (2017). The Global State of Helminth Control and Elimination in Children. The Pediatric Clinics of North America. doi:10.1016/j.pcl.2017.03.005

Singh (2013) highlights that diseases caused by such as intestinal as well as extra-intestinal STH parasites are prevalent in developing countries. This may cause additional public health problems and disease burden risk. However, it was noted that lack of epidemiological data on symptomatic patients could affect the true picture of STH distribution and its effect on the control of future parasitic infections.

In developing countries, school-aged children, aged between 5 to 15 years, are at highest risk of intestinal helminth infection and morbidities linked to it. The reasons are poor personal hygiene, poverty and increased outdoor activities. High-risk

behaviours, such as soil eating, as well as being young age with undeveloped immunity in environmental settings that support STH transmission, increase the likelihood of infection (Galgamuwa, Iddawela, & Dharmaratne, 2018).

Studies have shown that there is little evidence and research undertaken on the impact of STH has on cognitive and neurodevelopment in children. Cognitive development relates to the psychological process of acquiring knowledge, problem-solving, and decision making. Neurodevelopment process allows the development of the brain and its associated functions, such as memory, intellectual abilities, etc. However, a gap exists in research areas of risk possessed by STH on toddlers (1-3 years) and preschool aged (3-5 years) children (Pabalan et al., 2018).

STH can impair physical and mental development in children (Bopda et al., 2016). School- aged and preschool aged children are more vulnerable to malnutrition due to parasitic infection (Sherkhonov et al., 2013).

According to information from literature, MDA have focused more on school-aged children and those younger than 5 years old. More research is needed in the population of adults to identify the disease status if they live in the same community where children are receiving treatment. In Zambia, 2,829 adult stool examinations revealed 7.4% had combined prevalence of hookworm and *A. lumbricoides*. There is a possibility that adults act as reservoir of STH infection and increase transmission of infection to children on treatment. Hence, the need for adult deworming treatment was emphasised so treatment regime aligns with children (Halwindi, Lisulo, Magnussen, & Olsen, 2017).

There is also a need for comprehensive monitoring for the prevalence and intensity of STH infections. This is necessary to assess the effectiveness of control programmes like MDA. This outlines the need for more sensitive and specific diagnostic tools for STH infections (Mationg et al., 2017). Hawkins et al. (2016) highlights how low-intensity of infection poses a challenge to detect parasite eggs if the MDA strategy is in its late stage of treatment in a population. New diagnostic tools are needed to attain WHO's total helminth elimination goals with respect to the 2020 London Declaration on NTDs (Hawkins et al., 2016). Monitoring of MDA response should be aimed at individual as well as the community level. For a hookworm host, nutritional factors such as body

mass index (BMI), anaemia and dietary status affect the anthelminthic effectiveness; therefore, nutritional support may reduce STH impact in MDA assessment (Humphries et al., 2017).

In Burkina Faso, West Africa, large-scale chemotherapy administered twice a year, was successful in controlling STH infection in school-aged children. The author suggests that hookworm infections do persist even after many cycles of anthelminthic treatment in some areas. The suggestion has been made for the evaluation of preventative chemotherapy (Drabo et al., 2016).

Hawkins et al. (2016) argues that the presence of MDA has been underused and/or overused due to the absence of faster and sensitive testing techniques. Ortu et al. (2016) agrees using an 8 year MDA programme in Burundi suggesting previous studies in Africa failed to monitor recurrent MDA interventions and associated longitudinal effects. Clustering in population distribution due to repeated deworming was observed. An MDA programme needs to understanding of spatial distribution as well spatial heterogeneity patterns before the deworming programme is used in a population. This would enable a broader understanding of the impact on treatment and allow monitoring of its progress (Nikolay et al., 2015).

1.6 Prevalence of STH in Oceania region

The Oceania region consists of approximately 35 million people who live in tropical and subtropical islands located in the South Pacific Ocean. Approximately two thirds of the population (22.3 million) live in Australia, followed by Papua New Guinea (6.8 million), New Zealand (4.4 million), Fiji (860,000), Solomon Islands (538,000), French Polynesia (270,764), New Caledonia (254,000) and Vanuatu (239, 000), and many more smaller islands. In terms of NTDs, the highest prevalence of helminth infections has been observed in Oceania. STH infections are mostly due to hookworms (5.5 million cases), followed by ascariasis (1.2 million cases), trichuriasis (1.2 million cases) and strongyloidiasis (Kline et al., 2013).

1.6.1 STH prevalence in Australia and New Zealand

In Australia, prevalence of STH is low. The presence of clean water, good hygiene and sanitation capabilities have controlled helminth infection. In NT, Australia, the overall

prevalence of *T. trichiura* and hookworm is low at 0.65% and 0.17% respectively. Despite the presence of moist soil and the tropical environment, no prevalence of Ascaris infection has been reported. In contrast, STH is endemic to Aboriginals (indigenous Australians), especially *S. stercoralis* infection. The intestinal parasite is common in remote communities in tropical states, which include Western Australia (WA), Queensland, NT, and Northern New South Wales (NSW) (Gordon, Kurscheid, Jones, Gray, & McManus, 2017).

A cross-sectional survey by Gordon et al. (2017)- suggests long-term immigrants from South East Asia (SEA) and returning-travellers in Australia had STH present. *S. stercoralis* and *T. trichiura* were identified in East African communities, while a high prevalence of 42% was seen in Cambodian cohort. Additionally, 11.6% of Australian army veterans (Returned Service Personnel) had positive serology detection of *Stronglyloides*.

In NT, Mayer-Coverdale et al. (2017) undertook a study in, to find trends of *S. stercoralis* from 2002- 2012. The findings show that 0-5 year old age had the highest detection per number of faecal samples. Anaemia as a clinical symptom (44.8%), and laboratory-deduced eosinophilia (65.5% in 0-5 year olds), was observed in 49.9% of patients.

In Australia, public health intervention for STH control was introduced in 1995 with the use of Albendazole deworming. The study involved children younger than 10 years from remote Aboriginal settings for comparison of intestinal parasitic infection (IPIs) detection in 1994-1996 and 2010-2011. Even though reduction in positive faecal samples for *S. stercoralis, T. trichiura* and hookworm was evident in 1994-1996 and 2010-2011, higher detection rates still exist for *T. trichiura* (48.2%) and *S. stercoralis* (4.7%) (Holt et al., 2017).

Reports of hookworm being prevalent among Aboriginal Australians located in Northern Territory (NT) and Western Australia (WA) is recorded but is well controlled through MDA activities. Higher rates of *S. stercoralis* infection, as high as 60%, have been reported in Aboriginal populations. It was observed that STH was not a major public health concern, so recent data on prevalence were not available (Kline et al., 2013).

STH infections are nonendemic in New Zealand and data on the prevalence of human helminths is lacking (Kline et al., 2013). In comparison, anti-helminthic resistance was evident in sheep. However according to Leathwick (2014), New Zealand has maintained sustainable control of nematode infestation in flocks of sheep.

1.6.2 STH prevalence in Papua New Guinea

Hookworms have the highest prevalence in Papua New Guinea (PNG). It is estimated that 4.9 million people (two thirds of the total population) have hookworm infection. *N. americanus* is the most common hookworm species identified. Ascariasis has the second largest prevalence (748,000), followed by trichuriasis (204,000) (Kline et al., 2013).

1.6.3 STH prevalence in Solomon Islands

In Solomon Islands, trichuriasis accounts for the highest number of STH infections (338,000), followed by hookworm (192,000) and ascariasis (135,000) (Kline et al., 2013).

1.6.4 STH prevalence in Vanuatu

For Vanuatu the geographic distribution of STH infection is similar to that of Solomon Islands. The highest prevalence was recorded for trichuriasis (150,000), followed by hookworm (88,000) and ascariasis (59,000) (Kline et al., 2013).

1.6.5 STH prevalence in other smaller islands countries in Oceania region

In Republic of Marshall Islands, a cross-sectional study was undertaken to find the prevalence of IPIs and risk factors among school children. 400 school-aged children (aged 9.73 ± 2.5 years old) had their stool samples analysed for any presence of IPIs. The prevalence of IPIs was 22.8%. The presence of at least two different parasites was seen in 24.2% of samples. STH prevalence was quite low; A*. lumbricoides*, *T. trichiura*, and hookworm had a prevalence of 0.0%, 4.0%, and 0.5%. The authors suggested the reason for low STH prevalence may have been due to annual deworming strategies for school children in the Island (Liao et al., 2017).

In a cross-sectional survey in Tuvalu, 206 residents had their faecal samples examined to find the prevalence of STH, using hookworm and *T. trichiura* diagnosis only. Prevalence of STH was 69.9% in the overall population. High prevalence of *T. trichiura*,

(68.4%), was noted compared to hookworm (11.7%). The survey suggested that MDA reduced hookworm prevalence but had little impact on *T. trichiura* (Judith, Julie, & Tekaai, 2012; Speare et al., 2006).

1.7 WHO's global approach to STH control

WHO in 2001, together with the World Health Assembly representatives, universally recommended a resolution (WHA54.19) for STH-prone countries by developing plans for eradicating worms to control morbidity. The need for periodic STH treatment of people in endemic geographical areas was proposed. The at-risk populations were preschool as well as school-aged children, women during pregnancy and/or breastfeeding, and adults such as mine workers and farmers. As per recommendations by WHO, periodic deworming of individuals in STH-endemic areas were to be carried out once a year in communities that had a baseline STH infection of 20%. Deworming needs to be followed twice a year for communities with over 50% STH prevalence rates. Treatment intervention in populations, health and hygiene education, as well as the need for improved sanitation was also highlighted by the WHO. By 2016, with the success of deworming programmes, around 385 million or 68% of at-risk children were treated. Furthermore, hand washing, coupled with improvement of hygiene and sanitation standards increased in school education guidelines. By 2017, WHO updated and published evidence-informed guidelines for regular, large-scale treatment a for people affected by STH (WHO, 2018).

Unfortunately, NTDs were not part of the Millennium Development Goals (MDGs) of the United Nations in 2000. However, due to the emerging health impacts, the Bill and Melinda Gates Foundation provided funding for global health projects and research into NTDs. Collaborative efforts of NTD organisations worldwide led to the formation of the "London Declaration on NTDs" in 2006. By early 2012, stakeholders from the Bill and Melinda Gates Foundation, the World Bank, pharmaceutical companies, and through support from WHO's "Accelerating Work to Overcome the Global Impact of NTDs" initiative, the London declaration received a major boost. The need to speed-up research on NTDs, development of new anti-helminthic drugs, the importance on distribution of new effective drugs were outlined as prime aims of the London declaration (Nii-Trebi, 2017).

In 2015, WHO, in collaboration with the Global Fund Board included NTDs as one of the Sustainable Development Goals (SDGs), to include control measures to reduce infections and morbidities linked to NTDs. Group of Seven (G7) nations, which included United States of America (USA), Canada, the United Kingdom (UK), France, Japan, Germany and Italy, highlighted the need to include NTD research and support interventions. SDGs goal aimed to reduce the global NTD burden, especially in developing and underdeveloped nations. In many poor settings, NTDs have been described as an indicator for poverty as well (Molyneux, Savioli, & Engels, 2017).

Recent studies have suggested the need to focus on switching from STH control efforts towards elimination of intestinal parasites and other NTDs (Ásbjörnsdóttir, Means, Werkman, & Walson, 2017; Turner et al., 2017b). The WHO, together with MDA interventions has been focusing more on reducing morbidity in endemic settings. Reduction in intensity of infection due to MDA treatment in children has shown a positive outcome of the control strategy. Inclusion of geographical information systems (GIS) and remote sensing (RS) have improved the understanding of the ecology of STH. This allows data to be collected from satellites to detect target populations and provides a guide to MDA on a larger scale. In contrast, the adult population is often not included in the massive treatment coverage. This creates a gap since the adult populations are the reservoirs of reinfection. STH elimination could be possible if MDA is expanded to all communities irrespective of age. This may interrupt transmission of helminths and decrease the risk of potential resistance posed by parasites (Ásbjörnsdóttir et al., 2017).

1.8 Fiji and its Geography

Fiji is a tropical island nation located in the South Pacific Ocean between 15-22° south latitude and 177° west to 175 ° east longitude in the southern hemisphere. It is positioned at 5,100 km southeast of Hawaii, 3,150 km northeast of Australia and 1000 km north of New Zealand. Situated in the Melanesian group, Fiji is the fourth largest island in the Oceania region (Figure 5.0). Fiji is an archipelago (made up of a cluster of islands) of more than 330 smaller islands, of which only 110 have people inhabiting them. The nation covers a total land area of 18,333 km². Viti Levu is the largest island and Vanua Levu is the second largest, having land areas of 10,429 km² and 5,556 km² respectively.

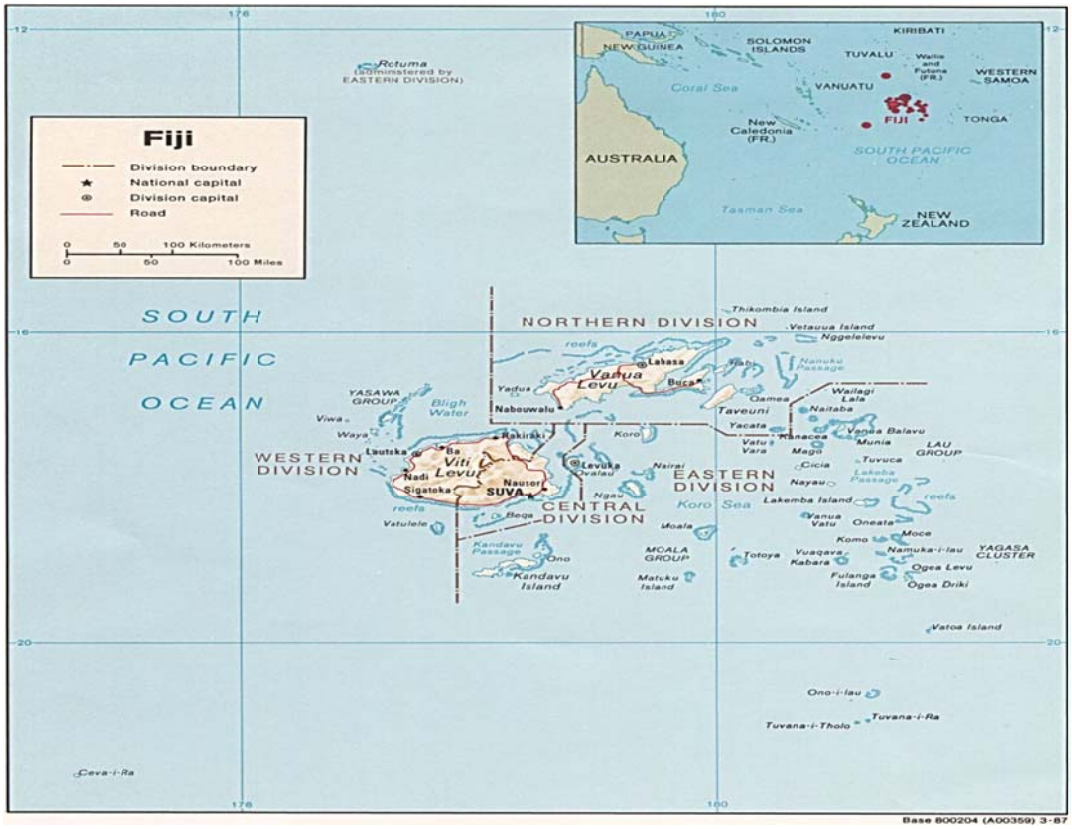

Figure 5. Location of Fiji with its four major geographic divisions
https://www.google.co.nz/search?q=fiji+geographical+map&tbm

1.8.1 Demographics and economic context of Fiji

According to the 2017 census on population and housing released in January 2018, Fiji has a population of 884,887 released in January 2018 (Bureau, 2018). The 2017 distribution of population based of different ethnicities has not yet been updated by the Fiji Bureau of Statistics. According to 2007 census, the total population was 837,271; there were 475,739, i-Taukei (Indigenous Fijians), 313,798, Indo-Fijians and 47,734 comprising of other races in the island nation. Other races that make up part of the total population are Chinese, European, part-European, Rotuman, and other Pacific Islanders.

Fiji is a multiracial country. The i-Taukei population are mostly of Christian faith, while Indo-Fijians follow Hindu and/or Muslim faith. English is the official language but Fijian and Fijian-Hindi (Hindustani) language is used daily. Adult literacy is around 94%. The geographical distribution of Fiji comprises of 15 provinces which are spread over four major divisions. The divisions are the northern, the central, the eastern and the

western regions of the island (Ministry of Health & Medical Services, 2014; WHO, 2011b).

The main sources of income for the island nation are tourism, agriculture, sugar, mining and export of bottled water(WHO, 2011a). Fiji's economic Gross Domestic Product (GDP) was $4.0 billion in 2013 with external debt of 25% (Bank, 2014). Farming and fishing are mostly for used by the people for subsistence needs in the rural and maritime areas, while some cash-crops are sold in vegetable markets (WHO, 2011b). According to the 2008-2009 survey on household income and expenditure by the Fiji Bureau of statistics (2010), 31% of population live below the poverty line.

Urban and rural population of Fiji

Compared with the population census of 2007, the Fijian urban population in 2017 had increased by 69,406 (16.3%), reaching 494,252 with a reduction in rural population by 21,790 (5.3%) (Figure 6.0).

According to the 2017 census, the urban areas in Fiji had a median age of 27.5 years, with the male median ages being 27.5 years and the female median age being 28.3 years.

Census Year	Population	Annual Growth Rate (%)	Median Age (years)	Urban	%	Rural	%
1976	588,068	2.1	17.8	218,495	37.2	369,573	62.8
1986	715,375	2.0	20.6	277,025	38.7	438,350	61.3
1996	775,077	0.8	21.2	359,495	46.4	415,582	53.6
2007	837,271	0.7	25.1	424,846	50.7	412,425	49.3
2017	884,887	0.6	27.5	494,252	55.9	390,635	44.1

Figure 6. Total population in Rural and Urban areas from 1976-2017
Bureau, o., Statistics, Fiji. (2018). *2017 Census of Population and Housing*. Suva, Fiji. Retrieved from http://www.statsfiji.gov.fj/census

Age and sex distribution in urban and rural population of Fiji

The proportions of males is higher is higher in the age groups; 0-4, 5-9, 10-14, 25-29 years and up to 45-49 years old. A higher female proportion is seen in the age groups; 15-19, 20-24, 50-54 years and higher age groups. Females being > 75 years old had proportion of 62.5% (Figure 7.0).

Age-Group	Total					Urban					Rural				
	Total	Male	%	Female	%	Total	%	Male	%	Female	%	Total	%	Male	%	Female	%
Total	884,887	448,595	50.7%	436,292	49.3%	494,252	55.9%	245,928	49.8%	248,324	502%	390,635	44.1%	202,667	51.9%	187,968	48.1%
0 - 4	91,897	47,195	51.4%	44,702	48.6%	47,904	52.1%	24,614	51.4%	23,290	486%	43,993	47.9%	22,581	51.3%	21,412	48.7%
5 - 9	88,295	45,243	51.2%	43,052	48.8%	45,436	51.5%	23,231	51.1%	22,205	489%	42,859	48.5%	22,012	51.4%	20,847	48.6%
10 -14	79,596	40,715	51.2%	38,881	48.8%	40,784	51.2%	20,676	50.7%	20,108	493%	38,812	48.8%	20,039	51.6%	18,773	48.4%
15 -19	74,088	38,032	51.3%	36,056	48.7%	42,345	56.8%	20,713	49.3%	21,332	507%	32,043	43.2%	17,319	54.0%	14,724	46.0%
20 -24	73,616	37,464	50.9%	36,152	49.1%	46,942	63.8%	23,397	49.8%	23,545	502%	26,674	36.2%	14,067	52.7%	12,607	47.3%
25 - 29	69,308	35,253	50.9%	34,055	49.1%	41,756	60.2%	21,030	50.4%	20,726	496%	27,552	39.8%	14,223	51.6%	13,329	48.4%
30 - 34	68,818	35,266	51.2%	33,552	48.8%	40,741	59.2%	20,609	50.6%	20,132	494%	28,077	40.8%	14,657	52.2%	13,420	47.8%
35 - 39	65,150	33,382	51.2%	31,768	48.8%	37,584	57.8%	18,904	50.2%	18,780	498%	27,466	42.2%	14,478	52.7%	12,988	47.3%
40 - 44	53,514	27,697	51.8%	25,817	48.2%	30,590	57.2%	15,476	50.6%	15,114	494%	22,924	42.8%	12,221	53.3%	10,703	46.7%
45 - 49	49,504	25,314	51.1%	24,190	48.9%	27,872	56.3%	13,998	50.2%	13,874	498%	21,632	43.7%	11,316	52.3%	10,316	47.7%
50 - 54	48,610	24,649	50.7%	23,961	49.3%	26,585	54.7%	13,241	49.8%	13,344	502%	22,025	45.3%	11,408	51.8%	10,617	48.2%
55 - 59	42,008	21,263	50.6%	20,745	49.4%	23,113	55.0%	11,249	48.7%	11,864	513%	18,895	45.0%	10,014	53.0%	8,881	47.0%
60 - 64	30,615	14,891	48.6%	15,724	51.4%	16,744	54.7%	7,805	46.6%	8,939	534%	13,871	45.3%	7,086	51.1%	6,785	48.9%
65 - 69	21,328	10,076	47.2%	11,252	52.8%	11469	53.8%	5,138	44.8%	6,331	552%	9,859	46.2%	4,938	50.1%	4,921	49.9%
70 - 74	14,148	6,367	45.0%	7,781	55.0%	7342	51.9%	3,131	42.6%	4,211	574%	6,806	48.1%	3,236	47.5%	3,570	52.5%
75+	14,392	5,788	40.2%	8,604	59.8%	7245	50.3%	2,716	37.5%	4,529	625%	7,147	49.7%	3,072	43.0%	4,075	57.0%
Median Age	27.5	27.2		27.8		27.9		27.5		28.3		27.0		26.9		27.1	

Figure 7. Population of Urban and Rural by Sex and Median Age, 2017
Bureau, o., Statistics, Fiji. (2018). *2017 Census of Population and Housing*. Suva, Fiji. Retrieved from http://www.statsfiji.gov.fj/census

For the rural areas of Fiji, the median age is 27.0, with males being 26.9 years and females 27.1 years. The proportion of male is higher in the age groups; 0-4 years up to 65-69 years. Females being > 75 years old had proportion of 57.0% (Bureau, 2018).

1.8.2 Central-Eastern Division of Fiji

According to the 2014 Ministry of Health and Medical Services (MOHMS) 2014 report on population and housing, the Central-Eastern Division of Fiji island has a population of 414,373 (Figure 8.0) (Ministry of Health & Medical Services, 2014). The central division of Fiji includes the eastern portion of largest island, Viti Levu, which consists of Naitasiri, Namosi, Rewa, Serua with Namosi and Tailevu provinces. Suva is the capital as well as the governing city of the island nation. The eastern division comprises of Lomaiviti group (which includes Levuka), Kadavu, Lau group (which includes Lomaloma and Lakeba), and Rotuma, which are smaller islands in their provinces.

Based on comparison of MOHMS 2014 annual report data from 2013-2014, the population of central division increased by 4,130, totalling 374,673, while the eastern division population rose by 1,233 giving a total of 39,651 (Ministry of Health & Medical Services, 2014).

Subdivision	2013	2014
Suva	216,540	217,597
Rewa	84,413	84,872
Naitasiri	20,002	20,232
Serua/Namosi	29,625	29,588
Tailevu	19,963	22,384
Lomaiviti	13,886	16,187
Kadavu	10,995	10,946
Lomaloma	4,332	3,358
Lakeba	7,284	7,294
Rotuma	1,921	1,866
Total	**408,961**	**414,373**
Central (Total Population)	**370,543**	**374,673**
Eastern (Total Population)	**38,418**	**39,651**

Figure 8. Population of Central-Eastern Division from 2013-2014
Ministry of Health & Medical Services, F. (2014). Fiji Ministry of Health & Medical Services Annual Report 2014 Fiji Islands: Ministry, Of, Health, &, Medical, Services.

Fiji's urban population is projected to increase to almost 61% by 2030. A high increase in population growth has been seen in the Nasinu area which is situated in central division of Viti Levu (WHO, 2011b).

1.8.3 Fiji and STH prevalence

According to WHO (2015b), Fiji has a long history of helminthiasis as it has for lymphatic filariasis (LF). LF, commonly known as elephantiasis, is also a neglected tropical disease where microfilariae worms are transmitted to humans through mosquitoes. Despite the presence of hot-humid climate, and often inadequate sanitation, the prevalence of STH is still not known (Kim et al., 2016).

Colonial War Memorial Hospital and NTDs

Colonial War Memorial hospital (CWMH) is the oldest and largest hospital Fiji, and is located in Suva, in the Central Eastern Division of Fiji. The geographical location is situated between 18° south latitude and 178° east longitude in the southern hemisphere. CWMH is a public hospital which was built in 1923 (The Fijian Government, 2013).

According to the divisional report from, Ministry of Health & Medical Services (2014), CWMH WM hospital is a referral hospital. The hospital referral caters for 6 sub-divisional hospitals, 15 health centres, and 31 nursing stations. Health services delivered in CWMH include inpatient and outpatient care, child and maternal health, emergency care, general and special outpatients service, maternal child health care, laboratory, pharmacy, nutritional, oral health, x-ray, physiotherapy, environmental,

school health, as well as special clinical and outreach services (Ministry of Health & Medical Services, 2014).

Faecal samples are tested in the microbiology laboratory department of CWMH .The smaller health centres and hospitals located in Suva, Nausori, Navua, and nearby islands within the division act as collection centres for stool samples which are sent to CWMH for analysis and identification of parasites (Ministry of Health & Medical Services, 2014). Direct microscopy is the only technique used to detect STH in CWMH, Suva, Fiji. The challenge for helminth detection is the lack of resources, equipment and technical expertise, which create shortfalls in sensitive diagnosis (Kim et al., 2016).

Fiji's MOHMS has included NTD as one of the key performance indicators for Sustainable Development Goals (SDGs). Communicable diseases and NTD have been included as part of the ministry's strategic plan towards health resilience (F. Ministry of Health & Medical Services, 2016).

In 2016, a transmission assessment survey (TAS) in school children revealed the prevalence of *S. stercoralis* was 3.5% in the Western Division in Fiji. However, the data on the health status of STH infection is inadequate in providing the full worm burden of other important STH parasites (Kim et al., 2016).

1.8.4 Socioeconomic relevance of STH

The term *socioeconomic* relates to the interaction of economic and social factors. According to the Asian Development Bank report on Country Partnership Strategy 2014-2018, 5.3% of children <5 years old in Fiji have malnutrition More than 30% people living below the World Bank recommended poverty threshold. There has been increase in the populations' access to safe water from 2000 to 2013, which was 91.2% to 96.3% and 87.2% of population have of access to sanitation (Bank, 2014).

It has been suggested that the increase in urbanisation, presence of natural hazards such as cyclones and floods, and effects of climate change have negatively affected the socioeconomic activity in Fiji (Government, 2017).

In a community, a good indicator of STH infection is lower socioeconomic status, low levels of education and use of improper sanitation (Ross et al., 2017). High prevalence

of STH has been associated with developing countries where lower socioeconomic level is common (Nelly, Tiangsa, & Muhammad, 2016).

In Indonesia, higher malnutrition was associated with children with increased STH infection (Nelly et al., 2016). Children are prone to intestinal parasite infection due to lack of adequate sanitation, poor personal hygiene conditions and decreased access to clean water. Studies have mentioned that the risk of helminth increases in people who live in overcrowded situations, are uneducated and have lack of access to healthcare (Abdi, Nibret, & Munshea, 2017; Clasen et al., 2014; Melo et al., 2016; Murray, 2016).

A WHO survey of children from 13 Pacific Island nations revealed that children with STH- related anaemia had almost 9 times increased possibility of having delayed growth with 4 times the risk of being underweight. High numbers of students and/or overcrowding is highly associated with helminth infection in children (Hughes et al., 2004).

1.8.5 Climate change contribution to STH

Direct effects of climate change are demonstrated by the increase in temperature, precipitation levels, and the effect they have on weather patterns. Precipitation relates to any form of water that falls from the atmosphere towards the surface of the Earth, such as rainfall and snow. Indirect effects of climate change could change the incidence and prevalence of parasitic disease and its effect on human populations (Short, Caminade, & Thomas, 2017).

In 2017, the Climate Vulnerability Report was prepared by the Fiji government for World Bank and Global Facility for Disaster Reduction and Recovery in collaboration with the African, Caribbean and Pacific (ACP) group and the European Union. The report highlights that the effects of tropical cyclones recently and in the past had impacted economic growth. Tropical Cyclone (TC) Winston in 2016 caused damages of almost $2 billion or 20% of the GDP. The report informs of other parallel implications of climate change, which were an increase in sea level, higher risk of flooding, increased transmission of vector-borne diseases and acidification of the ocean. The island nation of Fiji is profoundly prone to natural disasters and are at high risk of climate stresses (Government, 2017).

For children in developing countries, the implications of climate change are severe. Children exposed to extreme weather related to climate change have been predicted to suffer from its effects in future. Developing countries suffer from community-wide poverty, limited social safety, weak healthcare capacity and fragile government institutions, which poses a challenge to adapt and/or respond to climate change. In comparison to developed countries, a high dependency of children to adults and increased birth rates are seen in developing nations. This increases the risk of climate change effects in developing countries (Hanna & Oliva, 2016).

Health risks linked to climate change are severe especially for children in countries with lower-income. It has been estimated that disease burden due to environmental factors contribute to 25% of deaths worldwide; amidst children < 14 years old, this may increase to 36%. Diarrhoea, respiratory infections and malaria are common diseases that have been associated with changing climate behaviour and/or after natural disaster (Bartlett, 2008).

Effects of tropical cyclone

A tropical cyclone (TC) is a fast-turning storm surge, which is categorised by strong winds, thunderstorms and intense rainfall. From year 2000 onwards, Fiji had 3 cyclones, which were devastating and significant: TC Ami, category 3 cyclone in 2003, TC Evan, category 4 cyclone in 2012, and severe TC Winston, category 5 in 2016 (Government, 2017).

Increased flood frequency

In the last 40 years, Fiji has had at least one flood every year. The floods were either fluvial, which is caused by extreme rainfall causing rivers to overflow, or pluvial floods where rainfall affects flat land and urban areas due to blocked drains. Floods in 2002, 2004, twice in 2012, and 2014 were most devastating. The worst floods were noted in 2009 and 2012, in which 15 people died and 160,000 were directly affected (Government, 2017).

Hookworms, *A. lumbricoides* and *T. trichiura* live in soil before they infect a host. Changes in climate patterns could alter certain components in soil. In hookworm, an increase in temperature could increase larvae development within eggs, which may lead to a decrease the time needed for infectivity to take place. An increase in

precipitation due to rainfall could stop the withering of hookworm eggs and/or larvae, allowing greater rate of survival for the helminth. Compared to other helminth species, an increase in humidity level supports longer survival of hookworm in soil. This is because hookworm larvae have a higher risk of desiccation caused by increased temperatures. In Haiti, 6 years following frequent flooding, there was an increase in prevalence of hookworm infections from 0% to 15 % (Short et al., 2017).

Changes in landscapes due to modification and effects of climate change could pose additional challenges for studying the dynamics of nematode infection. Globally, little research evidence is available on the significance of hookworm infections in free-ranging wild animals and its association with host-parasite connections to humans (Seguel & Gottdenker, 2017).

1.9 Methods used to diagnose STH

STH infection is diagnosed by detecting and identifying helminth (worm) eggs, larvae, adult worms or the segment of worms in stool or gastrointestinal (GI) samples with the use of a microscope (WHO, 2015a). Clinically, other STH samples include urine, sputum, bronchoalveolar lavage and gastric aspirate. According to WHO recommendations, at least 3 fresh faecal samples are required within the period of ten days to successfully detect the parasite. Faecal samples should be approximately 10 ml or a large teaspoon size, and it is recommended that the samples reach medical laboratories within one hour of collection for diagnostic work to be carried out (WHO, 2015a).

STH detection tests should be sensitive, practical and reliable for the control of neglected tropical diseases (Nikolay et al., 2014). More sensitive diagnostic tools are needed when the prevalence of STH increases to support a successful treatment programme for the infected people and the community. Diagnosis of STH is dependent on the geographical distribution of parasites. Endemic parasitic areas have been associated with light-intensity infections. However, endemic areas have shown to have a repeated exposure with higher worm burden rates (Jourdan, Lamberton, Fenwick, & Addiss, 2017).

In medical laboratories, STH infections are diagnosed using conventional methods like microscopic techniques, culture techniques and serological assays, as well as advanced molecular-based methods (Khurana & Sethi, 2017).

1.9.1 Conventional diagnostic methods and challenges

The prime focus of conventional methods is to detect pathogens, with respect to their specific phase of lifecycle, using a microscope (Tang & Sikarwar, 2016). STH diagnostic methods include microscopy-based techniques like direct microscopy, faecal concentration and/or formol-ether (FEC) methods, and egg counting techniques. Egg counting methods include Kato- Katz (K-K), McMaster, FLOTAC and mini-FLOTAC techniques.

In direct microscopy (also called direct wet smear), a thin portion of faecal smear is made on a glass slide (with iodine or saline), which is then covered with a cover slip. The glass slide is examined under the microscope to detect helminthic eggs or larvae based on their size, shape, bile staining, etc. (Garcia, 2016; Khurana & Sethi, 2017).

The FEC method is recommended for stool samples containing lower numbers of parasites of interest. FEC methods are performed using either a flotation technique (with the use of formol-ether) or a sedimentation technique (with the use of zinc-sulphate or brine-flotation procedure).Due to low gravity of formol-ether, the parasites concentrate in sediment form. Use of flotation techniques, such as saturated sodium-chloride and/or zinc-sulphate flotation, have become less popular as a diagnostic tool since infertile *Ascaris* eggs and larvae of *Strongyloides* do not float, thus making parasite recovery difficult (Sayasone, Utzinger, Akkhavong, & Odermatt, 2015b).

The concentration techniques, either using flotation (using formol-ether) or sedimentation (using zinc-sulphate or brine-flotation) enables easier recovery and identification of helminth eggs and larvae. Faecal-concentration techniques work by allowing the separation of faecal debris from helminths by centrifugation and due to the difference in specific gravity of formol-ether. The low specific gravity of formol-ether allows the parasites to concentrate in the sediment (Figure 9.0) (Garcia, 2016).

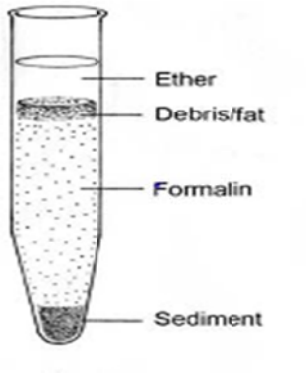

Figure 9. Different layers seen in tubes after centrifugation using FEC
Garcia, L. S. (2016). Diagnostic Medical Parasitology (6th Ed.) [LCCN 2015042284.Retrieved from http://estore.asm.org.doi:10.1128/9781555819002

Egg counting techniques such as K-K method, McMaster, FLOTAC and mini-FLOTAC techniques are widely practiced in STH diagnosis. WHO recommends the K-K method as a gold standard diagnostic test for STH, due its ability to differentiate and quantitate parasite eggs of STH. However, weaknesses in this reliable gold standard have been observed. An adverse effect in diagnosis leads to imprecise prevalence estimates of intestinal parasites (Pilotte et al., 2016). The K-K method is preferred in epidemiological field surveys of parasitic infestations because of low cost and the low level of skill needed for the procedure. WHO further suggests that duplicate slides should be viewed in K-K technique. To quantify parasite eggs per gram (EPG) of stool, the number of eggs in the smear is multiplied by 24. McMaster is another egg counting technique, where a faecal suspension is viewed under the microscope with the use of a counting chamber. The EPG is calculated by multiplying the number of parasite eggs by 50. The FLOTAC technique, a recent new procedure could also be used to perform egg counting of parasites. A FLOTAC apparatus is used here, where a faecal sample initially undergoes flotation in a centrifuge, the apical portion of floating suspension is cut off, and then the eggs are counted. Mini-FLOTAC is a simplified form of the FLOTAC method, and may be used for processing of a preserved faecal sample (Khurana & Sethi, 2017).

Looking at the limitations of the conventional methods, FLOTAC has the highest sensitivity rate, while direct microscopy has the lowest sensitivity. From a diagnostic improvement perspective, microscopic-based techniques have been shown to provide inadequate detection and lack species-specificity amongst STH parasites (Pilotte et al., 2016). Similar sensitivity patterns were seen in K-K and mini-FLOTAC techniques, even

though the K-K method results in higher egg counts compared to FLOTAC. The K-K method shows low sensitivity for low-intensity infection groups when compared with high-intensity infection groups. This suggests the need to account for variation if using the K-K method in specific settings. In comparison with the K-K method, the McMaster technique showed higher egg counts for Hookworm and *T. trichiura* infections (Sayasone et al., 2015b). Recent studies have shown that faecal concentration methods are used more in hospital-based laboratories, whereas K-K techniques are used more for public health surveillance, field studies, and parasitic-control programmes (Jourdan et al., 2017). Uses of conventional methods have shown to be time consuming and labour intensive. An impeding knowledge gap in STH detection coupled with lesser skills have been associated with increased possibility of human error in laboratories (Amoah, Singh, Stenström, & Reddy, 2017).

Culture-based diagnosis and challenges

Culture techniques are mostly used for the recovery of *S. stercoralis* larvae. Some of the techniques are Harada-Mori filter paper strip culture, filter paper/slant culture technique, charcoal culture, Koga agar plate culture and Baermann technique. The limiting factor of culture-based diagnosis is that it requires highly skilled technical expertise. It takes longer to process faecal samples, and its performance in field survey processing would be challenging. Furthermore, these techniques are not suitable for preserved or stored samples due to long delays in transporting to the laboratory (Khurana & Sethi, 2017).

There is no gold standard diagnostic method to estimate the prevalence of *S. stercoralis*. In population-based studies, faecal analysis underestimates the prevalence of the parasite (Holt et al., 2017).

Serology-based assays and challenges

Serology-based assay techniques, also known as serodiagnosis, are used for STH diagnosis when there is no faecal sample available. Either antigen-detection assays or antibody detection assays are used. Some of the techniques used are enzyme-linked immunosorbent assay (ELISA), Dot-ELISA, indirect immunofluorescent antibody test (IFAT), direct immunofluorescent antibody test, immunoblotting (also called Western

Blot), Luciferase immunoprecipitation system (LIPS) and indirect haemagglutination assay (IHA) (Yan et al., 2017).

An advantage of using a serology-based assay is the higher sensitivity compared to conventional diagnostic methods. Indirect immunofluorescent antibody test IFAT has been used widely and it has shown 97% sensitivity and 98% specificity. This assay is important in the diagnosis of *S. stercoralis* infection, especially in immunocompromised patients. The LIPS method has demonstrated a short processing time (2.5 hours), while maintaining a good sensitivity of 97% and specificity of 100%. Disadvantages of serology-based assays are that antibodies stay with patients even after treatment. Also the presence of more than one helminth infection (mixed infection) could affect accurate diagnosis, as this may not show the true activity of one parasitic infection (Nutman, 2017).

Recently, according to literature, new biomarkers have been developed for the ELISA technique, which may improve serodiagnosis of *S. stercoralis* infections. Two synthetic peptides biomarkers, complement factor 3 (C10) and factor D (D3), were used to test its potential in ELISA. High sensitivity of 95% was achieved for both factors, C10 and D3, while specificities were 89.2% for C10, and 92.5% for D3. The improvement in the ELISA technique shows high diagnostic efficiency and reduced cross-reactivity in strongyloidiasis detection. The synthetic peptides could be used for field surveillance studies (Feliciano et al., 2016).

Coproantigen assays are for group of antigens found in faeces which could also be used to detect hookworms and *Strongyloides* (Khurana & Sethi, 2017). In contrast Hossain (2016) mentions that irregular excretion of larvae might pose a challenge associated with the coproglogical technique. Thus, there is a high possibility of underestimation in diagnosis (Hossain, 2016).

Molecular-based diagnosis and challenges

Recent developments in molecular diagnostic methods have been substituting and supplementing the conventional methods. These methods allow efficient identification, isolation and characterisation of pathogens so optimum therapeutic treatment can be implemented (Tang & Sikarwar, 2016). Advanced molecular-based diagnosis allows fast and accurate measurement of STH egg count, as well as being less

labour intensive. These include Polymerase-chain reaction (PCR-based) techniques. Some of the recent updated methods are quantitative-PCR (qPCR) and multiplex-PCR.

Use of PCR- based technology could provide benefits in detecting a broad number of parasite species. This may be useful to improve the understanding of parasite distribution and gain awareness of the epidemiology related to parasite infections (Madinga et al., 2017).

In comparison to conventional STH diagnosis, qPCR is more sensitive. Recent studies show that for *A. lumbricoides* diagnosis molecular tests have 85-100% sensitivity compared to 70-85% achieved by direct-microscopy methods. Molecular detection of *S. stercoralis* and *T. trichiura* were 100% sensitive as compared to 20-50% (*S. stercoralis*) and 88% (*T. trichiura*) (Sayasone et al., 2015b).

In Canada, performance of strongyloidiasis detection was evaluated using serology, microscopy, and qPCR techniques. Serological analysis had a positive reactive detection of 6.1%, inconclusive results of 6.5%, and nonreactive results of 87.4%. Microscopy resulted in no larvae detection and positive detecting success using qPCR was 91.7%. The findings showed higher sensitivity and usefulness of molecular based diagnosis (Dong et al., 2016).

Whereas in Philippines, Mationg et al. (2017) compared the diagnostic accuracy between qPCR with K-K methods in STH infections. The sensitivity of qPCR in detecting at least one type of STH was recorded. The qPCR sensitivity results were *A. lumbricoides* (94.1%) and *T. trichiura* (89.9%) when compared to the K-K sensitivities which were *A. lumbricoides* (40.6%) and *T. trichiura* (30.3%). The findings showed higher accuracy and sensitivity of the qPCR technique.

As suggested by Mationg et al. (2017), qPCR may be suited to assess the effectiveness of preventative chemotherapy in STH infection. It could provide new diagnostic information especially for at-risk areas with low-intensity and/or low prevalence of helminth infection. Some studies suggest the need to optimise the use of multiplex assays, such as qPCR. This would enable simultaneous detection capacity of all STH from faecal samples (Minetti, Lacourse, Reimer, & Stothard, 2016).

In recent years, rapid diagnostic tests kits have been helpful in bridging the gap between clinical and surveillance aspects in regard to parasitosis. RIDASCREEN®, manufactured by R-Biopharm in Germany has shown high testing capability to detect Toxocariasis and Taeniasis. Ricciardi and Ndao (2015), suggest rapid diagnosis would allow mass helminth screening in at-risk communities. Furthermore, faster diagnosis enables monitoring and control of deworming programmes.

Other supporting diagnostics

Apart from laboratory investigation of faeces and related gastrointestinal samples (such as rectal swabs), other parameters support the successful diagnosis of STH infection. Full blood count (FBC), also known as hemogram, is used to assess a >6% eosinophilia; a white cell parameter, that is suggestive of a parasitic infection. Studies have shown a correlation between high eosinophil count and ascariasis (about 45% cases), trichuriasis (up to 77% cases), stronglyloidiasis (80% cases) and hookworm infection (about 60% cases). A low haemoglobin level of <5g/dl and/or low ferritin of <33% is associated with hookworm infections (J. T. Coulibaly et al., 2016; Garcia, 2016).

Severe anaemia due to gastrointestinal bleeding (bleeding in the digestive tract) is associated with hookworm infection. The use of a faecal occult-blood test in the laboratory detects presence of blood in stool (Alsubaie et al., 2016; Hamid et al., 2011).

Sputum and gastric washings could be tested to support STH infection diagnosis as well. Due to the larval migration phase in hookworm, *S. stercoralis* or ascariasis, sputum and gastric washing samples are tested for the presence of larvae. The presence of Charcot-Leyden crystals and eosinophils in sputum may be suggestive of ascariasis (Hawkins et al., 2016; Ricciardi & Ndao, 2015).

Use of endoscopy and diagnostic radiology could also aid in STH diagnosis. For *S. stercoralis* infections, gastrointestinal bleeding and ulceration is noted. Histological examination of gastric and duodenum sections can show the presence of eggs, larvae, and sometimes adult worms (Khurana & Sethi, 2017).

Evidence is available for the use of metabolic fingerprinting by high-resolution mass spectrometry (HRMS). In Brazil, researchers were able to detect *A. lumbricoides* in any

given location and at any stage of the parasite development. Knowledge of its biochemical characteristics could be used to detect *A. lumbricoides* in the environment and break the life cycle to disturb transmission to individuals in endemic communities. HRMS has the potential to provide efficient and accurate results (Melo et al., 2016).

1.9.2 STH diagnosis in Australasia

Australasia countries include Australia (including Tasmania), New Zealand and New Guinea (including Papua New Guinea and the Indonesian portion of the Island) and adjacent islands. These regions are located in the east and north of Australia in Pacific Ocean (Dent, 2010). In NT Australia, the FEC technique is used for faecal examination and identification of human helminthic parasites (Crowe, 2014; Gordon et al., 2017; Holt et al., 2017; Mayer-Coverdale et al., 2017). As of 2013, Australasian laboratories have started using multiplex PCR for diagnosis of protozoan parasites such as *Blastocystis species*, *Giardia lamblia, Entamoeba histolytica* and *Cryptosporidium species* etc. The Australian Society for Infection Diseases (ASID) and the Royal College of Pathologists of Australasia (RCPA) recommended the switch from microscopy techniques to PCR-based methods (Bowen, 2016).

STH diagnosis in Labtests and LabPlus, New Zealand

Labtests are privately owned community medical laboratories. They are part of Auckland Regional District Health Board (ARDHB), which provide commercial pathology services for general practitioners (GP's), Midwives and public healthcare facilities as required for diagnostic testing (Labtests, 2018).

LabPlus are the largest referral laboratory in New Zealand. This laboratory is part of Auckland District Health Board (ADHB), which provide analytical pathology services. Their diagnostic testing facility offers services to other local laboratories, including referred pathological samples within New Zealand, the Pacific region and international countries (LabPlus, 2018).

According to the findings from these two laboratories, the STH prevalence in New Zealand is low and nonendemic in the country. New Zealand lacks published research articles relating to prevalence studies on helminth parasites in humans.

Both laboratories use microscopy-based techniques and FEC methods to detect and quantify intestinal helminths. The workflow of processing of faecal sample using the concentration method can be used for both preserved and unpreserved specimens (Figure 10.0).

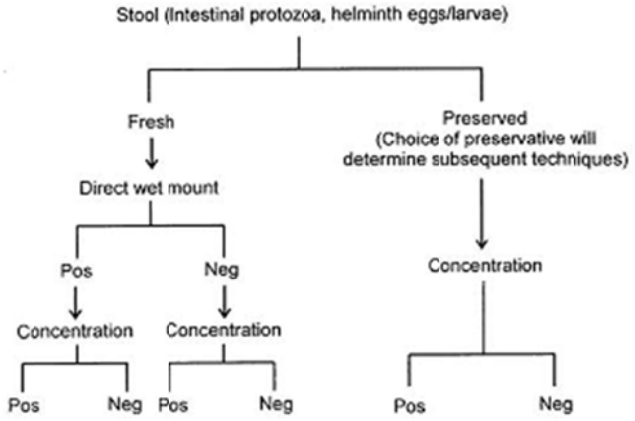

Figure 10. Workflow for faeces processing and the use of FEC
Garcia, L. S. (2016). *Diagnostic Medical Parasitology* (6th ed. [LCCN2015042284.Retrieved from http://estore.asm.org.doi:10.1128/9781555819002

Even though diagnosis of helminth infection in most developed countries is by the gold-standard K-K method, New Zealand still uses the FEC technique. The reason for this could be the low prevalence of worm burden in the country. Also, the health quarantine facilities are well equipped to discover and control parasitic infections with ease. However, multiplex PCR is used for diagnosis of protozoan parasites, which are single celled eukaryotes such as *Giardia lamblia, Cryptosporidium species*, *Entamoeba histolytica* and *Blastocystis species* etc.

1.9.3 STH diagnosis in CWMH, Central Eastern Division, Suva, Fiji

In CWMH microbiology laboratory in Fiji, diagnosis of STH is only by direct microscopy. This technique allows fast diagnosis as well as detection of helminth load for public health surveillance purposes. Even though a fresh sample is required, the laboratory receives stored and refrigerated faecal samples as well. Saline (0.5% NaCl) is the reagent of choice for wet smear preparation, and low-power examination (x10 or x40) of the smear is performed under the microscope (Figure 11).

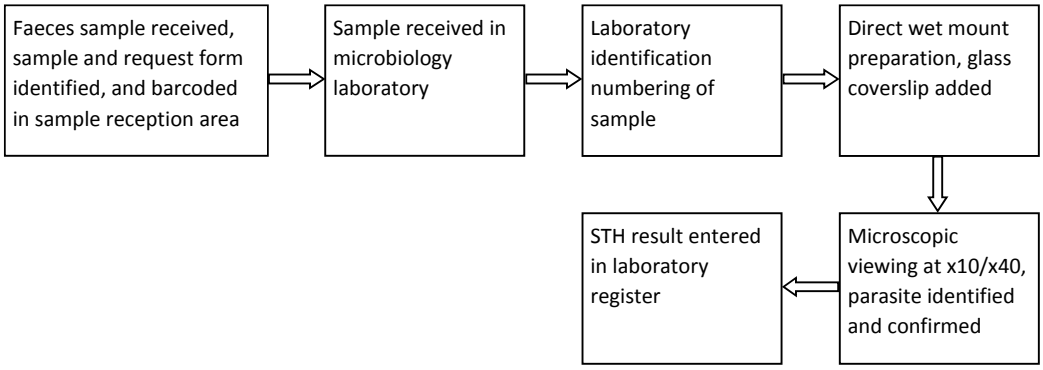

Figure 11. Workflow of STH diagnosis in CWMH microbiology laboratory with direct microscopy technique

Following discussion with microbiology laboratory staff at CWMH, it has been noted that the direct microscopy method is the only method used to diagnose parasitic infections in the hospital from 2008 to 2016. Averages of 75 stool samples per week are received in the hospital laboratory, which is also the major referral laboratory in the Central Eastern Division, and between 2 to 5 STH parasites are diagnosed. This excludes seasonal disease patterns, whereby more parasites could be identified after an outbreak of STH due to flooding or cross-infection. There is very little data available for STH prevalence studies as the country lacks published journal articles on parasitology research.

Studies have shown that the direct wet smear method does allow easier identification of *A. lumbricoides* compared to other STH parasites. Motility of *S. stercoralis* larvae can be seen with this method as well (Khurana & Sethi, 2017). However, this technique is not very sensitive in STH diagnosis. The uneven distribution of *Ascaris* eggs could be challenge with this method. Another factor to consider is the false-negative results. Some parasites may not being identified since only one sample is received from a patient instead of the WHO-recommended three consecutive day samples. This may affect the true prevalence of detection in laboratory as the actual picture of helminthic activity is not seen. Using direct microscopy methods may not give an accurate result if STH-suspected stool samples are coming from low-intensity areas of parasitic infection of patients after treatment (J. T. Coulibaly et al., 2016; Garcia, 2016; Ricciardi & Ndao, 2015).

The freshness of faecal samples does affect the direct wet smear also. This method is reliant on fresh and unpreserved sample for good results. However, since most of the

samples that come to CWMH from peripheral healthcare settings are not fresh, parasite identification could be a challenge due to storage and transportation effect of the sample.

1.10 Qualification framework for medical laboratory scientists in Fiji

In Fiji, medical laboratory diagnostic procedures are undertaken by scientists or technologists. Becoming a medical laboratory scientist requires a four year Bachelor of Medical Laboratory Science (BMLS) degree, which is provided by Fiji National University, College of Medicine, Nursing and Health Sciences. After graduation, students complete a one-year internship/apprenticeship attachment programme in either CWMH or Lautoka hospital pathology laboratory department. The internship programme gives hands-on training in the main departments of the laboratory major laboratory, supervised by senior scientists/technologists. Apart from the academic qualifications, registration is needed to practise in the laboratory. Professional registration is given by Fiji Institute of Medical Laboratory Science (FIMLS). Furthermore, an Annual Practicing License is required to undertake diagnostic procedures in the laboratory, which is provided by the Fiji Allied Health Practitioners Society (Ministry of Health), under the Allied Health Practitioners Decree, 2011. The ministry has an annual appraisal system in place to monitor competence levels of laboratory staff (Fiji, 2011).

As part of continuous quality improvement and competence assessment in CWMH laboratory, staff undertake internal and external quality assurance programmes (EQA). The use of in-house quality control samples and parasitic smear slides aid in routine laboratory work. As part of external quality assurance programmes, staff undertake Pacific Paramedical Training Centre (PPTC) assessments as well as the RCPA assessment of specimens. PPTC assessments are done 4 times per year, while RCPA assessments are done every month.

1.10.1 Competency shortfalls that may affect STH diagnosis

In CWMH microbiology laboratory, faecal samples are processed daily as part of routine procedure. All the staff performs parasitology testing on a rotational basis, whereby there are no permanent specialist personnel. This may affect STH diagnosis as there are chances of misdiagnosis. Detection of helminth eggs can be time consuming

and requires a highly skilled scientist for the examination of faecal samples (Ricciardi & Ndao, 2015). Experienced scientists can easily identify eggs and larvae; however, these could be easily missed by poor training skill set. Turner et al. (2017a) suggests that a laboratory scientist's lack of ability could affect the outcome of STH results. The challenge arises when technicians are unable to detect helminth eggs in post-treatment stool samples, and in samples with less worm burden. In CWMH laboratory, the problem further escalates when there is higher workload and competent senior staff members are absent. This could potentially lead to STH parasites not being detected. Amoah et al. (2017) informs on weakness present in conventional techniques such as microscopy based investigations. As well as being less sensitive, the author suggests these procedures are time consuming and require more labour and skills.

The saline solution is prepared manually by laboratory workers, which may have an adverse effect on parasite identification. There is no quality control followed for the preparation of saline solution used for direct microscopy technique, which may affect the sensitivity of the technique.

Due to overfilling or leakage of stool sample containers, some faecal samples are not processed as per laboratory guidelines. This reduces the chances of successful parasite detection, due to inadequate handling or storage of samples.

There are fewer opportunities available for continuous development within the profession. This limits the acquisition new knowledge in the work environment. There is also a high staff turnover rate, many experienced staff members have a high migration rate due to being overworked and underpaid. In house workshops or training provided to laboratory personnel could supplement motivation for learning new techniques, which could improve the helminth diagnosis process.

Within the laboratory, there are no clear job descriptions and microbiology staff are expected to master all diagnostic procedures. This may, for example result in staff performing competently on urine processing techniques while being less competent in parasitology work.

The standard operating procedure (SOP), which provides the guidelines for laboratory processing of samples, has not been recently updated with new and improved techniques. For STH diagnosis, direct microscopy is the only procedure used in microbiology laboratory. Despite studies showing this technique is not as sensitive as the FEC method, it has never been implemented as the laboratory SOP.

On the contrary, it is a requirement under ISO15189 Code of Practice for laboratory personnel to have a clear job description outlining the expected tasks for routine and emergency laboratory work. Management needs to improve and update its current laboratory procedures to meet the world standards. According to WHO, clinical laboratories are required to follow laboratory quality management system (LQMS) standards to keep in line with the changing diagnostic processes and demand for disease detection (LQMS, 2018).

Fiji lacks locally published research articles on distribution and prevalence in human parasitology and the impacts associated with it. There is very little evidence of monitoring STH in at-risk areas.

1.11 Descriptive analysis and retrospective study preference in STH prevalence

For epidemiological studies in health science, descriptive study design allows researchers to observe the possible risk factors of a defined population, or groups of subject from a population, so possibility of disease outcomes could be measured. Other literatures have suggested that descriptive studies aid in generating hypotheses, and simplify understanding population and disease. Some basic characteristics of descriptive studies of at-risk population include the age, sex, occupation, geography and time related to diagnosis and reporting of disease as outcome (Munnangi S & Boktor S.W, 2018).

Descriptive analysis uses prospective, retrospective, and if possible current data to inform on disease distributions and trends with respect to risk factors associated with it. The data are analysed and presented in terms of ratios, proportions, percentages, and rates; presented positive detection rates, incidence rates and prevalence rates (Weinger et al., 2003).

In Italy, a retrospective study from 2006-2011 was conducted at Infectious Disease clinic teaching hospital, Ancona. 5.7% patients were found to be harbouring at least one intestinal parasite, and detection rate was 48/5323 (0.9%) (Silvestri, 2013).

A laboratory-based retrospective data study in St Lucia was conducted using direct smear and 10% formalin concentration technique. Analysis of retrieved data from years 2002-2005 revealed high prevalence of intestinal parasite which was 13.3%. The prevalence was at 95% - confidence interval (CI) between 11.5% – 15.1%. Hookworm had the highest prevalence of 4.8%, followed by *S. stercoralis*, 2.9%, while *A. lumbricoides,* and *T. trichiura* had 2.5% respectively (Kurup, 2010)

Strengths of descriptive studies are that they are simple and easy to conduct. Most health related outcomes are assessed by this design as it provides a general exposure pattern rather than at individual level. Weaknesses of the study are lack of appropriate data and presence of lot of variable factors affect researchers control on study outcomes (Weinger et al., 2003).

1.12 Statistical analysis used globally for STH studies

In a 2018 study done in Thailand, Yanola et al. (2018) attempted to estimate the current prevalence rate of intestinal parasites in school-aged children. Data was analysed to find an association between parasitic infection and haematological and nutritional aspects. Fisher's exact test or Chi-square (X^2) was used to analyse variables (in which any character in data can be counted). One-way analysis on variance (ANOVA), *t*-test, *p*-values and confidence intervals (CI) were also used to calculate the prevalence rate.

In an Ethiopian study on STH prevalence in school children and vervet monkeys (*Chlorocebus aethiops*), Microsoft Office Excel 2007 package was used to collect data, which was analysed using data-analysis and statistical software (STATA). Z-statistics were also used, which helps measure two scores within data, since two laboratory-based diagnostic tests were also compared, the K-K and FEC methods (Teklemariam, Legesse, Degarege, Liang, & Erko, 2018).

In a Sri Lankan prevalence study on the association of *A. lumbricoides* with malnutrition, demographic and descriptive data analysis was performed using a

statistical package for the social sciences (SPSS) software version 17 (SPSS, Chicago, IL, USA). AnthroPlus 1.0.4 and Epi Info 3.5.1 (Centres for Disease Control and Prevention; Atlanta, USA) were also used. Chi-square (X^2) was used to analyse variables (age, gender, etc.). One-way analysis on variance (ANOVA), *t*-test, *p*-values and CI were also calculated. Multiple linear regressions, a model used to compare two or more variables, was used to find associations between the intensity of *A. lumbricoides* infection and nutrition patterns (Galgamuwa et al., 2018).

In a study carried out in central Africa, M'Bondoukwé et al. (2018) used frequencies (%) and Gaussian distribution to analyse sociodemographic data for its participants to compare malarial and STH parasite prevalence. Chi-square was used to measure frequency for different age groups and locations of participants. (ANOVA), *t*-test, *p*-values and confidence intervals (CI) were also used to find associations between the two parasite groups in context to age, sex, education level and socioeconomic status. Logistic regression was also used to find the odds ratio (OR) to estimate the strength the association. Furthermore, STATA version 13 (StataCorp, College Station, TX, USA) was used for data analysis.

In a cluster-randomised intervention trial in south-central Côte d'Ivoire, West Africa, the authors intended to study the epidemiology of intestinal parasites and its risk factors. A cluster-randomised intervention trial was performed, which is a form of randomised controlled trial research design whereby a group of subjects (instead of individual subjects) are randomised (chosen randomly). EpiInfo version 3.5.4 and STATA version 11.0 was used for data analysis (G. Coulibaly et al., 2018).

Hence, Jackson (2015) suggests there is no standardised statistical package used for analysis but multiple packages are used.

1.13 Parasitic zoonotic risk associated with STH

Zoonotic disease is caused by infection that can be transmitted between animals and humans. Domestication of animals such as dogs, cats, cattle, pigs, sheep and horses has led to a higher risk of parasite transmission to humans. In humans, protozoan parasites are common pathogens. These include *C. parvum, G. lamblia, Entamoeba polecki, E. histolytica, Toxoplasma gondii, Balantidium coli, Cyclospora cayetanesis* and *Blastocystis hominis*. Zoonotic helminths that infect humans include nematodes:

Ascaris suum, Trichinella papuae, and *Angiostrongylus cantonenesis*. Trematodes, which are intestinal flatworms, include *Paragonimus westermani*. Cestodes, which are called tapeworms, share the same taxonomic kingdom as trematodes. Common zoonotic cestodes are *Hymenolepsis nana* (*H. nana*) and *H. diminuta* (Bowen, 2016; Owen, 2005).

In Australia, the first zoonotic nematode infection associated with humans was reported in 1998. *Haycocknema perplexum*, found be transmitted by native animals, was linked to a rare cause of parasitic myositis, which causes muscle inflammation in humans. On the island of Tasmania, *Baylisascaris tasmaniensis*, spread by Tasmanian marsupial carnivores, is an emerging zoonotic disease (Bradbury, 2015).

In NT Australia, a retrospective study based on 12-year observational analysis in a public hospital revealed a high detection rate of cestode infection caused by *H. nana*. The authors have identified that *H. nana* is common in the indigenous population, especially for children <5 years old (Willcocks, McAuliffe, & Baird, 2015).

In New Zealand, sheep flocks have shown anthelminthic resistance in farms. A sustainable control tool termed “Refugia” is used to maintain less resistance to treatment in sheep. In the “refugia” process, the sheep is not exposed to drenching or oral administering of anthelminthic drugs. This allows some nonresistant worms to stay inside the animal for breeding purposes, which later supports dilution of resistance impact (Leathwick, 2014).

In PNG, Owen (2005) highlights potential risks associated with importation of domestic animals from nearby countries. The author suggests this may lead to introduction of cestodes, *Taenia solium* and *Echinococcus granulosus* and the nematode *A. suum*. Concerns about activity of zoonotic helminths were evident. Improving human hygiene, water supplies and thorough cooking of meat reduces infection risk.

1.14 Remoteness and accessibility issues with rural healthcare

Studies have highlighted the challenges that rural and remote communities face in accessing healthcare services. Geographical isolation of smaller health centres could possibly affect an individual’s ill health and the access for treatment. The concept of generalist care, unavailability of some prescription medications, together with the cost

and/or availability has been associated with inadequate access to health care in rural communities. (Bourke, Humphreys, Wakerman, & Taylor, 2012; Ursulica, 2016).

In Australia, Bourke et al. (2012) highlights the challenges of healthcare workers in rural settings and remote community hospitals. Even though doctors, nurses and other health professionals have high autonomy and enjoy collaboration with community members in their care, the struggle with increased on-call hours and multi-tasking demands due to increased health problems in rural communities. Lack of opportunities for professional development due to financial constraints and difficulties in retaining new staff pose a challenge in rural healthcare delivery of quality service.

Chapter 2 Topic

2.1 Research Question

Current data on the prevalence of intestinal helminth infection in Fiji is scarce (Kim et al., 2016). In the Oceania region, ascariasis, trichuriasis, and hookworm infections are prevalent, while the epidemiology and importance of parasitic infection caused by *Strongyloides stercoralis*, strongyloidasis, is not well known (Kim et al., 2016).

STH infection in the Central Eastern Division is determined by testing in the diagnostic laboratory located at Colonial War Memorial (CWM) hospital in a subdivision in Suva. With more than 30% of the population below the poverty line, data on the health status of STH infection in Fiji is inadequate. Insensitive laboratory diagnostic technique suggests limitations exist in positive detection and STH infections maybe underreported (Kim et al., 2016). There is no published data on STH infection and its association with NTDS, which limits information on trends relating to morbidity and efficacy of helminth control programmes. Very little parasitology research is done in Fiji. Inactive surveillance and inefficient mandatory reporting systems have been linked to poor STH estimations of the true burden of this disease (Martins-Melo et al., 2017).

2.2 Purpose and Research Objectives

The purpose of this research was to determine if CWMH reference diagnostic laboratory was using a sensitive and accurate STH examination technique and result reporting methodology in Central Eastern Division of Fiji. The major objectives of the research were to:

(1) Determine the prevalence of the STH helminths diagnosed at CWMH in Central Eastern Division from January 2008 to December 2016 according to data retrieved from the laboratory register.
(2) Identify the current laboratory techniques used for diagnosis of STH in Fiji and to compare these current recommended methods.
(3) Make recommendations to medical laboratories and the Fiji Ministry of Health to improve STH diagnosis.

2.3 Ethical Considerations

No ethical approval was needed from the AUT Ethics Committee (AUTEC) since the research did not include laboratory human sample analysis. To access patients' laboratory results for STH in Fiji, ethical approval for the research was obtained from the National Research Ethics Review Committee (FNRERC) based at the Ministry of Health and Medical Services (MOHMS), Suva. The ethics approval, FNRERC number: 2017.5.CEN could be viewed in Appendix A. Further approvals were obtained from the Fiji Ministry of Education (MOE) to carry out postgraduate research. Since data registers are kept at CWMH, approval was sought from the medical superintendent, the laboratory superintendent and the head of department for microbiology for use of their premises for data collection. All data received were treated as highly confidential, and were removed upon completion of the research work. AUTEC were notified once approval was given by respective authorities in Fiji.

Chapter 3 Methodology

3.1 Geographical Location of Study

The present study was undertaken at CWMH, in Suva, Fiji, which is the largest and oldest public hospital and referral health facility in the Central Eastern Division of Fiji. The hospital is located between 18° south latitude and 178° east longitude in the southern hemisphere (The Fijian Government, 2013). Apart from its health service delivery, CWMH also provides referral support for 6 subdivisional hospitals, 15 health centres, and 31 nursing stations within the Central Eastern Division, which includes the nearby smaller islands (Ministry of Health & Medical Services, 2014).

3.2 Study Design

Retrospective studies use existing data, which are used to assess the potential risk of exposure to a disease and the consequences of having the illness as an outcome (Hess, 2004). The present research was a retrospective study with the use of descriptive analysis of retrieved data from laboratory records for STH cases. Laboratory data were based on all faecal samples received from Central Eastern Division's health facilities that requested for STH investigation in CWMH microbiology laboratory over 9 years (2008-2016). The diagnosed results included of the 4 mentioned STH helminth parasites (*A. lumbricoides*, *T. trichiura*, hookworm and *S. stercoralis*) that were positively detected and identified. In the microbiology laboratory, confirmation of the presence and/or absence of STH helminth parasites is done by microscopic investigation of patient stool samples with the use of the direct microscopy method (Garcia, 2016). Data of the results were manually retrieved from microbiology laboratory registers in CWMH. The research focussed on achieving the requirements of the 3 objectives of the present study with respect to presence of STH and its detection in Central Eastern Division.

3.3 Retrieved Data Collection Strategy

The first objective of the study aimed to determine the detection and distribution of 4 STH parasites successfully diagnosed in CWMH microbiology laboratory over 9 years (2008-2016). Data for positively results were manually retrieved from laboratory registers according to the demographic distribution, which included

patients' age, gender, ethnicity, type of sample sent for investigation, the clinical history and symptoms, and the location of the health facility visited. Additionally, the positively identified parasite was recorded as well. Figure 12 summarises the process used in the present study.

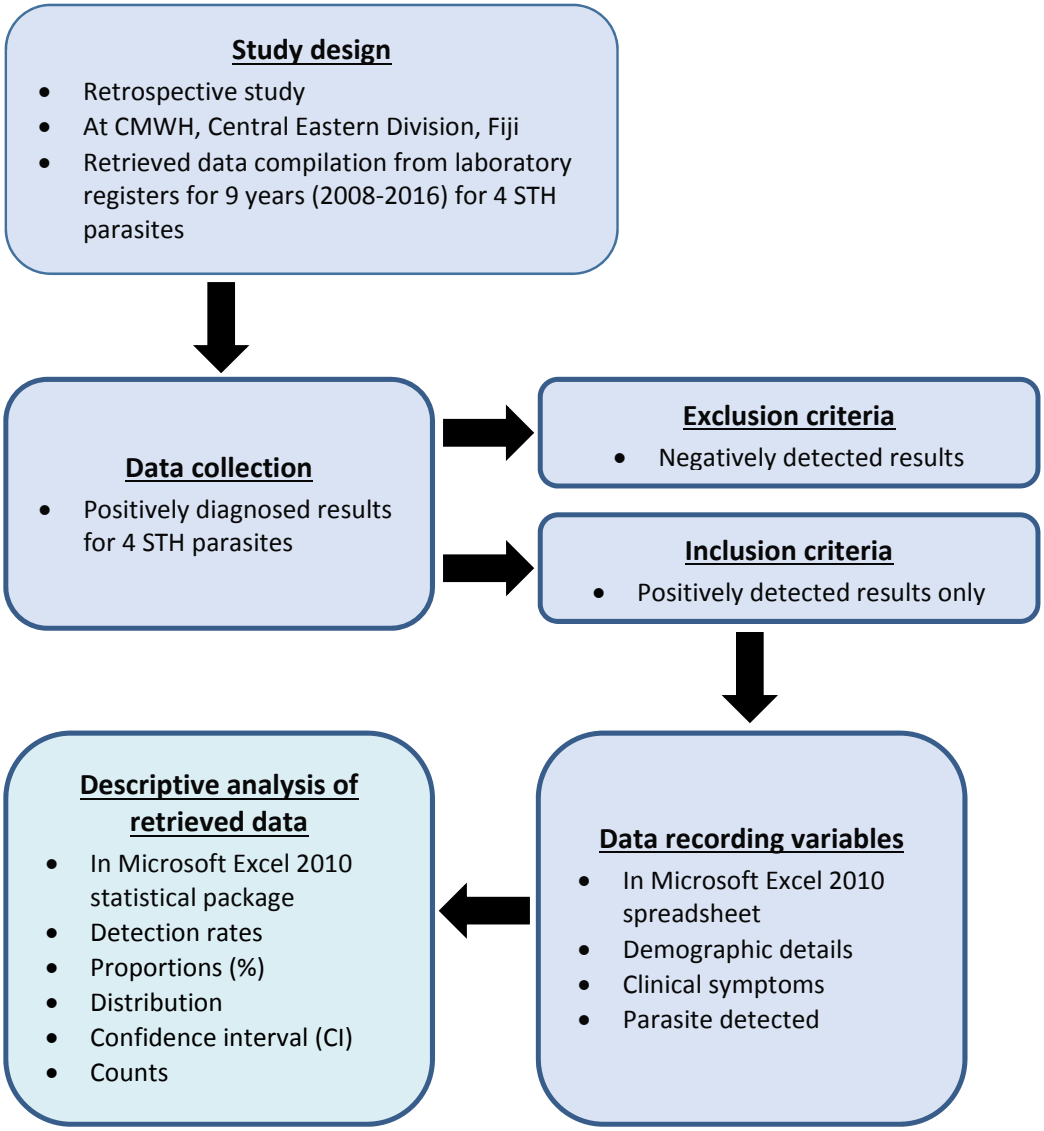

Figure 12. Outline of the study design

3.3.1 Inclusion criteria

The data included the recording of positively detected and diagnosed STH results only, which were for samples received in microbiology laboratory.

3.3.2 Exclusion criteria

Recording of data did not include stool samples that were negative for STH.

3.4 Data Collection Recording Procedure

Primary or raw data from the laboratory register were recorded in a Microsoft Excel 2010 spread sheet. The patients' details were recorded under the following variable characteristics during data retrieval for easier understanding:

- Month/year for which data were retrieved
- Patient code (to maintain patient result confidentiality)
- Demographics (age, gender, ethnicity, location of the healthcare setting where sample was taken)
- Clinical symptoms presented
- Sample type
- Initial sample or control sample (post-treatment)
- Type of laboratory test requested
- STH parasites detected (*A. lumbricoides, T. trichiura*, Hookworm, *S. stercoralis*)
- Single infestation/multiple infestation/other family members infected

3.5 Data Analysis

Descriptive analysis of retrieved data were analysed at Auckland University of Technology (AUT). The Microsoft Excel 2010 statistical package was used to analyse data to find detection rates, counts, distributions and trends, confidence-intervals (CI) and proportions (%). Descriptive analysis was convened to identify single/multiple infestations, presence/absence of symptoms, first isolation or controls after treatment, and individual patients and other families infected. Information from relevant literatures such as Polgar (2008) and (Buka, Rosenthal, & Lacy, 2018), provided statistical formulas to be used in descriptive analysis.

Data were analysed with the support of a biostatistician at AUT under the following criteria:

- Detection rates of STH positive results per 10,000 stool samples at CWMH from 2008-2016
- Summary of STH parasites identified according to years 2008 -2016 in CWMH
- Distribution based on count of STH parasites at CWMH from 2008-2016
- Age distribution of positive STH diagnosed cases at CWMH from 2008 -2016

- Gender distribution of positive diagnosed STH cases at CWMH from 2008 -2016
- Distribution of STH parasites identified according to ethnicity at CWMH from 2008-2016
- Distribution of the 4 STH parasites identified according gender and ethnicity characteristics at CWMH from 2008-2016
- Summary of signs and symptoms presented in STH positive cases diagnosed at CWMH from 2008-2016

After analysis of data, they were further interpreted and presented in terms of tables and graphs.

3.6 Data Confidentiality, Storage and Management

For confidentiality and safety of data storage, all relevant retrieved and research-related data was kept in computer files and external hard drives. The computer files were password-protected, while the hard copy folders were accessible only to the researcher of the present study.

In presentations of the research work, personal identifiers such as codes and numbers would be used to present results, which would include group level information only. Strict data safety practice would be maintained for the submission of the manuscript for publication and dissemination.

3.7 STH Diagnostic Comparison Visit to Labtests and LabPlus, New Zealand

The second objective was focused on comparing laboratory techniques for diagnosing STH in Fiji with other recommended methods. To gain more of an understanding of STH diagnostic protocol in New Zealand, the researcher from present study visited the parasitology processing sections of two New Zealand-based laboratories in Auckland. Information about stool examination protocols and methods of identifying parasites in New Zealand laboratories was used to compare to the procedures used in CWM hospital, Fiji.

The first laboratory visited was Labtests, based in Mount Wellington, followed by a visit to LabPlus, based in Auckland City Hospital in Grafton, Auckland. According to International Accreditation New Zealand (IANZ), both laboratories are accredited

analytical pathology service providers, well structures within the quality standard requirements of NZS/ISO15189 (IANZ, 2018).

3.8 Globally Recommended STH Diagnostic Protocols

The third objective of the present study was related to improvement and recommendations required for parasite investigation in medical laboratories in Fiji. The STH diagnosis techniques used were identified and compared with global recommended techniques according to literature-based search using Scopus database at AUT library, Google scholar, Pubmed, and Hinari website search engines were also used.

Chapter 4 Results

4.1 Positive Detection Rate of STH per 10,000 Stool Samples in CWMH

A total of 12,020 stool sample results were retrieved from the microbiology laboratory registers in CWMH from 2008 to 2016, out of which 261 or (2.2%) (95% CI: 1.4-2.9) were positive for at least 1 STH parasite. The conceptual summary of the processes used in attaining the results in the present study can be seen in Figure 13.

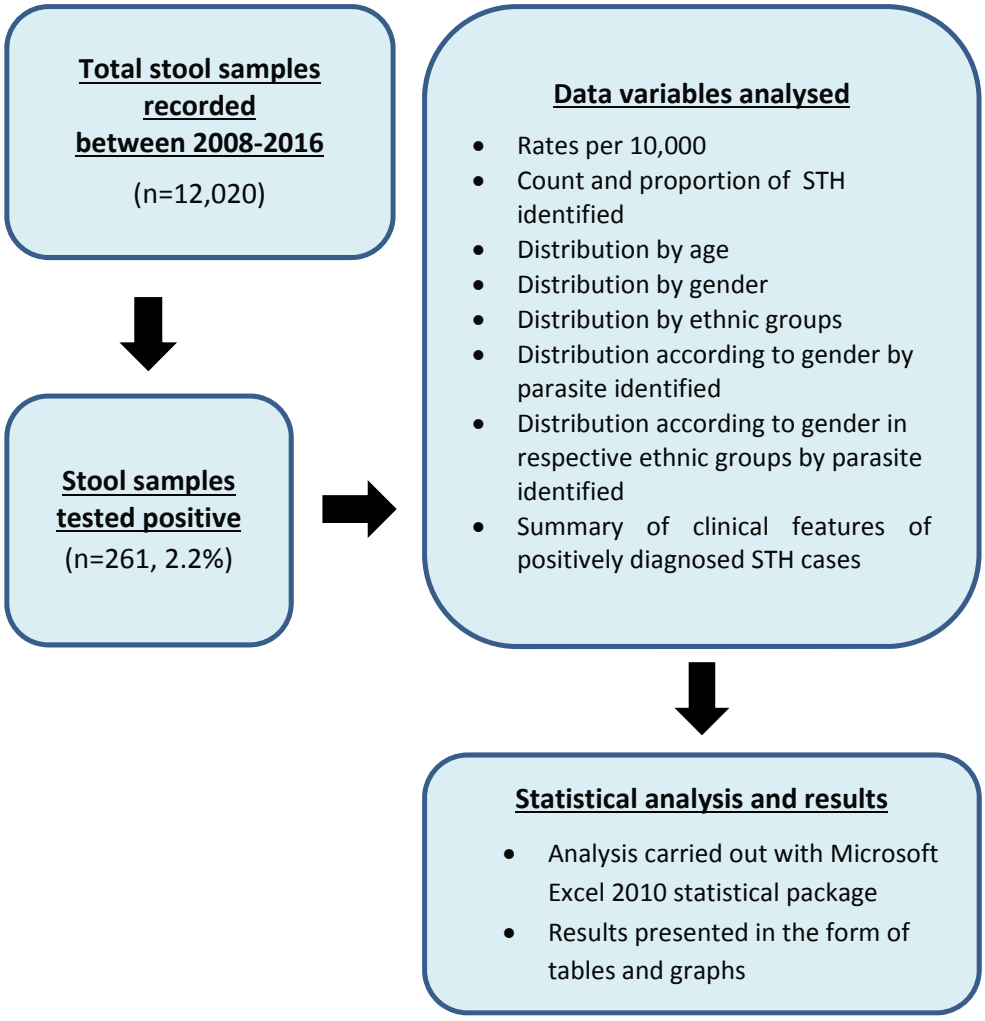

Figure 13. Strategy used for analysis and results

The data was presented as STH positives per 10,000 samples for easier validation and understanding (Table 1). The highest number of samples positive for STH parasite was found in 2014, which was 326 per 10,000 samples (95% CI: 240-420), followed by 2008 and 2011, which were 269.6 (95% CI: 190-350) and 250.2 (95% CI: 160-340) per 10,000

samples respectively. The lowest positive rate was seen in 2012, which was 102.0 per 10,000 (95% CI: 40-160) samples.

Table 1. Detection rates of STH positive results per 10,000 stool samples at CWMH from 2008 - 2016

Year	Samples	STH Positive Samples	Positives per 10,000 samples	95% CI (Min)	95% CI (Max)
2008	1,521	41	269.6	190	350
2009	1,111	19	171.0	90	250
2010	1,792	36	200.9	140	270
2011	1,159	29	250.2	160	340
2012	1,078	11	102.0	40	160
2013	1,273	23	180.7	110	250
2014	1,503	49	326.0	240	420
2015	1,221	23	188.4	110	260
2016	1,362	30	220.3	140	300
Total	12,020	261 (2.2%)	217.1	136	289

Note: CI = Confidence Interval.

A fluctuating trend was observed for the 9-year data presented for positive STH rates. Higher positive results (>200) were seen in 2008, 2011, 2014, and 2016 (Figure 14).

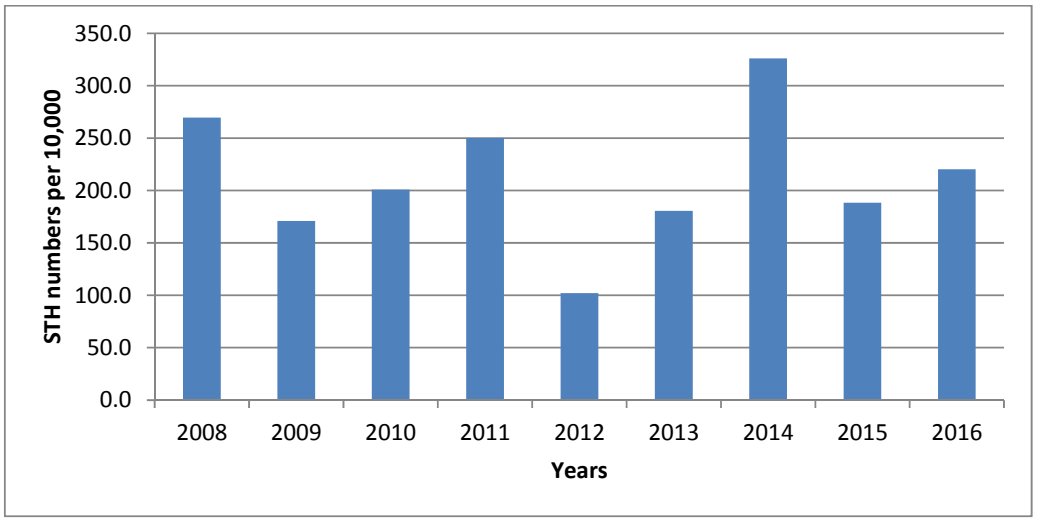

Figure 14. Detection rates of STH positive results per 10,000 stool samples at CWMH from 2008 -2016.

4.2 Count for STH Parasites Identified from 2008 to 2016 in CWMH

As shown in Table 2, *A. lumbricoides* was the most detected STH parasite in the microbiology laboratory in the 9 year period, where a total of 189 were found.

Hookworm was identified less often (61), followed by *S. stercoralis* (22) and *T. trichiura* (3). In 2014, *A. lumbricoides* was the most identified having a count of 37, compared to 2012 when only 8 were seen. Hookworm (*A. duodenale* and *N. americanus*) was the most detected in 2008, with a count of 19, and its least number was recorded in 2010, when only 2 were seen.

Table 2. Summary of STH parasites identified in CWMH from 2008 -2016

Year	*A. lumbricoides*	*T. trichiura*	*A. duodenale* and *N. americanus*	*S. stercoralis*
2008	19	-	19	6
2009	14	1	5	1
2010	31	-	2	2
2011	23	-	5	1
2012	8	1	3	-
2013	17	-	7	1
2014	37	1	10	5
2015	15	-	4	4
2016	25	-	6	2
Total	189	3	61	22

Note: Hookworm (*A. duodenale* and *N. americanus*).

Most *S. stercoralis* were detected in 2008, compared to zero in 2012. Equal number (n=19) of *A. lumbricoides* and hookworm parasites was found in 2008. There were no *T. trichiura* identified in 2008, 2010, 2011, 2013, and 2015-2016 (Figure 15).

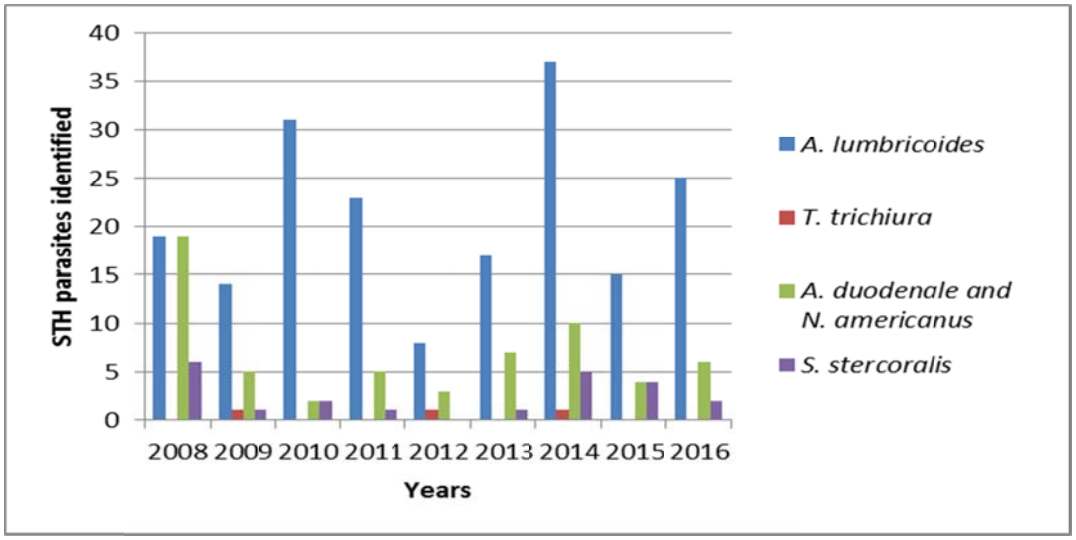

Figure 15. Summary of STH parasites Identified in CWMH from 2008 -2016. Note: Hookworm (*A. duodenale* and *N. americanus*).

4.3 Proportion of STH Parasites Identified According to Count in CWMH

From 2008 to 2016, 275 STH parasites were identified at CWMH, and there was a high number of *A. lumbricoides* seen which was 189 (68.7%). Hookworm was the second most identified parasite at 61 (22.2%), followed by *S. stercoralis* at 22 (8%), and the least identified was *T. trichiura* at 3 (1.1%) (Table 3).

Table 3. Distribution based on count of STH parasites at CWMH from 2008 -2016

STH Parasites	Count	Percentages (%)
A. lumbricoides	189	68.7
T. trichiura	3	1.1
A. duodenale / N. americanus	61	22.2
S. stercoralis	22	8.0
Total	275	

Note: Hookworm (*A. duodenale* and *N. americanus*). Percentages were calculated based on 261 positive STH samples (n=261).

4.4 STH Parasites Identified According to Age Groups in CWMH

From the perspective of age, STH were highest recorded for children <5 years old which was 85/261 (33%). STH positive cases for 5-14 year olds were 43/261 (17%); 15-24 year olds had the least positive results, 28/261 (11%) (Table 4). Almost equal proportions of 51/261 and 53/261 (20%) positive results were seen in the age ranges from 25-45 year olds and patients > 45 years. Even though *A. lumbricoides* detection was high amongst samples in all age groups, higher numbers were seen in children who were <5 years old, 70/261 (26.8%). Hookworm was the second most detected STH parasite amongst all age groups 61/261 (23.4%), but highest distributions were recorded for cases which were more in patients >45 years old 19 (7.3%).

Table 4. Age distribution of positive STH diagnosed cases at CWMH from 2008 -2016

Age	*A. lumbricoides*	*T. trichiura*	*A. duodenale / N. americanus*	*S. stercoralis*	Total	Percentages (n=261)
< 5 years	70 (26.8%)	-	11 (4.2%)	4 (1.5%)	85	33%
5-14 years	32 (12.2%)	1 (0.4%)	9 (3.4%)	1 (1.5%)	43	17%
15-24 years	22 (8.0%)	1 (0.4%)	4 (1.5%)	1 (0.4%)	28	11%
24-45 years	31 (11.8%)	1 (0.4%)	15 (5.8%)	4 (1.5%)	51	20%
>45years	24 (9.1%)	-	19 (7.3%)	10 (3.8%)	53	20%
Age not mentioned	10	-	3	2	15	
Total	189	3	61	22	275	

Note: Hookworm (*A. duodenale* and *N. americanus*). Percentages were calculated based on 261 positive STH samples (n=261).

However, it should be noted that there were 15 positive STH identifications that, did not have their age recorded in the laboratory register (Figure 16).

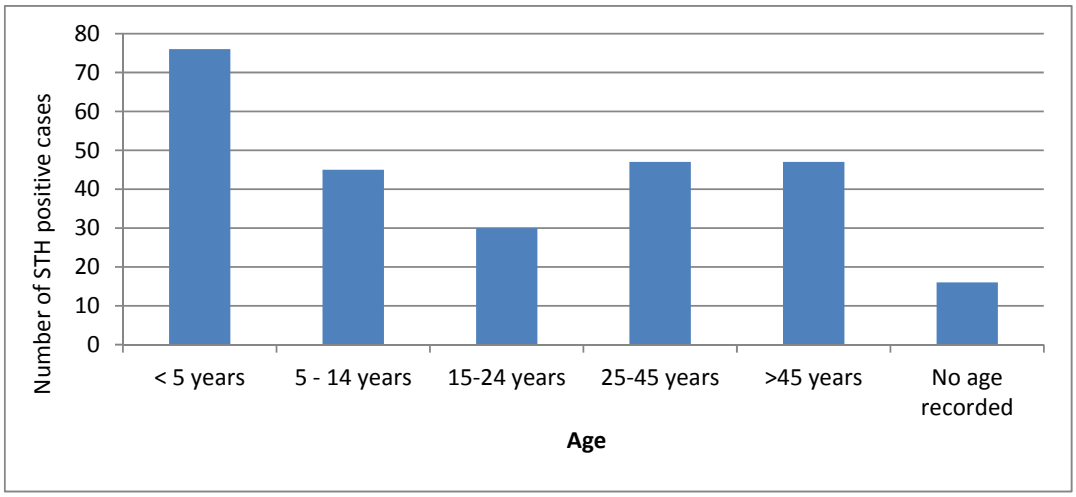

Figure 16. Age distribution of positive STH diagnosed cases at CWMH from 2008 -2016

4.5 Number of STH Parasites Identified According to Gender in CWMH

According to gender distribution of STH positive results (Table 5), more samples from male patients tested positive at 159/261 (61%), compared to samples from female patients at 101/261 (39%). Samples from male patients had the highest detection rate in 2008 and the lowest in 2012. Samples from female patients had the highest detection rate in 2014 and the lowest in 2012.

Table 5. Gender distribution of positive diagnosed STH cases at CWMH from 2008 -2016

Gender	Years										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total	(%)
Male	27 (10.3%)	10 (3.8%)	23 (8.8%)	19 (7.3%)	6 (2.3%)	17 (6.5%)	23 (8.8%)	13 (5.0%)	21 (8.0%)	159	61%
Female	14 (5.4%)	9 (3.5%)	13 (5.0%)	10 (3.8%)	5 (1.9%)	6 (2.3%)	25 (9.6%)	10 (3.8%)	9 (3.5%)	101	39%
Gender Not Mentioned	2	1	2	3	2	2	4	-	-	15	
Total	43	20	38	32	13	25	52	23	30	275	

Note: Percentages were calculated based on 261 positive STH samples (n=261).

However, there were 15 samples that were positive for STH, but had no information of gender in the laboratory registers. (Figure 17).

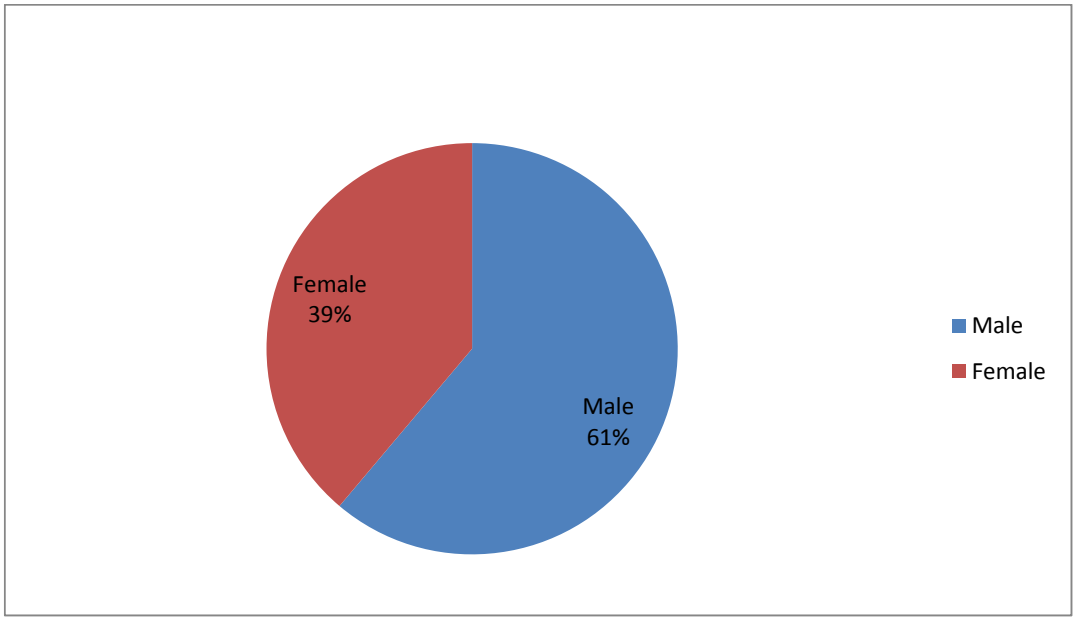

Figure 17. Gender distribution of positive diagnosed STH cases at CWMH from 2008 -2016

4.6 Trend of STH Parasites Identified According to Ethnic Groups in CWMH

From the 12,020 stool samples analysed, according to ethnicity distribution, Fijian (i-Taukei) had the most positive STH identifications at 242/261 (93%) (Table 6).

Table 6. Distribution of STH parasites identifications according to ethnicity at CWMH from 2008-2016

Ethnicity	Year										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total	(%)
Fijian (i-Taukei)	39 (14.9%)	19 (7.3%)	32 (12.3%)	27 (10.3%)	9 (3.4%)	20 (7.7%)	46 (17.6%)	20 (7.7%)	30 (11.5%)	242	93%
Indo-Fijian	2	-	4	2	2	2	2	2	-	16	6%
Others	-	-	-	-	-	-	1	1	-	2	1%
No information on ethnicity	2	-	2	3	2	3	2	1	-	15	
Total	41	19	36	29	11	22	49	23	30	275	

Note: Percentages were calculated based on 261 positive STH samples (n=261). Other races include Chinese, Europeans, part-Europeans, Rotumans, other Pacific Islanders, and all other races.

Indo-Fijian had 16/261 (6%) positive cases while 2/261 (1%) were for other races (Figure 18). There were 15 samples that were positive for STH, but had no mention of ethnicity in the laboratory register.

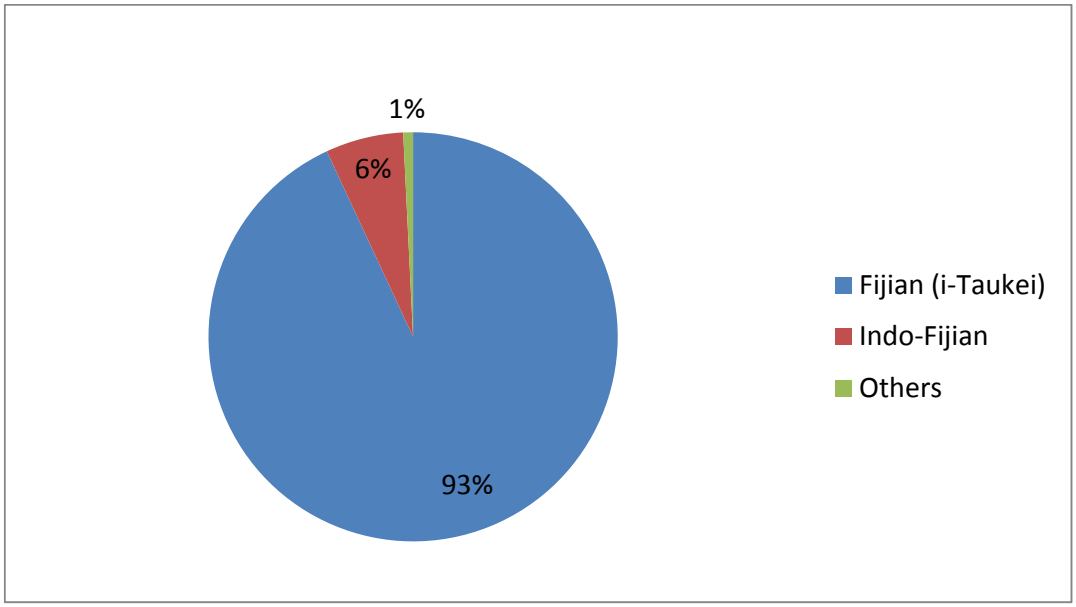

Figure 18. Ethnicity distribution of positive diagnosed STH cases at CWMH from 2008-2016

4.7 Distribution of STH Parasites Identified According to Gender in their Respective Ethnic Groups in CWMH

Further analysis of gender distribution data (Table 7), showed more male (i-Taukei) patients samples tested positive 133/275 (48.4%) compared to female (i-Taukei) patients samples 92/275 (33.5%). In samples from Indo-Fijian patients, more females had positive STH detection 13/275 (4.7%) compared to males 6/275 (2.2%). One male from the "other race" group had their sample diagnosed as positive for hookworm 1/275 (0.4%), while there were no positives for samples from female subjects of "other race" groups. There were 30 samples that were positive for STH but had no information of gender and/or race in the laboratory registers.

Table 7. Distribution of the 4 STH parasites identified according to gender and ethnicity characteristics at CWMH from 2008-2016

Gender	*A. lumbricoides*		*T. trichiura*	*A. duodenale / N. americanus*		*S. stercoralis*	Total	
Male (i-Taukei)	93	(33.8%)	1	28	(10.2%)	11	133	(48.4%)
Female (i-Taukei)	64	(23.3%)	1	20	(7.3%)	7	92	(33.5%)
Male (Indo-Fijian)	4	(1.5%)	0	2		0	6	(2.2%)
Female (Indo-Fijian)	7	(2.5%)	0	2	(0.7%)	4	13	(4.7%)
Male (Other races)	0		0	1		0	1	(0.4%)
Female (Other races)	0		0	0		0	0	
No information on gender and/or race	21		1	8		0	30	
Total	189		3	61		22	275	

Note: Note: Hookworm (*A. duodenale* and *N. americanus*).

Looking at the trend, the highest number of STH infections in i-Taukei samples were from *A. lumbricoides* infection where males were 93/275 (33.8%) and females at 64/275 (23.3%), followed by hookworm and *S. stercoralis* infections. In the Indo- Fijian samples, both genders were mostly infected by *A. lumbricoides*. Indo-Fijian females had higher *A. lumbricoides* infection 7/275 (2.5%) compared to males 4/275 (1.5%). *S. stercoralis* infections were higher in Indo-Fijian females 4/275 (1.5%) as compared to males of the same race. An equal number of male hookworm infections 2/275 (0.7%) were observed in both genders of Indo-Fijian subjects. There were less STH infections acquired from *T. trichiura* for both major races (Figure 19).

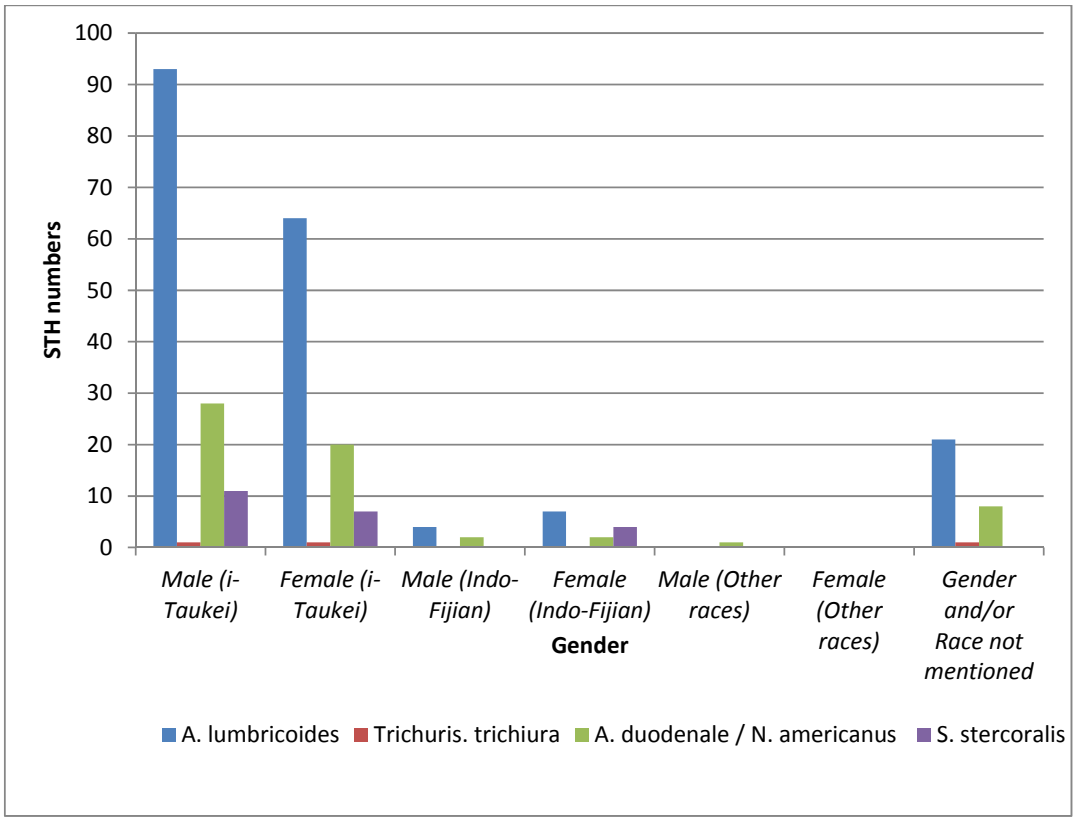

Figure 19. Distribution of the 4 STH parasites identified according gender and ethnicity characteristics at CWMH from 2008-2016. Note: Hookworm (A. duodenale and N. americanus).

4.8 Clinical Features of Positively Diagnosed STH Cases in CWMH

Clinical presentation of patients' signs and symptoms were summarised as per the laboratory register records (Table 8.0). In the 9 years analysed, most clinical presentations for STH stool analysis were for non-specific STH symptoms , 96/ 261 (36.8%). Non-specific symptoms included acute viral illness (AVI), typhoid, shigellosis, etc. Abdominal pain and/or acute gastroenteritis was the most specific symptom seen at 44/261 (16.9%), that led to a request for STH examination. This was followed by diarrhoeal symptom at 35/261 (13.4%).

Table 8. Summary of signs and symptoms presented in STH positive cases diagnosed at CWMH from 2008-2016

	signs and symptoms								
Years	Diarrhoea	Abdominal pain / AGE	Loss of appetite	Malnutrition	Abdominal bleeding / anaemia	Adult worms seen	Symptoms non-specific for STH	No signs and symptoms mentioned	Total
2008	3	5	-	-	3	-	22	8	41
2009	2	4	-	-	2	-	3	8	19
2010	4	8	-	-	4	1	13	6	36
2011	5	4	-	-	1	5	9	5	29
2012	2	2	-	-	-	1	3	3	11
2013	2	4	-	1	1	2	7	7	23
2014	10	8	-	1	3	1	16	10	49
2015	4	3	-	-	3	3	5	5	23
2016	3	6	-	-	-	1	18	1	30
Total	35	44	-	2	17	14	96	53	261
(%)	13.4	16.9	0%	0.8	6.5	5.4	36.8	20.3	

Note: AGE= Acute gastroentroentritis, has symptoms of diarrhoea and vomiting together: Non-specific symptoms include acute viral illness (AVI), typhoid, shigellosis, etc. Percentages were calculated based on 261 positive STH samples (n=261).

Other less common clinical symptoms were malnutrition, abdominal bleeding/anaemia, loss of appetite and adult worms seen. There were 53 laboratory test requests with no signs or symptoms specified (Figure 20).

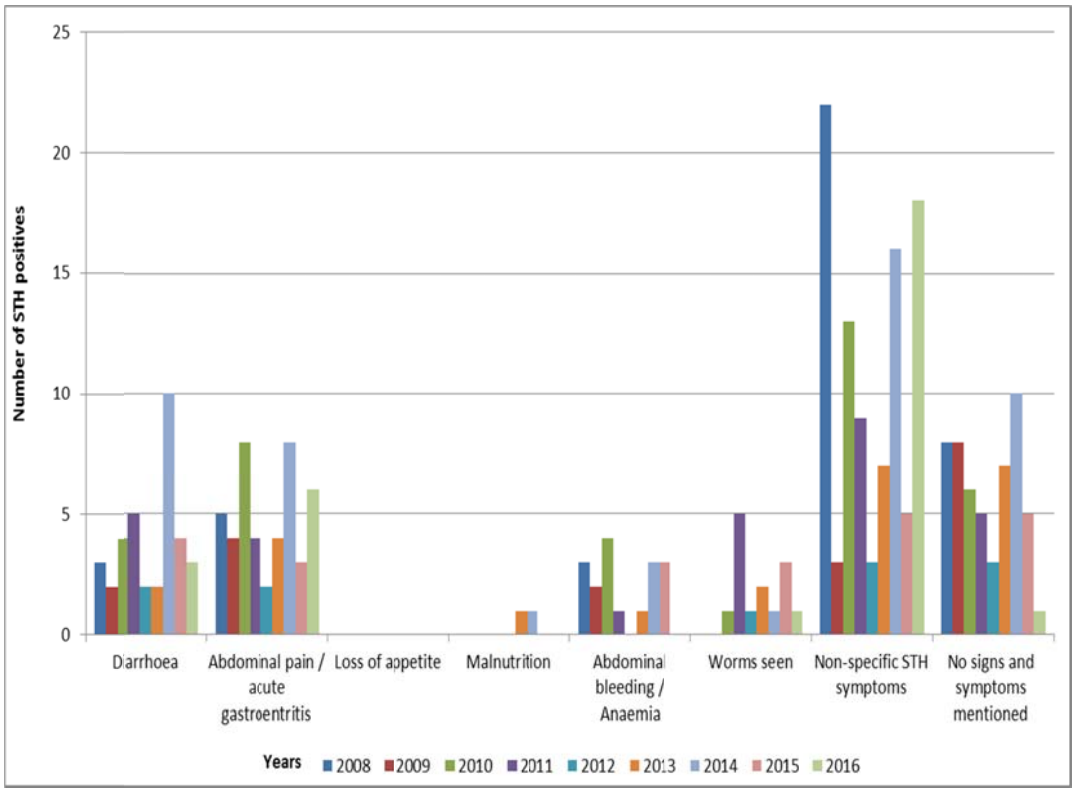

Figure 20. Distribution of signs and symptoms presented in STH positive cases diagnosed at CWMH from 2008-2016

Chapter 5 Discussion

Research studies on the distribution and prevalence of STH are necessary to understand the impact of this NTD in underdeveloped countries. These helminth infections affect approximately 1.5 billion people worldwide, and children are most at risk (Weatherhead et al., 2017). STH is mostly prevalent in rural areas, with overlapping geographical distributions. Poor sanitation conditions coupled with a humid and warm climate, favour helminth survival (Forrer et al., 2018; Oswald et al., 2017). The need for STH studies is important for Fiji to improve diagnostic capabilities, deworming protocols and prevention in at-risk areas (Kline et al., 2013).

5.1 Prevalence of STH in Central Eastern Division, Fiji, according to laboratory detection

The prevalence of STH was based on the detection rate of positive samples found using descriptive analysis. From the 12,020 faecal samples received in CWMH from 2008 to 2016, 261 samples were positive for the presence of the STH parasites. The positive detection rate was 2.2%. There were variations in positive results over the years. In 2008, 41 out of 1,521 faecal samples tested positive showing a detection rate of 269.6 per 10, 000 samples. However, in 2012, positive detection was 11 out of 1,078 samples with a detection value of 102 per 10,000 samples. This showed that an increase in samples did not equate to an increased rate of detection. Furthermore, the highest detection in the laboratory was in 2014 (326 per 10,000), while the lowest was in 2012 (102 per 10,000). The higher detection rate in 2014 could have been due to the occurrence of two tropical cyclones that affected Fiji. The first, severe tropical cyclone Ian, was a category 5 that affected the island on January 2nd, 2014 while the second, a category 3 severe tropical cyclone Lusi which came on March 7th (Fiji Metereological Services., 2018).

5.1.1 Variations in prevalence

Notable variations have been seen in the prevalence rate of intestinal parasites in developing countries. Thailand has a prevalence rate around 16%, Guinea had a rate of 53%, Ethiopia has a rate of 44%, and Turkey shows 88% (Daryani et al., 2017). In the present study, there was evidence of STH variability from 2009 to 2016 in Central Eastern Division of Fiji. The reason could include cultural differences, climate change

and the geographical locations of individuals as well as their access to healthcare. The rural to urban drift of population in Fiji may be a contributing factor for the increased demand in faecal testing. Since most of the native rural i-Taukei population live in clustered villages, the prevalence of cross-infection from infected and undiagnosed individuals would have been higher.

5.1.2 Distribution pattern of STH in Central Eastern Division, Fiji

The first objective of this study highlighted the prevalence of STH across the nine-year retrospective data analysis. In this thesis it was found that *A. lumbricoides* accounted for the highest number of intestinal helminth identified, which was 189 (68.7%). Hookworms were the second most detected parasite at 61 (22.2%), followed by *S. stercoralis* at 22 (8.0%) and *T. trichiura* at 3 (1.1%)). The highest parasite identified was *A. lumbricoides* in 2014, whereas hookworms were the second highest detected in 2008. Moser et al. (2017) highlighted that approximately 1.5 billion people get infected globally by at least one of the nematodes related to STH. The highest STH infections are from *A. lumbricoides* (820 million), followed by *T. trichiura* (470 million) and hookworm (420 million) (Moser et al., 2017). In this study, *A. lumbricoides* had the highest detection rate followed by Hookworm, then *S. stercoralis* and lastly *T. trichiura*.

In comparison to the geographic distribution of STH in Oceania, Fiji had the largest prevalence of trichuriasis, followed by hookworm and then ascariasis (Kline et al., 2013). However, this disagrees with the findings presented in this study. The reason could be that this study focussed on STH infections in the central-eastern division only, rather than the whole population of Fiji.

Furthermore, from a Nepal study by Singh (2013) it was found that STH detection rates were highest in hookworm (10.50%), followed by *A. lumbricoides* (5.72%), *S. stercoralis* (4.77%) and *T. trichiura* (0.95%) (Singh, 2013). Similar findings were also observed in this study where *S. stercoralis* (8%) and *T. trichiura* (1.1%) were less detected; however, *A. lumbricoides* (68.7%) was detected more than hookworm (22.2%). Interestingly, a higher prevalence of *A. lumbricoides* was seen compared to *T. trichiura*. One possible reason could be that *A. lumbricoides*' are able to withstand higher temperatures (> 40 ^{0}C) in the soil, and hence can survive extreme conditions whereas *T. trichiura* eggs cannot survive in higher temperatures (> 40 ^{0}C) in the soil (Oluwole et

al., 2017). The average temperature in Fiji is between 26 ^{0}C - 31 ^{0}C, meaning *A. lumbricoides* may have had a better survival chance compared to *T. trichiura*. Whereas for *S. stercoralis* infections a possible explanation could be that they have been overlooked or misdiagnosed, hence a poor detection rate.

Even though faecal diagnostic examinations using FEC, direct microscopy and K-K methods have been proven to detect eggs of STHs, these techniques have been less sensitive in detecting larvae. *S. stercoralis* larvae, which are the infective form of the parasite, need to be viewed under a microscope for a definitive diagnosis. Thus, using common faecal examination techniques could lead to misdiagnosis and hence *S. stercoralis* larvae may be overlooked. Many infections by *S. stercoralis* are of less intensity and the excretion of larvae is inconsistent, which may affect the true occurrence of the parasite (Ketzis & Conan, 2017). The findings in the present study show a lower detection rate of *S. stercoralis*; however a possible explanation could be attributed to the direct microscopy technique being the only method of diagnosis used in the microbiology laboratory in Fiji.

In a Canadian study by Dong et al. (2016) it was found that for *S. stercoralis* diagnosis, serological analysis showed positive detection rate of 6.1%, inconclusive result (unconfirmed) at 6.5%, and non-reactive (negative) results at 87.4%. Microscopy tests resulted in no larvae detection. However with qPCR testing showed 91.7% positive detection rate. The author highlights that qPCR is very sensitive for helminth testing. Evidence from other literatures show that stool microscopy may not be able to detect strongyloidasis in low worm burden cases, especially when immunosuppression is not present. In these cases serology methods could be used instead. In contrast, hyperinfections have been known to produce false negative serology results (Dong et al., 2016).

In India, researchers looked at 39 published reports for a literature review and meta-analysis study to find the prevalence of STH in India. The PRISMA (Preferred Reporting Items for Systematic Review and Meta-analysis) guidelines were used to gather publications from 19 different states from the period 2000 to 2015 on STH. Almost 90% of reported studies showed the presence of more than one type of STH species within the same population. *A. lumbricoides* had the highest prevalence rate of (>50%)

from six different states (Salam & Azam, 2017). This finding agrees with the findings of the present study, where *A. lumbricoides* was frequently detected.

In a cross-sectional survey in rural Philippines, Ross et al. (2017) found that parasitic prevalence rates of *T. trichiura* were higher (61.8%) than *A. lumbricoides* (36.5%) and hookworm (28.4%). However, harbouring of STH helminths had a higher prevalence rate of 75.6 %. However, almost 54% of children were infected by some form of STH. Authors previously found a link between the co-infection risks with STH helminths and their negative impact in children. The authors found that presence of more than one parasite infection has the potential to affect the nutritional well- being of children. As a result, intake of energy gets lowered and essential vitamins B complexes such as riboflavin and thiamine are affected (Ross et al., 2017).

In Ethiopia, a 2 month multi-level regression analysis was conducted on population-based data to find STH prevalence for school-aged children (6-15years). The researchers found prevalence of hookworm infection to be higher at 22% (95% CI: 20-24%), compared to *A. lumbricoides* at 14% (95% CI: 13-16%), and *T. trichiura* at 4% (95% CI: 4-5%) (Oswald et al., 2017). A similar trend was also seen in a study in Democratic Republic of Congo. School-aged children (9-15years age) had faecal examinations for the detection of STH using the K-K technique. A higher prevalence of hookworm was noted at 51.62% (95% CI: 32.40 -71.50%), the second most parasitic infection rate being *A. lumbricoides* at 15.77% (95% CI: 0.5-39.6%), followed by *T. trichiura* at 13.46% (95% CI: 0.5-33.20%) (Kabore et al., 2017).

In Brazil, a 12 year population-based research study was conducted that focused on STH-related mortality. Ninety-seven percent of parasitic deaths were due to ascariasis, and 2.9% was due to hookworm, and 0.1% due to trichuriasis. This agrees with the findings in the present study, where a similar distribution pattern of helminths was noted (Francisco et al., 2017).

5.1.3 STH distribution by age groups

According to age distributions of positive STH cases, there were variable results seen in this study. STH parasites were highest among patients aged < 5 years (33%). In contrast, primary school-aged children (aged 5-14 years) were infected 17%, while 15-

24-year old age group were infected 11%. The second highest age groups infected by STH were 24-45 age group and > 45 year age group which was 20%.

In the Marshal Islands, Liao et al. (2017) found school children (aged 9.73 ± 2.50 year old) had 17.6% prevalence of *T. trichiura* infections which agrees to the similar findings of the present study in regards to 17% detection rate in 5-14-year old children.

In Yemen, the highest infection rate was in the 10-11-year old group (31.8%), followed by 12-13-year old children (28.4%). The authors findings showed *A. lumbricoides* was highest (14.3%), followed by *T. trichiura* (9.3%) and *S. stercoralis* (0.8%) (Alsubaie et al., 2016).

In contrast, a study in NT Australia revealed that S. stercoralis was detected in 163 out of 164 (99.4%) children < 5years old (Mayer-Coverdale et al., 2017). In the present study, a high S. stercoralis count for similar age cohort was not observed since Fiji has a higher A. lumbricoides worm load compared to NT Australia which had higher prevalence of S. stercoralis.

In accordance with age group distribution in this present study, infections from *A. lumbricoides* (189/ 275) were highest in children < 5years old in terms of detection in the laboratory as expected. This is followed by hookworm (61/ 275), *S. stercoralis* (22/275), while the least detected is *T. trichiura* infections (3/275).

In Nepal, a study was conducted to find the distribution pattern of intestinal parasites for patients attending the Nobel Medical College Teaching hospital. The Highest prevalence was seen in patients aged 5-14 years (20.66%), followed by > 45 years age group (16.20%) and least in children aged < 5 years (Singh, 2013). In contrast, findings in this study showed the highest infection rate were in patients < 5 years (33%) and lowest in patients aged 15-24 years (11%). Comparatively, a higher detection rate of STH (especially *A. lumbricoides*) was seen amongst preschool and school-aged children (<5 years- 14 years) as expected. Studies have shown that hookworm and *T. trichiura* have shown some resistance to antihelminthic drugs, but regular deworming and improved education on hygiene practices could help in decrease the chance of reinfections (Liao et al., 2017).

In comparison, Ntonifor et al. (2016) found prevalence of STH was highest in the middle-age population (21-50 years) which was 55.44%, while the 6-12-year age group had lowest prevalence (30.38%) in a study convened in Cameroon. The highest intensity of infection was noted in middle-age group, which was (113±24.8), compared to 6-12-year group who had low intensity (20.95±9.33). Toilet use and age were predictors of the study. The findings show that the use of a jetty-toilet, an inadequate defecation facility, increased the risk of infection in the higher age groups (Ntonifor et al., 2016).

Following treatment, reinfection in human hosts may be due to the inability to acquire immunity, which may be linked to exposure to the untreated reservoir of infection again. The reservoir for helminths is the natural environment in which it lives and reproduces, such as a human host (Sarkar et al., 2017). In Ethiopia, rapid reinfection was observed amongst school-aged children who underwent a three-month intensive deworming programme. STH prevalence showed increased reinfection by *A. lumbricoides*, 23.8%, *T. trichiura*, 26.2%, and hookworm, 1.0 % at 95% CI (Zerdo, Yohanes, & Tariku, 2016).

The eggs of *A. lumbricoides* have the potential to stay in soil in the infective stage for years. The sticky nature of the eggs allows easier attachment to raw vegetables and fruits. Helminth contamination and soil pollution can transfer *Ascaris* eggs through air or dust, which can infect individuals (Galgamuwa et al., 2018). The present study shows highest STH infection by A*. lumbricoides*, which may be suggestive of soil contamination and improper defecation practices in rural areas.

Weatherhead et al. (2017) while referring to Global Burden of Disease (2015) report, highlighted that the intensity of ascariasis and trichuriasis is highest amongst school-aged children (6 to12 years). In comparison, a higher prevalence of hookworm infection is common amongst adults. A MDA by using single-dose mebendazole or albendazole, was initiated in early 2005 by the WHO, and has been able to reduce the global prevalence of ascariasis by 12%. This has led to a further decline of 20% in standardised age rates, a method which compares and adjusts for the difference in population age. The same could not be said for trichuriasis and hookworm infections, where the effect of MDA control programme might be unachievable globally unless

the MDA is administered to the whole community (adults and young children) (Weatherhead et al., 2017).

In India, a mass deworming strategy trial was conducted to assess its effectiveness in reducing hookworm infection. The study suggested that an MDA strategy could be more effective if tried in a short period of time, especially in endemic areas where a long-term deworming programme might pose a challenge (Sarkar et al., 2017).

The WHO-recommended use of preventative chemotherapy as the current method used for control of STH in at-risk populations. However this does not prevent re-infections after treatment. This may lead to underreporting of actual prevalence pertaining to STH infections (Mationg et al., 2017).

In Iran, a meta-analysis study using children of preschool and school-age groups showed that school-aged children (5-15 years) are more at risk of STH infections compared to adults. Prevalence of intestinal parasites can be improved if proper sanitation facilities are provided. Health awareness, coupled with education on improved personal hygiene, can be a reducing factor in STH infections (Daryani et al., 2017).

Apart from inadequate hygiene and sanitation, children are more susceptible due to their immature immune system and increased contact with the soil. Having more contact with other children and domestic animals mean children are more at risk (Martins-Melo et al., 2017)

There is evidence from published journals showing an association between STH and sanitation levels based on household levels of latrine usage, rather than at a community level (Clasen et al., 2014). However from an Ethiopian cross-sectional survey, there was no evidence of association found between the prevalence of STH infections amongst school-aged children (6-15 years) and the use of community sanitation (Oswald et al., 2017).

STH has the capability of affecting the cognitive and educational performance in school- aged children. Studies have shown that children of the preschool age group do not receive STH deworming programme as routine treatment. Evidence suggests that children infected early in their life tend to have adverse effects in their later years of

development, as far as adolescence years. It has been recommended that periodic deworming be implemented to preschool children as well (Pabalan et al., 2018).

5.1.4 Gender-wise distribution of parasites

In this study, more males (61%) were observed to have STH infection compared to females (39%). From further detailed study of gender distribution, the highest number of STH infection in i-Taukei samples were from *A. lumbricoides* infection (males, 93/275 (33.8%) compared to females, 64/275 (23.3%), followed by hookworm ,then *S. stercoralis* infections and lastly *T. trichiura*. Furthermore, in the Indo-Fijian samples, both genders were mainly infected by *A. lumbricoides*, but females had a higher infection rate 7/275(2.5%) compared to males 4/275 (1.5%). *S. stercoralis* infections were higher in Indo- Fijian females 4/275 (1.5%), and had equal amounts of hookworm infestations 2/275 (0.7%) in both genders. There were low infection rates from *T. trichiura* for both major races.

In terms of gender distribution pattern of the helminths identified, *A. lumbricoides* was highy detected in the laboratory 189/275 (68.7%) compared to hookworms 61/275 (22.2%), *S. stercoralis* 22/275 (8%) and *T. trichiura* 3/275 (1.1%).

Ross et al. (2017), used mixed-effect logistic regression model to predict risk factors associated with STH. The findings show that apart from low socioeconomic status, poor sanitation, the proximity of people to water sources, occupation (such as farming and fishing) and male gender were quite likely to be good indicators of STH infection. Similar findings were seen in Australia's NT where more males > 5 years old (60.9%) to later old age cohort (55.5%) were infected (Mayer-Coverdale et al., 2017). This supports findings of this present study, where more male i-Taukei patients were infected than females. Most of the i-Taukei population are based near coastal areas and depend on food sourced from rivers and the sea.

There is evidence that more males are likely to be linked to STH-related death, but a study done in Brazil found no difference between genders in regards to mortality. However, a difference in prevalence between genders could be associated with close contact to water and soil and the level of exposure in infection (Liao et al., 2017; Martins-Melo et al., 2017).

5.1.5 Ethnicity distribution affected by STH

In this study, 12,020 faecal samples were further analysed according to ethnicity distribution. It showed that i-Taukei' population had the most positive STH identification of 242/261 (93%). Indo-Fijians had 16/261 (6%) positive cases while 2/261 (1%) were from other races. 15 patients' details did not specify their ethnicity details.

In the Central Eastern Division of Fiji, higher prevalence of STH infection among indigenous populations could be linked to limited access to health care facilities. These include the availability of transportation and the remoteness of their settlement, as most of the i-Taukei population are based in rural areas and smaller islands in the nearby maritime zones. The cost of seeing a doctor could be another factor that may determine early diagnosis and treatment. Martins-Melo et al. (2017), found an increase in helminth infections in rural indigenous children compared to school children in urban areas. The authors suggest the indigenous communities maybe vulnerable to STH infections. The increased risk of helminth infection maybe due to sanitary and health disparities, socioeconomic issues, remoteness and limited access to healthcare facilities which determines the complications associated with STH.

In the present study, agreement is observed with the findings of Mayer-Coverdale et al. (2017); where STH had been observed to be endemic in the Aboriginal (indigenous Australians) population, especially *S. stercoralis* infection. This intestinal parasite is common in remote communities in tropical states, which include Western Australia (WA), Queensland, NT, and Northern New South Wales (NSW).

5.1.6 Clinical symptoms of the positive STH cases

From the retrospective data collated, most clinical presentations stated on the request form was for nonspecific STH symptoms, 96/261 (36.8%). Nonspecific symptoms included acute viral illness (AVI), typhoid, shigellosis, etc. Abdominal pain and/or acute gastroenteritis was the most specific symptom seen, 44/261 (16.9%) that led to a request for STH analysis testing. This was followed by diarrhoeal symptoms, 35/261 (13.4%). Other less common clinical symptoms presented were malnutrition, abdominal bleeding/anaemia, loss of appetite and the presence of adult worms.

However, there were 53 laboratory test requests for patients with no signs or symptoms.

Martins-Melo et al. (2017) found that symptoms associated with the digestive system and parasitic infections were more likely to be linked to STH-related death. *A. lumbricoides* has been linked with symptoms such as malnutrition, peritonitis and intestinal obstruction. Terminal disease conditions have shown patients presenting with pneumonia, respiratory failure and sepsis, which may increase the complexity of STH infections. Higher malnutrition was evident in children with increased STH infection (Nelly et al., 2016). In this study, there were a lower proportion of patients who presented with malnutrition as a clinical symptom.

S. stercoralis infections possess a major challenge in immunosuppressed individuals. Patients may appear asymptomatic and eosinophilia may be absent. These patients, especially those on corticosteroid drugs, may be at a risk of developing hyperinfection syndrome, which involves rapid and uncontrolled multiplication of the parasite (Rego Silva et al., 2018). The increase in autoinfection has a high mortality rate of around 80%, mostly due to the unique life cycle of the parasite (Schär et al., 2016). Recipients of organ transplant have a higher risk of *S. stercoralis* infection. It is suggested that in order to avoid complications during transplantation, the donor and the recipient should be tested to rule out strongyloidasis (Nutman, 2017).

In comparison, findings in this study showed that a higher proportion of patients (36.8%) who undertook clinical examination had nonspecific diagnosis pertaining to diseases of the gastrointestinal system. This may be due to stool samples being routinely requested in cases such as typhoid which increase during outbreaks in Fiji. Furthermore, this could be due to passive detection of STH in smaller health centres, where stool samples are not routinely required. In the present study, 53 laboratory request forms had no signs or symptoms mentioned in them. This may have been due to incomplete entry of patients details by the doctors attending the patients in clinical settings, or non-entry of records in the laboratory register by laboratory technologists. Chen (2016) highlights that helminth have the capacity to cause unbearable chronic infections in hosts and yet show nonspecific clinical symptoms in helminth infections.

5.1.7 Co-infection risk to STH cases

Studies have shown that co-infections possess a risk to helminth diagnosis and treatment (Babamale, Ugbomoiko, & Heukelbach, 2018). In adults and children, the occurrence of *A. lumbricoides*, hookworms and *T. trichiura* are considered the most common parasitic infection. In children, the consequence of co-infection with more than one parasite and increased parasitic load has been associated with growth retardation and slow cognitive development (Forrer et al., 2018; Houmsou et al., 2015). Ortu et al. (2016) found that similar to other contagious diseases, there is an association between the low socioeconomic nature of a geographical condition and an increased risk of co-infections in a population (Ortu et al., 2016).

In a cross-sectional survey of 2,576 participants in the Preah Vihear province, Cambodia, 49.0% were infected with hookworm and 48.6% with *S. stercoralis*. Interestingly, 43.8% of co-infections were noted for both parasites (Forrer et al., 2018). A similar trend of co-infection was also seen in the Kwara state, Nigeria, where a high malaria association (caused by *Plasmodium. falciparum*) association was seen with STH infection. A high prevalence of *A. lumbricoides* (63.1%) was also seen in individuals with a higher prevalence of *P. falciparum* infection (63.7%). This shows the importance of co-infection risk in the public health sector and the need for intervention using multitargeted prevention approaches (Babamale et al., 2018).

In the Democratic Republic of Congo, authors found that polyparasitism (multiple parasite infection) was common in the community. The co-infections were linked to *T. solium*, STHs, and *Schistosoma* species. The authors further suggested the need for more research on helminth con-infections, especially the dynamics and the distribution patterns (Madinga et al., 2017).

Liao et al. (2017) found lower prevalence (5.5%) of polyparasitism in the Marshal Islands. In comparison, higher polyparasitism was noted at 40.4% in southern Laos and 28.8% in Iran. Unhygienic water and food sources have also been linked to increased polyparasitism (Liao et al., 2017).

In the Polynesian nations of Tuvalu and the Cook Islands, Judith et al. (2012) found a high association of STH co-infection risk with tuberculosis (TB). Overcrowding, climate

change, and socioeconomic deprivation have been observed as determinants of helminth infections (Judith et al., 2012).

In this study, very little information on multiple parasite infection was retrieved, so it was not presented in the findings of the result chapter. Data on family members infected by STH (family infestation) due to transmission from positively diagnosed STH individuals was not available in laboratory records. Hence co-association between STH and infection rates cannot be established.

5.2 Laboratory Techniques for STH Detection

The second objective of this study aimed to identify the current laboratory techniques used in diagnosing STH in Fiji, and comparing these with current recommended methods. In Australia and New Zealand, STH infection is non-endemic. In New Zealand 2 medical laboratories were visited (Labtests and LabPlus) where it was found that FEC and multiplex PCR are used for diagnosis of intestinal protozoan parasites, such as, *E. histolytica*, *G. lamblia*, Cryptosporidium species and Blastocystis species. The use of FEC and multiplex PCR methods has been effective in investigation of intestinal protozoan parasites, which has been recommended by RCPA and ASID for Australasia (Bowen, 2016; Kline et al., 2013; LabPlus, 2018; Labtests, 2018). In 2018, FEC method provided significant information on presence of intestinal protozoan infections within school aged children in Fiji. The author found that Giardia infections had a prevalence of 1.6% overall, whereby western division had a 2.2% prevalence, while the central and northern division had 0.8% respectively (Kim et al., 2018).

According to the findings of Khurana and Sethi (2017) there are conventional microscopy-based techniques like direct microscopy, FEC, the egg counting techniques such as K-K, McMaster, FLOTAC and mini-FLOTAC techniques. Some serology-based techniques used are also used. These are enzyme-linked immunosorbent assay (ELISA), Dot-ELISA, indirect immunofluorescent antibody test (IFAT), direct immunofluorescent antibody test, immunoblotting (also called Western blot), Luciferase immunoprecipitation system (LIPS) and indirect haemagglutination assay (IHA). There are some rapid diagnostic tests (RDTs) that could also be used,such as rapid immunochromatographic tests (Yan et al., 2017). The Serology-based assays have a

higher sensitivity rate compared to conventional diagnostic methods (Khurana & Sethi, 2017).

In this study, direct microscopy is the only method used for detecting STH at CWMH microbiology laboratory. However laboratory testing may not be uniform across all the population in the Central Eastern Division, which suggests underestimation of the presence of parasite eggs and larvae. Stored stool samples are also processed as routine specimens. This may delay processing time and lead to nondetection of certain intestinal parasites. However, there is a possibility of patients' presenting late to doctors, which may decrease the chances of successful parasite detection in the laboratory.

Kim et al. (2016) combined 2 techniques, the Baermann method and qPCR analysis that found higher detection of *S. stercoralis* prevalence of 3.5% with 177 school children. In this thesis, *S. stercoralis* had a prevalence was 1.5% for school aged children. This may be suggestive of a less sensitive parasitic diagnostic technique used in CWMH.

In the Caribbean, Ketzis (2017) attempted to improve the *S. stercoralis* diagnosis method, however he found technical and external challenges that limited the new detection capabilities in the laboratories. The modified Baermann culture technique was compared with FEC and direct microscopy techniques and was demonstrated to ten laboratories. Obstacles were observed in adaptation of the new updated standard operating procedure manuals (SOPs). Technical limitations observed were communication gaps with physicians about the need for stool examination and lack of awareness in sensitivity of the methods. External factors include the cost related to using two parallel methods on a single faecal sample (Ketzis, 2017). Improvements in the ELISA technique have shown high efficiency in serodiagnosis of *S. stercoralis* infections. Two synthetic peptides biomarkers, complement factor 3 (C10) and factor D (D3) were used to test their potential in ELISA. A high sensitivity of 95% was achieved for both factors, C10 and D3, while specificities were 89.2% for C10 and 92.5% for D3. High diagnostic efficiency and reduced cross-reactivity in strongyloidasis detection were observed. The synthetic peptides could be used for surveillance fieldwork (Feliciano et al., 2016).

In a study in South East Asia, it was highlighted that many STH examinations in laboratories use the K-K method. A high possibility of *S. stercoralis* neglect was observed. It was found that Koga agar culture is more preferred to the Baermann method. Faecal sample storage, time constraints and resource intensiveness affect *S. stercoralis* detection (Schär et al., 2016).

Whereas advanced molecular-based diagnosis allows fast and accurate measurement of STH egg count, as well as being less labour intensive. These include PCR based techniques. Some of the recent updated methods are quantitative-PCR (qPCR) and multiplex-PCR. In comparison to conventional STH diagnosis, qPCR is more sensitive. Recent studies show that for *A. lumbricoides* diagnosis molecular tests have 85-100% sensitivity rates compared to 70-85% achieved by direct microscopy methods (Khurana & Sethi, 2017). Molecular detection of *S. stercoralis* and *T. trichiura* were 100% sensitive compared to direct microscopy results, which were 20-50% for (*S. stercoralis*) and 88% for (*T. trichiura*) (Sayasone et al., 2015). In comparison, Kim et al. (2016), found *S. stercoralis* prevalence of 3.5% from a survey on 177 school children in the Western Division of Fiji. The higher detection in the survey could have been due to use of 2 combined techniques, the Baermann method and qPCR for which stool samples were analysed in the Netherlands. In another study on IPIs in Fiji, qPCR methods found an increased prevalence of giardiasis 22.4%, when compared to FEC which was 1.6% (Kim et al., 2018).

As recommended by WHO, the K-K method (an egg-counting technique) remains the prime diagnostic tool for helminth detection in medical laboratories. It is the most reliable, has a better efficiency, is accurate and produces a high predictive value, especially in resource-poor countries. However, K-K techniques were used in only 15% of studies and have shown less sensitivity in single stool examination. To increase this technique's sensitivity, perhaps multiple stool samples are necessary to find the actual prevalence of STH eggs (Salam & Azam, 2017).

Current trends in STH diagnosis are focused more towards the interruption of transmission, rather than the control of morbidity. Precise, accurate detection and measurement of intestinal parasites are equally necessary to identify the intensity and prevalence of infection (Ricciardi & Ndao, 2015). Newly emerging qPCR techniques are

becoming the “new gold-standard”, outpacing the recommended K-K microscopy (Mationg et al., 2017). To understand variation amongst *A. lumbricoides* quantification in Western Kenya, K-K and qPCR methods were used. The precision of the two methods were compared for egg intensity measurements. Easton et al. (2017) found that the qPCR proved to be a better diagnostic technique showing approximately 3.6 times more precise results in measuring *A. lumbricoides* egg intensity as compared to the K-K method. Stool samples only needed to be tested once which could be cost-effective. Researches have proven that qPCR could be advantageous to assess population-level intensity, design of epidemiological surveys and monitoring of deworming programmes (Easton et al., 2017).

J. T. Coulibaly et al. (2016) highlighted that the K-K technique has some limitations in its use as a diagnostic tool. The presence of uneven egg distribution in single faecal sample and fluctuating day-to-day egg numbers could cause variations in microscopy results. Hookworm eggs are very prone to damage and decrease in numbers (Holt et al., 2017). To increase validity of the K-K method, duplicate tests are undertaken. In duplicate tests, two faecal slides are viewed for each sample. It is recommended that stool samples are fresh and processed within 30 minutes of sample preparation in a laboratory (J. T. Coulibaly et al., 2016).

Khurana and Sethi (2017) highlighted that the K-K method may be weak in detecting transmission of STH infections, however low infection levels decrease the sensitivity when this technique is used. Reappearance of parasites is common if treatment control programmes are not monitored well due to insensitive testing. This increases the cost of retesting of population who are at risk of re-infection, adds to the cost associated with restarting the control treatment process. Turner et al. (2017a) suggested that some studies have observed an increased presence of antiparasitic drug resistance in animals. For human populations, there is a need to develop more alternative, sensitive and cost-effective methods which could aid in early detection of drug resistance in helminths (Turner et al., 2017a).

Technical and biological factors tend to decrease an accurate and precise count by the K-K method. Technical factors could be due to clumping of egg samples within the stool sample, the quality of the slide and the human error. Biological factors may

include person-to-person differences in the consistency and volume of stool. Consistency changes could be due to variation in a person's diet, age, and immune system, which may somewhat influence the eggs per gram of stool (EPG) counts and worm survival.

Even though qPCR has a higher sensitivity in comparison to K-K method, qPCR presents some variations in STH diagnosis (Tang & Sikarwar, 2016). Since qPCR detects and measures the deoxyribonucleic acid (DNA) of STH eggs, it may not detect the presence of adult male worms or prepatent females. The *prepatent* period, also known as the *silent or latent period* is the time interval the parasite needs to infect the host, up until it is detected in a patient's sample. Inefficient DNA extraction, improper pipetting and choice of target for amplification could cause further technical variations (Easton et al., 2017). In Cameroon, genomic DNA analyses of STH parasites with the use of real-time PCR have shown promising molecular diagnostic characteristics of parasite species and controlling their transmission (Campbell et al., 2017).

J. T. Coulibaly et al. (2016) suggest that even though general deworming and control programmes are aimed at reducing the helminthic load, it is very important to use sensitive and accurate diagnostic tools. This may keep track of progress in control of NTDs. More importantly, community-based studies are needed to improve treatment and management of patients' health.

PCR-based techniques maybe expensive and technically demanding for a small economy of Fiji, but K-K and FEC techniques may provide high sensitivity results in STH diagnosis. The K-K technique allows fixation of a sample and this could be processed later. This may remove the need for field laboratories for STH diagnosis, which would be viable financially and logistically sensible (Nikolay et al., 2014). The FEC technique has an advantage as it could be used to analyse preserved (refrigerated) samples. Aiemjoy et al. (2017), in an Ethiopian study, used preschool-aged children's faecal samples preserved in sodium acetate-acetic acid-formalin, and later examined them using the FEC method. The STH detection rate was observed at 95% CI and were significant for *A*. *lumbricoides*, *T. trichiura* and hookworm eggs. This would be helpful for smaller health centres in Fiji, which are not able to send fresh faecal samples to CWMH on a daily basis. However, it is important to know that parasitic infections could

be seasonal and low-intensity areas could be underdiagnosed. This could have a negative impact on public health surveillance and control of STH. In New Zealand medical laboratories, the FEC method is one of the recommended diagnostic tools for protozoan investigations (Campbell Craig, Lam, & Horvath Andrea, 2018; LabPlus, 2018; Labtests, 2018).

Fiji still depends on direct microscopy and is lacking behind in STH diagnosis. It is recommended that the updated parasitic investigation techniques are implemented according to WHO helminth testing standards in medical laboratories in Fiji.

5.3 Socioeconomic Deprivation

An increase in socioeconomic deprivation in a population has been linked to higher environmental risks and their associated health problems (Salmond & Crampton, 2012). Children are less prepared for the risk associated with deprivation as they are in the phase of growth and development (Bartlett, 2008; Judith et al., 2012).

In a community, STH infection is not only due to low socioeconomic status and poor hygiene practice. It has been suggested that occupations such as fishing and farming increase the likelihood of infection. The male gender could also be a reliable indicator, since they are more involved in outdoor activities such as subsistence farming. The increased contact with STH-infected soil increases chance of helminth infection (Judith et al., 2012; Ross et al., 2017).

The WHO has recommended the importance of the “WASH” intervention programme, where safe water, adequate sanitation and hygiene are needed to prevent transmission of STH (WHO, 2015c). There is evidence of barriers that limit successful WASH implementation in communities. For example, in rural communities in India, the authors found that behavioural and social barriers may affect the control of STH. The open defecation problems in communities were linked to socialising patterns, habits, social customs and daily routines. This showed that behavioural aspects had higher preference, rather than the absence of toilet infrastructure and proper sanitation (Sarkar et al., 2017).

The Oceania region has a population of almost 35 million people, in which most island countries in the region are developing and/or underdeveloped. NTDs have been a

major concern in the region. Fiji, a tropical and developing country has lacked STH data and published articles to fully substantiate the impact of helminth distribution. In Fiji, around 31% of the approximately 860,000 population live in poverty (Kline et al., 2013). Most of the NTDs are endemic to Fiji, but STH remains a major concern. The tropical hot and humid climate, high risk of natural disasters, and lower socioeconomic nature, still favours helminth survival and increases the health risks.

5.4 Accessibility

A study in India showed that lack of proper sanitation and increased poverty levels affect families' access to sanitary toilets. Healthcare professionals need to consider that communities need access to adequate clean water for successful anthelminthic control (Murray, 2016). Ursulica (2016), from his study in Romania, found an inverse relationship between accessibility to health services and healthcare needs of individuals, especially in rural settings. Low accessibility was attributed to the travel distance to the nearest medical facility, and deprivation of health services in rural areas. In the present study, an increase in STH detection in the adult indigenous population may have been due to travelling long distances and unavailability of transport to the nearest health facility in rural areas and/or in island populations. In urban areas, cost-related factors of seeing a physician could potentially lead to increased detection rates.

5.5 Remoteness

In Australia, Gordon et al. (2017) agreed that intestinal parasites are common in remote communities and tropical states which include Western Australia (WA), Queensland, NT, and Northern New South Wales (NSW). In this study, factors such geographical isolation of individuals, rural laboratories lacking in STH diagnostic experience, and faecal sample storage could have led to lower helminth detection.

5.6 Climate and Seasonal Effects

There is evidence that suggests that climate change has the potential to alter the distribution of helminths. This may lead to the potential emergence or re-emergence of parasites in endemic areas (Short et al., 2017).

In developing countries, natural disasters due to climate change give rise to endemic diseases (Hanna & Oliva, 2016). This weakens the health services' ability to cope with an increased demand for management of emerging diseases. Not only does this have adverse implications on children's health and nutrition, but it affects sanitation and proper hygiene needs (Hanna & Oliva, 2016).

According to Bartlett (2008) floods, droughts and heat waves also contribute to the increase in infectious disease burden, especially in children. Environmental factors related to climate change contribute to almost 25% of deaths in human populations and for children under the age of 14 years, the risk increases to around 36% (Bartlett, 2008).

Since 2000, Fiji has had 3 cyclones, which were devastating and significant: TC Ami, category 3 cyclone in 2003, TC Evan, category 4 cyclone in 2012, and severe TC Winston, category 5 in 2016. Additionally, floods in 2002, 2004, twice in 2012, and 2014 were most devastating. The worst floods were noted in 2009 and 2012, in which 15 people died and 160,000 were directly affected (Government, 2017).

Several studies confirm that hookworm can infect multiple species of animals including humans. It is important to understand some of the factors of pathogenicity in hookworm infections related to climate change. This may paint a clear picture of the variation in prevalence and intensity of hookworm infections. Environmental conditions, especially the effect of temperature and humidity of soil are necessary for survival of the infective larvae of hookworms. Higher populations of host animals increase the density of nematodes larvae infectivity rate. Reviewed literature suggests that larger hookworms have a higher potential to be more pathogenic (Seguel & Gottdenker, 2017).

5.7 Rural to Urban Drift

Emigration of locals from one region to another may carry the risk of transmitting STH. In Fiji, there is a high movement of individuals from remote areas towards the Central Eastern Division. The capital city, Suva, with its developing infrastructure, the large health facilities, the job opportunities and the presence of more education institutions, attract a higher population into the urban areas.

In a cross-sectional survey on long-term immigrants from South East Asia and travellers returning to Australia detected STH presence. *S. stercoralis* and *T. trichiura* were identified in East African communities, while a high prevalence of 42% was seen in the Cambodian cohort (Gordon et al., 2017). Additionally, Australian army veterans (Returned Service Personnel) had 11.6% positive serology detection of *Strongyloides* (Gordon et al., 2017).

Whereas in Yemen, in a comparative study concerning protozoan and helminthic parasites between rural and urban school children, revealed higher infection rates in urban children (64.5%), as compared to rural children (49.2%) (Alsubaie et al., 2016). The highest infection rate was in the 10-11-year age group (31.8), followed by 12-13-year old children (28.4%). For STH parasites the distribution pattern showed *A. lumbricoides* was highest (14.3%), followed by *T. trichiura* (9.3%) and *S. stercoralis* (0.8%) (Alsubaie et al., 2016). Information from other literature supports these findings and similar findings where more urban children were infected than rural. Similar findings were seen in the present study, and this may be attributed to urbanisation which is evident in the Central Eastern Division (Government, 2017).

However tourism is the major income generator in Fiji's economy and a popular tourist destination as well. There are possibilities for tourists and travellers returning from endemic nations to transmit STH infections to the local populations. Army and police servicemen and women could also be potential carriers of parasites. However immigration screening policies may need to include geohelminth examinations for these at-risk travellers.

5.8 Follow-up on Cases

The higher intensity risk of worms and its impact on morbidity in patients is evident from various sources (Kaliappan et al., 2013). Lack of follow-up of patients by physicians post-treatment has the potential to increase hookworm re-infections, which could be almost 60% post-treatment. High poverty has also been observed to cause co-infection with *S. stercoralis* (Cepon-Robins et al., 2014). However, retreatment may be necessary if individuals are re-exposed to contaminated areas and unhygienic practices (Kaliappan et al., 2013; Savioli, Albonico, Engels, & Montresor, 2004; Yap et al., 2013).

In the present study, data on re-infection related to STH was not available in laboratory records.

5.9 Health Information Records

For many years, Fiji's medical laboratories have relied on manual entry or paper-based recording of patients' results in registers. There is a high probability of data and diagnostic information relating to STH being missed and under-recorded. In this study, 9 years of data was retrieved in CWMH during which it was observed that, demographic details, clinical history, location of health facilities and even physician's names were not recorded in some of the results. This may have a bias and may affect proper data analysis.

5.10 Limitations of the Study

According to WHO, helminth diseases are neglected in developing nations and not many studies pertaining to STH are undertaken (WHO, 2012). The data for the present retrospective study was initially intended for 10 years, from 2007 to 2016; however, the 2007 data was missing and the researcher used 9 years of data (2008-2016). Obtaining the ethical approval from Fiji National Health Research and Ethics Review Committee (FNHRERC) was also delayed. Hence appropriate results in data analysis may not have been performed.

Descriptive analysis of data was based on the positively diagnosed results of STH patients' faecal samples which were examined in the CWMH microbiology laboratory. Assumption is based on those STH- infected cases that were tested to represent the prevalence in the Central-Eastern Division.

Lack of complete data information in the laboratory was noted during retrieval of information from laboratory register. Some demographic information such as age, gender and ethnicity details were missing. There was an occasion where some raw data did not specify the name of the physician who requested the laboratory tests. There were records that were missing details on which health centre or hospital the stool samples came from for STH investigation. However there were no follow-up records on patients after treatment, which increases possibility of reinfections in the studied population.

Information on family members being infected by STH (family infestation) due to transmission by a confirmed STH carrier (STH positive family member) was barely available in laboratory records, and could not be easily traced. Also, there were no adequate records on patients' consecutive samples in the laboratory register. There were no laboratory records for information on initial samples (pre-treatment) and control samples (i.e. faecal sample examination after treatment), thus they were not found. These limitations affected the descriptive analysis of the mentioned variables characteristics. STH are neglected diseases in the Oceania region; there are limited available data and research articles that outline the exact prevalence and distribution.

5.11 Recommendations

The third aim of this study was to provide recommendations to the Ministry of Health for improving the diagnostic capabilities of detecting STH in medical laboratories in Fiji.

As recommended by WHO, the K-K technique should be implemented for routine stool sampling in microbiology laboratories in Fiji. For laboratory result validation, 3 stool samples taken on consecutive days for each individual should be mandatory. The need for 3 stool samples should be explained to patients by physicians, for successful implementation of diagnosis. There would be a need to train laboratory scientists on the K-K technique, as well as updating SOPs. PCR-based techniques are the new emerging diagnostic tool for helminthic detection; however, but tests are costly and require skilled scientists, which may be difficult for the small, developing economy of Fiji.

According to WHO (2015c), it has recommended that water, sanitation and hygiene (WASH) strategies are needed for sustainable, long-term control and elimination of NTDs. WASH as one strategy framework implemented by WHO for the 2015-2020 period, emphasises the need to increase regular STH treatment of preschool and school-aged children from 75% coverage to 100% by 2020. There is a need to prevent open defecation and improve faeces management. Adequate sanitation facilities are equally important. Hand washing with soap is also necessary to reduce STH transmission (WHO, 2015c). Elimination strategies could be used to disturb the transmission of STH, but evidence from larger community-wide trials are needed to

determine the efficacy and feasibility of community-wide MDAs (Ásbjörnsdóttir et al., 2017).

There is a need to strengthen public health surveillance of STH in at-risk areas, so outbreaks and reinfections could be easily detected and monitored. Molyneux et al. (2017) suggested the need for regular deworming not only in younger aged children, but in adults as well. This would reduce the STH transmission permanently which is one of the aims of SDGs.

Sustainable control and elimination of STH infections can be limited with regular mass deworming of at-risk populations. Access to safe and clean water in remote areas, use of proper waste disposal techniques and behavioural changes are mandatory to reduce transmission rates. Holistic changes in policies to eradicate helminth infections would require the inclusion of NTDs in SDGs' framework (Molyneux et al., 2017).

For the 3 major hospitals and some health centres of Fiji, medical information is communicated through a health information system which currently use software programmes such as patient information system (PATIS), PATISplus, and Laboratory Information system (LIS) in diagnostic laboratories . There is a need to have STH data profiles included in these information systems, so outbreaks, co-infections, re-emergence and family infestations can easily be monitored.

Studies have shown that STH reinfections can occur within six months in areas with a higher intensity of prevalence above 50%. This implies that periodic MDA alone could not control and prevent STH infections in endemic areas (Steinmann et al., 2015). Oluwole et al. (2017) recommends improvements in 3 major intervention aspects for elimination of STH burden in any endemic areas as a long-term control tool. These include improvements to sanitation, anti-helminthic drug treatment and health education.

5.12 Suggestions for Future Research

Future research should explore the need for faster, more accurate and more sensitive diagnostic techniques, which could be used for examination of STH samples. This may have the potential to provide more information on intestinal parasite for clinical, environmental, epidemiological, taxonomic biology and pharmaceutical interest.

5.12.1 Suggestions for future research in Fiji

More STH research and publications are needed to inform stakeholders on the trends and distribution of STH throughout Fiji. This would ensure better control and monitoring of one of the most important NTDs in the country. More collaborative research is needed with other Oceania countries, especially Australia and New Zealand, so comparison of parasitic burdens could be made and detection capabilities could be improved.

In Fiji, future prospective and retrospective research on STH should include data from other divisional laboratories, such as the Western and Northern division, to get the entire picture of helminth impact in the country. There is a need for physicians and laboratory scientists to include all demographic data in patients' diagnostic request forms and laboratory records.

Studies on zoonotic infections and their dynamics of transmission are needed in Fiji. Animals have the potential to transmit nematode and protozoan infections to humans. For public health monitoring, emerging digital PCR (dPCR) technology has been able to accurately detect *A. lumbricoides* in parasite-contaminated soil and/water reservoirs (Acosta Soto et al., 2017). In recent times, development of automated image analysis software has been developed for STH detection and quantitation. Currently aimed at environmental samples such as irrigated water, close to 100% sensitivity in results has been reported (Amoah et al., 2017). Further research is needed in Fiji, to find the association between and impact of animal-transmitted nematodes affecting human health. Zoonotic studies in Fiji may improve quarantine and biosecurity strategies based on animal welfare, veterinary disease control, and sustainable policies.

Recent studies show the need to investigate the impact of zoonosis (humans infected by diseases of animals). A good example is Toxocariasis, caused by *Toxocara. canis* or *T. cati*, which are roundworms found in animal faeces of dogs and cats. This animal helminth has a similar life cycle to *A. lumbricoides*. These infections are widespread in developing and developed countries, and are prevalent in children when they accidently ingest eggs belonging to worms present in dogs or cats (Weatherhead et al., 2017).

5.12.2 Emerging diagnostic techniques

Currently, there are emerging, advanced molecular-based techniques, such as qPCR, which are higher in sensitivity for helminth detection in medical laboratories. The qPCR has a higher sensitivity and specificity compared to the K-K method. However, further work is required to evaluate its effectiveness in multiple faecal sample processing. To eradicate progress of STH, public health surveillance could be enhanced by developing a more broad-spectrum diagnostic tool which is easy to use yet provides higher sensitivity.

5.12.3 Future diagnostic technologies

Clinical use of bioinformatics (a hybrid science that uses computational methods to link biological data) in emerging molecular techniques could achieve a milestone if more nematode databases are developed. This would provide reference databases with genetic information on clinical, zoonotic and environmental nematodes. Knowledge about nematode biology and their taxonomy (naming and classification) is necessary to trace evolution trends and discover new vaccines (Seesao et al., 2016).

Nano biotechnology may have future potential in improving the identification and treatment of NTDs. Efficacy in nanocarrier development has proven to increase therapy benefits such as less dosage needed for treatment and reduced toxicity levels (Islan et al., 2017).

Future diagnostic methods could involve automated counting of faecal parasites in humans. In a veterinary study done in USA, researchers using a cellular smartphone, and fluorescence labelling, were able to do egg counts of *Strongyle* (a blood worm that infects horses) and *Ascaris* eggs in faecal samples from horse, sheep and cattle. The automated egg counting method showed strong correlation with the manual McMaster technique (R^2=0.98) with quite a low coefficient of variance (p = 0.0177). This suggests that future STH diagnosis could be less time consuming and have less cost associated with it. Furthermore, use of cellular smartphones would require less technical knowledge from staff, and samples could be tested on site (Slusarewicz et al., 2016).

The flow cytometry technique is another diagnostic tool which has been successful in detecting *Cryptosporidium parvum* oocysts (dormant stage), a protozoan intracellular

parasite, in water samples has been experimented in mice (Amoah et al., 2017). *Cryptosporidium* infection is common in HIV/AIDS patients (Dacal et al., 2018). Since this fluorescence (laser-based) technology works on differentiating cell types according to volume and size, there is potential for its use for STH diagnosis (Amoah et al., 2017).

5.12.4 Phylogenetic research

Phylogenetic studies provide an evolutionary history of relationships that exist among individuals and/or collections of species (Nejsum et al., 2017; Rosa et al., 2018). They also provide scientific evidence of a species evolution trend within human and animal populations. Phylogeny investigations of nematodes are essentially important to understand the relationship between parasites. *A. lumbricoides* and *A. suum* are present in human hosts and pigs, and are globally widespread. They both share similar genetic features, but are two different species (Nejsum et al., 2017). Recent evidence suggests that there is possibility of cross-infection (transfer of disease-causing organisms) between both host species. In Ecuador, Nissen et al. (2012) conducted genetic analysis of *T. trichiura* (from humans) and *T. suis (*from pigs). The authors' findings suggested no zoonotic infections but showed an association of genetic material exchanged between the two species. The use of phylogenetic analysis tools, such as phylogeny trees and genetic sequencing (of nucleotides and amino acids) could help to understand the epidemiological crossover of genetic material between human and animals (Nissen et al., 2012).

5.12.5 Emergence and/or re-emergence of NTDs

Migration of humans could influence the emergence and/or re-emergence of NTDs in nonendemic areas. Immigrants are prone to chronic health problems linked to NTDs, which could become an emerging public health concern (Martelli et al., 2017). In the United Arab Emirates, Dafalla et al. (2017) conducted an investigation on 21,347 expatriate workers to ascertain the level of IPIs. The immigrant workers were food handlers (cooks), housemaids and drivers. Faecal samples revealed STH prevalence of *A. lumbricoides* (11.9%), hookworm (4.8%), *T. trichiura* (4.7%) and *S. stercoralis* (1.8%) (Dafalla et al., 2017). It has been suggested that expatriate food handling workers may have a higher risk of STH infection. Similar findings were seen in Spain, where the prevalence of parasitic disease was seen in immigrant children. Immigration screening protocols are needed for human parasite infections, especially for countries of origin

and the destination country of entry (Belhassen-García et al., 2017; Dafalla et al., 2017).

5.12.6 Helminth therapy

Helminth co-infections have shown some therapeutic properties in asthma, inflammatory bowel disease and multiple sclerosis cases. Intestinal parasites have the potential to modulate (regulate) the immune system of hosts as a response reaction to foreign pathogenic antigens. A study was undertaken in Europe by McFarlane et al. (2017) to find an association between Respiratory Syncytial Virus (RSV) which is a major cause of respiratory infection in infants less than 2 years of age, and the antiviral effects of enteric helminths. With the aid of an animal model, mice with *Heligmosomoides polyrus* (an enteric helminth present in mice) were co-infected with RSV. The authors noted that the enteric helminth had protective antiviral effects against RSV in the lungs. This suggested that there was modulation of microbiota-dependent type 1 interferon response. Some commensal bacteria, which are nonpathogenic, provide antivirus protection against influenza (flu) infection by inducing type 1 interferon production in humans. In Malaysia, faecal microbiota from 51 individuals with helminth infection showed an increase in species diversity and number to adjust the stability of commensals in the intestine (McFarlane et al., 2017).

Helminth therapy using *T. trichiura* and hookworm have also shown healing properties in psoriasis, coeliac disease and allergies. Interestingly online companies such as Wormsell allow the purchase of hookworm and *T. trichiura* eggs for medicinal benefit (Gordon et al., 2017).

5.13 Conclusion

The present retrospective study using 9 years of retrieved data confirms that the Central Eastern Division of Fiji has a significant prevalence of 4 STH parasites. *A. lumbricoides* contributes to most STH infections, followed by hookworm, *S. stercoralis* and *T. trichiura*. The highest prevalence of STH is found in < 5 year age group. The second most affected age groups are amongst 24-45 year olds and >45 year olds while the least affected are between 5-14 year olds and 15-24 year olds. More males are infected by STH than females. In regard to ethnic groups, a higher proportion of the i-Taukei population has helminth infections compared to Indo-Fijians and other races.

According to gender distribution, male i-Taukei individuals are mostly infected followed by female i-Taukei, the Indo-Fijian females and Indo-Fijian males, while other races are the least infected.

The K-K technique has been recommended by the WHO as the gold-standard for STH diagnosis in medical laboratories and should be implemented to diagnose STH in Central Eastern Division in Fiji. The qPCR technique is an emerging molecular diagnostic technology and is considered superior to the K-K method, due to its increased sensitivity and specificity. However, molecular techniques could have higher costs involved in processing samples and maintenance of equipment, and there would be the need for specialist technical staff.

Socioeconomic factors, improper hygiene practices, climate change, rural-urban migration and remoteness could also contribute towards STH infections.

The prevalence study provides important epidemiological data on the STH parasites in the Central Eastern Division in Fiji. To obtain a complete understanding of worm burden throughout the country, further research could be expanded with a prospective and retrospective research design to include the Northern Division and Western Divisions. For future potential investigations of helminth infections, sustainable parasite control factors should be investigated to evaluate their effectiveness.

References

Abdi, M., Nibret, E., & Munshea, A. (2017). Prevalence of intestinal helminthic infections and malnutrition among schoolchildren of the Zegie Peninsula, northwestern Ethiopia. *Journal of Infection and Public Health, 10*, 84-92.

Acosta Soto, L., Santísima-Trinidad, A. B., Bornay-Llinares, F. J., Martín González, M., Pascual Valero, J. A., & Ros Muñoz, M. (2017). Quantitative PCR and Digital PCR for detection of *Ascaris lumbricoides* eggs in reclaimed water. *BioMed Research International, 2017*, 7515409-7515409.

Aiemjoy, K., Gebresillasie, S., Stoller, N. E., Shiferaw, A., Tadesse, Z., Chanyalew, M., . . . Keenan, J. D. (2017). Epidemiology of soil-transmitted helminth and intestinal protozoan infections in preschool-aged children in the Amhara region of Ethiopia. *The American Journal Of Tropical Medicine And Hygiene*.

Alsubaie, A. S. R., Azazy, A. A., Omer, E. O., Al-shibani, L. A., Al-Mekhlafi, A. Q., & Al-Khawlani, F. A. (2016). Pattern of parasitic infections as public health problem among school children: A comparative study between rural and urban areas. *Journal of Taibah University Medical Sciences, 11*(1), 13-18.

Amoah, I. D., Singh, G., Stenström, T. A., & Reddy, P. (2017). Detection and quantification of soil-transmitted helminths in environmental samples: A review of current state-of-the-art and future perspectives [Review Article]. *Acta Tropica, 169*, 187-201.

Ásbjörnsdóttir, K. H., Means, A. R., Werkman, M., & Walson, J. L. (2017). Prospects for elimination of soil-transmitted helminths. *Current Opinion in Infectious Diseases, 30*(5), 482-488.

Awasthi, S., Peto, R., Pande, V. K., Fletcher, R. H., Read, S., & Bundy, D. A. P. (2008). Effects of deworming on malnourished preschool children in India: An open-labelled, cluster-randomized trial. *PLoS Neglected Tropical Diseases, 2*(4), e223.

Babamale, O. A., Ugbomoiko, U. S., & Heukelbach, J. (2018). High prevalence of *Plasmodium falciparum* and soil-transmitted helminth co-infections in a periurban community in Kwara State, Nigeria [Article]. *Journal of Infection and Public Health, 11*, 48-53.

Bank, A. D. (2014). *Country Partnership Strategy Fiji 2014-2018*: Asian Development Bank. Retrieved from https://www.adb.org

Bartlett, S. (2008). The Implications of Climate Change for Children in Lower- Income Countries [Article]. *Children, Youth & Environments, 18*(1), 71-98.

Belhassen-García, M., Pardo-Lledías, J., Pérez del Villar, L., Velasco-Tirado, V., Siller Ruiz, M., Cordero-Sánchez, M., . . . Muro, A. (2017). Original article: Screening for parasite infections in immigrant children from low-income countries. *Detección de infecciones parasitarias en menores inmigrantes procedentes de países en vías de desarrollo (Spanish; Castilian), 35*, 27-32.

Bethony, J., Brooker, S., Albonico, M., Geiger, S. M., Loukas, A., Diemert, D., & Hotez, P. J. (2006). Soil-transmitted helminth infections: ascariasis, trichuriasis, and hookworm. *Lancet, 367*(9521), 1521-1532.

Betson, M., Nejsum, P., Bendall, R. P., Deb, R. M., & Stothard, J. R. (2014). Molecular Epidemiology of Ascariasis: A Global Perspective on the Transmission Dynamics of Ascaris in People and Pigs. *The Journal of Infectious Diseases, 210*(6), 932-941.

Bopda, J., Nana-Djeunga, H., Tenaguem, J., Kamtchum-Tatuene, J., Gounoue-Kamkumo, R., Assob-Nguedia, C., & Kamgno, J. (2016). Prevalence and intensity of human soil transmitted helminth infections in the Akonolinga health district (Centre Region, Cameroon): Are adult hosts contributing in the persistence of the transmission? *Parasite Epidemiology and Control, 1*, 199-204.

Bourke, L., Humphreys, J. S., Wakerman, J., & Taylor, J. (2012). Understanding rural and remote health: A framework for analysis in Australia. *Health & Place, 18*(3), 496-503.

Bowen, A. C., Sheorey, H., Bryant, A.P., Robson, J., Burgner, D.P. (2016). *Polymersae chain reaction testing for faecal parasites: risks and alternatives*. Retrieved from

https://www-mja-com-au.ezproxy.aut.ac.nz/system/files/issues/204_07/10.5694mja15.01327.pdf

Bradbury, R. (2015). A disease from the devil? Could *Baylisascaris tasmaniensis* cause disease in humans? *Australian Journal of Medical Science, 36*(1), 15-17.

Buka, S. L., Rosenthal, S. R., & Lacy, M. E. (2018). Epidemiological Study Designs: Traditional and Novel Approaches to Advance Life Course Health Development Research [Buka2018]. In N. Halfon, C. B. Forrest, R. M. Lerner, & E. M. Faustman (Eds.), *Handbook of Life Course Health Development* (pp. 541-560). Retrieved from https://doi.org/10.1007/978-3-319-47143-3_22

Bureau, o., Statistics, Fiji. (2018). *2017 Census of Population and Housing*. Suva,Fiji. Retrieved from http://www.statsfiji.gov.fj/census

Campbell Craig, A., Lam, Q., & Horvath Andrea, R. (2018). An evidence- and risk-based approach to a harmonized laboratory alert list in Australia and New Zealand *Clinical Chemistry and Laboratory Medicine (CCLM)* (Vol. 0).

Campbell, S. J., Stothard, J. R., O'Halloran, F., Sankey, D., Durant, T., Ombede, D. E., . . . Tchuem-Tchuenté, L.-A. (2017). Urogenital schistosomiasis and soil-transmitted helminthiasis (STH) in Cameroon: An epidemiological update at Barombi Mbo and Barombi Kotto crater lakes assessing prospects for intensified control interventions [journal article]. *Infectious Diseases of Poverty, 6*(1), 49.

Cepon-Robins, T. J., Liebert, M. A., Gildner, T. E., Urlacher, S. S., Colehour, A. M., Snodgrass, J. J., . . . Sugiyama, L. S. (2014). Soil-Transmitted Helminth Prevalence and Infection Intensity Among Geographically and Economically Distinct Shuar Communities in the Ecuadorian Amazon. *Journal of Parasitology, 100*(5), 598-607.

Chen, W.-J. (2016). News and Perspectives: Honoring antiparasitics: The 2015 Nobel Prize in Physiology or Medicine [Short Survey]. *Biomedical Journal, 39*, 93-97.

Clasen, T., Boisson, S., Routray, P., Torondel, B., Bell, M., Cumming, O., . . . Schmidt, W.-P. (2014). Articles: Effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: a cluster-randomised trial [Article]. *The Lancet Global Health, 2*, e645-e653.

Coulibaly, G., Ouattara, M., Dongo, K., Hürlimann, E., Bassa, F. K., Koné, N., . . . N'Goran, E. K. (2018). Epidemiology of intestinal parasite infections in three departments of south-central Côte d'Ivoire before the implementation of a cluster-randomised trial [Article]. *Parasite Epidemiology and Control, 3*, 63-76.

Coulibaly, J. T., Ouattara, M., Becker, S. L., Lo, N. C., Keiser, J., N'Goran, E. K., . . . Utzinger, J. (2016). Comparison of sensitivity and faecal egg counts of Mini-FLOTAC using fixed stool samples and Kato-Katz technique for the diagnosis of *Schistosoma mansoni* and soil-transmitted helminths [Article]. *Acta Tropica, 164*, 107-116.

Cowan, N., Vargas, M., & Keiser, J. (2016). In vitro and in vivo drug interaction study of two lead combinations, oxantel pamoate plus albendazole and albendazole plus mebendazole, for the treatment of soil-transmitted helminthiasis [Article]. *Antimicrobial Agents and Chemotherapy, 60*(10), 6127-6133.

Crowe, A. L., Smith, P., Ward, L., Currie, B, B.J., Balrd, R. . (2014). Decreasing prevalence of *Trichuris trichiura* (whipworm) in the Norther Territory from 2002 to 2012. *The Medical Journal of Australia, 200*, 286-289.

Dacal, E., Saugar, J. M., de Lucio, A., Hernández-de-Mingo, M., Robinson, E., Köster, P. C., . . . Carmena, D. (2018). Prevalence and molecular characterization of *Strongyloides stercoralis*, *Giardia duodenalis*, *Cryptosporidium spp*., and *Blastocystis spp*. isolates in school children in Cubal, Western Angola. *Parasites & Vectors, 11*, 1.

Dafalla, A. I. A., Almuhairi, S. A. S. O., AlHosani, M. H. J., Mohamed, M. Y., Alkous, M. I. A., AlAzzawi, M. A., . . . ElBakri, A. (2017). Intestinal parasitic infections among expatriate workers in various occupations in Sharjah, United Arab Emirates. *Revista do Instituto de Medicina Tropical de São Paulo, 59*, e82.

Daryani, A., Hosseini-Teshnizi, S., Hosseini, S.-A., Ahmadpour, E., Sarvi, S., Amouei, A., . . . Sharif, M. (2017). Intestinal parasitic infections in Iranian preschool and school children: A systematic review and meta-analysis. *Acta Tropica, 169*, 69-83.

Dent, L. A. (2010). Murine nematode immunology in Australasia. *Parasite Immunology, 32*(8), 560.

Dong, M. D., Karsenti, N., Lau, R., Ralevski, F., Cheema, K., Burton, L., . . . Boggild, A. K. (2016). Strongyloidiasis in Ontario: Performance of diagnostic tests over a 14-month period. *Travel Medicine and Infectious Disease, 14*, 625-629.

Drabo, F., Ouedraogo, H., Bougma, R., Bougouma, C., Bamba, I., Zongo, D., . . . Zhang, Y. (2016). Successful control of Soil-transmitted helminthiasis in achool age children in Burkina Faso and an Example of community-based assessment via Lymphatic Filariasis transmission assessment survey. *PLoS Neglected Tropical Diseases, 10*(5).

Easton, A. V., Oliveira, R. G., Walker, M., O'Connell, E. M., Njenga, S. M., Mwandawiro, C. S., . . . Anderson, R. M. (2017). Sources of variability in the measurement of *Ascaris lumbricoides* infection intensity by Kato-Katz and qPCR [journal article]. *Parasites & Vectors, 10*(256), 1-14.

Feliciano, N. D., Ribeiro, V. S., Gonzaga, H. T., Santos, F. A. A., Fujimura, P. T., Goulart, L. R., & Costa-Cruz, J. M. (2016). Short epitope-based synthetic peptides for serodiagnosis of human strongyloidiasis [Article]. *Immunology Letters, 172*, 89-93.

Fiji, G. o. (2011). *Allied Health Practitoners Decree*. Suva: Fiji Government. Retrieved from http://www.health.gov.fj/wp-content/uploads/2014/09/2_Allied-Health-Practitioners-Decree-2011.pdf

Fiji Metereological Services., F. (2018, 10/03/18). *Fiji Metereological Service*. Retrieved from http://www.met.gov.fj/about_us.php

Forrer, A., Khieu, V., Schär, F., Vounatsou, P., Chammartin, F., Marti, H., . . . Odermatt, P. (2018). *Strongyloides stercoralis* and hookworm co-infection: spatial distribution and determinants in Preah Vihear Province, Cambodia. *Parasites & Vectors, 11*, 1.

Francisco et al. (2017). Epidemiology of soil-transmitted helminthiases-related mortality in Brazil. *Parasitology, 144*(5), 669-679.

Galgamuwa, L. S., Iddawela, D., & Dharmaratne, S. D. (2018). Prevalence and intensity of *Ascaris lumbricoides* infections in relation to undernutrition among children in a tea plantation community, Sri Lanka: a cross-sectional study. *BMC Pediatrics, 18*, 1.

Garcia, L. S. (2016). *Diagnostic Medical Parasitology* (6th ed.). Retrieved from http://estore.asm.org

Getachew, M., Tafess, K., Zeynudin, A., & Yewhalaw, D. (2013). Prevalence Soil Transmitted Helminthiasis and malaria co-infection among pregnant women and risk factors in Gilgel Gibe dam area, Southwest Ethiopia. *BMC Research Notes, 6*(1), 263.

Gordon, A. C., Kurscheid, J., Jones, K. M., Gray, J. D., & McManus, P. D. (2017). Soil-Transmitted Helminths in Tropical Australia and Asia. *Tropical Medicine and Infectious Disease, 2*(4).

Government, O., Fiji, World, Bank,and,Global, Facility, for, Disaster, Reduction, and Recovery. (2017). *Fiji 2017- Climate Vulnerability Assessment - Making Fiji Resilient*. World Bank, Washington, DC,. Retrieved from http://www.ourhomeourpeople.com.

Halwindi, H., Lisulo, M., Magnussen, P., & Olsen, A. (2017). Potential contribution of adult populations to the maintenance of schistosomiasis and soil-transmitted helminth infections in the Siavonga and Mazabuka districts of Zambia. *Journal of Biosocial Science, 49*(2), 265-275.

Hamid, F., Wiria, A. E., Wammes, L. J., Kaisar, M. M., Lell, B., Ariawan, I., . . . Supali, T. (2011). A longitudinal study of allergy and intestinal helminth infections in semi urban and rural areas of Flores, Indonesia (ImmunoSPIN Study) [journal article]. *BMC Infectious Diseases, 11*(1), 83.

Hanna, R., & Oliva, P. (2016). Implications of climate change for children in developing countries [Article]. *Future of Children, 26*(1), 115-132.

Hawkins, K. R., Cantera, J. L., Storey, H. L., Leader, B. T., & de los Santos, T. (2016). Diagnostic tests to support late-stage control programs for schistosomiasis and soil-transmitted helminthiases. *PLoS Neglected Tropical Diseases, 10*(12), 1-15.

Hess, D. R. (2004). Retrospective studies and chart reviews. *Respiratory Care, 49*(10), 1171.

Holt, C. D., Shield, J., Harris, M. T., Mounsey, E. K., Aland, K., McCarthy, S. J., . . . Kearns, M. T. (2017). Soil-Transmitted Helminths in Children in a Remote Aboriginal Community in the Northern Territory: Hookworm is Rare but *Strongyloides stercoralis* and *Trichuris trichiura* Persist. *Tropical Medicine and Infectious Disease, 2*(4).

Hossain, M., Alam, M. D. S., Khair, M., Sayeed, M. D. A., & Bhuiyan, M. J. U. (2016). Prevalence and risk factors of *Strongyloides stercoralis* infection in selected tea garden of Sylhet. Bangladesh. *Journal of Tropical Diseases, 4 (206)*(2).

Hotez, P. J., Beaumier, C. M., Gillespie, P. M., Strych, U., Hayward, T., & Bottazzi, M. E. (2016). Advancing a vaccine to prevent hookworm disease and anemia. *Vaccine, 34*, 3001-3005.

Houmsou, R. S., Elkanah, S. O., Garba, L. C., Wama, B. E., Amuta, E. U., & Kela, S. L. (2015). Original article: Spatial distribution of soil-transmitted helminthiases and co-infection with schistosomiasis among school children in Nigeria [Article]. *Asian Pacific Journal of Tropical Disease, 5*, 779-785.

Hsieh, M.-H., Lin, Y.-Y., Hsu, Y.-K., Yang, J.-F., Hsu, Y.-C., Chen, W.-C., . . . Ho, C.-K. (2011). Intestinal parasitic infections in foreigners detected by stool examination in Taiwan. *The Open Infectious Diseases Journal, 5*(1).

Hughes, R. G., Sharp, D. S., Hughes, M. C., Akau'ola, S., Heinsbroek, P., Velayudhan, R., . . . Galea, G. (2004). Environmental influences on helminthiasis and nutritional status among Pacific schoolchildren. *International Journal of Environmental Health Research, 14*(3), 163-177.

Humphries, D., Nguyen, S., Kumar, S., Quagraine, J. E., Otchere, J., Harrison, L. M., . . . Cappello, M. (2017). Effectiveness of Albendazole for Hookworm varies widely by community and correlates with nutritional factors: A cross-sectional study of school-age children in Ghana. *The American Journal Of Tropical Medicine And Hygiene, 96*(2), 347-354.

IANZ. (2018). *International Accreditation New Zealand*. Retrieved 15/05/18, 2018, from http://www.ianz.govt.nz/services/accreditation-2/accreditation/laboratories/medical

Islan, G. A., Durán, M., Cacicedo, M. L., Nakazato, G., Kobayashi, R. K. T., Martinez, D. S. T., . . . Durán, N. (2017). Nanopharmaceuticals as a solution to neglected diseases: Is it possible? *Acta Tropica, 170*, 16-42.

Jackson, S. L. (2015). *Research Methods and Statistics* (5th ed.). USA: Cengage Learning.

Jourdan, P. M., Lamberton, P. H. L., Fenwick, A., & Addiss, D. G. (2017). Soil-transmitted helminth infections. *Lancet (London, England)*.

Judith, L., Julie, P., & Tekaai, N. (2012). Helminths and TB in Polynesia: The implications for health practice. *Annals of Anthropological Practice, 36*(2), 274-294.

Kabore, A., Ibikounle, M., Tougoue, J. J., Mupoyi, S., Ndombe, M., Shannon, S., . . . Awaca, N. (2017). Initiating NTD programs targeting schistosomiasis and soil-transmitted helminthiasis in two provinces of the Democratic Republic of the Congo: Establishment of baseline prevalence for mass drug administration. *Acta Tropica, 166*, 177-185.

Kaliappan, S. P., George, S., Francis, M. R., Kattula, D., Sarkar, R., Minz, S., . . . Kang, G. (2013). Prevalence and clustering of soil-transmitted helminth infections in a tribal area in southern India. *Tropical Medicine & International Health, 18*(12), 1452-1462.

Kaminsky, R. G., Ault, S. K., Castillo, P., Serrano, K., & Troya, G. (2014). High prevalence of soil-transmitted helminths in Southern Belize-highlighting opportunity for control interventions. *Asian Pacific Journal of Tropical Biomedicine, 4*(5), 345-353.

Ketzis, J. K. (2017). Limitations to the adoption of a standardized *Strongyloides stercoralis* diagnostic method: Case study in the Caribbean. *Acta Tropica, 170*, 178-183.

Ketzis, J. K., & Conan, A. (2017). Estimating occurrence of *Strongyloides stercoralis* in the Caribbean island countries: Implications for monitoring and control. *Acta Tropica, 171*, 90-95.

Khurana, S., & Sethi, S. (2017). Laboratory diagnosis of soil transmitted helminthiasis. *Tropical Parasitology, 7*(2), 86-91.

Kim et al. (2016). Short communication: Epidemiological assessment of *Strongyloides stercoralis* in Fijian children. *Parasite Epidemiology and Control, 1*(3), 263-267.

Kim et al. (2018). Island-Wide Surveillance of Gastrointestinal Protozoan Infection on Fiji by Expanding Lymphatic Filariasis Transmission Assessment Surveys as an Access Platform. *The American Journal Of Tropical Medicine And Hygiene, 98*(4), 1179-1185.

Kline, K., McCarthy, J. S., Pearson, M., Loukas, A., & Hotez, P. J. (2013). Neglected tropical diseases of Oceania: review of their prevalence, distribution, and opportunities for control. *PLoS Neglected Tropical Diseases, 7*(1), 1-9.

Kurup, K., Hunjan, G.S. (2010). Intestinal Parasites In St Lucia: A retrospective, laboratory-based study. *Journal of Rural and Tropical Public Health 9*, 24-30.

LabPlus. (2018). *Auckland District Health Board* Retrieved 18/05/18, from http://www.adhb.health.nz/our-services/a-z-services/labplus

Labtests. (2018). Healthscope New Zealand. Retrieved 18/05/18 Retrieved from https://labtests.co.nz/

Leathwick, D. M. (2014). Sustainable control of nematode parasites – A New Zealand perspective. *Small Ruminant Research, 118*(1), 31-34.

Liao, C.-W., Chuang, T.-W., Huang, Y.-C., Chou, C.-M., Chiang, C.-L., Lee, F.-P., . . . Fan, C.-K. (2017). Intestinal parasitic infections: Current prevalence and risk factors among schoolchildren in capital area of the Republic of Marshall Islands. *Acta Tropica, 176*(Supplement C), 242-248.

Lisovski, S., Dijk Jacintha, G. B., Klinkenberg, D., Nolet Bart, A., Fouchier Ron, A. M., Klaassen, M., & Elderd, B. (2018). The roles of migratory and resident birds in local avian influenza infection dynamics. *Journal of Applied Ecology*.

LQMS. (2018). *Laboratory Quality Management System*. Retrieved 10/05/18, from https://extranet.who.int/lqsi/content/who-lqms-information-quality-standards

M'Bondoukwé, N. P., Kendjo, E., Mawili-Mboumba, D. P., Lengongo, J. V. K., Mbouoronde, C. O., Nkoghe, D., . . . Bouyou-Akotet, M. K. (2018). Prevalence of and risk factors for malaria, filariasis, and intestinal parasites as single infections or co-infections in different settlements of Gabon, Central Africa. *Infectious Diseases of Poverty, 7*(6), 1-17.

Madinga, J., Polman, K., Kanobana, K., van Lieshout, L., Brienen, E., Praet, N., . . . Speybroeck, N. (2017). Epidemiology of polyparasitism with *Taenia solium*, schistosomes and soil-transmitted helminths in the co-endemic village of Malanga, Democratic Republic of Congo. *Acta Tropica*.

Martelli, G., Di Girolamo, C., Zammarchi, L., Angheben, A., Morandi, M., Tais, S., . . . Verucchi, G. (2017). Original article: Seroprevalence of five neglected parasitic diseases among immigrants accessing five infectious and tropical diseases units in Italy: a cross-sectional study [Article]. *Clinical Microbiology and Infection*.

Martin, R., Pullan, R. L., Smith, J. L., Brooker, S. J., & Jasrasaria, R. (2014). Global numbers of infection and disease burden of soil transmitted helminth infections in 2010. *Parasites & Vectors, 7*.

Martins-Melo, F. R., Ramos Ramos, A. N., Alencar, C. H., Lima, M. S., & Heukelbach, J. (2017). Epidemiology of soil-transmitted helminthiases-related mortality in Brazil. *Parasitology, 144*, 669-679.

Mascarini-Serra, L. (2011). Prevention of Soil-transmitted Helminth Infection. *Journal of Global Infectious Diseases, 3*(2), 175-182.

Mationg, M. L. S., Gordon, C. A., Tallo, V. L., Olveda, R. M., Alday, P. P., Reñosa, M. D. C., . . . Gray, D. J. (2017). Status of soil-transmitted helminth infections in schoolchildren in Laguna Province, the Philippines: Determined by parasitological and molecular diagnostic techniques. *PLoS Neglected Tropical Diseases, 11*(11), 1-16.

Mayer-Coverdale, K. J., Crowe, A., Smith, P., & Baird, W. R. (2017). Trends in *Strongyloides stercoralis* Faecal Larvae Detections in the Northern Territory, Australia: 2002 to 2012. *Tropical Medicine and Infectious Disease, 2*(2).

McFarlane, A. J., McSorley, H. J., Davidson, D. J., Fitch, P. M., Errington, C., Mackenzie, K. J., . . . Schwarze, J. (2017). Enteric helminth-induced type I interferon signaling protects against pulmonary virus infection through interaction with the microbiota. *The Journal of Allergy and Clinical Immunology*.

Melo, C. F. O. R., Esteves, C. Z., de Oliveira, R. N., Guerreiro, T. M., de Oliveira, D. N., Lima, E. d. O., . . . Catharino, R. R. (2016). Early developmental stages of *Ascaris lumbricoides* featured by high-resolution mass spectrometry. *Parasitology Research, 115*(11), 4107-4114.

Minetti, C., Lacourse, E. J., Reimer, L., & Stothard, J. R. (2016). Focusing nucleic acid-based molecular diagnostics and xenomonitoring approaches for human helminthiases amenable to preventive chemotherapy. *Parasitology Open, 2*, e16.

Ministry of Health & Medical Services. (2014). *Fiji Ministry of Health & Medical Services Annual Report 2014* Fiji Islands: Ministry of Health & Medical Services, .

Ministry of Health & Medical Services, F. (2016). *Annual Corporate Plan, 2016* Fiji Islands: Ministry of Health & Medical Services,Fiji.

Molyneux, D. H., Savioli, L., & Engels, D. (2017). Neglected tropical diseases: progress towards addressing the chronic pandemic. *The Lancet, 389*(10066), 312-325.

Montresor, A., Deol, A., à Porta, N., Le Thanh, N., & Jankovic, D. (2016). Markov model predicts changes in STH prevalence during control activities even with a reduced amount of baseline information. *PLOS Neglected Tropical Diseases |, 10*, 1-15.

Moser, W., Labhardt, N. D., Cheleboi, M., Muhairwe, J., & Keiser, J. (2017). Unexpected low soil-transmitted helminth prevalence in the Butha-Buthe district in Lesotho, results from a cross-sectional survey. *Parasites & Vectors, 10*(1), 72-72.

Munnangi S, & Boktor S.W. (2018). Epidemiology, Study Design. *StatPearls*.

Murray, J. S. (2016). Soil-transmitted Helminthiasis in India. *Journal for Specialists in Pediatric Nursing, 21*(2), 48-53.

Nejsum, P., Hawash, M. B. F., Betson, M., Stothard, J. R., Gasser, R. B., & Andersen, L. O. (2017). Research paper: Ascaris phylogeny based on multiple whole mtDNA genomes. *Infection, Genetics and Evolution, 48*, 4-9.

Nelly, S., Tiangsa, S., & Muhammad, A. (2016). Nutritional status of soil-transmitted helminthiasis-infected and uninfected children. *Paediatrica Indonesiana, Vol 55, Iss 3, Pp 136-41 (2016)*(3), 136.

Nii-Trebi, N. I. (2017). Emerging and Neglected Infectious Diseases: Insights, Advances, and Challenges. *BioMed Research International*, 1-15.

Nikolay, B., Brooker, S. J., & Pullan, R. L. (2014). Sensitivity of diagnostic tests for human soil-transmitted helminth infections: a meta-analysis in the absence of a true gold standard. *International Journal for Parasitology, 44*(11), 765-774.

Nikolay, B., Mwandawiro, C. S., Kihara, J. H., Okoyo, C., Cano, J., Mwanje, M. T., . . . Brooker, S. J. (2015). Understanding Heterogeneity in the Impact of National Neglected Tropical Disease Control Programmes: Evidence from School-Based Deworming in Kenya. *PLoS Neglected Tropical Diseases, 9*(9).

Nissen, S., Al-Jubury, A., Hansen, T. V., Olsen, A., Christensen, H., & Thamsborg, S. M. (2012). Genetic analysis of *Trichuris suis* and *Trichuris trichiura* recovered from humans and pigs in a sympatric setting in Uganda. *Vet Parasitol, 188*.

Ntonifor, H., Sumbele, I., & Ebot, T. (2016). *Soil-transmitted helminth infections and associated risk factors in a neglected region in the Upper Nkongho-mbo area, South-West Region, Cameroon* (Vol. 16)

Nutman, T. B. (2017). Human infection with *Strongyloides stercoralis* and *other related Strongyloides species*. *Parasitology, 144*(3), 263-273.

Oluwole, A. S., Isiyaku, S., Aliero, A. A., Nwosu, C., William, A., Elhassan, E., & Ekpo, U. F. (2017). Assessment of the burden of soil-transmitted helminthiasis after five years of

mass drug administration for Onchocerciasis and Lymphatic filariasis in Kebbi State, Nigeria [Article]. *Parasite Epidemiology and Control, 2*, 21-29.

Ortu, G., Wittmann, U., Knowles, S., Clements, M., Basáñez, M. G., Fenwick, A., . . . Clements, A. (2016). The impact of an 8-year mass drug administration programme on prevalence, intensity and co-infections of soil-transmitted helminthiases in Burundi [Article]. *Parasites and Vectors, 9*(1), 1-17.

Oswald, W. E., Stewart, A. E. P., Kramer, M. R., Endeshaw, T., Zerihun, M., Melak, B., . . . Moe, C. L. (2017). Association of community sanitation usage with soil-transmitted helminth infections among school-aged children in Amhara Region, Ethiopia. *Parasites & Vectors, 10*(1), 91-91.

Owen, I. L. (2005). Parasitic zoonoses in Papua New Guinea. *Journal of Helminthology, 79*(1), 1-14.

Pabalan, N., Singian, E., Tabangay, L., Jarjanazi, H., Boivin, M. J., & Ezeamama, A. E. (2018). Soil-transmitted helminth infection, loss of education and cognitive impairment in school-aged children: A systematic review and meta-analysis. *PLoS Neglected Tropical Diseases, 12*(1).

Pilotte, N., Papaiakovou, M., Grant, J. R., Bierwert, L. A., Llewellyn, S., McCarthy, J. S., & Williams, S. A. (2016). Improved PCR-based detection of soil transmitted helminth infections using a next-generation sequencing approach to assay design. *PLoS Neglected Tropical Diseases, 10*(3), 1-18.

Polgar, S., Thomas, S.A. (2008). *Introduction to Research In the Health Sciences* (5th ed.). Philadelphia, USA: Elservier Ltd.

Rego Silva, J., Macau, R. A., Mateus, A., Cruz, P., Aleixo, M. J., Brito, M., . . . Ramos, A. (2018). Successful treatment of *Strongyloides stercoralis* hyperinfection in a kidney transplant recipient: case report. *Transplantation Proceedings, 50*(3), 861-866.

Ricciardi, A., & Ndao, M. (2015). Diagnosis of parasitic infections: What's going on? *Journal of Biomolecular Screening, 20*(1), 6-21.

Rosa, B. A., Supali, T., Gankpala, L., Djuardi, Y., Sartono, E., Zhou, Y., . . . Mitreva, M. (2018). Differential human gut microbiome assemblages during soil-transmitted helminth infections in Indonesia and Liberia. *Microbiome, 6*, 1.

Ross, A. G. P., Olveda, R. M., McManus, D. P., Harn, D. A., Chy, D., Li, Y., . . . Ng, S.-K. (2017). Risk factors for human helminthiases in rural Philippines. *International Journal of Infectious Diseases, 54*, 150-155.

Salam, N., & Azam, S. (2017). Prevalence and distribution of soil-transmitted helminth infections in India. *BMC Public Health, 17*(1).

Salmond, C. E., & Crampton, P. (2012). Development of New Zealand's deprivation index (NZDep) and its uptake as a national policy tool. *Canadian Journal of Public Health / Revue Canadienne de Sante'e Publique, 103*, S7-S11.

Sarkar, R., Rose, A., Mohan, V. R., Ajjampur, S. S. R., Veluswamy, V., Srinivasan, R., . . . Kang, G. (2017). Study design and baseline results of an open-label cluster randomized community-intervention trial to assess the effectiveness of a modified mass deworming program in reducing hookworm infection in a tribal population in southern India. *Contemporary Clinical Trials Communications, 5*, 49-55.

Savioli, L., Albonico, M., Engels, D., & Montresor, A. (2004). Progress in the prevention and control of schistosomiasis and soil-transmitted helminthiasis. *Parasitology International, 53*(2), 103-113.

Sayasone, S., Utzinger, J., Akkhavong, K., & Odermatt, P. (2015a). Multiparasitism and intensity of helminth infections in relation to symptoms and nutritional status among children: A cross-sectional study in southern Lao People's Democratic Republic. *Acta Tropica, 141*(Part B), 322-331.

Sayasone, S., Utzinger, J., Akkhavong, K., & Odermatt, P. (2015b). Repeated stool sampling and use of multiple techniques enhance the sensitivity of helminth diagnosis: A cross-sectional survey in southern Lao People's Democratic Republic [Article]. *Acta Tropica, 141*(Part B), 315-321.

Schär, F., Giardina, F., Khieu, V., Muth, S., Vounatsou, P., Marti, H., & Odermatt, P. (2016). Occurrence of and risk factors for *Strongyloides stercoralis* infection in South-East Asia [Article]. *Acta Tropica, 159*, 227-238.

Seesao, Y., Gay, M., Merlin, S., Viscogliosi, E., Aliouat-Denis, C. M., & Audebert, C. (2016). A review of methods for nematode identification. *Journal of Microbiological Methods*.

Seguel, M., & Gottdenker, N. (2017). The diversity and impact of hookworm infections in wildlife. *International Journal for Parasitology: Parasites and Wildlife*.

Sherkhonov, T., Yap, P., Mammadov, S., Sayfuddin, K., Martinez, P., Amoss, W. P., . . . Steinmann, P. (2013). National intestinal helminth survey among schoolchildren in Tajikistan: Prevalences, risk factors and perceptions. *Acta Tropica, 126*(2), 93-98.

Short, E. E., Caminade, C., & Thomas, B. N. (2017). Climate change contribution to the emergence or re-emergence of parasitic diseases. *Infectious Diseases: Research & Treatment, 10*, 1-7.

Silvestri, e., al. (2013). Intestinal parasitosis:data analysis 2006-2011 in a teaching hospital of Ancona,Italy. *Le Infezioni in Medicina, 1*, 34-39.

Singh, G. K., Parajuli, K. P., Shrestha, M., Pandey, S., & Yadav, S. C. . (2013). The Prevalence Of Intestinal Parasitic Infestation In A Tertiary Care Hospital-A Retrospective Study. *Journal of Nobel Medical College, 2*(1), 13-17.

Slusarewicz, P., Pagano, S., Mills, C., Popa, G., Chow, K. M., Mendenhall, M., . . . Nielsen, M. K. (2016). Automated parasite faecal egg counting using fluorescence labelling, smartphone image capture and computational image analysis. *International Journal for Parasitology, 46*, 485-493.

Speare, R., Latasi, F. F., Nelesone, T., Harmen, S., Melrose, W., Durrheim, D., & Heukelbach, J. (2006). Prevalence of soil transmitted nematodes on Nukufetau, a remote Pacific island in Tuvalu. *BMC Infectious Diseases, 6*(1), 110.

Steinmann, P., Yap, P., Utzinger, J., Du, Z.-W., Jiang, J.-Y., Chen, R., . . . Zhou, X.-N. (2015). Control of soil-transmitted helminthiasis in Yunnan province, People's Republic of China: Experiences and lessons from a 5-year multi-intervention trial [Article]. *Acta Tropica, 141*(Part B), 271-280.

Storey, H. L., John-Stewart, G., Walson, J. L., Singa, B., Naulikha, J., Horton, H., & Richardson, B. A. (2017). Soil transmitted helminth infections are not associated with compromised antibody responses to previously administered measles and tetanus vaccines among HIV-1 infected, ART naïve Kenyan adults. *Parasite Epidemiology and Control, 2*(1), 13-20.

Supali, T., Djuardi, Y., Wibowo, H., van Ree, R., Yazdanbakhsh, M., & Sartono, E. (2010). Relationship between Different Species of Helminths and Atopy: A Study in a Population Living in Helminth-Endemic Area in Sulawesi, Indonesia [Article]. *International Archives of Allergy & Immunology, 153*(4), 388-394.

Tang, W., & Sikarwar, A. (2016). *Diagnostics: conventional versus modern methods* (Vol. 8). Retrieved from https://www.researchgate.net/publication/304508696_Diagnostics_Conventional_Versus_Modern_Methods/link/5771f23508ae6219474a6367/download

Tchuem Tchuenté, L. A. (2011). Control of soil-transmitted helminths in sub-Saharan Africa: Diagnosis, drug efficacy concerns and challenges. *Acta Tropica, 120, Supplement 1*, S4-S11.

Teklemariam, D., Legesse, M., Degarege, A., Liang, S., & Erko, B. (2018). *Schistosoma mansoni* and other intestinal parasitic infections in schoolchildren and vervet monkeys in Lake Ziway area, Ethiopia. *BMC Research Notes, 11*, 1.

The Fijian Government. (2013). CWM Hospital celebrates 90 years of caring. Suva: Ministry of Communications.

Turner, H. C., Bettis, A. A., Dunn, J. C., Whitton, J. M., Hollingsworth, T. D., Fleming, F. M., & Anderson, R. M. (2017a). Economic considerations for moving beyond the Kato-Katz technique for diagnosing intestinal parasites as we move towards elimination. *Trends in Parasitology, 33*(6), 435-443.

Turner, H. C., Bettis, A. A., Dunn, J. C., Whitton, J. M., Hollingsworth, T. D., Fleming, F. M., & Anderson, R. M. (2017b). Opinion: Economic Considerations for Moving beyond the Kato-Katz Technique for Diagnosing Intestinal Parasites As We Move Towards Elimination. *Trends in Parasitology*.

Ursulica, T. E. (2016). The relationship between health care needs and accessibility to health care services in Botosani County- Romania. *Procedia Environmental Sciences, 32*, 300-310. doi:https://doi.org/10.1016/j.proenv.2016.03.035

Weatherhead, J. E., Mejia, R., & Hotez, P. J. (2017). The global state of helminth control and elimination in children. *The Pediatric Clinics of North America*.

Weinger et al. (2003). Retrospective data collection and analytical techniques for patient safety studies. *Journal of Biomedical Informatics, 36*(1), 106-119.

WHO. (2011a). *Country Health Information Profiles*. Retrieved from who@sp.wpro.who.int

WHO. (2011b). *The Fiji islands health system review (Health Systems in Transition)*. Geneva,Switzerland: World Health Organisation Press. Retrieved from who@sp.wpro.who.int

WHO. (2012). *Research Priorities for Helminth Infections*. Geneva, Switzerland. Retrieved from www.who.int

WHO. (2015a). *Assessing the Epidemiology of STH during a Transmission Asssessment Survey in the global programme for eliminnation of Lymphatic Filariasis*. Gebeva, Switzerland: WHO. Retrieved from https://www.ntdenvision.org/resource/who_guidance_forms

WHO. (2015b). *PCT databank*. Retrieved from http://www.who.int/neglected_diseases/preventive_chemotherapy/lf/en/.

WHO. (2015c). *Water, sanitation & hygiene, NTD, a global strategy, 2015-2020*. Geneva, Switzerland. Retrieved from who@sp.wpro.who.int

WHO. (2018). *Preventive chemotherapy and data control (PCT)*: WHO. Retrieved from http://www.who.int/neglected_diseases/preventive_chemotherapy/lf/en/

Willcocks, B., McAuliffe, G. N., & Baird, R. W. (2015). Dwarf tapeworm in the Northern Territory. *Journal of Paediatrics and Child Health, 51*(10), 982-987.

Yan, L., Gonzales, G., Shao-Hong, C., Hao, L., Yu-Chun, C., Yan-Hong, C., . . . Jia-Xu, C. (2017). Urgent needs in fostering neglected tropical diseases (NTDs) laboratory capacity in WHO Western Pacific Region: results from the external quality assessment on NTDs diagnosis in 2012-2015. *Infectious Diseases of Poverty, 6*, 1.

Yanola, J., Nachaiwieng, W., Duangmano, S., Prasannarong, M., Somboon, P., & Pornprasert, S. (2018). Current prevalence of intestinal parasitic infections and their impact on hematological and nutritional status among Karen hill tribe children in Omkoi District, Chiang Mai Province, Thailand. *Acta Tropica, 180*, 1-6.

Yap, P., Du, Z.-W., Wu, F.-W., Jiang, J.-Y., Chen, R., Zhou, X.-N., . . . Steinmann, P. (2013). Rapid Re-Infection with Soil-Transmitted Helminths after Triple-Dose Albendazole Treatment of School-Aged Children in Yunnan, People's Republic of China. *The American Journal Of Tropical Medicine And Hygiene, 89*(1), 23-31.

Zender, M., & Plate, D. K. (2015). Designing and Evaluating a Health Program in Africa: Hygiene Matters [Article]. *Visible Language, 49*(1/2), 40-61.

Zerdo, Z., Yohanes, T., & Tariku, B. (2016). Soil-Transmitted Helminth Reinfection and Associated Risk Factors among School-Age Children in Chencha District, Southern Ethiopia: A Cross-Sectional Study. *Journal of Parasitology Research, 2016*.

Appendices

Appendix A: Ethics approval from Ministry of Health & Medical Services, Fiji

MINISTRY of HEALTH & MEDICAL SERVICES
Shaping Fiji's Health

Fiji National Health Research and Ethics Review Committee

Level 2 Dinem House
88 Amy Street, Toorak.
Box 2223, Govt. Building
Suva, Fiji

Phone : (679) 3306177 / 3221 424
Fax : (679) 3318227
Email: rosimina.tubuitamana@govnet.gov.fj
Website: www.health.gov.fj

8th February 2017

Anish Praneel Singh
Auckland University of Technology
New Zealand

Project Title: "Prevalence of Soil Transmitted Helminthiasis (STH) in Central Eastern Division, Fiji Islands".

FNRERC Number:	2017.5.CEN
Primary Investigator(s):	Anish Praneel Singh, AUT, New Zealand
Primary Supervisor(s):	Dr. Fabrice Merien, AUT, New Zealand
Co-Supervisor(s):	Dr. Miomir Vidicki, AUT, New Zealand

Dear Anish,

This is to inform you that the Fiji National Health Research Ethics Review Committee (FNHRERC) has granted scientific, technical and ethical **approval** to your proposal titled "*Prevalence of Soil Transmitted Helminthiasis (STH) in Central Eastern Division, Fiji Islands*".

As the Principle Investigator, it is **your responsibility to ensure that all the people associated with this particular project area aware of the conditions of this approval and copy of the final report is also submitted to the Ministry of Health and Medical Services at the conclusion of your project for our records.**

The following conditions apply to your approval. Failure to abide by these conditions may result in suspension or discontinuation of approval and/or disciplinary action.

1. **Variation to the project:** Any subsequent variation s or modifications you may wish to make to your project must be notified formally to the Chair, FNHRERC for further considerations and approval. If the Chair considers that the proposed changes are significant, you may be required to submit a new application for approval of the revised project.

2. **Incidence or adverse events:** Researchers must report immediately to the Chair FNHRERC anything which may affect the ethical acceptance of the protocol including adverse effects on subjects or unforeseen events that may affect continued ethical acceptability of the project. Failure to do so may result in suspension or cancellation of approval.

3. **Monitoring:** Projects are subject to monitoring at any time by the Committee

4. **Annual/Final Report:** You must submit a progress report at 6 months of your study and an annual/final report at the end of the year or at the conclusion of the project if it continues for less than or more than a year. Also you are to present the evidence back to the participating institutions.

Please quote the FNHRERC number and the name of the project in any future correspondence.

If you have any further queries or require any additional information, please do not hesitate to contact the Secretariat on telephone: (679) 3306177 ext. 340170 or email: rosimina.tubuitamana@govnet.gov.fj.

We wish you all the best in your study.

Mr. Shivnay Naidu
Chairperson
Fiji National Health Research Ethics Review Committee

Appendix B: Research Output –Summarized Demographic data

							2008					
Month	**Patient code**	**Date**	**Age**	**Gender**	**Ethnicity**	**Location**	**Clinical Symptom**	**Sample**	**Parasite detected**			
									AL (Roundworm)	**TT (Whipworm)**	**AD/NA (Hookworm)**	**SS (Threadworm)**
January	2008001	15-01-08	56	M	F	Men's Wd	Chronic Diarrhoea	Stool				SS larvae
	2008002	21-01-08	19	M	F	Tvni(MWD)	AGE	Stool			Hookworm larvae	
	2008003	28-01-08	NA	F	NA	NA	NA	Stool			Hookworm ova	
											Total Sample Received = 244	
February	2008004	02-02-08	3	F	F	CHWD-2	Anaemia	Stool	AL ova		Hookworm ova	SS larvae
	2008005	07-02-08	NA	NA	F	PICU	Meningitis	Stool	AL worm			
	2008006	08-02-08	NA	M	F	PICU	NA	Stool			Hookworm ova	
	2008007	11-02-08	10	M	F	CHWD-2	Amoebic liver dz	Stool	AL ova			
	2008008	14-02-08	25	M	F	AMW	AFI	Stool	AL ova			
	2008009	15-02-08	24	M	F	Lami HC	RME	Stool				SS larvae
	2008010	19-02-08	NA	F	I	SOPD	RME	Stool	AL ova			
	2008011	24-02-08	7	F	F	PICU	Acute Abd	Stool	AL ova			
	2008012	28-02-08	2	F	F	WBKSI	Entritis	Stool			Hookworm ova	
	2008013	28-02-08	15	F	NA	WBKSI	? Typhoid	Stool			Hookworm ova	
	2008014	29-02-08	13	F	F	WBKSI	? Typhoid	Stool			Hookworm ova	
	2008015	29-02-08	68	M	F	Korovou	Chronic Diarrhiea	Stool			Hookworm ova	
	2008016	02-03-08	40	M	F	MMW	AGE	Stool			Hookworm ova	
											Total Sample Received = 320	
March	2008017	12-03-08	24	M	F	MMW	Typhoid	Stool	AL ova			
	2008018	13-03-08	NA	F	I	GOPD	RME	Stool				SS larvae
	2008019	26-03-08	NA	M	F	GOPD	RME	Stool	AL ova			
	2008020	28-03-08	NA	M	F	GOPD	RME	Stool				SS larvae
											Total Sample Received = 182	
April	2008021	11-04-08	20	M	F	Lami HC	Diarrhoea	Stool			Hookworm ova	
	2008022	17-04-08	7	M	F	PICU	AGE	Stool	AL ova			
	2008023	17-04-08	1976 (32yrs)	M	F	Vunidawa	S.typhi	Stool			Hookworm ova	
											Total Sample Received = 94	

May	2008024	18-05-08	1yr 8mths	M	F	PICU	AGE	Stool	AL ova				
	2008025	20-05-08	6	M	F	Nuffeld	NA	Stool	AL ova		Hookworm ova		
	2008026	22-05-08	12	F	F	GOPD	NA	Stool	AL ova				
	2008027	27-05-08	23	F	F	GOPD	NA	Stool	AL ova				
	2008028	29-05-08	37	NA	F	Nuffeld	Gastroentritis	Stool			Hookworm ova		
											Total Sample Received = 72		
June	2008029	10-06-08	72	M	F	Nuffield	Screening	Stool			Hookworm ova		
	2008030	11-06-08	38	F	F	Nuffield	Screening	Stool	AL ova				
											Total Sample Received = 76		
July	2008031	03-07-08	2	M	F	CHWD-1	NA	Stool	AL ova				
	2008032	17-07-08	11 months	F	F	PICU	Dehydration	Stool	AL ova				
											Total Sample Received = 108		
August	2008033	12-08-08	1yr 8mths	M	F	CHWD-1	Seizure	Stool			Hookworm larvae		
	2008034	14-08-08	1yr 8mths	M	F	CHWD-2	Afebrile convulsions	Stool	AL ova				
	2008035	28-08-08	3	M	F	PICU	Fever	Stool	AL ova				
											Total Sample Received = 115		
September	2008036	28-09-08	1946	M	F	AMW	AGE	Stool				SS larvae	
											Total Sample Received = 72		
October	**No STH Parasites seen**		**Total Sample Received = 94**										
November	2008037	03-11-08	6	M	F	CHWD- 2	Acute Febrile Illness	Stool	AL ova				
	2008038	03-11-08	25	M	F	Vunidawa	LBM	Stool			Hookworm ova		
	2008039	06-11-08	50	F	F	ASW	Bloody Stool	Stool			Hookworm ova		
	2008040	09-11-08	12	F	F	Diarrhoea- PICU	GI bleeding	Stool	AL ova		Hookworm ova		
	2008041	13-11-08	27	M	F	GOPD	NA	Stool			Hookworm ova		
											Total Sample Received = 86		
December	**No STH Parasites seen**		**Total Sample Received = 58**										

2009

Month	Patient code	Date	Age	Gender	Ethnicity	Location	Clinical Symptom	Sample Type	Parasite detected				
									AL (Roundworm)	TT (Whipworm)	AD/NA (Hookworm)	SS (Threadworm)	
January	2009001	15-01-09	4	F	F	PICU- Diarrhoea	AGE	Stool			Hookworm ova		
											Total Sample Received =		**78**
February	2009002	01-02-09	2yrs 2mths	F	F	PICU-Diarrhoea	AGE	Stool	AL ova				
	2009003	02-02-09	11	M	F	CHWD-2	R/o Dengue	Stool	AL ova				
	2009004	16-02-09	42	M	F	SOPD	S.typhi	Stool	AL ova				
											Total Sample Received =		**96**
March	2009005	01-03-09	2	M	F	CHWD-2	AGE	Stool	AL ova				
	2009006	22-03-09	38	M	F	Korovou H/C	NA	Stool			Hookworm ova		
	2009007	25-03-09	4	F	F	CHOPD	Bloody Stool	Stool	AL ova				
	2009010	27-03-09	1952	M	F	AMW	R/o S.typhi	Stool			Hookworm ova	SS larvae	
											Total Sample Received =		**97**
April	2009011	02-04-09	9	M	F	PICU	NA	Stool		TT ova			
	2009012	03-04-09	15	M	F	PWD-ANZ	LBM	Stool	AL ova				
											Total Sample Received =		**68**
May	2009013	08-05-09	7	NA	F	CHWD	NA	Vomitus	AL larvae				
	2009014	18-05-09	68	F	F	Korovou hosp	Bloody Diarrhoea	Stool			Hookworm ova		
											Total Sample Received =		**116**
June	2009015	002-06-09	21	F	F	WMW	NA	Stool	AL ova				
	2009016	02-06-09	2	F	F	CHOPD	NA	Stool	AL ova		Hookworm ova		
	2009017	22-06-09	1944	F	F	WMW	NA	Stool	AL ova				
											Total Sample Received =		**87**
July	**No STH Parasites seen**		**Total Sample Receiv**		**99**								
August	2009018	13-08-09	1976 (33yrs)	F	F	Plastic	Liver Abcess	Stool	AL ova				
											Total Sample Received =		**85**
September	**No STH Parasites seen**		**Total Sample Received =**			**100**							
October	**No STH Parasites seen**		**Total Sample Received =**			**69**							
November	**No STH Parasites seen**		**Total Sample Received =**			**98**							
December	2009019	02-12-09	7	M	F	Paeds	Dysentry	Stool	AL ova				
	2009020	04-12-09	NA	M	F	CHOPD	Shigellosis	Stool	AL ova		**Total Sample Received =**		**118**
	2009021	06-12-09	2	F	F	PICU-Diarrhoea	AGE	Stool	AL ova				

2010

Month	Patient code	Date	Age	Gender	Ethnicity	Location	Clinical Symptom	Sample	Parasite detected				Single
									AL (Round	TT (Whipv	AD/NA (Hookworm)	SS (Thread	Infestation
January	2010001	18-01-10	1965 (45yrs)	M	F	A/E	Diarrhoea	Stool	AL ova				
										Total Sample Received = 107			
February	2010002	16-02-10	1 2/3	F	F	PICU- Diarrhoea	AGE	Stool	AL ova				
	2010003	19-02-10	1978 (32)	M	F	A/E	AGE	Stool	AL ova				
	2010004	21-02-10	1978 (32)	M	F	A/E	AGE	Stool	AL ova				
	2010005	21-02-10	NA	M	I	MMW	Arthritis	Stool	AL ova				
	2010006	23-02-10	1978(32)	M	F	A/E	NA	Stool	AL ova				Single Infestation
	2010007	24-02-10	1930	F	F	SOPD	NA	Stool	AL ova				
	2010008	24-02-10	26	M	F	Levuka	AFI	Stool			Hookworm ova		
	2010009	25-02-10	77	F	I	Nuffield	Anaemia	Stool	AL ova				
	2010010	26-02-10	40	M	F	AMW	Bloody Diarrhoea	Stool	AL ova				
								Stool		**Total Sample Received = 194**			
March	2010011	14-03-10	9	M	F	PICU	Typhoid	Stool	AL ova				
	2010012	17-03-10	21	M	F	Plastic	? S.typhi	Stool	AL ova				
	2010013	17-03-10	1987 (23yrs)	M	F	PWD-ANZ	S.Typhi infection	Stool	AL ova				
	2010014	19-03-10	34	NA	F	WBKSI	AGE	Stool	AL ova				
	2010015	19-03-10	8	F	F	PICU	NA	Stool	AL ova				
	2010016	22-03-10	34	M	F	Vunidawa	Jaundice	Stool	AL ova				
	2010017	25-03-10	3	F	F	CHWD	R/o AGN	Stool	AL ova				
	2010018	24-03-10	1yr 8mths	F	F	PICU-Diarrhoea	AGE	Stool	AL ova				
	2010019	25-03-10	1985 (25)	F	NA	GOPD	R/o S.typhi	Stool	AL ova				
	2010020	29-03-10	23	M	F	PWD	Diarrhoea	Stool	AL ova				
	2010021	29-03-10	41	M	F	A/E	Typhoid fever	Stool	AL ova				
										Total Sample Received = 233			
April	2010022	23-04-10	1969 (41yrs)	F	I	Beqa	Anaemia	Stool				SS	
										Total Sample Received = 199			

May	2010023	02-05-10	2006 (4 yrs)	M	F	PICU-Diarrhoea	AGE	Stool	AL ova				
	2010024	17-05-10	29	F	F	Navua	UTI	Stool	AL ova				
	2010025	19-05-10	46	M	F	MMW	Septicaemia	Stool					SS
	2010026	21-05-10	19	M	F	MMW	Typhoid	Stool	AL ova				
	2010027	31-05-10	1	M	F	PICU	Colitis	Stool			Hookworm ova		
										Total Sample Received = 149			
June	2010028	01-06-10	3yrs 5mths	M	F	CHOPD	R/o Typhoid	Stool	AL ova				
	2010029	18-06-10	3	NA	F	Vunidawa	Dysentery	Stool	AL ova				
	2010030	21-06-10	1995(15yrs)	M	F	AMW	? Parasites	Stool	AL worm				
	2010031	29-06-10	2	F	NA	Vunidawa - CHWD	Dysentery	Stool	AL ova				
	2010032	29-06-10	36	F	I	Gynae	Bleeding stool	Stool	AL ova				
										Total Sample Received = 142			
July	2010033	06-07-10	2yrs 4mths	M	F	WBKSI	AGE	Stool	AL worm				
										Total Sample Received = 132			
August	**No STH Parasite Seen**		**Total Sample Received = 148**										
September	2010034	20-09-10	2	F	F	CHWD-1	AGE	Stool	AL ova				
	2010035	24-09-10	21	F	F	Korovisilou	S.typhi	Stool	AL ova				
										Total Sample Received = 131			
October	**No STH Parasite Seen**		**Total Sample Receive**		**129**								
November	2010036	18-11-10	19	M	F	Valelevu	NA	Stool	AL ova				
										Total Sample Received = 125			
December	**No STH Parasite Seen**		**Total Sample Receive**		**103**								

2011

Month	Patient code	Date	Age	Gender	Ethnicity	Location	Clinical Symptom	Sample Ty	Parasite detected			
									AL (Round	TT (Whipv	AD/NA (Hookworm)	SS (Threadworm)
January	2011001	04-01-11	60	M	F	MMW	Chronic Diarrhoea	Stool			Hookworm ova	
	2011002	17-01-11	7	M	NA	Valelevu	Parasite in stool	Stool	AL ova			
	2011003	18-01-11	1	M	F	Plastic	NA	Stool			Hookworm ova	
	2011004	30-01-11	1994 (17 yrs)	M	F	AMW	R/o Typhoid	Stool	AL ova			
											Total Sample Received = 108	
February	2011005	07-02-11	1943	F	NA	WMW	Diarrhoea	Stool	AL ova			
	2011006	10-02-11	1949	M	F	Plastic	AGE	Stool	AL ova			
											Total Sample Received = 113	
March	2011007	14-03-11	1990 (21yrs)	F	F	A/E	NA	Vomitus	AL worm			
	2011008	27-03-11	20	F	F	PWD-ANZ	Viral Illness	Stool			Hookworm ova	
	2011009	27-03-11	2	F	F	CHWD	AGE	Stool	AL ova			
											Total Sample Received = 147	
April	2011010	14-04-11	2007 (4 yrs)	M	F	CHWD-1	NA	Vomitus	AL worm			
											Total Sample Received = 103	
May	2011011	04-05-11	18	NA	F	Taveuni-(Me	NA	Stool	AL ova			
	2011012	12-05-11	2	M	F	CHWD-1	R/o Shigellosis	Stool	AL ova			
	2011013	18-05-11	22	F	F	WMW	Acute Gastroentritis	Stool	AL ova			
											Total Sample Received = 104	
June	2011014	02-06-11	6	F	F	WMW	Worm ID	Stool	AL worm			
											Total Sample Received - 125	
July	No STH Parasites seen		**Total Sample Received = 80**									
August	No STH Parasites seen		**Total Sample Received = 80**									

September	2011015	14-09-11	40	M	F	Lami HC	Bloody stool	Stool	AL ova						
	2011016	14-09-11	3	NA	F	Korovou HC	Dysentery	Stool	AL ova						
	2011017	16-09-11	2005 (6yrs)	M	F	CHWD-2	Chronic Diarrhoea	Stool	AL ova						
	2011018	16-09-11	52	F	I	CHWD-1	Diarrhoea	Stool	AL ova						
	2011019	21-09-11	76	M	I	SOPD	NA	Stool	AL ova						
	2011020	22-09-11	1978 (33)	F	F	Plastic	? Helminths	Worm	AL worm						
	2011021	26-09-11	57	F	F	A/E	TBM	Stool			Hookworm ova				
											Total Sample Received = 88				
October	2011022	08-10-11	2009 (2 yr)	M	NA	PICU	AGE	Stool	AL ova						
	2011023	20-10-11	1972 (39)	F	F	ASW	? Parasite	Stool	AL worm				SS worm		
	2011024	20-10-11	26	NA	F	Taveuni	AVI	Stool	AL ova						
											Total Sample Received = 75				
November	2011025	02-11-11	9 months	M	F	CHWD-1	AGE	Stool			Hookworm ova				
	2011026	02-11-11	1981(30)	M	F	AMW	R/o Typhoid	Stool	AL ova						
											Total Sample Received = 73				
December	2011027	05-12-11	9	M	F	PICU	Septicaemia	Worm	AL worm						
	2011028	13-11-11	34	M	F	ASW	Bowel Obstruction	Worm	AL worm						
	2011029	20-12-11	2010 (1 yr)	M	F	CHWD-1	Worm Infection	Worm	AL worm						
											Total Sample Received = 60				

2012

Month	Patient code	Date	Age	Gender	Ethnicity	Location	Clinical Symptom	Sample	Parasite detected				
									AL (Roundworm)	TT (Whipworm)	AD/NA (Hookworm)		SS (Threadworm)
January	2012001	31-01-12	1	F	I	CHWD-1	R/o Shigellosis	Stool	AL ova				
												Total Sample Received = 83	
February	No STH Parasites seen		**Total Sample Received = 107**										
March	2012002	13-03-12	24	F	F	LWD	? Worms	Stool	AL ova				
	2012003	19-03-12	1977(35yrs)	F	F	NA	AGE	Stool	AL ova				
	2012004	20-03-12	2 3/4	NA	NA	Taveuni	Dysentery	Stool	AL ova				
												Total Sample Received = 109	
April	No STH Parasites seen		**Total Sample Received = 80**										
May	2012005	28-05-12	1994 (13yrs)	F	F	TB	NA	Stool	AL ova				
												Total Sample Received = 76	
June	2012006	01-06-12	2 3/4	M	F	PICU	Typhoid	Stool	AL ova				
	2012007	27--06--12	1982(30yrs)	NA	I	Korovou	NA	Stool		Whipworm	Hookworm		
												Total Sample Received = 92	
July	No STH Parasites seen		**Total Sample Received = 74**										
August	2012008	15-08-12	1967 (45yrs)	M	F	NSRI	NA	Stool			Hookworm ova		
	2012009	23-08-12	3	M	F	ER	Shigellosis	Stool	AL ova				
												Total Sample Received = 88	
September	2012010	18-09-12	1946	M	NA	NA	Diarrhoea	Stool			Hookworm ova		
	2012011	20-09-12	1 1/52	F	F	CHWD-1	AGE	Stool	AL worm				
												Total Sample Received = 83	
October	No STH Parasites seen		**Total Sample Received = 99**										
November	No STH Parasites seen		**Total Sample Received = 96**										
December	No STH Parasites seen		**Total Sample Received = 91**										

2013

Month	Patient code	Date	Age	Gender	Ethnicity	Location	Clinical Symptom	Sample	Parasite detected			
									AL (Round	TT (Whipv	AD/NA (Hookworm)	SS (Threadworm)
January	2013001	15-01-13	3	M	F	CHWD-1	Hookworm Infestation	Stool	AL ova			
											Total Sample Received = 89	
February	2013002	19-02-13	1941	M	I	SOPD	Recurrent diarrhoea	Stool	AL ova			
	2013003	21-02-13	50	M	NA	Korovou	R/O Shigella	Stool			Hookworm ova	
											Total Sample Received = 110	
March	2013004	13-03-13	NA	M	F	NA	NA	Stool			Hookworm ova	
											Total Sample Received = 85	
April	No STH Parasites seen		Total Sample Received = 98									
May	2013005	22-03-13	NA	F	F	AMW	Post ASD	Worm	AL worm			
											Total Sample Received = 104	
June	2013006	30-06-13	2005 (8yrs)	M	F	PICU	Mastoditis	Worm	AL worm			
	2013007	01-07-13	8	M	F	GOPD	Chronic Bedsore	Worm	AL worm			
											Total Sample Received	94
July	2013008	11-07-13	2yrs1mth	F	F	Raiwaqa	NA	Stool	AL ova			
	2013009	28-07-13	7	M	NA	CHWD-2	? Typhoid	Stool	AL ova			
	2013010	30-07-13	14	M	F	PICU	Malnutrition	Stool	AL ova			
	2013011	31-07-13	37	M	F	ED	AGE	Stool	AL ova		Hookworm ova	
											Total Sample Received	135
August	2013012	09-08-13	1yr 2mths	NA	NA	Taveuni	NA	Stool			Hookworm ova	
											Total Sample Received = 106	

September	2013013	15-09-13	1yr 6 mths	F	F	PICU	?Worms	Stool	AL ova						
	2013014	18-09-13	2000 (13yrs)	NA	F	CHWD-2	Abd pain	Stool	AL ova						
	2013015	20-09-13	64	M	F	ICU	NA	Stool					SS larvae		
	2013016	24-09-13	NA	M	F	AMW	Diarrhoea	Stool			Hookworm ova				
	2013017	24-09-13	2	F	F	NA	Bloody Stool	Stool	AL ova						
											Total Sample Received = 117				
October	2013018	23-10-13	1973 (39yrs)	F	F	Gynae	Bowel obstruction	Stool	AL ova						
											Total Sample Received = 97				
November	2013019	06-11-13	14	M	F	CHWD-2	NA	Stool	AL ova		Hookworm ova				
	2013020	12-11-13	55	M	I	SOPD	NA	Stool	AL ova						
	2013021	14-11-13	2	M	F	CHWD	AGE	Stool	AL ova						
	2013022	20-11-13	3	M	F	CHWD	AGE	Stool	AL ova						
											Total Sample Received = 100				
December	2013023	19-12-13	1997 (16 yrs)	F	I	WMW	Malaria +	Stool			Hookworm ova				
											Total Sample Received = 138				

2014

Month	Patient code	Date	Age	Gender	Ethnicity	Location	Clinical Symptom	Sample Ty	Parasite detected			
							On Therapy or not		AL (Round	TT (Whipv	AD/NA (Hookworm)	SS (Threadworm)
January	2014001	14-01-14	1992 (12yrs)	F	F	NA	NA	Stool	AL ova		Hookworm ova	
	2014002	23-01-14	1966	M	I	MMW	NA	Stool			Hookworm ova	
	2014003	28-01-14	1956	M	F	WMW	?AFB	Stool				SS larvae
	2014004	30-01-14	2008(6yrs)	F	F	CHWD-2	AVI	Stool	AL ova			
											Total Sample Received = 118	
February	2014005	03-02-14	4	M	F	CHOPD	NA	Stool	AL ova			
	2014006	03-02-14	9	F	F	NA	NA	Stool	AL ova			
	2014007	06-02-14	2012(2 yrs)	F	F	NA	Diarrhoea	Stool	AL ova			
	2014008	12-02-14	1yr 6mths	F	F	PICU	?Worms	Stool	AL ova			
											Total Sample Received = 121	
March	2014009	04-03-14	1973(41 yrs)	F	F	NA	R/o Typhoid	Stool	AL ova			
	2014010	05-03-14	48	NA	F	Korovou Hosp	LBM	Stool	AL ova			
	2014011	14-03-14	2	NA	NA	Nuffield	Diarrhoea	Stool	AL ova			
	2014012	18-03-14	2	M	F	NA	Gastroentritis	Stool			Hookworm ova	
											Total Sample Received = 222	
April	2014013	29-04-14	64	F	F	NA	NA	Stool			Hookworm ova	
	2014014	30-04-14	64	F	F	NA	NA	Stool			Hookworm ova	
											Total Sample Received = 126	
May	2014015	04-05-14	1956	F	F	MMW	Dysentery	Stool	AL ova			
	2014016	06-05-14	12	F	F	CHWD-1	R/o Typhoid	Stool	AL ova			
	2014017	16-05-14	5	F	F	CHWD	NA	Stool	AL ova			
	2014018	22-05-14	5	M	F	NA	AGE	Stool	AL ova			
	2014019	23-05-14	5	M	F	NA	AGE	Stool	AL ova			
	2014020	23-05-14	46	M	F	Levuka	NA	Stool	AL ova		Hookworm ova	
											Total Sample Received = 140	
June	2014021	02-06-14	23	F	F	Taveuni	R/o Typhoid	Stool	AL ova			
	2014022	16-06-14	2006 (8yrs)	M	F	CHWD-2	? Amoebiasis	Stool	AL ova		Hookworm ova	
	2014023	22-06-14	32	M	F	PWD-ANZ	Immunocompromised	Stool			Hookworm ova	

	2014024	23-06-14	4	F	F	CHWD-1	NA	Stool	AL ova						
	2014025	30-06-14	1996 (18yrs)	M	F	Plastic	S.typhi case	Stool	AL ova						
											Total Sample Received = 137				
July	2014026	02-07-14	2011(3yrs)	M	F	CHOPD	Dysentery	Stool	AL ova						
	2014027	03-07-14	2011(3yrs)	M	F	CHOPD	Dysentery	Stool	AL ova						
	2014028	03-07-14	2005(9yrs)	M	F	CHWD-3	Hepatitis	Stool	AL ova						
	2014029	21-07-14	2005 (9yrs)	M	F	CHWD-2	NA	Stool	AL ova						
											Total Sample Received = 128				
August	2014030	06-08-14	71	M	F	Vunisea	? Typhoid	Stool			Hookworm ova		SS worm		
	2014031	26-08-14	1948	M	F	ED	PR bleeding	Stool			Hookworm ova				
	2014032	26-08-14	32	F	F	Levuka	NA	Stool	AL ova						
											Total Sample Received = 100				
Sepetmber	2014033	19-09-14	NA	NA	F	Taveuni (QHC)	AGE	Stool	AL ova						
	2014034	19-09-14	NA	M	NA	Taveuni	AGE	Stool	AL ova						
	2014035	19-09-14	NA	NA	0	Taveuni	AGE	Stool	AL ova						
	2014036	25-09-14	11 months	F	F	ED	Malnutrition	Stool	AL ova						
	2014037	30-09-14	86	F	F	Everest	AGE	Stool					SS worm		
	2014038	30-09-14	64	F	F	Amini	NA	Worm					SS worm		
	2014039	30-09-14	86	F	F	Everest	AGE	Stool	AL ova						
	2014040	30-09-14	1945	F	F	Talei	AGE	Stool	AL ova						
	2014041	30-09-14	2	M	F	Michelle	Acute Appendicities	Stool	AL ova						
											Total Sample Received = 91				
October	2014042	15-10-14	54	M	F	Violetta	Diarrhoea	Worm	**AL worm**						
	2014043	16-10-14	55	M	F	Violetta	Diarrhoea	Stool	AL worm						
	2014044	20-10-14	1950	M	F	Mai Ling	Anaemia	Stool	AL worm						
	2014045	27-10-14	1989 (15yrs)	F	F	Aloima	R/o Typhoid	Stool		**TT**					
											Total Sample Received = 116				
November	2014046	03-11-14	3	M	F	Mataika	Febrile Seizures	Stool	AL ova						
	2014047	04-11-14	21	F	I	NA	R/o Typhoid	Stool	AL ova						
	2014048	14-11-14	2013 (1yr)	F	F	Manasa	Diarrhoea	Stool					SS worm		
											Total Sample Received = 108				
December	2014049	12-12-14	1982 (32yrs)	F	F	NA	Anaemia	Stool	AL ova						
											Total Sample Received = 96				

2015

Month	Patient code	Date	Age	Gender	Ethnicity	Location	Clinical Symptom	Sample	Parasite detected			
									AL (Roundworm)	TT (Whipworm)	AD/NA (Hookworm)	SS (Threadworm)
January	2015001	01-01-15	2010 (5 yrs)	F	I	CHOP-ER	Chronic Diarrhaoea	Stool				SS worm
	2015002	14-01-15	1941	M	F	AMW	Intestinal Worm	Stool	AL ova			
											Total Sample Received = 89	
February	2015003	06-02-15	2012 (3yrs)	F	F	CHWD-1	Febrile Seizures	Stool				SS worm
	2015004	22-02-15	1981 (34 yrs)	M	F	Sukuna-PWD	SLE	Stool				SS worm
	2015005	25-02-15	1999 (16yrs)	M	F	Navua	Dysentery	Stool	AL ova			
											Total Sample Received = 106	
March	2015006	15-03-15	2013 (2yrs)	F	F	CHWD	AGE	Stool	AL ova			
											Total Sample Received = 122	
April	2015007	02-04-15	2004 (11yrs)	F	F	Navua	Dysentry	Stool	AL ova			
	2015008	22-04-15	2013 (2yrs)	M	F	CHWD-1	NA	Stool	AL ova			
	2015009	24-04-15	2013 (2yrs)	M	F	CHWD-1	Sepsis	Stool	AL ova			
	2015010	26-04-15	1936	M	F	PWD-Sukuna	UGIB	Stool			Hookworm ova	
	2015011	30-04-15	NA	F	F	Navua	NA	Stool	AL ova			
											Total Sample Received = 115	
May	2015012	03-05-15	8	M	F	Navua	NA	Stool			Hookworm ova	
	2015013	10-05-15	1992 (23yrs)	F	F	ANW	AGE	Stool	AL ova			
	2015014	27-05-15	4	M	NA	Korovou	Bloody Stool	Stool	AL ova			
											Total Sample Received = 119	
June	2015015	27-06-15	2012 (3yrs)	F	F	CHWD-1	Shigellosis	Stool	AL ova			
											Total Sample Received = 140	
July	2015016	06-07-15	1998 (17yrs)	F	F	ICU	? Hookworm	Stool	AL ova			
	2015017	07-07-15	1957	F	F	ED	Dengue	Stool			Hookworm ova	
	2015018	08-07-15	NA	M	F	PICU	AGE	Stool	AL ova			SS worm
	2015019	21-07-15	1951	F	I	ED	Chronic Diarrhoea	Stool	AL ova			
	2015020	22-07-15	NA	M	F	PICU	Parasitic Worms	Stool	AL worm			
											Total Sample Received = 104	

August	2015021	02-08-15	51	M	F	Navua	PR bleeding	Stool	AL ova				
	2015022	31-08-15	1987 (28yrs)	M	O	PWD-Sukuna	NA	Stool			Hookworm ova		
											Total Sample Received = 85		
September	**No STH Parasites seen** **Total Sample Received = 81**												
October	**No STH Parasites seen** **Total Sample Received = 93**												
November	2015023	13-11-15	2	M	F	CHWD-1	NA	Stool	AL ova				
											Total Sample Received = 75		
December	**No STH Parasite seen** **Total Sample Received = 92**												

2016

Month	Patient co	Date	Age	Gender	Ethnicity	Location	Dr	Clinical Symptom	Sample Typ	Parasite detected			
								On Therapy or not		AL (Round	TT (Whipv	AD/NA (Hookworm)	SS (Threadworm)
January	2016001	02-01-16	1990 (16yrs)	F	F	ANW	Miri	LBM	Stool	AL ova			
											Total Samples Received = 124		
February	2016002	09-02-16	1970 (46yrs)	M	F	ED	Mafi	NA	Stool				SS
	2016003	11-02-16	24-10-2015 (1yr)	M	F	CHOPD	Ohi	R/O Dysentery	Stool	AL ova			
	2016004	25-02-16	1982 (34yrs)	F	F	MICU	Int Lili	Post Partum	Vomit				SS
											Total Sample Received = 111		
March	2016005	07-03-16	61	M	F	A/E	NA	Severe Sepsis	Stool	AL ova		Hookworm ova	
	2016006	13-03-16	2014 (2yrs)	M	F	CHWD-1	Erum	Dysentery	Stool	AL ova			
	2016007	13-03-16	2yrs	M	F	CHWD-1	Shai	AGE	Stool	AL ova			
	2016008	11-03-16	76	M	F	Korovou	Javin	Typhoid	Rectal Swab			Hookworm ova	
	2016009	11-03-16	NA	M	F	Korovou	Sokini	? Typhoid	Stool	AL ova			
	2016010	20-03-16	1966	F	F	ED	Adriel	Septicaemia	Stool	AL			
	2016011	20-03-16	2	M	F	PICU	Liz	SevereDehydration	Stool	AL ova			
	2016012	27-03-16	31	M	F	Navua	Banuve	AVI	Stool	AL ova		N.americanus ova	
											Total Sample Received = 154		
April	2016013	04-04-16	21-06-2014 (2yrs)	M	F	PICU	Anette	Abdominal Pain	Stool	AL worm			
	2016014	05-04-16	44	M	F	ICU	Su	Dysentry	Stool			Hookworm ova	
	2016015	14-04-16	1	F	F	CHWD-1	NA	AGE	Stool	AL ova			
	2016016	27-04-16	2013 (3yrs)	M	F	Navua (Gopd)	Talei	Abd pain	Stool	AL ova			
											Total Sample Received = 132		
May	2016017	15-05-16	3	M	F	Navua	Ana	AGE	Stool	AL			
											Total Sample Received = 104		
June	2016018	08-06-16	5	F	F	CWM-Endoscopy	Aminiasi	? Worm	Stool	AL			
	2016019	26-06-16	14	M	F	CHWD-2	Antoinette	Malaria	Stool	AL ova		Hookworm ova	
											Total Sample Received = 119		

July	2016020	03-07-16	1967 (49yrs)	F	F	PWD-Beqa	Anushka	AGE	Stool	AL						
	2016021	10-07-16	11-08-2011 (5yrs)	M	F	CHWD-2	NA	Shigellosis	Stool	AL						
											Total Sample Received = 115					
August	2016022	02-08-16	1983 (32yrs)	F	F	Gynae	SB	S.typhi	Stool	AL ova						
	2016023	15-08-16	2015 (1 yrs)	M	F	CHWD-1	Ashnita	Meningitis	Stool	AL ova						
											Total Sample Received = 115					
September	2016024	21-09-16	35	F	F	Lancaster- CWMH	Wen	Typhoid	Stool	AL ova						
	2016025	23-09-16	35	F	F	Lancaster- CWMH	Wen	Typhoid	Stool	AL ova						
											Total Sample Received = 93					
October	2016026	07-10-16	7	M	F	WBKSI-NSRI	Navela	R/o Typhoid	Stool	AL ova						
											Total Sample Received = 90					
November	2016027	15-11-16	29	M	F	Korovou	NA	hematochezia	Stool			Hookworm ova				
	2016028	25-11-16	51	M	F	Korovou	Lasaro	? Typhoid	Stool	AL ova						
											Total Sample Received = 99					
December	2016029	04-12-16	1985 (31yrs)	M	F	ED-CWMH	Nikansha	Clinical Sepsis	Stool	AL ova						
	2016030	13-12-16	1yr 2months	M	F	CHWD-1	Int Sisi	AGE	Stool	AL ova						
											Total Sample Received = 106					

Appendix C: Direct Microscopy features of STH

lumbricoides eggs which consist of bile (greenish tinge) like stain which is not seen in other STH parasites. Fertilized *A. lumbricoides* eggs are between 40 to 70 µm long consisting of a thick shell and an external mammillated layer. The mammillated layer appears like having small nipples or protuberances. Unfertilized *A. lumbricoides* eggs are slightly larger and elongated, around 90 µm, with a thinner shell.

Microscopically, hookworm eggs, which measure around 65 µm x 35 µm, could be seen, but differentiation between *A. duodenale* and *N. americanus* could be a challenge. The reason being the eggs are colourless, and have thin shells.

Eggs of *T. trichiura* appear approximately 50 µm x 25 µm; have a barrel- shape with a thick shell.

Unsheathed larvae of *S. stercoralis* measure in-between 200 µm x 16 µm, and show a large bulb oesophagus, which is a typical rhabditiform (Khurana & Sethi, 2017).

Appendix D: Finding margin of error

Total number of STH positive stool samples at CWMH from 2008-2016

Year	Samples	Positive	Proportion	Margin error	CI (Min)	CI (Max)
2008	1,521	41	0.027	0.008	0.019	0.035
2009	1,111	19	0.017	0.008	0.009	0.025
2010	1,792	36	0.020	0.006	0.014	0.027
2011	1,159	29	0.025	0.009	0.016	0.034
2012	1,078	11	0.010	0.006	0.004	0.016
2013	1,273	23	0.018	0.007	0.011	0.025
2014	1,503	49	0.033	0.009	0.024	0.042
2015	1,221	23	0.019	0.008	0.011	0.026
2016	1,362	30	0.022	0.008	0.014	0.030
Total	12,020	261	0.022			

How to calculate margin of error

The statistical analysis of finding margin of error was done using Microsoft Excel (2010), under the guidance and support of Dr Nick Garrett (biostatistician from AUT) and Dr Vitali Babakov (post-graduate learning advisor from AUT). The following formula was used in the calculation:

Margin of error = $z \times \frac{\sigma}{\sqrt{n}}$

n = sample size • σ = population standard deviation • z = z-score

1. Get the population standard deviation (σ) and sample size (n).
2. Take the square root of your sample size and divide it into your population standard deviation
3. Multiply the result by the z-score consistent with your desired confidence interval according to the following table:

Reference: https://www.surveymonkey.com/mp/margin-of-error-calculator/