LATRINE COVERAGE AND USE IN THE LIMPOPO PROVINCE OF SOUTH AFRICA

by

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DECLARATION OF INDEPENDENT WORK

I, Mpumeleo Casper Rikhotso (Student no: 11606599), hereby declare that the dissertation for the Masters of Science Degree in Microbiology (MSc MB) at the University of Venda, hereby submitted by me, has not been submitted previously for a degree at this or any other university, that it is my own work in design and in execution, and that all reference material contained therein has been duly acknowledged.

Signature: _____ Date: 22/April/2016

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DEDICATION

I earnestly dedicate this dissertation to my dear parents Nzama and Nombulelo Rikhotso. Your contribution both spiritually, morally and financially shall eternally be in my memory. May God bless you abundantly.

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LATRINE COVERAGE AND USE IN THE LIMPOPO PROVINCE OF SOUTH AFRICA

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Background: Sanitation facilities are not adequate in many countries including South Africa and in spite of investments in sanitation programmes, the number of people with access to safe sanitation remains low, especially in rural areas. The need for good quality water and adequate sanitation are widely recognized as two essential components of social and economic development because it contributes to the enhancement of human dignity and provides a kind of freedom to people, mainly women and children.

Objective: The primary objective of this study was to assess the sanitation coverage of rural households in three wards of the Thulamela Municipality region in Vhembe district, Limpopo of South Africa. In addition 20% of toilet seats were swabbed for microbiological assessment to establish prevalence of pathogenic *E. coli* strains which could pose a health risk to vulnerable people in the households.

Methods: Assessments of rural household sanitation facilities were done between July and September 2015. Demographic questionnaires were used to assess the study households. For sample collection, four villages were chosen randomly in each of the three wards and in each village a total of 34 households were randomly visited and consent forms were given to the owner/grown up >16 years of the family to be completed. A total of 408 households were visited during the study and 136 samples were collected from each ward. A total of 84 (20%) toilet seat swab(s) samples were collected from all three wards for microbiological assessment using Total coliforms and *E. coli*. counts. An m-PCR protocol was used to determine pathogenic *E. coli* strains in swab samples.

Results: The findings of this study indicated that most of the households had functional VIP latrines. However most of the sanitation facilities required maintenance

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especially on the superstructures. Some latrines had unstable and collapsing walls while some of the facilities had broken seats and seat covers. This affected the usage of latrine by rural households due to the fact that household members were afraid of the structures collapsing on them. A total of 14 toilet seat swab samples tested positive for the presence of *E. coli* and were further assessed for the presence of pathogenic *E. coli* strains. *E. coli* strains identified included Commensal *E. coli,* Atypical Enteropathogenic *E. coli*, Enterotoxigenic *E. coli* in ward 15; Atypical Enteropathogenic *E. coli*, typical Enteropathogenic *E. coli,* Enterotoxigenic *E. coli* and Enterohaemorrhagic *E. coli* in ward 18; Commensal *E. coli,* Atypical Enteropathogenic *E. coli*, typical Enteropathogenic *E. coli*, and Enterotoxigenic *E. coli* in ward 19. The prevalence of DEC strains on the toilet seats indicated a potential for disease transmission in these households.

Conclusion: The results showed high sanitation coverage in the study population of the three wards. Coverage provided a good indication of the challenges faced by the rural communities. Several factors such as poverty, lack of awareness and water shortage forced households to adopt unsanitary practices. This study has showed encouraging practices in the use of latrines and the utilization of latrines was satisfactory.

Keywords: Sanitation coverage, *Escherichia coli* (*E. coli*)

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LIST OF ABBREVIATIONS

DWAF	:	Department of Water Affairs and Forestry
E. coli	:	*Escherichia coli*
EAEC	:	Entero-aggregative *Escherichia coli*
EHEC	:	Entero-hemorrhagic *Escherichia coli*
EIEC	:	Entero-invasive *Escherichia coli*
EPEC	:	Entero-pathogenic *Escherichia coli*
ETEC	:	Entero-toxigenic *Escherichia coli*
MPN	:	Most Probable Number
M - PCR	:	multiplex Polymerase Chain Reaction
PCR	:	Polymerase Chain Reaction
VIP	:	Ventilated improved latrine
WHO	:	World Health Organization
MDGs	:	Millennium Development Goals
HH	:	Household
SSA	:	Statistics South Africa
PBS	:	Phosphate buffer saline
TC	:	Total Coliforms
FC	:	Full coverage
GPS	:	Global Positioning System
JMP	:	United Nations Joint Monitoring Programme
MDG	:	Millennium Development Goal
WASH	:	Water, Sanitation and Hygiene
WHO	:	World Health Organization
WRC	:	Water Research Commission
SANS	:	South African National Standard

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CHAPTER 1

GENERAL INTRODUCTION

1.1 STUDY RATIONALE

The lack of sanitation affects billions of people, particularly the poor and disadvantaged. Inadequate sanitation facilities encourage people to practice open defecation and this increases the risk of transmission of diseases (WHO/UNICEF, 2014). The impact of inadequate sanitation on the health of the community is seen by the 90% of an estimated 2.2 million death cases of diarrhea in children under the age of 5 (Mwenda et al., 2010). Other diseases associated with inadequate sanitation include typhoid, bilharzia, malaria, cholera, eye infections and skin diseases (DWAF, 2004; Tladi et al., 2002; DWAF, 1996). It is estimated that about 1.8 million people die every year due to diarrheal diseases, and children under the age of 5 years account for about 90% of diarrheal deaths worldwide. It is further reported that about 88% of diarrheal diseases are associated with unsafe water supply, inadequate sanitation, and poor hygiene (WHO, 2004).

The United Nations (UN), through the Millennium Development Goals (MDG), had set a target of halving by 2015 the proportion of the population without sustainable access to improved sanitation. To achieve this target, approximately 1 billion people in urban areas and 900 million people in rural areas had to gain access to improved sanitation by 2015 (WHO/UNICEF 2012). In 2004, the World Health Organization and UNICEF's Joint Monitoring Programme for Water Supply and Sanitation released their mid-term assessment of progress, which showed that during the period 1990 to 2002 world sanitation coverage had improved from 49% to 58%. The MDG target stated that sanitation coverage should have been above 79% by 2015. However, realization of the target was requiring the rate of sanitation delivery to double from 80 million to over 160 million people per annum (1990-2015) (WHO/UNICEF, 2014). By contrast, the sanitation target, to reduce by half the proportion of people without access to safe sanitation, was declared seriously off-track and unlikely to be achieved (WHO/UNICEF, 2013). Whereas 780 million people are estimated to lack access to an 'improved' source of drinking water, an estimated 2.5 billion lack access to an 'improved' sanitation facility (WHO/UNICEF, 2013).

Despite investments in sanitation programmes, the number of people with access to safe sanitation remains low (Stephen, 2003), especially in rural areas. Poor sanitation affects the

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quality of life, and in many cases, can result in deaths and diseases which place an additional financial and health burden on poor families (Johnstone et al., 2003; Tumwine et al., 2003).

Good quality water and adequate sanitation protects community health by limiting the transmission of infectious diseases; assists in the maintenance of a sanitary home environment; contribute to the enhancement of human dignity and provides a kind of freedom to people, mainly women and children (Awoke and Muche, 2013). Several studies in developing countries such as Ethiopia, Bangladesh and India have been done on sanitation coverage and use (Akter and Amehrab, 2014; Awoke and Muche, 2013; Barnard et al., 2013; WHO/UNICEF, 2006) and have shown that available information paints a grim picture of the water and sanitation conditions in almost all developing countries. Unfortunately very little information is available on sanitation coverage and use in rural areas of South Africa.

The current study will therefore investigate sanitation coverage and use in rural households from the Limpopo province (South Africa) with a view of outlining the benefits of good quality sanitation and the progress made so far. Rural communities were chosen because they generally have little or no basic services (water, sewerage system, communications, and electricity) compared to urban areas, even when these communities are located adjacent to large towns (DWAF, 2002; Tladi et al., 2002; DWAF, 1996).

1.2 PROBLEM STATEMENT

Proper sanitation is an important basic need that contributes to human well-being. Therefore sanitation quality has to be ensured through continuous assessment. There is currently very little information available on the quality and type of sanitation structures used in rural communities in South Africa. Therefore this study seeks to:

- Provide a detailed picture of sanitation coverage and use in three wards of the Thulamela Municipality region in the Vhembe district, Limpopo of South Africa.
- Investigate the adequacy of the sanitation structures and assess the potential health risk associated with the prevalence of enterobactericeae pathogens on latrine seats.

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1.3 OBJECTIVES

1.3.1 PRIMARY OBJECTIVE

- To assess the sanitation coverage of rural households in the Thulamela Municipality region in Vhembe district, Limpopo of South Africa.

1.3.2 SPECIFIC OBJECTIVE(S)

- To use an adapted mapping tool developed by WaterAid to assess sanitation coverage in three wards of the Thulamela Municipality of the Vhembe district area.
- To assess the quality of sanitation structure through a detailed questionnaire.
- To assess 20% toilet seats for microbiological contamination by pathogenic *E. coli* strains using a published m-PCR protocol.

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LITERATURE REVIEW

2.1 BACKGROUND

The MDG (Millennium Development Target goal) sanitation target has strived to reduce the proportion of the world's population without access to improved sanitation from 51% in 1990 to 25% in 2015. Worldwide coverage of improved sanitation increased from 49% in 1990 to 64% in 2012. Over the past 22 years, the number of people practicing open defecation fell by a remarkable 21%, from 1.3 billion in 1990 to one billion in 2012 (WHO/UNICEF, 2014). Between 1990 and 2012, almost two billion people gained access to an improved sanitation facility, and open defecation decreased from 24% to 14% (WHO/UNICEF, 2014). Geographic, sociocultural and economic inequalities in access persist and in some countries have increased (WHO/UNICEF, 2014). However despite significant progress on sanitation, in 2012, 2.5 billion people did not have access to an improved sanitation facility, down from 2.7 billion in 1990, a decrease of only 7%. It stands to prove that there were still almost 2.4 billion people without access to an improved sanitation facility at the end of 2015, falling short of the MDG sanitation target. A large majority (70%) of those without access to an improved sanitation facility live in rural areas (WHO/UNICEF, 2014).

There are several available documents on assessment of latrine coverage and use worldwide (Awoke and Muche 2013; Nnadozie et al., 2006; Johnstone et al., 2003). In the District of Bahir Dar Zuria in Ethiopia, a cross sectional study was conducted on latrine coverage and associated factors among rural communities by Awoke and Muche (2013). They found that latrine coverage was far from the national target of 100% (Awoke and Muche, 2013). In Bangladesh, rural sanitation, hygiene and water supply were assessed (WHO/UNICEF, 2006) and of all the latrines in the rural areas, only 32% met the international standards for a sanitary latrine in that they completely isolated excreta from the human environment through the use of a water seal U-bend or some other lid or barriers. A study conducted in Ghana (Water Aid Report, 2009) estimated that coverage for rural water and sanitation was 52% while that of urban areas was 55% in 2005.

Basic sanitation refers to the provision of a sanitation facility which is easily accessible to a household together with the sustainable operation of the facility which includes the safe removal of human waste and wastewater from the premises where this is appropriate and necessary, and the application of good sanitation, hygiene and related practices (DWAF, 2012). A recent report

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by Nnadozie et al (2006), shows that water supply and sanitation are inadequate across Africa and about two thirds of the African population lives in rural areas, where water supply and sanitation services coverage is poor. According to Sigenu (2006) socio-economic issues such as poverty greatly influence access to water and sanitation. Poverty is linked with low coverage of water and sanitation in rural areas (Gabru, 2005). People with the lowest status and wealth in the social hierarchy, often suffer disproportionately when water supplies are limited. The poor invariably are at greatest risk from weak infrastructure. A study conducted by Gabru (2005) on water rights in South Africa argued that beyond racial categorization, the poor were traditionally vulnerable in terms of access to the rights.

Approximately 3 billion people in Africa lack access to adequate sanitation (Stephen, 2003; DWAF, 2002; Tladi et al., 2002). Sanitation facilities are not adequate in many countries including South Africa (Johnstone et al., 2003; Alcock, 1999). At the dawn of democracy in South Africa approximately 15.2 million people had no access to basic water supply (at least 25 liters of safe water within 200m of the home), and an estimated 20.5 million lacked basic sanitation (a household toilet of at least a VIP standard) in South Africa (DWAF, 2012). This figure went down to 18 million in 2001 (DWAF, 2001). However, in spite of investments in sanitation programmes, the population with access to safe sanitation remains low (Stephen, 2003), especially in rural areas. There are different types of sanitation technologies that are currently used in South Africa, including buckets (priority has been given to eradicating this system), pit latrines (with or without ventilation), chemical toilets (also to be replaced with more appropriate technology types), flush toilets with on-site septic tanks and disposal, and flush toilets with waterborne and central treatment works. In 1994, only 49% of people had access to sanitation facilities (DWAF, 2012). A study done by Still (2002) mentioned that pit latrines in particular are becoming more and more common in South Africa's rural areas (Still, 2002). Research conducted by Makgoka (2005) revealed that approximately 70% of household in Sekuruwe in South Africa have corrugated iron structure pit latrines which were poorly constructed, unhygienic and without seat covers and pit ventilation while there have been substantial improvements in the rollout of water services infrastructure and the rendering of free basic water and sanitation in South Africa, the sector does face some challenges going forward as implementation capacity remains a constraint (Water and Sanitation, 2011). However sustainability of existing infrastructure cannot be neglected and is requiring more and more funding as infrastructure ages. In addition, the cost of extending the network infrastructure to outlying communities is not cost-effective or sustainable, which points to the need to explore alternative service delivery options (Water and Sanitation, 2011). This infrastructure problem is

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further compounded by the fact that many municipalities, especially the smaller and more rural municipalities, do not manage their assets (VIP latrines given to communities) strategically (Water and Sanitation, 2011). They are often unaware of what assets they have, where those assets are located, how old those assets may be and what investments are required to extend the useful life of these assets. Without this information, it is almost impossible to determine the investment needs required (Water and Sanitation, 2011). The development of an asset register is also a costly exercise, as many municipalities outsource this function as they do not have the requisite in house capacity. As a result of funding constraints, this exercise is often deferred or completed through a phased approach (Water and Sanitation, 2011). Efforts to provide all people with sanitation infrastructure are being constrained by skills shortages within the sector. Several reforms and measures are being implemented to improve the efficiency of the water sector as well as measures to improve sanitation and prevent outbreaks of related diseases (Water and Sanitation, 2011).

Another study in South Africa by Pelser et al. (2009) clearly mentioned that service delivery in rural areas has always lagged behind that of urban areas due to a number of reasons. Supplying services to remote and geographical spread out population makes infrastructure development and maintenance, as well as ensuring supply of services such as water provision, costly and difficult to maintain. Some of the poorest municipalities are situated in densely populated, deep rural areas that are characterized by backlogs in service delivery (Pelser et al., 2009). In a detailed article of water for growth and development framework by Pelser et al. (2009) it was mentioned that many of the larger villages in South Africa are located on hillsides and generally have unplanned layouts and in these circumstances the provision of a basic water supply to each household is complicated and costly. A study done by Arenas (2003) revealed that the South African settlement structure is considered as one of the most inefficient and distorted of the world. The scattered nature of rural settlements presents major challenges for providing water and sanitation services (Arenas, 2003).

Predominantly rural and poverty-stricken communities around the Vhembe area of the Limpopo Province of South Africa face challenges of inadequate sanitation and still depend on standard pit latrines and VIP latrines as their adequate toilet facilities on a daily basis (Vhembe district municipality profile, 2010/2011).

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2.2 SANITATION COVERAGE IN SOUTH AFRICA

The 2000 Municipal Infrastructure Investment Framework (MIIF) review document estimated that 26% of urban households and 76% of rural households had inadequate sanitation (DWAF, 2001). Table 2.1 summarizes the types of toilet facilities being used by South African households during the period 2002– 2010. It indicates that in 2010, more than half (58.7%) of households used flush toilets connected to a public sewerage system (GHS, 2011). The second and third most used toilet system nationally was a pit latrine without a ventilation pipe (18.8%) and pit latrines with ventilation pipes respectively (12.5%). There have also been signs of pit latrine upgrades with a significant increase in pit latrines with ventilation pipes (from 4.4% in 2002 to 12.5% in 2010) and a decrease of pit latrines without ventilation pipes (from 25.2% to 18.8%). Households using no toilet facilities also decreased from 10% in 2002 to 5.3% in 2010 (GHS, 2011).

Table 2.1: Type of toilet facility used by households (numbers in thousands), 2002-2010

Type of toilet facility	Statistics	Year								
		2002	2003	2004	2005	2006	2007	2008	2009	2010
Flush toilet connected to a public sewage system in dwelling	Number	6 120	6 421	6 459	6 685	6 523	7 347	7 362	7 770	8 112
	%	55,6	56,5	55,2	55,4	52,4	57,4	55,4	56,3	58,7
Flush toilet connected to a septic tank	Number	216	247	436	493	1 048	494	564	400	467
	%	2,0	2,2	3,7	4,1	8,4	3,9	4,2	2,9	3,4
Chemical toilet	Number	36	43	50	117	54	78	62	50	59
	%	0,3	0,4	0,4	1,0	0,4	0,6	0,5	0,4	0,4
Pit latrine with ventilation pipe	Number	479	595	824	862	923	1 134	1 328	1 799	1 734
	%	4,4	5,2	7,0	7,2	7,4	8,9	10,0	13,0	12,5
Pit latrine without ventilation pipe	Number	2 770	2 757	2 679	2 730	2 850	2 747	2 938	2 846	2 595
	%	25,2	24,3	22,9	22,6	22,9	21,4	22,1	20,6	18,8
Bucket toilet	Number	278	241	235	269	291	220	198	147	110
	%	2,5	2,1	2,0	2,2	2,3	1,7	1,5	1,1	0,8
None	Number	1 103	1 052	1 022	904	770	791	831	760	728
	%	10,0	9,3	8,7	7,5	6,2	6,2	6,3	5,5	5,3
Other	Number	-	-	-	-	-	-	-	39	22
	%	-	-	-	-	-	-	-	0,3	0,2
Sub-total	Number	11 004	11 358	11 705	12 062	12 459	12 811	13 283	13 811	13 827
	%	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
Unspecified	Number	9	4	7	13	0	90	13	1	478
	%	0,1	0,0	0,1	0,1	0,0	0,7	0,1	0,0	3,3
Total	Number	11 013	11 362	11 712	12 075	12 459	12 901	13 296	13 812	14 305

Source: GHS series, Volume III, Water and Sanitation, 2002-2010 in South Africa.

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Data reveals significant differences between provinces (Table 2.2). Even though the use of improved pit latrines has increased nationally since 2002, there were still some provinces with a high prevalence of substandard sanitation facilities such as pit latrines without ventilation pipes. The use of pit latrines in its various forms was most prevalent in Limpopo (69.8%), Mpumalanga (51.9%), KwaZulu-Natal (47.1%) and Eastern Cape (40.6%), (GHS, 2011). In practice it is quite often expensive and difficult to install flush toilets everywhere, especially in areas that do not have a lot of water and/ or in dispersed settlements. The addition of ventilation pipes to pit latrines is a basic improvement to reduce smells and bacterial transmission through vectors such as flies (GHS, 2011).

Table 2.2: Type of toilet facility used, by province (numbers in thousands), 2010 (GHS series, Volume III, Water and Sanitation, 2002-2010) in South Africa.

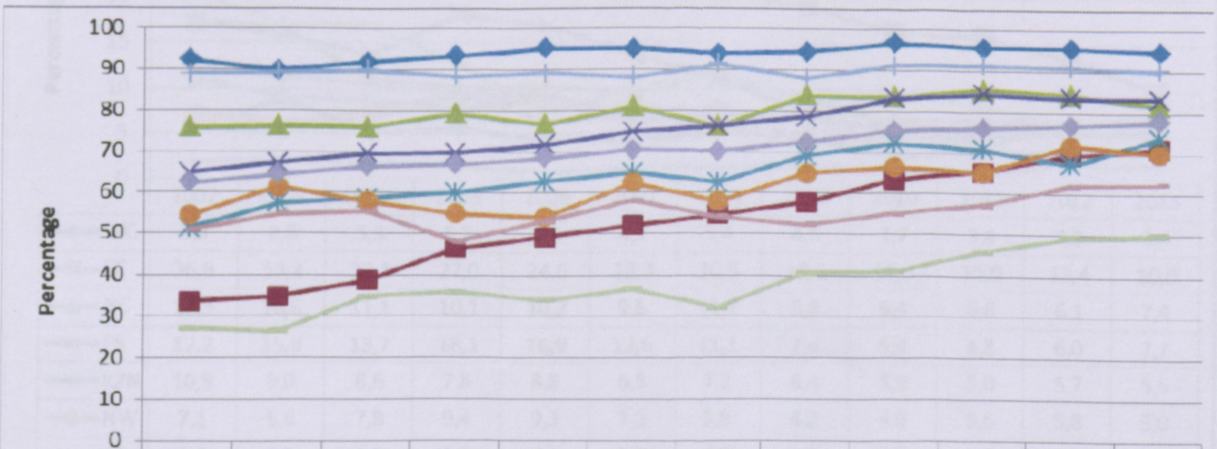
Type of toilet facility	Statistics	Year									
		WC	EC	NC	FS	KZN	NW	GP	MP	LP	RSA
Flush toilet connected to a public sewage system in dwelling	Number	1 357	694	210	598	1 135	389	3 116	363	250	8 112
	%	90,4	40	68,7	73,8	43,6	40,6	87,2	37	18,4	58,7
Flush toilet connected to a septic tank	Number	84	40	16	13	104	74	61	40	34	467
	%	5,6	2,3	5,2	1,7	4	7,7	1,7	4,1	2,5	3,4
Chemical toilet	Number	6	2	4	3	20	1	19	1	3	59
	%	0,4	0,1	1,2	0,4	0,8	0,1	0,5	0,1	0,2	0,4
Pit latrine with ventilation pipe	Number	6	333	27	47	663	171	74	130	284	1 734
	%	0,4	19,2	8,7	5,7	25,5	17,9	2,1	13,2	21,0	12,5
Pit latrine without ventilation pipe	Number	1	370	27	99	524	280	253	380	662	2 595
	%	0,1	21,4	9	12,2	20,1	29,2	7,1	38,7	48,8	18,8
Bucket toilet	Number	26	15	3	36	10	0	17	2	0	110
	%	1,7	0,9	1,1	4,5	0,4	0	0,5	0,2	0	0,8
None	Number	19	276	18	13	148	41	27	65	120	728
	%	1,3	15,9	6	1,6	5,7	4,3	0,8	6,7	8,8	5,3
Other	Number	3	4	1	2	1	2	8	0	2	22
	%	0,2	0,2	0,2	0,2	0,1	0,2	0,2	0	0,2	0,2
Sub-total	Number	1 502	1 734	306	811	2 605	958	3 575	981	1 355	13 827
	%	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
Unspecified	Number	30	47	14	74	107	24	109	34	39	478
	%	2,0	2,6	4,4	8,4	3,9	2,4	3,0	3,3	2,8	3,3
Total	Number	1 532	1 781	320	885	2 712	982	3 684	1 015	1 394	14 305

WC= Western Cape; **EC**= Eastern Cape; **NC**=Northern Cape; **FS**= Free State; **KZN**= Kwa-Zulu natal; **NW**= North West; **GP**= Gauteng province; **MP**= Mpumalanga; **LP**= Limpopo province; **RSA**=Republic of South Africa

Figure 2.1 identifies the percentage of households per province that had access to RDP standard toilet facilities, i.e. flush toilets connected to a public sewerage system or a septic tank, and a pit toilet with a ventilation pipe (Statistics SA, 2013). Nationally, the percentage of households with

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access to RDP– standard sanitation increased from 62.3% in 2002 to 77.9% in 2013. The majority of households in Western Cape (94.8%) and Gauteng (90.2%) had access to adequate sanitation, while about half those in Limpopo (50%) and just under two-thirds of those in Mpumalanga (62.7%) had adequate access. It is notable that access to adequate sanitation grew most rapidly in Eastern Cape (+37.7 percentage points) between 2002 and 2013 (Statistics SA, 2013).



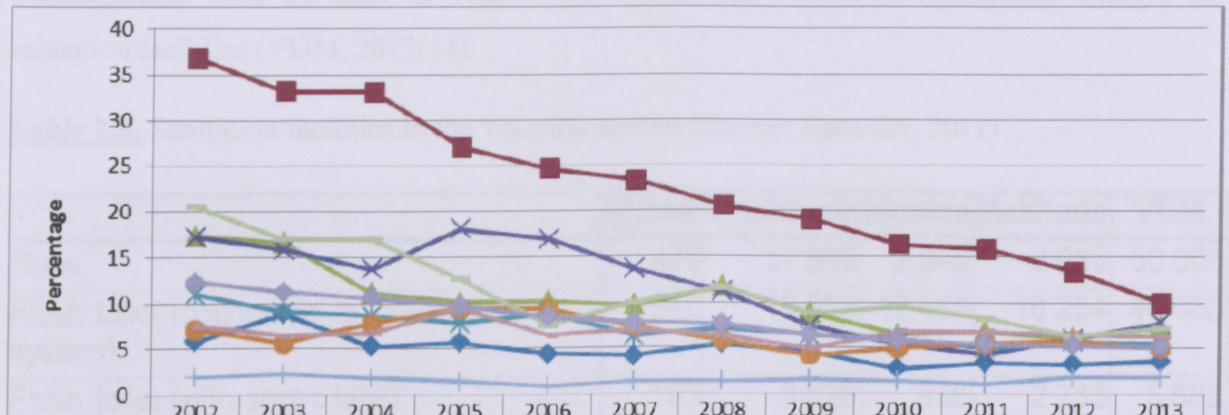
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
WC	92,2	89,7	91,8	93,4	95,2	95,0	93,8	94,5	96,7	95,6	95,6	94,8
EC	33,5	34,7	38,6	46,5	49,3	52,1	54,7	57,8	63,4	65,5	69,6	71,2
NC	75,8	76,1	76,0	79,3	76,7	80,8	76,1	83,7	83,5	85,3	84,4	81,7
FS	64,9	67,2	69,7	69,9	71,7	74,8	76,3	78,6	83,2	84,4	83,4	83,3
KZN	51,4	57,4	58,7	60,1	62,8	64,8	62,5	69,3	72,3	70,9	67,4	73,9
NW	54,5	61,4	58,0	55,1	54,2	62,3	57,9	64,8	66,4	65,1	71,9	70,0
GP	88,9	89,3	89,9	88,5	89,1	88,1	91,3	88,0	91,2	91,4	91,0	90,2
MP	50,9	54,7	55,5	48,3	53,2	58,1	54,1	52,4	55,2	57,2	62,2	62,7
LP	27,0	26,3	34,6	35,8	34,0	36,6	32,1	40,6	40,9	45,8	49,4	50,0
RSA	62,3	64,4	66,4	67,0	68,5	70,4	70,1	72,4	75,4	76,0	76,9	77,9

Figure 2.1: Percentage of households that have access to improved sanitation per province, 2002-2013 (Statistics South Africa, General Household Survey, 2013)

Despite the improved access to RDP-standard sanitation facilities, many households continued to be without any proper sanitation facilities (Statistics SA, 2013). Figure 2.2 shows the percentage of households that either had no sanitation facilities or that had to use bucket toilets. According to Statistics South Africa (SSA, 2013), nationally, the percentage of households that continued to live without proper sanitation facilities had been declining consistently between 2002 and 2013, decreasing from 12.3% to 5.1% during this period. The most rapid decline over this period was observed in Eastern Cape (-26.8%), Limpopo (-13.3%), Northern Cape (-9.9%) and Free State (-9.5%). Scores of households in Eastern Cape (10%), Free State (7.7%), Northern Cape

(7.4%) and Limpopo (7.2%) remained without any sanitation facilities in 2013 (Statistics SA, 2013).

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	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
WC	5,8	8,8	5,3	5,7	4,4	4,1	5,4	4,5	2,7	3,4	3,2	3,6
EC	36,8	33,2	33,1	27,0	24,6	23,3	20,5	19,1	16,3	15,8	13,4	10,0
NC	17,3	16,6	11,1	10,1	10,2	9,6	11,7	8,8	6,4	6,8	6,1	7,4
FS	17,2	15,8	13,7	18,1	16,9	13,6	11,1	7,4	5,4	4,3	6,0	7,7
KZN	10,9	9,0	8,6	7,8	8,8	6,3	7,2	6,4	5,9	5,0	5,7	5,5
NW	7,1	5,6	7,8	9,4	9,3	7,3	5,8	4,2	4,9	5,5	5,8	5,0
GP	1,9	2,2	1,8	1,4	0,9	1,3	1,3	1,6	1,3	1,0	1,8	1,8
MP	7,5	6,4	6,8	9,5	6,4	7,0	6,3	5,0	6,8	6,8	6,4	6,3
LP	20,5	17,0	17,0	12,6	7,5	10,0	11,6	8,8	9,4	8,2	6,3	7,2
RSA	12,3	11,2	10,6	9,7	8,4	7,8	7,6	6,4	5,8	5,4	5,3	5,1

Figure 2.2: Percentage of households that have no toilet facility or that have been using bucket toilet per province, 2002-2013(Statistics South Africa, General Household Survey, 2013)

The percentage of households that have access to improved sanitation facilities such as flush toilets or pit toilets with ventilation pipes have increased from 62.3% in 2002 to 77.9% in 2013. Only 50% of households in Limpopo and about two-thirds (62.7%) of households in Mpumalanga had access to improved sanitation facilities (SSA, 2013). More than one-quarter of households that shared toilet facilities complained about the poor hygiene (25.6%) and poor lighting (25.1%) at these facilities. A further 22% felt that their physical safety were threatened when they had to use the facilities, while 13.1% of households felt that the toilets were not adequately enclosed (SSA, 2013).

2.3 SANITATION COVERAGE IN THE VHEMBE DISTRICT

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Table 2.3 indicates Sanitation facilities in the households in the Vhembe district local Municipalities with the total of 70,869 VIP toilets and 30,006 of households without any sanitation facilities (VDM, 2013/14).

Table 2.3: Sanitation facilities in the Vhembe district (Source: Stats SA, 2011)

	Mutale	Thulamela	Musina	Makhado	VDM
None	478	17 896	2 645	8 986	30 006
Flush toilet (connected to sewerage system)	910	16 803	12 664	16 284	46 660
Flush toilet (with septic tank)	193	2 526	636	2 233	5 588
Chemical toilet	100	1 198	39	1 036	2 373
Pit toilet with ventilation (VIP)	14 077	26 014	1 479	29 300	70 869
Pit toilet without ventilation	7 900	89 431	2 252	75 073	174 656
Bucket toilet	37	292	130	748	1 207
Other	58	2 433	197	1 229	3 916

Table 2.3 also indicates the latrine facilities which have been provided by the government from 2003 to 2012 and the number of latrines which are still pending. Table 2.4 summarizes the number of VIP toilet facilities provided since 2003 to 2012 by the Vhembe district Municipality in the different local municipalities. It also indicates the outstanding work that is still due to be done (VDM, 2012). It is noticeable that sanitation is moving forward with the outstanding work having been done so far. With so much work still to be done to provide decent and functional sanitation for all, it is appropriate to assess the work that has been done on sanitation improvement from a decade ago.

Table 2.4: VIP toilets provided since 2003/12 and backlog (Source: VDM 2012)

VIP TOILETS		Thulamela	Makhado	Musina	Mutale	VDM
2003/4-2011/12	Backlog	91 710	75 413	182	8 980	176 285
	Completed	35 937	39 750	600	20 292	96 579
2012/13 Backlog		55 773	35 663	510	2 251	91 436

2.4 VENTILATED IMPROVED PIT (VIP) LATRINE STANDARDS IN SOUTH AFRICA

The VIP latrine is similar to a conventional pit latrine, but includes a vertical ventilation pipe beside or within the latrine superstructure. Two problems encountered with a standard pit latrine are odors and the presence of flies. The design of the VIP latrine (Figure 2.3) largely eradicates these problems as air flows down into the latrine pit through the latrine squat hole and up out of the ventilation pipe, thus removing odors from the latrine (DWAF, 2003).

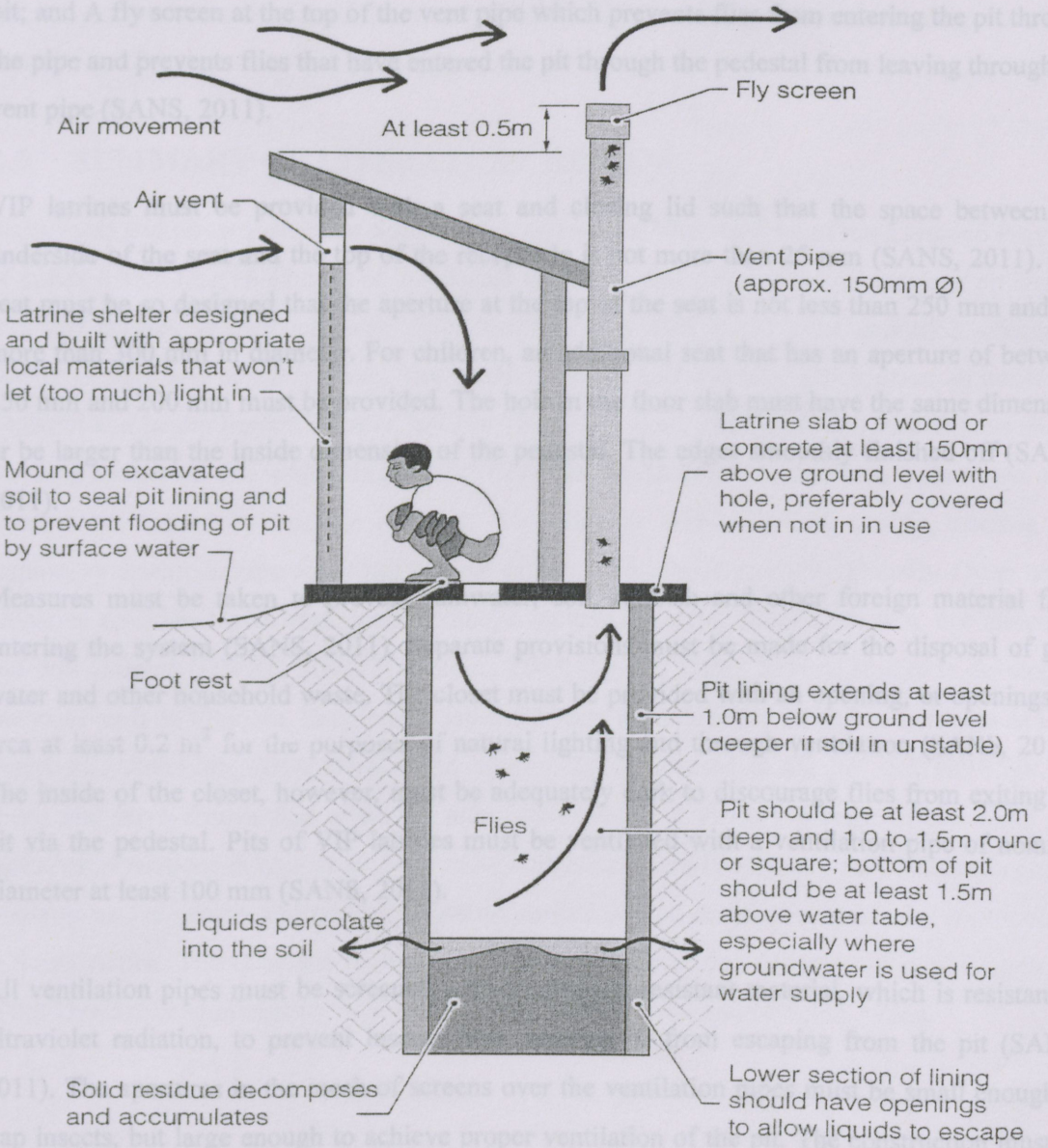


Figure 2.3: Diagram of VIP latrines (Harvey, 2007)

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The South African National Standard (SANS) data on Ventilated improved pit toilet (VIP) indicates the requirements for compliance with Non-Water-Borne Means of Sanitary Disposal of the National Building Regulations (SANS, 2011). The requirements set by SANS for VIP latrines comprise:

- A pit into which the excreta fall and from which the liquid fraction seeps into the surrounding ground; A slab which covers the pit and which has two holes, one for the excreta to fall through and one for the vent pipe; A superstructure which provides privacy and which prevents light from entering the pit; A pedestal seat and seat cover; A vent pipe which removes odor from the pit; and A fly screen at the top of the vent pipe which prevents flies from entering the pit through the pipe and prevents flies that have entered the pit through the pedestal from leaving through the vent pipe (SANS, 2011).

- VIP latrines must be provided with a seat and closing lid such that the space between the underside of the seat and the top of the receptacle is not more than 25 mm (SANS, 2011). The seat must be so designed that the aperture at the top of the seat is not less than 250 mm and not more than 300 mm in diameter. For children, an additional seat that has an aperture of between 150 mm and 200 mm must be provided. The hole in the floor slab must have the same dimension or be larger than the inside dimension of the pedestal. The edges smoothly finished off (SANS, 2011).

- Measures must be taken to prevent rainwater, soil, rubbish and other foreign material from entering the system (SANS, 2011). Separate provisions must be made for the disposal of grey water and other household waste. The closet must be provided with an opening, or openings, of area at least 0.2 m^2 for the purposes of natural lighting and through-ventilation (SANS, 2011). The inside of the closet, however, must be adequately dark to discourage flies from exiting the pit via the pedestal. Pits of VIP latrines must be ventilated with a ventilation pipe of nominal diameter at least 100 mm (SANS, 2011).

- All ventilation pipes must be screened with a corrosion-resistant material, which is resistant to ultraviolet radiation, to prevent insects from entering or from escaping from the pit (SANS, 2011). The apertures in the mesh of screens over the ventilation pipes must be small enough to trap insects, but large enough to achieve proper ventilation of the pit. The construction must be such that it is not possible for leaves and other debris to accumulate on top of the screen (SANS, 2011).

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- According to SANS (2011) measures must be taken to install a vent pipe which removes odor from the pit; and A fly screen at the top of the vent pipe which prevents flies from entering the pit through the pipe and prevents flies that have entered the pit through the pedestal from leaving through the vent pipe (SANS, 2011). All ventilation pipes must be screened with a corrosion-resistant material, which is resistant to ultraviolet radiation, to prevent insects from entering or from escaping from the pit (SANS, 2011). The apertures in the mesh of screens over the ventilation pipes must be small enough to trap insects, but large enough to achieve proper ventilation of the pit. The construction must be such that it is not possible for leaves and other debris to accumulate on top of the screen (SANS, 2011). Wall ventilation openings should be fitted with a fly-screen.

2.5 SUMMARY OF LITERATURE REVIEW

Many rural and poverty-stricken communities around the Vhembe area of the Limpopo Province of South Africa face challenges of inadequate sanitation and still depend on standard pit latrines and VIP latrines as their adequate toilet facilities on a daily basis. Poor sanitation affects the quality of life, and in many cases, can result in deaths and diseases which place an additional financial and health burden on poor families (Tumwine et al., 2003). Several studies have shown that poor sanitation and sanitation practices have dire health impacts. Diarrhea, typhoid and other diseases are spread by bacteria in feces. According to WHO/UNICEF (2006), diarrhea and respiratory disease are the combined leading causes of childhood mortality globally. Other health problems associated with inadequate sanitation include bilharzia, malaria, cholera, eye infections and skin diseases (DWAF, 2004; Tladi et al., 2002; DWAF, 1996). Several studies in developing countries such as Ethiopia, Bangladesh and India have been done on sanitation coverage and use (Akter and Amehrab, 2014; Awoke and Muche, 2013; Barnard et al., 2013; WHO/UNICEF, 2006) and have shown that available information paints a gloomy picture of the water and sanitation conditions in almost all developing countries. There is currently very little information available on the quality and type of sanitation structures used and available in rural communities in South Africa. Therefore the study seeks to assess the sanitation coverage of rural households in the Thulamela Municipality region in Vhembe district, Limpopo of South Africa.

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3.1 STUDY SITE

This study was done in Vhembe District; Limpopo of South Africa which is located in the northern part of the Limpopo province (South Africa) (Figure 3.1). It shares borders with Zimbabwe and Botswana in the north-west and Mozambique in the south-east through the Kruger National Park.Vhembe district has a size of about 25 597 km and is one of five districts found in the Limpopo province with a population size of about 1 472 615 and a total number of 821 communities. There are 4 Local Municipalities within the Vhembe district (Musina, Mutale, Makhado and Thulamela). The study focused specifically on the Thulamela district area looking at wards 15, 18 and 19. Thulamela municipality is a flat area with valleys and the land is used mostly for agricultural activities (Vhembe district municipality profile, 2010/2011).

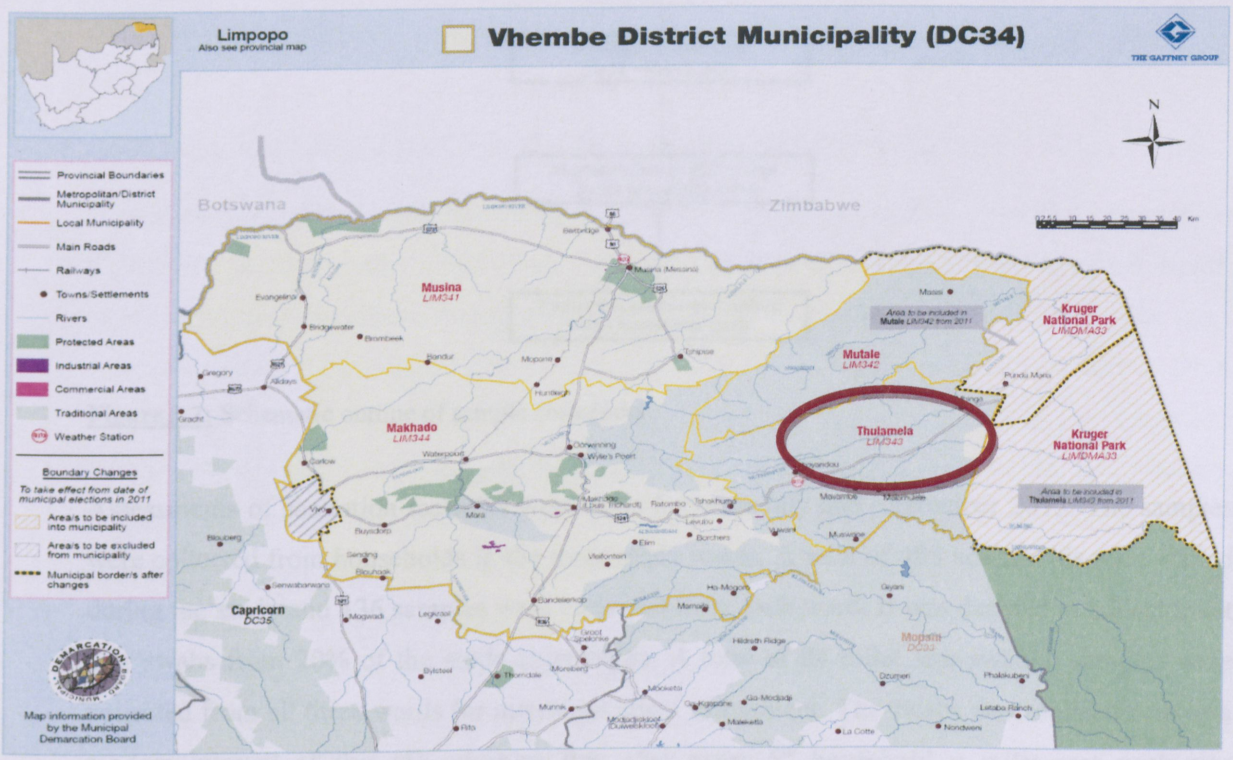


Figure 3.1: Map showing the Vhembe district municipality and indicating study area Thulamela (https://www.google.co.za/search?q=vhembe+district+municipalityandbiw=1524andbih=746andsource=lnmsandtbm=ischandsa=Xandved=0ahUKEwipzqHv5rrJAhUGWxoKHbP8B6IQ_AUIBygCanddpr=1.05).

3.2 SAMPLE COLLECTION

A schematic outline of sample collection is shown in Figure 3.2. During the study tribal authorities were visited to request for permission to conduct research in the selected villages to ensure good governance with the chiefs as the local authorities. For sample collection, four villages were chosen randomly in each of the three wards. In each village a total of 34 households were randomly visited and consent forms were given to the owner/grown up >16 years of the family to be completed. Ethical clearance was obtained from the university of Venda research committee.

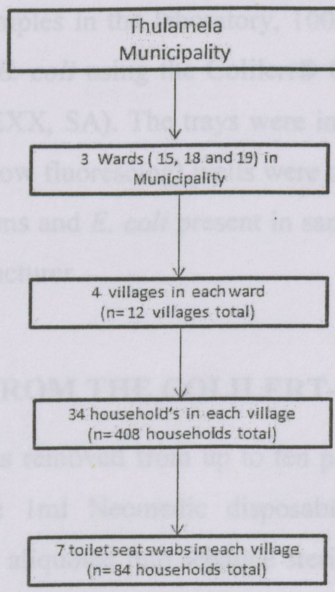


Figure 3.2: Schematic outline of sample collection.

Assessments of sanitation facilities were done between July and September 2015. The samples were collected from households in the three study wards. A total of 408 households were visited during the study and 136 samples were collected from each ward. It was decided to collect toilet seat swabs from 20% of the study households. A total of 84 toilet seat swab(s) samples were collected from all three wards for microbiological assessment. The swabs were collected using a random interval of five (5), meaning that after every 5th household, a toilet seat swab was collected.

During the study demographic questionnaires (appendix A) were used to assess the households. A digital camera was used to capture pictures of the sanitation facilities in the study area

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(Samsung camera, 20 pixels). A global positioning system (GPS - GARMIN /72H) was used to determine the exact ground position of each household latrine facility visited. Sterile swabs purchased from LABCHEM, (SA) were used for swabbing toilet seats. PBS solution (pH=7.4) purchased from LABOCHEM, (SA), was used to place swabs in until they were processed.

3.3 MICROBIAL ANALYSIS

3.3.1 MICROBIOLOGICAL ANALYSIS OF SWABS FROM TOILET SEATS

For toilet seat swabs, each swab was placed in a sterile collection bottle with 110ml sterile PBS pH 7.4. All samples were placed at 4°C until being processed within approximately six hours of collection. Upon recipient of samples in the laboratory, 100ml PBS solution was tested for the prevalence of total coliform of *E. coli* using the Colilert® Quanti-Trays/2000 according to the manufacturer's instructions (IDEXX, SA). The trays were incubated at 35°C for 18 to 22 hours and the positive (yellow and yellow fluorescing) wells were counted and converted into the most probable number of total coliforms and *E. coli* present in samples respectively, using tables and formulae provided by the manufacturer.

3.3.2 DNA EXTRACTION FROM THE COLILERT-TRAYS/2000

A total of 2 ml of the media was removed from up to ten positive *E. coli* wells of each of the Colilert-Trays/2000 with sterile 1ml Neomedic disposable syringes with mounted needle (Kendon Medical Suppliers) and aliquoted into separate sterile 2ml eppendorf tubes. The tubes were centrifuged for 5 min at 13,000 × g to pellet the cells and the supernatant discarded. DNA was extracted from the collected bacterial cells using an adapted version of the guanidium thiocyanate/silica method reported by Boom et al., (1990) using homemade spin columns prepared as reported by Borodina et al., (2003). The changes to the DNA extraction method included the addition of 250µl 100% ethanol to the lysis buffer to enhance the binding of DNA to the celite. The celite containing the bound DNA was loaded into spin columns before doing the washing steps. DNA was eluted from the celite with 100µl Qiagen elution buffer (Southern Cross Biotechnology). The extracted DNA was used as template in all PCR reactions (Omar et al., 2010).

3.3.3 MULTIPLE POLYMERASE CHAIN REACTIONS (m-PCR)

The m-PCR protocol published by Omar and Barnard (2014) was used to detect the presence of Diarrheagenic *E. coli* (DEC) genes in all toilet seat swab samples. All m-PCR reactions were

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performed in a Biorad Mycycler™ Thermocycler in a total volume of 20 µl. The genes used are shown on Table 3.1. Each reaction consisted of 1X Qiagen® PCR multiplex mix (containing HotstartTaq® DNA polymerase, m-PCR buffer and dNTP mix) (Qiagen, USA); 2 µl of the primer mixture [0.1 lM of *mdh* and *lt* primers, 0.2 lM of *ial*, *eagg*, *astA*, *bfp* and *gapdh* primers (F and R), 0.3 lM of eaeA and stx2 primers (F and R), 0.5 lM of *stx1* and *st* primers], 2 µl of DNA sample 1 µl of *gapdh* cDNA and 5 ul of PCR grade water. The reactions were subjected to an initial activation step at 95^{0}C for 15 min, 35 cycles that consisted of denaturation at 95^{0}C for 45s, annealing at 55^{0}C for 45s, extension at 68^{0}C for 2 min and final elongation at 72^{0}C for 5 min (Omar and Barnard, 2014).

Table 3.1: Primers used in the m-PCR reaction (Omar and Barnard, 2014)

Pathogen	Primer	Sequence(5'-3')	Size (bp)	Conc. (µM)	Reference
E. coli	mdh (F) mdh (R)	GGT ATG GAT CGT TCC GAC CT GGC AGA ATG GTA ACA CCA GAG T	304	0.1	Tarr et al., (2002)
EIEC	ial (F) ial (R)	GGT ATG ATG ATG ATG AGT CCA GGA GGC CAA CAA TTA TTT CC	650	0.2	Lo´pez-Saucedo et al., (2003)
EHEC/Atypical EPEC	eaeA (F) eaeA (R)	CTG AAC GGC GAT TAC GCG AA CCA GAC GAT ACG ATC CAG	917	0.3	Aranda et al., (2004)
Typical EPEC	bfpA (F) bfpM (R)	AAT GGT GCT TGC GCT TGC TGC TAT TAA CAC CGT AGC CTT TCG CTG AAG TAC CT	410	0.3	Aranda et al., (2004)
EAEC	eagg (F) eagg (R)	AGA CTC TGG CGA AAG ACT GTA TC ATG GCT GTC TGT AAT AGA TGA GAA C	194	0.2	Pass et al., (2000)
EHEC	stx1 (F) stx1 (R) stx2 (F) stx2 (R)	ACA CTG GAT GAT CTC AGT GG CTG AAT CCC CCT CCA TTA TG CCA TGA CAA CGG ACA GCA GTT CCT GTC AAC TGA GCA CTT TG	614 779 	0.5 0.3 	Moses et al., (2006)
ETEC	lt (F) lt (R) st (F) st (R)	GGC GAC AGA TTA TAC CGT GC CGG TCT CTA TAT TCC CTG TT TTT CCC CTC TTT TAG TCA GTC AAC TG GGC AGG ATT ACA ACA AAG TTC ACA	360 160 	0.1 0.5 	Pass et al., (2000)
E. coli toxin	astA (F) astA (R)	GCC ATC AAC ACA GTA TAT CC GAG TGA CGG CTT TGT AGT C	106	0.3	Kimata et al., (2005)
External control	gapdh (F) gapdh (R)	GAG TCA ACG GAT TTG GTC GT TTG ATT TTG GAG GGA TCT CG	238	0.3	Mbene et al., (2009)

F forward primer,

R reverse primer

3.4 ANALYSIS OF DATA

The data collected from the questionnaires were entered into Microsoft Excel Spread Sheets for analyses. The results thereafter were used for comparisons and illustrations to give a detailed picture of the status of sanitation coverage and associated factors in the three study wards.

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RESULTS AND DISCUSSION

The study information used in this write-up was obtained using a questionnaire (appendix A). Coverage was done using a GPS (Global positioning system) and data collected was used for drawing maps (appendix B and C).

4.1 SOCIO-DEMOGRAPHIC ASSESSMENT OF STUDY POPULATION

Household profile

Table 4.1 provides a descriptive summary of the study population. Among the study participants that responded to the questionnaire 209 (51%) were the head of the families; 68 (16%) were house wives and 131 (32%) were other family members (Table 4.1). According to gender distribution, 287 (70%) were female and 121 (30%) were male. The study population was equally distributed by family size. The gender distribution in the households 963 (57%) were females and 720 (43%) were males. Looking at age distribution in the households 528 (33%) of the respondents were aged between 16 - 32 years, while 99 (6%) were aged between 64 - 100 years and Children under five years were 9% (150). The level of education in the wards indicated that only 40 (4%) had tertiary education (Table 4.1).

Table 4.1: Socio-demographic characteristics of respondents (Ward 15, 18 and 19)

Variable	Overall study population (n =408)	Ward 15 (n=136)	Ward 18 (n=136)	Ward 19 (n=136)
Respondent to questionnaire				
Head	209 (51%)	77 (56%)	69 (51%)	63 (46%)
Spouse	68 (16%)	12 (9%)	28 (20%)	28 (20%)
Son	50 (12%)	16 (11%)	17 (12%)	17 (12%)
Daughter	69 (17%)	28 (20%)	17 (12%)	24 (18%)
Other (relative, friend etc.)	12 (3%)	2 (2%)	5 (4%)	4 (3%)
Gender distribution of respondents				
Male	121 (30%)	36 (26%)	44 (32%)	41 (30%)
Female	287 (70%)	99 (73%)	92 (68%)	95 (70%)
Gender distribution in households (n = 1683)				
Male	720 (43%)	234 (40%)	240 (43%)	246 (45%)
Female	963 (57%)	354 (60%)	311 (56%)	298 (55%)
Age distribution (n= 1683)				
Under 5 years	150 (9%)	42 (8%)	47 (9%)	61 (12%)
5 – 16 years	386 (24%)	127 (23%)	133 (25%)	126 (25%)
16- 32 years	528 (33%)	190 (34%)	167 (32%)	171 (33%)
32-48 years	250 (16%)	83 (15%)	92 (17%)	75 (15%)
48-64 years	177 (11%)	60 (11%)	69 (13%)	48 (9%)
64 – 100 years	99 (6.2%)	49 (9%)	20 (4%)	30 (6%)
Unknown	93 (23%)	30 (22%)	33 (24%)	30 (22%)

Family size				
≥5	174 (43%)	58 (43%)	52 (38%)	62 (45%)
≤5	234 (57%)	78 (57%)	82 (60%)	74 (54%)
Level of education (n= 971)				
Primary school	353 (36%)	142 (39%)	114 (34%)	97 (35%)
Secondary school	578 (59%)	208 (58%)	207 (62%)	163 (59%)
Tertiary school	40 (4%)	11 (3%)	14 (4%)	15 (5%)

4.2 SANITATION COVERAGE

Table 4.2 summarized the coverage of sanitation in the study villages. All 408 (100%) households used VIP latrines and all build by the South African government (appendix B and C). The ventilated improved latrine facility structures in the study population were categorized into two types:

- A structure built of local materials (bricks), non-removable steel door, fitted with a ventilation pipe, ventilation openings and a fly screen (Figure 4.1).

- A Commercial Manufactured system, the structure is made of precast concrete, non-removable steel swivel door, ventilation pipe, ventilation openings and a fly screen (Figure 4.1).

A



B



Figure 4.1: Pictures representing commercial manufactured system with Ventilated improved latrine (**A**) and BRICK Ventilated improved latrine (**B**). Found in study area.

During the study, majority 342 (84%) of the households were not sharing their latrine with their neighbors, only 66 (16%) were sharing their latrines with neighbors (Table 4.2). The shared status of a sanitation facility is very important, as shared facilities by neighbors or communities can be less hygienic than facilities used by a single household. In the present study, very few households were sharing their sanitation facility. Therefore the spread of pathogens could be minimal unlike in a shared facility.

Recommendations by SANS (2011) are to build latrine with a minimum of 6 meters distance from the home in order to avoid the associated health risk and inconvenience. The recommended distance of > 6 meters is to prevent the transmission of pathogens from the latrine to the home through vectors (e.g. fly); this can affect the household negatively because the transmission of pathogens to the house can lead to disease through faecal- oral -route transmission (Lindsay et al., 2013). This poses negative impact on health and can cause serious diarrheal diseases which can lead to death if not given attention. The observed 70 (17%) of the none compliant latrines build ≤6 from the house may give a possible explanation for the reported episodes of diarrhea in Vhembe district as was reported by Potgieter et al. (2005) which showed that Diarrheal diseases are common in children aged less than five years, and consumption of contaminated water and food is the major source of infection (Table 4.2). Such infections include urinary tract infections, haemolytic colitis, neonatal meningitis, nosocomial septicaema, haemolytic uremic syndrome and surgical site infections (Obi et al., 2004). Amongst the available latrines 338 (83%) were

located at a distance of more than 6 meters from the house (Table 4.2). It was noticeable that ward 18 was the only ward which had 70 (51%) of latrine facility located at a recommended distance.

During the study, 253 (62%) of the latrines were constructed two or more years prior to the time of the study and 398 (98%) latrines were functional and satisfactory (Table 4.2); which is higher than that reported in a study conducted in rural Zinder in Niger (Diallo et al., 2007) where functional percentage was only 86%. Another study done in Bahir Dar Zuria reported 62% functional latrines. Another study done in Ethiopia (Awoke and Muche, 2013) reported 87% functional latrines, this compares to a study which was done in Hulet Ejju Enessie district of Ethiopia functional latrines constituted 86.7% (Anteneh and Kumie, 2010). During the study overall 10 (2%) of the latrines were not functional (Table 4.2). This was not encouraging when considering the fact that lack of sanitation facilities compels people to practice open defecation which results in the transmission of pathogens through fecal-oral-route transmission. When people practice open defecation the chances of spreading and contamination with potential health risk pathogens is high (WHO/UNICEF, 2012). In the present study there were very few households lacking sanitation facilities. Majority of the families received their latrines from the government 408 (100%), Table 4.2.

Table 4.2: Sanitation coverage in study wards

Variable	Overall study population (n =408)	Ward 15 (n=136)	Ward 18 (n=136)	Ward 19 (n=136)
Having latrine				
Yes	408 (100%)	136 (100%)	136 (100%)	136 (100%)
No	-	-	-	-
Who built the toilet				
Owner	-	-	-	-
Government	408 (100%)	136 (100%)	136 (100%)	136 (100%)
NGO	-	-	-	-
Latrine year of construction				
< 2 years	155 (38%)	34 (25%)	56 (41%)	65 (48%)
≥ 2 years	253 (62%)	101 (74%)	80 (89%)	72 (53%)
Functional latrine				
Yes	398 (98%)	129 (95%)	133 (98%)	136 (100)
No	10 (2%)	7 (5%)	3 (2%)	-
Distance of Latrine location from home				
≤6 meters	70 (17%)	-	70 (51%)	-
≥6 meters	338 (83%)	136 (100%)	66 (48%)	136 (100%)
Sharing with neighbor's				
Yes	66 (16%)	27 (20%)	15 (11%)	24 (18%)
No	342 (84%)	109 (80%)	121 (89%)	112 (82%)

4.3 SANITATION STRUCTURES

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This section will be discussing the sanitation structure parts individually.

- **Latrine superstructure**

According to SANS (2011), latrines should have a superstructure which provides privacy and have stable walls. The closet must be constructed with a floor and a roof material adequate for its purpose. During the evaluation of latrines in the present study, the materials used for latrine structures were bricks 359 (88%) and 49 (12%) were concrete structures (Table 4.3). Majority 403 (99%) of the wall structures were stable. The majority of latrines superstructures were in accordance with the SANS (2011) standards as they met the requirements which indicates that latrines should have a superstructure which provides privacy and have stable walls. According to (SANS, 2011) the inside of the closet must be adequately dark to discourage flies from exiting the pit via the pedestal. During the study majority 325 (80%) of the latrine were dark inside (Table 4.3).



Figure 4.2: Latrine with unstable walls (structures built by the Government)

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Table 4.3: Latrine structure

Variable	Overall study population (n=408)	Ward 15 (n=136)	Ward 18 (n=136)	Ward 19 (n=136)
Material of structure				
Brick	359 (88%)	120 (88%)	136 (100%)	103 (76%)
Concrete	49 (12%)	16 (12%)	-	33 (24%)
Latrine dark inside				
Yes	325 (80%)	95 (70%)	133 (98%)	97 (71%)
No	83 (20%)	41 (30%)	3 (2%)	39 (29%)
Walls stable				
Yes	403 (99%)	132 (97%)	136 (100%)	13 5 (99%)
No	5 (1%)	4 (3%)	-	1 (0.7%)

- **Latrine door**

According to SANS (2011) guidelines the latrine must be provided with a door or other means which must ensure privacy of the occupant of such a latrine. During the study 398 (98%) latrines were having doors whereas 10 (2%) of the latrines were not having doors. It was observed that majority 408 (100%) of the latrine door material were corrugated iron. During the study majority 397 (97%) of the latrine were private (Table 4.4). however 11 (3%) were not private during the study. This was discouraging to the households; they felt like their privacy was compromised during the utilization of latrine. It was observed during the study that doors were either broken or not closing properly (Table 4.4). Majority of the doors were in a poor condition. In the present study 387 (95%) of the latrine doors were facing prevailing winds (Table 4.4), among the latrine majority 359 (88%), had their doors kept shut (Table 4.4), the practice of keeping doors shut is highly recommended since it prevents the flies to escape from the latrine to the house. This is important when considering health risk associated factors. Keeping the doors shut also contributes to good hygiene practice.



Figure 4.3: Latrine with broken door

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Table 4.4: Latrine door

Variable	Overall study population (n=408)	Ward 15 (n=136)	Ward 18 (n=136)	Ward 19 (n=136)
Door available and framed				
Yes	398 (98%)	128 (94%)	136 (100%)	134 (98%)
No	10 (2%)	8 (6%)	-	2 (1.5%)
Material of door				
Corrugated iron	408 (100%)	136 (100%)	136 (100%)	136 (100%)
other	-	-	-	-
Latrine private				
Yes	397 (97%)	128 (94%)	134 (98%)	135 (99%)
No	11 (3%)	8 (6%)	2 (1%)	1 (0.7%)
Door facing prevailing winds				
Yes	387 (95%)	123 (90%)	136 (100%)	128 (94%)
No	21 (5%)	13 (9%)	-	8 (6%)
Door kept shut				
Yes	359 (88%)	105 (77%)	132 (97%)	122 (90%)
No	49 (12%)	31 (23%)	4 (3%)	14 (10%)

- **Latrine roof**

According to guidelines set by SANS, (2011) the closet must be constructed with a roof of material adequate for its purpose. Majority of the latrine roof were corrugated iron 359 (88%) and 49 (12%) concrete (Table 4.5). During the present study most of the roof materials were in a good condition. Looking at the roof of latrines 356 (87%) had a roof tightly attached to the building structure, with only 401 (98%) water proof. Majority of the latrine in the wards complied with the SANS (2011) standards because most of the structures were water proof, adequate roof and roof attached to building structure (Table 4.5).



Figure 4.4: Latrine roof

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Table 4.5: Roof of latrine

Variable	Overall study population (n=408)	Ward 15 (n=136)	Ward 18 (n=136)	Ward 19 (n=136)
Material of roof				
Corrugated Iron	359 (88%)	120 (88%)	136 (100%)	103 (76%)
Concrete	49 (12%)	16 (12%)	-	33 (24%)
Roof tightly attached to roof				
Yes	356 (87%)	103 (76%)	123 (90%)	130 (95%)
No	52 (13%)	33 (24%)	13 (9%)	6 (4%)
Roof water proof				
Yes	401 (98%)	131 (96%)	135 (99%)	135 (99%)
No	7 (2%)	5 (4%)	1 (0.7%)	1 (0.7%)

- **Latrine floor**

It was noted that 359 (88%) of the latrine floor had a slab on the floor whereas 49 (12%) had a concrete floor (Table 4.6). It was noted that most 402 (99%) of the latrine had dry floors and 6 (1.7%) were not dry (Table 4.6).



Figure 4.5: Latrine floor

Table 4.6: Latrine floor

Variable	Overall study population (n=408)	Ward 15 (n=136)	Ward 18 (n=136)	Ward 19 (n=136)
Materials of floor				
Slab	359 (88%)	120 (88%)	136 (100%)	103 (76%)
Concrete	49 (12%)	16 (12%)	-	33 (24%)
Dry floor				
Yes	402 (99%)	134 (98%)	135 (99%)	133 (98%)
No	6 (1.7%)	2 (1.5%)	1 (0.7%)	3 (2%)

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- **Ventilation pipe**

According to the SANS (2011) guidelines a latrine must have wall ventilation openings, fly-screen and a ventilation pipe. During the study it was noted that 321 (79%) of latrines had wall ventilation openings with only 178 (44%) having fly-screen on ventilation openings whereas 230 (56%) had no fly-screen on ventilation openings (Table 4.7). In the current study 407 (99%) of the latrine had ventilation pipe with majority 402 (98%) having ventilation pipe higher than building structure which is in accordance with SANS (2011) standards (Table 4.7). It was observed in ward 15 and 19, that the entire latrine had ventilation pipe 136 (100%), (Table 4.7). Majority 393 (96%) of the ventilation pipe were straight, among these latrines 239 (59%) had fly-screens on ventilation pipe, majority of latrine with fly-screens were observed in ward 18, with 104 (76%). It was noted that 382 (94%) of the latrine allowed light entry (Table 4.7), this was in accordance with SANS (2011) standards. Flies in the pit are attracted to the light from the vent pipe, but as the vent pipe has a fly- screen at the top they cannot manage to escape and eventually they die. Flies outside the pit are attracted to the top of the vent pipe by the pit odor, but they cannot enter because of the presence of the fly-screen. Overall, most of the latrine in the present study had a ventilation pipe and wall openings, the availability of fly-screens was relatively low, most of the latrine were not in line with the SANS (2011) standards. Most of the ventilation pipes 291 (71%) were white in color, whereas 177 (29%) were black in color. Majority 402 (99%) of the latrine had ventilation pipe fixed to slab (Table 4.7). This was encouraging when considering the fact that the ventilation pipe play an important role in allowing the flow of air and prevent the entry and escape of flies. Very few latrine facilities were lacking ventilation pipes, the ventilation pipes were either broken or not installed from the time of latrine built. The absence of this ventilation pipes could pose serious health risk to vulnerable people using this latrine facilities.



Figure 4.6: Latrine ventilation pipe

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Table 4.7: Latrine ventilation

Variable	Overall study population (n=408)	Ward 15 (n=136)	Ward 18 (n=136)	Ward 19 (n=136)
Walls ventilation openings				
Yes	321 (79%)	85 (62%)	134 (98%)	102 (75%)
No	87 (21%)	51 (37%)	2 (1%)	34 (25%)
Fly-screens on ventilation openings				
Yes	178 (44%)	36 (26%)	101(74%)	41 (30%)
No	230 (56%)	100 (73%)	35 (26%)	95 (70%)
Ventilation pipe				
Yes	407 (99%)	136 (100%)	135 (99%)	136 (100%)
No	1 (0.24%)	-	1 (0.7%)	-
Ventilation pipe higher than structure				
Yes	402 (98%)	132 (97%)	136 (100%)	134 (98%)
No	6 (2%)	4 (3%)	-	2 (1.5%)
Ventilation pipe straight				
Yes	393 (96%)	135 (99%)	136 (100%)	122 (90%)
No	15 (4%)	1 (0.7%)	-	14 (10%)
Fly screen on ventilation pipe				
Yes	239 (59%)	58 (43%)	104 (76%)	77 (57%)
No	169 (41%)	78 (57%)	32 (23%)	59 (43%)
Light entry at ventilation pipe				
Yes	382 (94%)	135 (99%)	132 (97%)	115 (84%)
No	26 (6%)	1 (0.7%)	4 (3%)	21 (15%)
Ventilation pipe color				
Black	117 (29%)	40 (29%)	39 (29%)	38 (28%)
White	291 (71%)	96 (70%)	97 (71%)	98 (72%)
Ventilation pipe fixed to slab				
Yes	402 (99%)	135 (99%)	135 (99%)	132 (97%)
No	6 (1%)	1 (0.7%)	1 (0.7%)	4 (3%)

- **Larine cover slab and seat**

The guidelines set by SANS (2011) indicate that measures must be taken to provide a latrine with a seat, seat cover and have a cover slab. It was noted during the study that 402 (99%) of the latrine cover slab were well sealed and among these 405 (99%) of the latrine upper part were lined according to the standards set by SANS (2011). In the present study, 365 (89%) of the latrine hand a bench seat and among these only 296 (73%) had a seat cover (Table 4.8). Majority of the latrine in the wards complied with the SANS (2011) standards as they had seat covers and bench seats. The covers prevent the flies from escaping the pit and eventually dying inside the pit without the possibility of escaping and having the potential to go out and spread pathogens.



Figure 4.7: Latrine without a seat and seat cover

Table 4.8: Latrine cover slab and seat

Variable	Overall study population (n=408)	Ward 15 (n=136)	Ward 18 (n=136)	Ward 19 (n=136)
Cover slab well sealed				
Yes	402 (99%)	134 (98%)	134 (98%)	134 (98%)
No	6 (1%)	2 (1.5%)	2 (1.5%)	2 (1.5%)
Upper part of latrine lined (1m)				
Yes	405 (99%)	136 (100%)	135 (99%)	134 (98%)
No	3 (1%)	-	1 (0.7%)	2 (1%)
Bench seat				
Yes	365 (89%)	123 (90%)	136 (100%)	106 (78%)
No	43 (11%)	13 (9%)	-	30 (22%)
Seat cover				
Yes	296 (73%)	108 (79%)	95 (70%)	93 (68%)
No	112 (27%)	28 (20%)	41 (30%)	43 (32%)

- **Hand washing facility**

During the present study 357 (87%) households had hand-washing facilities; only 51 (13%) had no form of hand-washing facilities (Table 4.9). The lack of hand-washing facilities in the rural households was viewed as dangerous to vulnerable people because it could affect the household negatively since there could be transmission of pathogens to the house due to not washing hands after using the latrine and lead to diseases such as intestinal illness including diarrheal and nausea through faecal-oral-route transmission (Lindsay et al., 2013).

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Table 4.9: Sanitation structure

Variable	Overall study population (n =408)	Ward 15 (n=136)	Ward 18 (n=136)	Ward 19 (n=136)
Availability of Hand washing facility				
Yes	357 (87%)	123 (90%)	128 (94%)	106 (78%)
No	51 (13%)	13 (9%)	8 (6%)	30 (22%)

4.4 HYGIENE OF LATRINES IN THE STUDY POPULATION

According to SANS (2011) guidelines the latrine must be built to discourage the presence flies (SANS, 2011). In this study 235 (58%) latrines were having fly activity (Table 4.10). The presence of flies in the latrine could only pose serious health risk because if the latrine structure allows the escape of flies from the latrine into the household, this could affect the household negatively in terms of health because they act as vectors of diarrheal diseases and carry fecal bacteria, including pathogens such as *E. coli* strains that cause diarrhea. Moreover, since these flies are also strongly attracted to raw meat and fish, they are likely to contaminate foodstuffs with bacterial pathogens in the house (Lindsay et al., 2013).

In this study 396 (97%) of the latrines were accessible to children (Table 4.10). Ward 15 had majority of the latrine families not accessible to children. The standards set by SANS (2011) states that for children, an additional seat that has an aperture of between 150 mm and 200 mm must be provided; the additional seat is to prevent children from falling into the pit while using the latrine. In addition the additional seat ensures safety and accessibility of latrine use to children. The inaccessibility of sanitation facility to children increases the risk of faecal-oral-route transmission and is a major risk factor in exposing children to pathogens and infectious diseases (Silva, 2005). Pathogens (such as *Escherichia coli*, *Salmonella* spp and Shigella spp) cause severe diarrhea that can claim up to 2.2 million lives per year worldwide (Rheingans et al., 2006). During the present study 383 (94%) of the respondents washed hands after visiting the latrine (Table 4.10), this supports the findings of the number of hand-washing facilities found during the study with 357 (87%) households having hand washing facilities. In addition it was observed during the study that other households never washed hands after visiting the latrine due to the lack of hand-washing facilities. It was established that the presence of school children in the households were significant predictors of good hygiene practices. The fact that students were more exposed to hygiene information in the school environment, their presence positively favored the persuasion of hygiene practices in the home environment. Peer pressure was also associated with the extent of hygiene practice. This is due to the fact that people can learn to accept, adopt and utilize latrine facilities with good hygiene practice easily by following role

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model individuals than mere advice and enforcement. Of the 383 (94%) respondents that washed hands after visiting the latrine indicated that they only used water without any form of soap (Table 4.10).

During the present study, it was observed among the households that the majority 267 (65%) of children under-five were not using the latrines (Table 4.10). The reasons given by respondents for why under-five children did not use the latrines were: being just a child and large squatting hole. The method of handling of faeces of under-five children in the present study varied among respondents: 100 (71%) disposing faeces in the latrine and 41 (29%) burying around the house either in the bush or in the garden. The behavior of burying faeces around the house either in the bush or in the garden is entirely unacceptable practice of handling faeces, because flies, children or pets can reach the faeces and facilitate the transmission of pathogens such as *E. coli* to the households and result in sickness such as eye infection and diarrhea. However the use of latrine for safe disposal of children faeces in this present study was better compared to other studies reported in Kenya where safe disposal of children faeces was found to be 53% (Daniels et al., 1990), Lesotho 50% and Philippines 39% (Van Deslice et al., 1994).

During this study faeces were not visible in 326 (80%) of the latrines (Table 4.10). One most important aspect is cleanliness; a latrine which is dirty and soiled with excreta will soon be abandoned, due to the fact that users don't feel safe and think they might get sick trough exposure to diarrheal pathogens. When people use a dirty latrine, they expose themselves to health risk pathogens such as *Escherichia coli*, *Salmonella* spp and Shigella spp. These pathogens usually occur on the surfaces of the toilet seat and when people touch the surfaces and not wash their hands after visiting the latrine they are most likely to carry and transmit these pathogens to the households. Diarrhea is one of the common diseases which results from these pathogens (*Escherichia coli*, *Salmonella* spp and Shigella spp). In this study it was noted that most latrines 263 (64%) were clean. Most of the clean latrines were observed in ward 19 [102 (75%)] (Table 4.10).

Majority of the households 244 (60%) cleaned their latrines once a week, followed by 106 (26%) which indicated that they cleaned their latrine only once in a month, about 17 (4%) indicated that they never cleaned their latrine (Table 4.10). Majority of the households that indicated never cleaning their latrines were in ward 19 with 12 (8%) indicating that they never clean their latrine. Good hygiene practice points out that people should clean their sanitation facilities in order to prevent contamination of disease. In this present study, majority of the household cleaned their

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latrine frequently. The use of dirty latrine also compromise hygiene practices in the house, because if users are not washing their hands after the utilization of the latrine, the pathogens contracted from the latrine through touching surfaces are going to be taken into the household eventually (e.g. drinking water and food) (Lindsay et al., 2013). Of the households that cleaned their latrines, the majority 227 (56%) used powdered soap and water to clean their latrine, whereas 78 (19%) used toilet detergents (such as Domestos) and 68 (17%) used wastewater to clean their latrine (Table 4.10). Majority of the households using the right latrine detergent were observed in ward 15 with 46 (34%). The use of wrong latrine detergents to clean the latrines was considered not safe and could have negative health implications on the household since pathogens such as *Escherichia coli*, *Salmonella* spp and Shigella spp could survive on the toilet seats and surfaces in the toilet due to the ineffectiveness of the detergents. During the study households were using powder soup which is used for washing clothes, this was an indication that the households had an idea that the cleaning of latrines is important for their health, but unfortunately they were not using the correct latrine detergents known to be effective in killing pathogens (such as *Escherichia coli*, *Salmonella* spp and Shigella spp). The use of powdered soup was better compared to households using wastewater to clean their latrines because wastewater was used after domestic purposes use (e.g. bathing or cleaning of the floors in the house) and was considered dirty. The use of wrong toilet detergents was not good hygiene practice because they were not as effective as the correct detergents used for cleaning latrines.



Figure 4.8: Unclean ventilated improved latrine

Dirty toilets do present risks from infectious diseases; the surfaces that people touch in the toilet with hands can be contaminated with pathogens (such as *Escherichia coli*, *Salmonella* spp and

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Shigella spp). After touching surfaces then it's really easy for you to spread those pathogens from your hands to your nose and mouth. From there, they get inside your body.

Table 4.10: Hygiene of latrine and study population hygiene practices

Variable	Overall study population (n=408)	Ward 15 (n=136)	Ward 18 (n=136)	Ward 19 (n=136)
Clean latrine				
Yes	263 (64%)	92 (68%)	69 (51%)	102 (75%)
No	145 (36%)	44 (32%)	67 (49%)	34 (25%)
Insect activity at latrine				
Yes	235 (58%)	61 (45%)	99 (73%)	75 (55%)
No	173 (42%)	75 (55%)	37 (27%)	61 (45%)
Odor present				
Yes	206 (50%)	59 (43%)	77 (57%)	70 (51%)
No	202 (50%)	77 (57%)	59 (43%)	66 (48%)
Faeces visible				
Yes	82 (20%)	14 (10%)	48 (35%)	20 (15%)
No	326 (80%)	122 (90%)	88 (65%)	116 (85%)
Cleaning of latrine				
Every day	41 (10%)	21 (15%)	8 (6%)	12 (8%)
Once a week	244 (60%)	71 (52%)	92 (68%)	81 (59)
Once a month	106 (26%)	42 (31%)	33 (24%)	31 (22%)
Never	17 (4%)	2 (1.5%)	3 (2%)	12 (8%)
Detergent used for cleaning latrine				
Powder soap and water	227 (56%)	106 (78%)	56 (41%)	65 (48%)
Toilet detergent	78 (19%)	46 (34%)	16 (12%)	16 (12%)
Wastewater	68 (17%)	3 (2%)	39 (29%)	26 (19%)
Other	35 (8%)	-	15 (11%)	20 (15%)
Accessible to children				
Yes	396 (97%)	128 (94%)	136 (100%)	132 (97%)
No	12 (3%)	8 (6%)	-	4 (3%)
Children use the latrine				
Yes	141 (35%)	64 (47%)	42 (31%)	35 (25%)
No	267 (65%)	72 (53%)	94 (69%)	101 (74%)
Wash hands after toilet use				
Yes	383 (94%)	130 (95%)	130 (95%)	123 (90%)
No	25 (6%)	6 (4%)	6 (4%)	13 (9%)
Detergent used for Hand washing				
Nothing (water only)	408 (100%)	136 (100%)	136 (100%)	136 (100%)
Soap	-	-	-	-

4.5 ASSESSMENT OF POTENTIAL HEALTH RISK OF LATRINES TO STUDY POPULATION

In this study, total coliform and *Escherichia coli* (*E. coli*) counts were assessed for the microbiological quality of toilet seats to ensure safety of latrine facilities in the rural households from harmful pathogens. The presence of total coliforms is an indication that opportunistic pathogens might be present. *E. coli* bacteria are good indicator organisms of fecal contamination

and their presence does not necessarily mean that pathogens are present, but rather indicates a potential health hazard (Parker et al., 2010; Leclerc et al., 2001).

Total coliform bacteria are Gram-negative, non-spore forming, rod-shaped facultative anaerobes that are part of the family *Enterobacteriaceae* (Leclerc et al., 2001; Bergey and Holt, 1994). They are characterized by their ability to ferment lactose at 35°C, resulting in gas formation (Leclerc et al., 2001; Bergey and Holt, 1994). Total coliforms include bacteria of known faecal origin such as *E. coli* as well as bacteria that may not be of faecal origin such as *Klebsiella* spp, *Citrobacter* spp, *Serratia* spp and *Enterobacter* spp which are found in nutrient rich water, soil decaying vegetation and drinking water with relatively high levels of nutrients (WHO, 1996). The presence of total coliforms in water sample are therefore, an indication that opportunistic pathogens bacteria such as *Klebsiella* and *Enterobacter* which can multiple in water environment and pathogenic pathogens such as *Salmonella* spp, *E. coli*, *Vibrio cholera*, *Campylobacter* spp (DWAF, 1996; Grabow, 1996) might be present.

Escherichia coli bacteria are a subgroup of fecal coliform bacteria. Even within this species, there are numerous different strains, some of which can be harmful (Parker et al., 2010). However, the release of these naturally-occurring organisms into the environment is generally not a cause for alarm, but other disease causing bacteria, which can include some pathogenic strains of *E. coli*, or viruses, may also be present in these wastes and pose a health threat (Parker et al., 2010). *E. coli* bacteria are good indicator organisms of fecal contamination because they generally live longer than pathogens, are found in greater numbers, and are less risky to collect or culture in laboratory than pathogens. However, their presence does not necessarily mean that pathogens are present, but rather indicates a potential health hazard (Parker et al., 2010). The WHO, data on faecal coliform bacteria group them into the following risk categories: 0 cfu/100ml (conformity); 1–10 cfu/100 ml (low risk); 10–100 cfu/100 ml (intermediate risk); 100–1000 cfu/ 100ml (high risk); and 41000 cfu/100 ml (very high risk)(WHO, 2008). Although *E. coli* has been mostly used as an indicator of faecal pollution, the group consists of both commensal (ComEC) and diarrhoegenic types (DEC) which do not only indicate the presence of intestinal pathogens or parasites but also constitute a human health risk themselves (Kaper et al., 2004; Grabow et al., 2003). The DEC types identified are enterohaemorrhagic *E. coli* (EHEC), entero-invasive *E. coli* (EIEC), enteroaggregative *E. coli* (EAEC), enterotoxigenic *E. coli* and enteropathogenic *E. coli* (EPEC) (Ashbolt, 2004; Kaper et al., 2004). Waterborne outbreaks of diseases caused by pathogenic strains of *E. coli* have been described in many parts of the world. One such outbreak which received worldwide publicity was in Canada in 2000, where the

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causative pathogen was an EHEC strain designated *E. coli* 0157:H7 (Muller et al., 2001). Effleret et al. (2001) has also reported a major water-borne outbreak from *E. coli* in Swaziland.

From the VIP latrines in the study population 84 toilet seat swabs (20% of total samples in each ward) were collected and assessed for the prevalence of Total coliform and *E. coli* counts (Table 4.11). A total of 14 toilet seat swab samples tested positive for the presence of *E. coli* and were further analyzed and pathogenic *E. coli* strains were isolated and identified.

From the results it was found that overall 6% of the tested toilet seats tested positive and had TC above 100 counts /100ml, indicates a high health risk (Table 4.11). It was noted that overall 11% of the toilet seats tested positive and displayed intermediary TC risk level TC (10- 100 counts /100ml). This is in agreement with findings by other studies who conducted similar listings (NSF, 2011).

The results also indicated that overall 1.2% of the toilet seats tested positive for *E. coli* counts above 100 counts/ 100ml (Table 4.11). It was noted that overall 1.2% of the toilet seats tested positive and displayed intermediary risk level *E. coli* (10- 100 counts /100ml). This compares to a study done by Mohamed et al. (2015) on extraintestinal pathogenic and antimicrobial resistant *Escherichia coli* contamination of 56 public restrooms in the greater Minneapolis-St. Paul metropolitan area which indicated that 32% tested positive for *E. coli* (Mohamed et al., 2015).

Table 4.11: Number of VIP latrine seats positive for Total coliform and *E. coli*

Risk levels (WHO,2006)	TC				*E. coli*			
	Ward 15 (n= 28)	Ward 18 (n= 28)	Ward 19 (n= 28)	Overall (n=84)	Ward 15 (n= 28)	Ward 18 (n= 28)	Ward 19 (n= 28)	Overall (n=84)
0 CFU/100ml (Conform)	43% (12/28)	39% (11/28)	29% (8/28)	37% (31/84)	93% (26/28)	85% (24/28)	75% (21/28)	84.5% (71/84)
0 -10 CFU/100ml (Low risk)	43% (12/28)	46% (13/28)	50% (14/28)	46.4 % (39/84)	7% (2/28)	11% (3/28)	21% (6/28)	13.1% (11/84)

10 -100 CFU/100ml (Intermediate risk)	7.1% (2/28)	7.1% (2/28)	18% (5/28)	11% (9/84)	-	-	4% (1/28)	1.2% (1/84)
>100 CFU/100ml (High risk)	7.1% (2/28)	7.1% (2/28)	4% (1/28)	6% (5/84)	-	4% (1/28)	-	1.2% (1/84)

In ward 15, three (3) of the samples were *E.coli* positive and Pathogenic *E.coli* strains were isolated and identified. One sample tested positive for the presence of Commensal *E. coli*. One sample had Atypical Enteropathogenic *E. coli*, while a third sample tested positive for Enterotoxigenic *E. coli* (Table 4.2). The ingestion of pathogenic *E. coli* strains is known to cause stomach and intestinal illness including diarrheal and nausea, and even lead to death (Potgieter et al., 2005).

In ward 18, four (4) of the samples were positive and pathogenic *E. coli* strains isolated and identified were Atypical Enteropathogenic *E. coli*, typical Enteropathogenic *E. coli,* Enterotoxigenic *E. coli* and Enterohaemorrhagic *E. coli* (Table 4.12). The results of the presence of these pathogens on toilet seat swabs are in agreement with previous reports (Brown et al., 2013). These enteric bacteria are reportedly causative agents of various diseases and their complications, such diseases include haemolytic uraemic syndrome which is a consequence of *Eschericha coli* (Brown et al., 2013; Grawbow, 1996). This is in agreement with findings by other studies who conducted similar studies (Sherifa, 2013).

In ward 19, seven (7) samples tested positive with Commensal *E. coli,* Atypical Enteropathogenic *E. coli*, typical Enteropathogenic *E. coli*, and Enterotoxigenic *E. coli* (Table 4.12). Pathogenic *E. coli* strains may account for life-threatening infections; such infections include urinary tract infections, haemolytic colitis, neonatal meningitis, nosocomial septicaema, haemolytic uremic syndrome and surgical site infections (Brown et al., 2013).

Table 4.12: Pathogenic *E. coli* strains identified in wards 15, 18 and 19

Ward Number positive	**Sample No/ Place collected**	***E. coli* Patho-type**
	(T17) Mafanele	Commensal *E. coli*
	(T21) Mafanele	Atypical Enteropathogenic *E. coli*

15 (n=3)	(T2) Mavambe	Atypical Enteropathogenic *E. coli*, Enterotoxigenic *E. coli*
18 (n=4)	(T59) Khakhanwa	Atypical Enteropathogenic *E. coli*
	(T62) Khakhanwa	Atypical Enteropathogenic *E. coli*, Enterohaemorrhagic *E. coli*, Typical Enteropathogenic *E. coli*, Atypical Enteropathogenic *E. coli*, Enterotoxigenic *E. coli*
	(T74) Dididi	Typical Enteropathogenic *E. coli*, Atypical Enteropathogenic *E. coli*, Enterotoxigenic *E. coli*
	(T78) Dididi	Atypical Enteropathogenic *E. coli*
19 (n=7)	(T35) Budeli	Atypical Enteropathogenic E. coli, Enterotoxigenic E. coli
	(T39) Mutoti	Atypical Enteropathogenic *E. coli* , Enterotoxigenic *E. coli*
	(T50) Dumasi	Commensal *E. coli*
	(T51) Dumasi	Atypical Enteropathogenic *E. coli*
	(T53) Dumasi	Atypical Enteropathogenic *E. coli*
	(T55) Dumasi	Atypical Enteropathogenic *E. coli*
	(T56) Dumasi	Typical Enteropathogenic *E. coli*, Atypical Enteropathogenic *E. coli*

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The objective of the study was to assess the sanitation coverage of rural communities in three wards of the Thulamela municipality in the Limpopo province of South Africa. The results showed high coverage in the study population. Coverage provided a good indication of the challenges faced by the rural communities. Several factors such as poverty, lack of awareness and water shortage forced households to adopt unsanitary practices. This study has showed encouraging practices in the use of latrines and the utilization of latrines was satisfactory. The presence of school children in a household, duration of owning a latrine by the households and peer pressure were the major factors affecting utilization of latrines and sanitary practices.

Different pathogenic strains of *E. coli* were detected and isolated from the toilet seat swab samples. Atypical Enteropathogenic *E. coli,* Typical Enteropathogenic *E. coli*, Enteropathogenic *E. coli,* Enterotoxigenic *E. coli* and Enterohaemorrhagic *E. coli* were isolated and identified. These pathogenic *E. coli* strains are dangerous as they can cause diseases of gastrointestinal, urinary and central nervous systems in human host and can result in death if not treated. These pathogens may pose health risk for young children and people with severely compromised immune systems.

- The coverage was high as 98% of the latrines were functional during the study.
- Hygiene practice was encouraging showing 94% of the respondents washed hands after visiting the latrine.
- The majority (84%) of the households were not sharing their latrine with other households.
- The results indicated that (35%) children ≤5 years use the latrines.

5.2 RECOMMENDATIONS

There is a need to develop sanitation improvement strategies for rural communities where sanitation is not available. Public awareness concerning the importance of sanitation and good hygiene practice and the human health consequences when people adopt unsanitary practices is highly recommended, strengthening the connection between sustained utilization and continued hygiene education remain important.

An integrated system incorporating plans and activities aiming at preventing or minimizing the number of people not using sanitation facilities and good hygiene practice would be the starting point for the people living in the rural households in the Vhembe region. Sanitation and hygiene education promotion should be done regularly, repeatedly and continuously to adopt behavior or practice on latrine use among the community. Particularly to mothers who spend most of their time on the caring of their children and families at home. Promotion activities among the community should be done by focusing on maintenance and reconstruction of latrine facilities to have sustainable utilization and to bring about positive impacts on childhood diarrhea.

Despite these challenges, the conditions of sanitation are improving in the rural households in Vhembe district. In order to further improve it, increased awareness of sanitary latrine use, periodic home visits to monitor usage, and maintenance of latrines is needed. Further studies concerning the assessment of sanitation coverage should be conducted in order to provide more information on what is happening in the rural households.

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Appendix A

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Survey questionnaire used to collect data during the study

Section A Household Profile

Question 1: Respondent details

1.1	What is the name of the respondent?
1.2	What is the relationship of the respondent to the head of the household (HHH)?
1.3	What is the marital status (MS) of the respondent? (Use legend provided)
1.4	What is the gender of the respondent? (Use legend provided)
1.5	How old is the respondent?

1.3 Marital status	Single	Married	Divorced/ Separated	Widowed	Live in Partner
Code	1	2	3	4	5

1.1 Name	1.2 Relationship to HHH	1.3 MS	1.4 Gender		1.5 Age
	Head of household		M	F	
	Spouse		M	F	
	Son		M	F	
	Daughter		M	F	
	Brother-in-law		M	F	
	Sister-in-law		M	F	
	Sister		M	F	
	Brother		M	F	
	Mother of head		M	F	
	Father of head		M	F	
	Mother of wife		M	F	
	Father of wife		M	F	
	Other (other relatives, live-in partners etc)		M	F	

Question 2: Household Members

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HH

2.1	What is the ethnicity of the household (HH)? (Tick)
2.2	What language does the HH predominantly speak?
2.3	What is the first name of each HH member? (Including the respondent)
2.4	What is each member's relationship to the HHH? (Use legend provided)
2.5	What is the marital status of each member? (Use legend provided)
2.6	What is the gender of each member? (Use legend provided)
2.7	How old is each member?
2.8	What is the highest level of education for each member? (Use legend provided)
2.9	Indicate who collect water in the household? (Tick)

2.1 Ethnic group	Black	Coloured	Asian	White	Other
Tick					

Other_____

2.2 Language	

2.4 Rel to HHH	Code
Head of household	1
Spouse	2
Son	3
Daughter	4
Brother-in-law	5
Sister-in-law	6
Sister	7
Brother	8
Mother of head	9
Father of head	10
Mother of wife	11
Father of wife	12
Other (other relatives, live-in partners etc)	13

2.8 Highest qualification level	Code
Pre-primary	1
Grade R	2
Grade 1	3
Grade 2	4
Grade 3	5
Grade 4	6
Grade 5	7
Grade 6	8
Grade 7	9
Grade 8	10
Grade 9	11
Grade 10	12
Grade 11	13
Grade 12	14
Tertiary Certificate/Diploma/Degree (specify)	15
ABET (Adult school)	16

2.5 Marital status (MS)	Single	Married	Divorced/ Separated	Widowed	Live in Partner
Code	1	2	3	4	5

ID	2.3 First name	2.4 Relationship to HHH	2.5 MS	2.6 Gender		2.7 Age	2.8 Education	2.9 Collect water
1				M	F			
2				M	F			
3				M	F			
4				M	F			
5				M	F			
6				M	F			
7				M	F			
8				M	F			
9				M	F			
10				M	F			

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Section B sanitation facility profile and usage

Question 1: Hygiene practice

HH

1.1	Do you wash hands after visiting a toilet? (Tick)
1.2	If yes, do you wash hands always after visiting the toilet? ? (Tick)
1.3	If answer to 1 above is yes. Where do you get the water? (Tick)
1.4	If applicable, how far is the washing point from the toilet?

1.1 Wash hands	Yes	No
Tick		

1.2 Wash hands always	Yes	No
Tick		

1.3 Where	Tap	Storage container	other
Tick			

1.4 If applicable, how far is the washing point from the toilet? _____

Question 2: Latrine geographic information

2.1. Site/ village_____

2.2. Elevation_____

2.3. Latitude_____

2.4. Longitude_____

2.5. Year of construction_____

2.6 Who funded it?	Owner	Government	NGO (Specify name)

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Tick				HH

Question 3: Engineering specifications & status

3.1 Distance of toilet from the nearest water point (m) _____

3.2 Status

3.2.1 Toilet	Functional	Non-functional	Other
Tick			

Section C Sanitation Service Profile

Question 20: Sanitation

20.1a	Do you have a toilet facility? (Tick)
20.1b	If yes, do you share your toilet with your neighbour? (Tick)
20.2	If not, what do you use as an alternative? (Tick)
20.3	Is the toilet inside or outside of the dwelling? (Tick)
20.4	Describe the toilet.
20.5	Evaluate the facility if they have one. (Tick)
20.5a	From what materials is the structure made of?
20.5b	Assess the safety of the structure?
20.5c	Assess the hygiene of the toilet?
20.6	How long have you had this pit?
20.7	Measure the distance from the house to the toilet used by household members.
20.8	What do you do with a full pit? (Tick)
20.9	Do you clean your toilet? (Tick)
20.10	When do you clean your toilet? (Tick)
20.11	What do you clean the toilet with? (Tick)
20.12	Does the small children also use the pit latrine? (Tick)
20.13	If not, what do the children use as an alternative place to relieve themselves? (Tick)
20.14	Observe where the children go to relieve themselves. (Tick)

20.1a Toilet facility			
Yes		No	
20.1b If yes, do you share with your neighbours?			
Yes		No	

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20.2 Alternative	Neighbour's	Bush	Bucket system	Other
Tick				

20.3 Toilet in/outside			
Inside		Outside	

20.4 Toilet	Water borne toilet (Flush)	Pit latrine	Bucket system	Chemical toilet	Other
Tick					

20.5 Evaluation of toilet	
20.5a Materials of structure	
Materials of walls	Tick
Brick	
Concrete blocks	
Corrugated iron	
Mud	
Other (specify)	
Materials of roof	
Corrugated iron	
Thatch	
Concrete slab	
No roof	
Other (specify)	
Materials of door	
Wood	
Corrugated iron	
No door	
Other (specify)	
Materials of floor	
Concrete floor/slab	
Corrugated iron floor	
Dirt floor	
Dung floor	
Other	
(Specify)	

20.5b Safety of structure	Yes	No
Accessible to children		
If not, give reason		
Walls stable		
Walls water proof		
Roof tightly attached to walls		
Roof water proof		
Roof slope away from door		
Door is framed		
Metal in structure not rusted		
Bench seat		
Seat cover		
Seat height 450mm at least		
If not, estimate height		
Seat with 300mm		
If no, estimate width		

20.5c Hygiene of toilet	Yes	No
Toilet private		
Toilet dark		
Insect activity at toilet		
Odour present		
Faeces visible		
Walls ventilation		

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openings		
Fly screens on ventilation openings		
Door facing prevailing winds		
Door kept shut		
Ventilation pipe		
Pipe higher than structure		
Pipe straight		
Fly screen on pipe		
Pipe outside structure		
Light entry at pipe		
Black ventilation pipe		
If not, name colour of pipe		
Pipe fixed to cover slab		
Dry floor		
Cover slab well sealed		
Cover slab at least 75mm thick		
Upper part of pit lined (1m)		

20.6 Age of pit	Tick
>6 months	
6-12 months	
3-5 years	
>5 years	

20.7 Distance	GPS
Direction	
Measured	

20.8	Dig a new pit	Cover the full pit	Squad next to it	Other
Tick				

20.9 Clean toilet	Yes		No	

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20.10 Cleaning time	Every day	Once a week	Once a month	Never	Other
Tick					

20.11 Reagent	Powder soap and water	Toilet soap and water	Waste water	Other
Tick				

20.12 Children use toilet	Yes		No	

20.13 Children alternate toilet	Open space in yard	Open space out in bush	Open space in the street	Children's toilet	Other
Tick					

20.14 Observe Children alternate toilet	Flies present	Odour present	Faeces visible	Plastic, tin and feathers	Estimate distance from house	Accessible to children
Tick						

Specify other:

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Appendix B

Global positioning system (GPS) coordinates of the household's latrine facility visited (Wards 15, 18 & 19)

Table 1: The global positioning system (GPS) coordinates of households visited in ward 15

Household visited	Village (Ward 15)	Waypoint	
		Latitude	Longitude
1	Jerome	-22.9744	30.68384
2	Jerome	-22.9745	30.68497
3	Jerome	-22.9753	30.68495
4	Jerome	-22.975	30.68475
5	Jerome	-22.9748	30.68403
6	Jerome	-22.9756	30.6841
7	Jerome	-22.9756	30.68413
8	Jerome	-22.9759	30.68501
9	Jerome	-22.9754	30.68483
10	Jerome	-22.9748	30.68754
11	Jerome	-22.9753	30.68859
12	Jerome	-22.974	30.68551
13	Jerome	-22.9756	30.6877
14	Jerome	-22.9759	30.68645
15	Jerome	-22.9769	30.68444
16	Jerome	-22.9776	30.6849
17	Jerome	-22.9768	30.68491
18	Jerome	-22.9765	30.68715
19	Jerome	-22.9769	30.68778
20	Jerome	-22.976	30.688
21	Jerome	-22.9757	30.68909
22	Jerome	-22.9771	30.68958
23	Jerome	-22.974	30.68562

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24	Jerome	-22.9766	30.68939
25	Jerome	-22.9777	30.68908
26	Jerome	-22.978	30.68639
27	Jerome	-22.9777	30.68517
28	Jerome	-22.9782	30.68478
29	Jerome	-22.9741	30.68805
30	Jerome	-22.9744	30.68689
31	Jerome	-22.9742	30.68595
32	Jerome	-22.9742	30.68563
33	Jerome	-22.9747	30.68598
34	Jerome	-22.9745	30.68488
35	Mafanele	-22.9799	30.67109
36	Mafanele	-22.9768	30.67536
37	Mafanele	-22.976	30.67722
38	Mafanele	-22.9759	30.67813
39	Mafanele	-22.9756	30.67844
40	Mafanele	-22.9745	30.67983
41	Mafanele	-22.975	30.67878
42	Mafanele	-22.975	30.67757
43	Mafanele	-22.9761	30.67594
44	Mafanele	-22.9761	30.67605
45	Mafanele	-22.9759	30.67585
46	Mafanele	-22.98	30.6717
47	Mafanele	-22.9762	30.67545
48	Mafanele	-22.9763	30.67501
49	Mafanele	-22.9767	30.67308
50	Mafanele	-22.9764	30.67261
51	Mafanele	-22.9775	30.67186
52	Mafanele	-22.9782	30.6705
53	Mafanele	-22.9786	30.66997
54	Mafanele	-22.9784	30.67022
55	Mafanele	-22.9786	30.66955

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56	Mafanele	-22.9795	30.66857
57	Mafanele	-22.9797	30.67212
58	Mafanele	-22.979	30.66974
59	Mafanele	-22.9797	30.66886
60	Mafanele	-22.9804	30.66932
61	Mafanele	-22.9806	30.66894
62	Mafanele	-22.9811	30.66933
63	Mafanele	-22.9798	30.6724
64	Mafanele	-22.9795	30.6725
65	Mafanele	-22.978	30.67398
66	Mafanele	-22.9769	30.67533
67	Mafanele	-22.977	30.67528
68	Mafanele	-22.9767	30.6759
69	Makumeke	-22.9782	30.63431
70	Makumeke	-22.976	30.63856
71	Makumeke	-22.976	30.63872
72	Makumeke	-22.976	30.6393
73	Makumeke	-22.976	30.63938
74	Makumeke	-22.9761	30.63998
75	Makumeke	-22.9773	30.64033
76	Makumeke	-22.9774	30.64118
77	Makumeke	-22.9791	30.64068
78	Makumeke	-22.9787	30.63963
79	Makumeke	-22.9815	30.63951
80	Makumeke	-22.9781	30.63433
81	Makumeke	-22.9816	30.63966
82	Makumeke	-22.9787	30.6391
83	Makumeke	-22.9789	30.63877
84	Makumeke	-22.9796	30.63694
85	Makumeke	-22.98	30.63708
86	Makumeke	-22.9809	30.63695
87	Makumeke	-22.9801	30.63722

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88	Makumeke	-22.9797	30.63713
89	Makumeke	-22.979	30.6364
90	Makumeke	-22.9794	30.63543
91	Makumeke	-22.9779	30.63527
92	Makumeke	-22.9794	30.63462
93	Makumeke	-22.9799	30.63289
94	Makumeke	-22.9797	30.63384
95	Makumeke	-22.9798	30.63331
96	Makumeke	-22.9802	30.63396
97	Makumeke	-22.9777	30.63522
98	Makumeke	-22.9762	30.63515
99	Makumeke	-22.9768	30.63519
100	Makumeke	-22.976	30.63714
101	Makumeke	-22.976	30.63793
102	Makumeke	-22.9759	30.6386
103	Mavambe	-22. 99793	30.63358
104	Mavambe	-22.99626	30.63156
105	Mavambe	-23. 00199	30. 62719
106	Mavambe	-23.00109	30.62717
107	Mavambe	-23. 00036	30. 6288
108	Mavambe	-22. 99963	30. 63139
109	Mavambe	-22.99920	30. 63270
110	Mavambe	-22.99951	30.63145
111	Mavambe	-22. 99882	30. 63113
112	Mavambe	-22.99898	30. 63327
113	Mavambe	-23. 00576	30. 64183
114	Mavambe	-23. 00566	30. 64077
115	Mavambe	-23. 00641	30. 64060
116	Mavambe	-23. 00534	30. 63893
117	Mavambe	-23. 00541	30. 63882
118	Mavambe	-23.00438	30. 63937
119	Mavambe	-22. 99541	30. 63415

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120	Mavambe	-22.99643	30. 63111
121	Mavambe	-22. 99783	30. 62885
122	Mavambe	-22.99840	30. 62929
123	Mavambe	-23.00066	30. 63123
124	Mavambe	-23. 00114	30. 63245
125	Mavambe	-23. 00153	30. 63389
126	Mavambe	-23. 00257	30. 63309
127	Mavambe	-23. 00228	30. 63188
128	Mavambe	-23. 00318	30. 63212
129	Mavambe	-23. 00354	30. 63313
130	Mavambe	-22.99985	30. 63338
131	Mavambe	-23. 00034	30. 63439
132	Mavambe	-23. 00112	30. 63474
133	Mavambe	-22. 99917	30. 63578
134	Mavambe	-22. 99971	30. 63615
135	Mavambe	-22. 99927	30. 63518
136	Mavambe	-22. 99850	30. 63500

Table 2: The global positioning system (GPS) coordinates of households visited in ward 18

Household visited	Village (Ward 18)	Waypoint	
		Latitude	Longitude
1	Dovheni	-23.02	30.51228
2	Dovheni	-22.9882	30.62076
3	Dovheni	-22.9891	30.62055
4	Dovheni	-22.9893	30.62051
5	Dovheni	-22.9908	30.62041
6	Dovheni	-22.9906	30.62041
7	Dovheni	-22.9914	30.62001
8	Dovheni	-22.9941	30.62003
9	Dovheni	-22.9944	30.61988

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10	Dovheni	-22.9959	30.61973
11	Dovheni	-22.9962	30.61964
12	Dovheni	-22.9858	30.62104
13	Dovheni	-22.9968	30.61955
14	Dovheni	-22.9978	30.6209
15	Dovheni	-22.9985	30.62093
16	Dovheni	-22.9967	30.62008
17	Dovheni	-22.9962	30.61975
18	Dovheni	-22.9959	30.61977
19	Dovheni	-22.9959	30.61979
20	Dovheni	-22.9954	30.6202
21	Dovheni	-22.996	30.62021
22	Dovheni	-22.9963	30.6215
23	Dovheni	-22.9854	30.62101
24	Dovheni	-22.9948	30.6211
25	Dovheni	-22.9939	30.62019
26	Dovheni	-22.9925	30.62036
27	Dovheni	-22.9919	30.62038
28	Dovheni	-22.9915	30.62165
29	Dovheni	-22.9855	30.62099
30	Dovheni	-22.9865	30.62089
31	Dovheni	-22.9871	30.62081
32	Dovheni	-22.9875	30.62055
33	Dovheni	-22.9882	30.62066
34	Dovheni	-22.9883	30.62069
35	Khakhanwa	-23.02	30.59911
36	Khakhanwa	-23.0206	30.59839
37	Khakhanwa	-23.0198	30.59891
38	Khakhanwa	-23.0193	30.59837
39	Khakhanwa	-23.0191	30.5983
40	Khakhanwa	-23.0202	30.59728
41	Khakhanwa	-23.0206	30.59832

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42	Khakhanwa	-23.0212	30.59771
43	Khakhanwa	-23.0213	30.59765
44	Khakhanwa	-23.0209	30.59725
45	Khakhanwa	-23.0216	30.59684
46	Khakhanwa	-23.0208	30.59718
47	Khakhanwa	-23.02	30.59631
48	Khakhanwa	-23.0198	30.59584
49	Khakhanwa	-23.019	30.59547
50	Khakhanwa	-23.0203	30.59565
51	Khakhanwa	-23.0194	30.59618
52	Khakhanwa	-23.0191	30.59673
53	Khakhanwa	-23.0184	30.59693
54	Khakhanwa	-23.0194	30.59623
55	Khakhanwa	-23.0185	30.5959
56	Khakhanwa	-23.0209	30.59891
57	Khakhanwa	-23.0191	30.59535
58	Khakhanwa	-23.0184	30.59588
59	Khakhanwa	-23.0181	30.59521
60	Khakhanwa	-23.0178	30.59564
61	Khakhanwa	-23.0177	30.59426
62	Khakhanwa	-23.0181	30.59495
63	Khakhanwa	-23.0216	30.59947
64	Khakhanwa	-23.0219	30.5996
65	Khakhanwa	-23.0218	30.59911
66	Khakhanwa	-23.0224	30.59904
67	Khakhanwa	-23.0225	30.59894
68	Khakhanwa	-22.9648	30.59475
69	Mulenzhe	-23.0082	30.55874
70	Mulenzhe	-23.0103	30.56389
71	Mulenzhe	-23.0048	30.55691
72	Mulenzhe	-23.0047	30.55655
73	Mulenzhe	-23.003	30.55743

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74	Mulenzhe	-23.0028	30.55654
75	Mulenzhe	-23.0031	30.5577
76	Mulenzhe	-23.003	30.55852
77	Mulenzhe	-23.0026	30.55927
78	Mulenzhe	-23.0028	30.55973
79	Mulenzhe	-23.0037	30.55995
80	Mulenzhe	-23.0091	30.5642
81	Mulenzhe	-23.0037	30.56092
82	Mulenzhe	-23.0044	30.55954
83	Mulenzhe	-23.0034	30.55862
84	Mulenzhe	-23.0045	30.55885
85	Mulenzhe	-23.0047	30.56047
86	Mulenzhe	-23.0053	30.56084
87	Mulenzhe	-23.0052	30.56188
88	Mulenzhe	-23.0055	30.56041
89	Mulenzhe	-23.0056	30.56025
90	Mulenzhe	-23.007	30.56035
91	Mulenzhe	-23.0092	30.56366
92	Mulenzhe	-23.008	30.56122
93	Mulenzhe	-23.0085	30.56177
94	Mulenzhe	-23.0079	30.56271
95	Mulenzhe	-23.0077	30.56375
96	Mulenzhe	-23.0089	30.56409
97	Mulenzhe	-23.0087	30.56274
98	Mulenzhe	-23.0098	30.56207
99	Mulenzhe	-23.0088	30.56259
100	Mulenzhe	-23.0097	30.56196
101	Mulenzhe	-23.0094	30.56095
102	Mulenzhe	-23.0084	30.55973
103	Dididi	-23.0184	30.51298
104	Dididi	-23.01882	30.51268
105	Dididi	-23.01890	30.51226

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106	Dididi	-23. 01918	30.51225
107	Dididi	-23.01935	30.51156
108	Dididi	-23. 01965	30. 51140
109	Dididi	-23. 01980	30.51125
110	Dididi	-23. 01931	30. 51065
111	Dididi	-23. 01897	30.51084
112	Dididi	-23. 01892	30. 51127
113	Dididi	-23. 01872	30. 51119
114	Dididi	-23.18610	30.51117
115	Dididi	-23.01843	30.51171
116	Dididi	-23. 01744	30.51223
117	Dididi	-23.01720	30. 51198
118	Dididi	-23. 01770	30. 51189
119	Dididi	-23. 01807	30.51136
120	Dididi	-23. 01813	30. 51091
121	Dididi	-23.01833	30.51093
122	Dididi	-23.01854	30.51058
123	Dididi	-23.01865	30.51042
124	Dididi	-23. 01911	30.51060
125	Dididi	-23. 01905	30. 50969
126	Dididi	-23.01913	30. 50970
127	Dididi	-23. 02032	30.51032
128	Dididi	-23. 02070	30.50992
129	Dididi	-23. 02114	30. 150995
130	Dididi	-23. 02102	30. 50888
131	Dididi	-23. 02140	30.50875
132	Dididi	-23. 02100	30. 51044
133	Dididi	-23. 02078	30. 51070
134	Dididi	-23. 02005	30.51177
135	Dididi	-23.01984	30. 51211
136	Dididi	-23.02000	30.51227

Table 3: The global positioning system (GPS) coordinates of households visited in ward 19

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Household visited	Village (Ward 19)	Waypoint	
		Latitude	Longitude
1	Budeli	-22.9655	30.56326
2	Budeli	-22.9641	30.56331
3	Budeli	-22.9639	30.56323
4	Budeli	-22.9641	30.56396
5	Budeli	-22.9634	30.56323
6	Budeli	-22.9633	30.56278
7	Budeli	-22.9641	30.56133
8	Budeli	-22.9639	30.56198
9	Budeli	-22.964	30.56149
10	Budeli	-22.9636	30.56085
11	Budeli	-22.9629	30.562
12	Budeli	-22.9627	30.56252
13	Budeli	-22.9628	30.56282
14	Budeli	-22.9624	30.56322
15	Budeli	-22.9627	30.56335
16	Budeli	-22.966	30.56362
17	Budeli	-22.9662	30.56317
18	Budeli	-22.9664	30.56329
19	Budeli	-22.9669	30.56351
20	Budeli	-22.9691	30.56533
21	Budeli	-22.969	30.56546
22	Budeli	-22.9659	30.5625
23	Budeli	-22.9697	30.56459
24	Budeli	-22.9699	30.56488
25	Budeli	-22.9699	30.56551
26	Budeli	-22.9697	30.56519
27	Budeli	-22.9698	30.56572
28	Budeli	-22.9657	30.56165
29	Budeli	-22.9651	30.56143
30	Budeli	-22.965	30.56139

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31	Budeli	-22.9648	30.56207
32	Budeli	-22.9641	30.56275
33	Budeli	-22.9643	30.56282
34	Budeli	-22.9655	30.56283
35	Dumasi	-22.9621	30.52467
36	Dumasi	-22.9574	30.56587
37	Dumasi	-22.9575	30.56508
38	Dumasi	-22.9571	30.5658
39	Dumasi	-22.9568	30.56571
40	Dumasi	-22.9567	30.56544
41	Dumasi	-22.9567	30.56395
42	Dumasi	-22.9566	30.56488
43	Dumasi	-22.956	30.56482
44	Dumasi	-22.9557	30.56324
45	Dumasi	-22.9555	30.56428
46	Dumasi	-22.9543	30.56794
47	Dumasi	-22.9557	30.56495
48	Dumasi	-22.9561	30.56562
49	Dumasi	-22.9557	30.56753
50	Dumasi	-22.9557	30.56811
51	Dumasi	-22.955	30.56713
52	Dumasi	-22.9548	30.56711
53	Dumasi	-22.9549	30.56659
54	Dumasi	-22.955	30.56641
55	Dumasi	-22.9549	30.56337
56	Dumasi	-22.955	30.56432
57	Dumasi	-22.9547	30.56792
58	Dumasi	-22.955	30.56485
59	Dumasi	-22.9547	30.56535
60	Dumasi	-22.9551	30.56523
61	Dumasi	-22.9541	30.56691
62	Dumasi	-22.9533	30.56674

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63	Dumasi	-22.9549	30.56886
64	Dumasi	-22.9555	30.5694
65	Dumasi	-22.9575	30.56927
66	Dumasi	-22.9578	30.56844
67	Dumasi	-22.958	30.56691
68	Dumasi	-22.9578	30.56589
69	Mutoti	-22.9666	30.59766
70	Mutoti	-22.9647	30.59482
71	Mutoti	-22.9643	30.5956
72	Mutoti	-22.9647	30.59493
73	Mutoti	-22.9655	30.59625
74	Mutoti	-22.9658	30.598
75	Mutoti	-22.9662	30.59727
76	Mutoti	-22.9659	30.59808
77	Mutoti	-22.9665	30.59769
78	Mutoti	-22.9665	30.59887
79	Mutoti	-22.9665	30.59902
80	Mutoti	-22.9648	30.59475
81	Mutoti	-22.968	30.59988
82	Mutoti	-22.9682	30.60149
83	Mutoti	-22.9685	30.60083
84	Mutoti	-22.9667	30.59944
85	Mutoti	-22.9664	30.59895
86	Mutoti	-22.9652	30.59853
87	Mutoti	-22.9658	30.5981
88	Mutoti	-22.9654	30.59746
89	Mutoti	-22.9648	30.59801
90	Mutoti	-22.965	30.59675
91	Mutoti	-22.9634	30.5925
92	Mutoti	-22.9651	30.59674
93	Mutoti	-22.9647	30.59638
94	Mutoti	-22.9641	30.59675

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95	Mutoti	-22.964	30.59658
96	Mutoti	-22.9632	30.59537
97	Mutoti	-22.9631	30.59203
98	Mutoti	-22.9629	30.592
99	Mutoti	-22.9623	30.59248
100	Mutoti	-22.9634	30.5931
101	Mutoti	-22.9632	30.59392
102	Mutoti	-22.9639	30.59488
103	Tshikudini	-22.9632	30.59536
104	Tshikudini	-22.9647	30.53177
105	Tshikudini	-22.9629	30.53151
106	Tshikudini	-22.9626	30.5324
107	Tshikudini	-22.9625	30.53159
108	Tshikudini	-22.963	30.53078
109	Tshikudini	-22.9628	30.53038
110	Tshikudini	-22.9628	30.53024
111	Tshikudini	-22.9633	30.52792
112	Tshikudini	-22.9633	30.52598
113	Tshikudini	-22.9638	30.5249
114	Tshikudini	-22.9622	30.53488
115	Tshikudini	-22.9643	30.52603
116	Tshikudini	-22.964	30.5265
117	Tshikudini	-22.9639	30.5272
118	Tshikudini	-22.9638	30.5279
119	Tshikudini	-22.9639	30.52926
120	Tshikudini	-22.9635	30.52996
121	Tshikudini	-22.9641	30.53053
122	Tshikudini	-22.9644	30.529
123	Tshikudini	-22.9646	30.52709
124	Tshikudini	-22.9649	30.52682
125	Tshikudini	-22.9632	30.53444
126	Tshikudini	-22.9646	30.52694

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127	Tshikudini	-22.9648	30.52558
128	Tshikudini	-22.9647	30.52606
129	Tshikudini	-22.9624	30.52494
130	Tshikudini	-22.962	30.52486
131	Tshikudini	-22.9633	30.53389
132	Tshikudini	-22.963	30.53396
133	Tshikudini	-22.9636	30.5335
134	Tshikudini	-22.9635	30.53216
135	Tshikudini	-22.9634	30.53159
136	Tshikudini	-22.9636	30.53107

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Appendix C

The maps showing coverage in the rural villages of the study area

All study household's dad VIP latrines

Coverage in rural villages (ward 15)

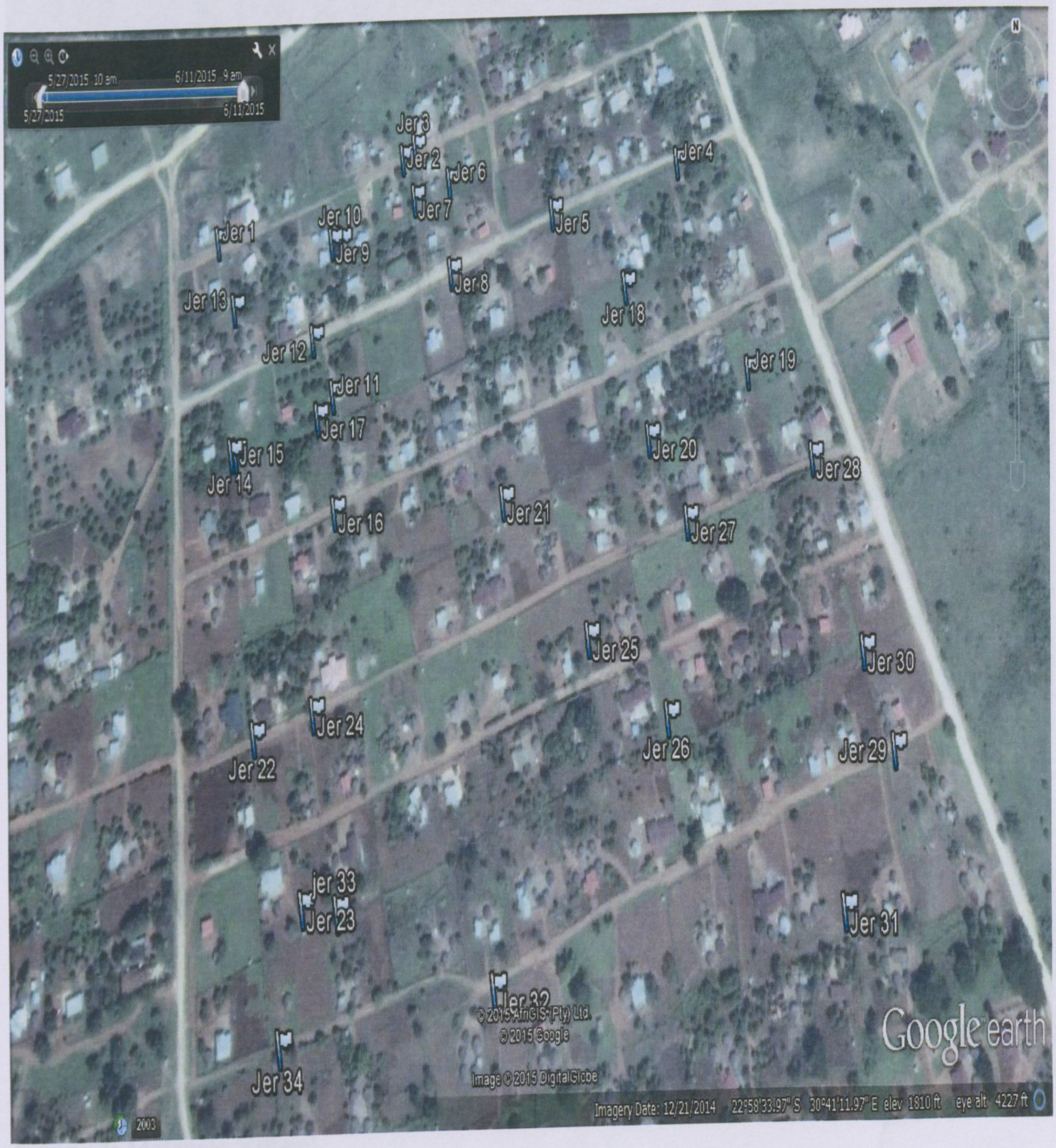


Figure 1: Jerome Village

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Figure 2: Mafanele Village

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Figure 3: Makumeke village

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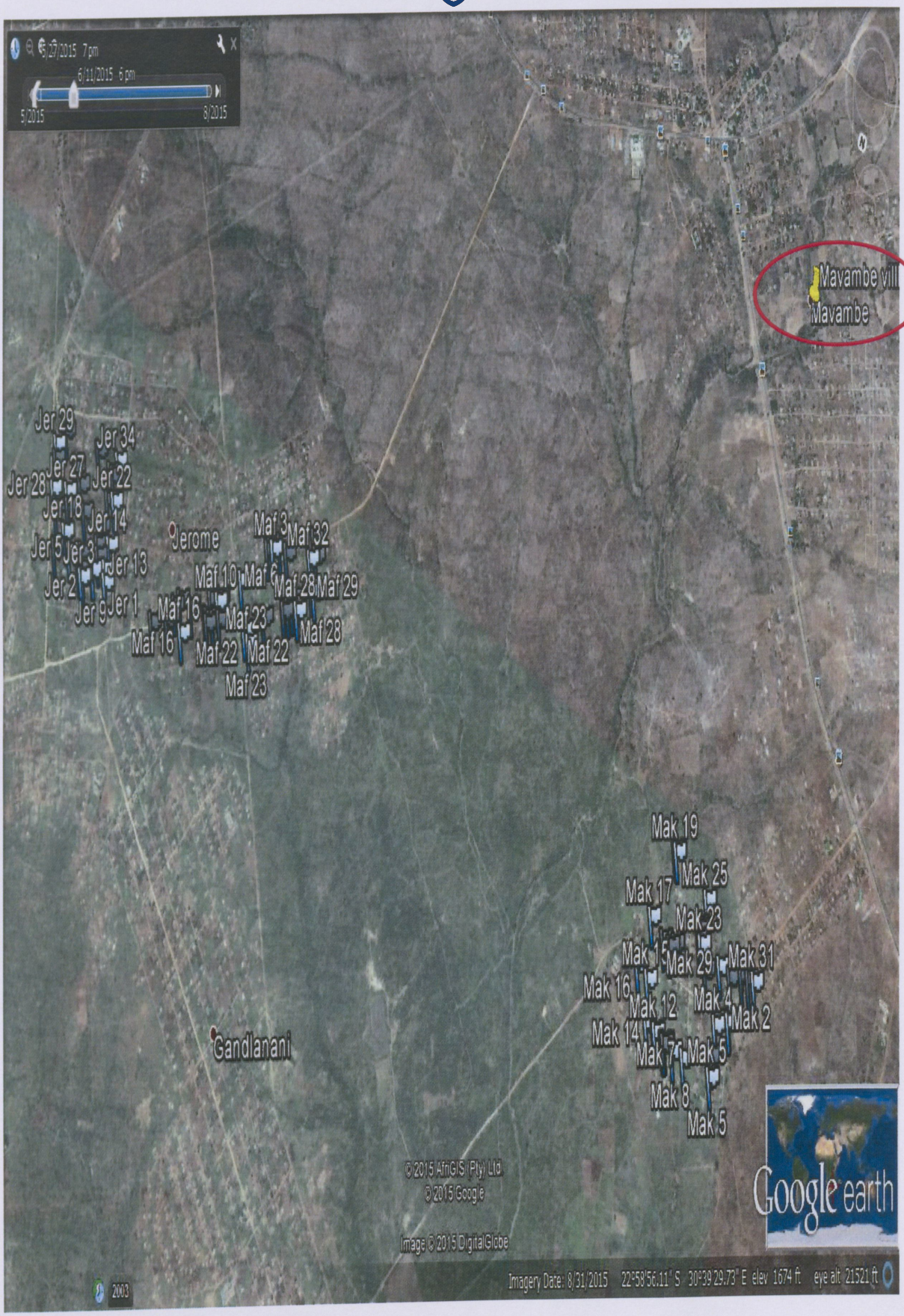


Figure 4: Mavambe village

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Figure 5: Dididi village

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Figure 6: Dovheni village

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Figure 7: Khakhanwa village

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Figure 8: Mulenzhe village

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Coverage in rural villages (ward 19)



Figure 9: Budeli village

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Figure 10: Dumasi village

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Figure 11: Mutoti village

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Figure 12: Tshikudini village

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