Improving Water Quality and Sanitation in Rural Namibian Communities

A Baseline Assessment on Odendaal Farms and Development of Community-Integrated Implementation





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Date: May 4, 2011

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PROJECT NUMBER: NAM5

DIVISION NUMBER: 42

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A Baseline Assessment on Odendaal Farms and Development of Community-Integrated Implementation

An Interactive Qualifying Project submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science

Sponsoring Agency: Desert Research Foundation of Namibia

Submitted to
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ABSTRACT

Groundwater contamination poses a risk to Namibian farming communities. Our goal was to analyze and improve water quality and sanitation on Odendaal farms in southern Namibia. Through interviews with farmers, meetings with local experts, and water tests, we established a baseline with social and environmental components. In collaboration with communities, we organized an approach to improve water and sanitation, and piloted a dry sanitation system. We created recommendations for the Desert Research Foundation to allow for continued improvement.

EXECUTIVE SUMMARY

Water is among the most essential resources needed to sustain life; contaminated sources pose life threatening health risks to consumers. In the rural regions of Namibia, farming communites struggle to obtain water fit for human consumption. Poor sanitation practices, limited education, geographic isolation, and insufficient governmental communication amplify this challenge. The Ministry of Agriculture, Water,and Forestry (MAWF) is responsible for providing suitable water to such communities, although due to insufficient funding MAWF has failed to do so. The Desert Research Foundation of Namibia (DRFN) seeks to support and empower the decision makers of these communities through participatory identification and implementation of appropriate treatment and preventative solutions.

BACKGROUND

Odendaal farms were the target of our study. During apartheid, the National Party of South Africa implemented the Odendaal Plan in what was formerly “South West Africa”, now Namibia. In an effort to ethnically segregate the country, the government purchased a large area of land and installed boreholes as water points. Homesteads, called Odendaal farms, formed around these water points. Many of these farms still exist today in the Hardap region of Namibia. Fifty years of poor sanitation and livestock activity has contaminated local ground water. While the government has rehabilitated some boreholes, they are not regularly maintained. The quality of the water they provide is neither monitored nor treated.

The Directorate of Water Supply and Sanitation Coordination (DWSSC), a sub-department of MAWF, manages the water supply of Odendaal farms. The DWSSC is responsible for all major borehole repairs. Communities must contact the DWSSC and responses typically take a minimum of one month. If a community requires installation of specific mechanical parts, repairs are further delayed. As such, communities in need of repair often go without adequate water supply for extended periods. To facilitate borehole maintenance communities appoint one member to be a caretaker. He or she is responsible for minor repairs and the DWSSC is obligated to provide training to these individuals. However, an educational gap has developed. Often, community members with proper training move and new residents do not receive formal instruction.

The DRFN is working to assess water quality and educate rural communities. The Water-Desk at the DRFN is coordinating a project entitled *Sustainable use of Namibia's natural resources: contributing towards* ***enhancing the capacity*** *of future decision makers* (E-CAP). The DRFN recruited us to work on E-CAP specifically in rural communities of the Hardap region. Our initiative was to provide targeted support to rural decision makers to improve their water and sanitation management. Our research was directed towards the Nico-Noord Farmstead and its surrounding communities; a preliminary study conducted by DRFN suggested these farms had hazardous groundwater contamination.

The most threatening parameters of water quality were elevated levels of nitrate and coliform bacteria, both of which are byproducts of fecal contamination. In excess, nitrate causes methaemoglobinaemia in young children. This condition is also known as blue baby syndrome, as it fatally inhibits oxygen carrying capacity. Ingestion of coliform bacteria yields gastrointestinal illness which manifests as violent vomiting, diarrhea, and cramps. The dangers of these conditions alone provide justification for an extensive assessment of water quality in the Hardap farming communities.

METHODOLOGY

Our initial task was to conduct a baseline assessment of eight Odendaal farms in the Hardap region and develop specific solutions for their water quality and sanitation issues. As part of our baseline assessment we performed infrastructural analyses, water quality tests, and community interviews. We conducted preliminary chemical testing on site, and collected samples for extensive bacteriological and chemical analysis by a professional laboratory service. Upon return to the DRFN we compiled data and created a general profile for each farm. In conjunction with our sponsors, Dr. Patrik Klintenberg and Ms. Faith Simataa, we compiled a list of recommendations to improve the quality of water and sanitation and ultimately promote community health. Among these recommendations were the construction of dry sanitation systems and installation of ion exchange filters.

In a second field visit we conducted two community meetings in which we presented our concerns regarding nitrate and bacteria. We prepared a workshop focusing primarily on causes and prevention of contamination. Our intention was to encourage the community members to share ideas and opinions to instill personal investment regarding the improvement of their water and sanitation. During both meetings we discussed conducting a study involving implementation of dry sanitation systems and filters. By our observation, the communities were enthusiastic about participating in a pilot study; with the approval and support of the DRFN, we returned for a third visit and began implementation.

In the final field visit we coordinated the construction of an Otji-Toilet dry sanitation system. We selected a community member to receive the system who demonstrated enthusiasm and motivation to participate in the first stage of the DRFN pilot study. We involved several members of surrounding communities, including a local mason, in the planning and construction. Our objective was to develop a sense of ownership and pride among the community through the construction of the sanitation system. Following completion of the system, we finalized a list of recommendations for the DRFN, emphasizing continuation of pilot system installation and study.

COMMUNITY-INTEGRATED IMPLEMENTATION: COMMUNITY MEMBERS ACTIVELY INVOLVED IN CONSTRUCTION OF A PILOT DRY SANITATION SYSTEM

RESULTS

Water Quality

The final classification for the water on each farm was categorized by chemical and bacteriological quality. Of eight farms tested, two had acceptable water, four had water of low health risk, and two had water unfit for human consumption. Though several testing parameters were considered, these poor classifications were primarily attributed to high nitrate levels and coliform bacteria.

Infrastructure

Visual evaluations showed that a majority of the water infrastructure is functional. All communities were equipped to draw and store water. Leaking pipes were the most prevalent infrastructural issue. Another minor problem was the poor condition of reservoirs, which we found had many holes and were in need of cleaning.

Social Baseline

The majority of communities believed that the water was of suitable quality. None mentioned observing any changes in water quality over time, as many community members had recently moved. Almost all people claimed to use no sanitation systems, and instead relied on "bush" or "bucket" waste systems. Some communities attributed instances of local sickness to poor water quality. Regarding waste management, all simply burned their garbage.

Community Meetings

Communities expressed that they were unaware of the dangerous implications of water contamination by human and livestock defecation. Although all community members were aware of flush sanitation systems, none were familiar with the concept of dry sanitation. The communities all demonstrated interest in piloting dry sanitation systems, ion exchange filters, and chlorination treatment; however, they were concerned with the cost of such solutions.

Pilot Study

Community-integrated implementation of the Otji-Toilet system was highly successful. Construction was conducted primarily by the recipient, though members of neighboring communities were heavily involved. The recipient even incorporated personal variation into the system design, further demonstrating his investment in the pilot. By our recommendation, the DRFN has begun to organize implementation of ion exchange filters, chlorine treatment, and more dry sanitation systems in the rural Hardap communities. The DRFN will study the success of these pilot solutions to make future recommendations to the DWSSC.

CONCLUSIONS

We have identified nitrate and coliform bacteria as the most threatening contaminants. We attribute this contamination primarily to two sources: livestock defecation in the vicinity of boreholes and human sanitation practices such as open defecation, pit latrines, and the bucket system.

We conclude that the water on six of the eight farms evaluated is in need of treatment. Although on two of the farms the water was considered "acceptable for human consumption", steps must be taken to prevent further contamination of their water source; in comparing our results to the preliminary DRFN study it is clear that nitrate levels have risen.

Regarding infrastructure, we conclude that all farms are functionally equipped to draw and store groundwater. Only minor repairs are needed, mainly small cracks and leaks in the pipes and reservoirs. Through our observation, we determined that the wear of the pipes was primarily due to old age and exposure to livestock.

Lastly, we conclude that education and community involvement are essential to effectively improving water quality and sanitation. We found that communities are not aware of the causes and implications of groundwater contamination, but are willing to learn and participate in treatment and prevention.

RECOMMENDATIONS

In concordance with our results and conclusions we have developed recommendations to improve water quality and sanitation systems on Odendaal farms.

Relocation of Livestock

In order to prevent further contamination of the groundwater we recommend that livestock be relocated further from the borehole. Additionally, fencing should be installed to insure that livestock remain away from the borehole.

Installation of Dry Sanitation Systems

We recommend the DRFN continue installation of dry sanitation systems, specifically the Otji-Toilet. The Otji-Toilet will not only improve community hygiene, but will also prevent contaminants from entering the groundwater. Case studies conducted in Havanna and Aranos have demonstrated that these toilets are effective sanitation methods in the Namibian environment. We recommend regular quarterly inspection to ensure the systems are running properly. We suggest the DRFN evaluate the success of these systems for a duration exceeding one year. If studies indicate these systems are sustainable, future recommendations can be made to the DWSSC.

Installation of Nitrate Ion Exchange Filters

We recommend the installation of nitrate ion exchange filters in select households as pilots. We have identified ion exchange filters as the most affordable, small-scale solution to nitrate contamination. The majority of taps will need to have a T-junction installed. This will allow one side to be used solely for filtered drinking water and the other side to be used for all other purposes. Water meters should also be installed to monitor water consumption. We suggest the DRFN monitor and inspect filters quarterly for a duration exceeding one year to evaluate their success. If determined effective, the DRFN can recommend ion exchange filters as a sustainable solution to the DWSSC.

Chlorination Treatment

For farms with bacterial contamination, we recommend water treatment with calcium hypochlorite (HTH) powder. Under the guidance of water treatment professionals, we have determined that HTH is the most appropriate solution. We suggest that the DRFN conduct a pilot study with chlorination, and give priority to communities with the most severe biological contamination. We recommend the DRFN conduct biological water tests quarterly for a duration exceeding one year to measure its effectiveness. If HTH is identified as an effective solution, recommendation can be made to the DWSSC.

Development of Routine Water Testing

We recommend that the DWSSC conduct routine, quarterly water testing to ensure water is safe for human consumption. In addition, this will allow the DWSSC to handle potential problems before they become severe issues.

Standardized Training to Water Point Committee Members

We recommend more extensive involvement of the DWSSC in educating the communities on water and sanitation. Information workshops should be held at least on a yearly basis. Regular visits to farms will improve communication between community and government, thus improving infrastructural maintenance.

Community Integrated Implementation

We recommend that community members be present and involved in implementation of all recommendations. Involvement in all steps of the process will ensure that community members are dedicated to maintaining and supporting all efforts of the DRFN and DWSSC.

SUMMARY

The residents on Odendaal farms face serious health risks due to contamination of their water sources. Livestock defecation and poor sanitation practices are the primary causes of pollution. Our baseline assessment indicates that contaminant levels, most importantly nitrate, are rising. To improve local health, communities require immediate water treatment. At the conclusion of our research, we initiated a DRFN pilot study that will implement solutions to improve the water quality and sanitation in these communities. These solutions will directly treat drinking water, prevent future contamination, and ultimately improve consumer health.

ACKNOWLEDGMENTS

We would like to extend thanks to the following individuals, institutions, and organizations for their support and contribution to the success of this Interactive Qualifying Project.

- The Desert Research Foundation of Namibia for sponsoring our project, providing us a space to work, and supplying us with the necessary resources to complete our project.
- Our Sponsor, Dr. Patrik Klintenberg, for his endless support and guidance through the duration of our project.
- Ms. Faith Simataa, Mrs. Fransiska Nhighitila, Mr. Justus Kauatjirue, and to all other members of the Water Desk, for their generous support and assistance.
- Kenneth (Lucky) !Ganeb of the DRFN for acting as a liaison and interpreter between our group and the farming communities.
- Dr. Mary Seely, founder of the DRFN, for sharing her knowledge with us and overseeing our project.
- Dr. Thomas Honor from Aqua Services & Engineering for being a continued resource of information that contributed greatly to the completion of this project.
- Dr. Andreas Weinecke, of the Habitat Research and Development Center for sharing his knowledge of dry sanitation methods with us.
- Mr. Ben Freyer, Deputy Director of the DWSSC for his cooperation and guidance.
- The DWSSC members who supported our project and were present for baseline assessments and meetings.
- Mrs. Sara Bock for her hospitality and guidance on Odendaal Farms
- The communities of the Odendaal Farms, who were welcoming and extremely helpful in our research.
- Prof. Ingrid Shockey and Prof. Ulrike Brisson, of Worcester Polytechnic Institute, for their guidance and support throughout the completion of this project.
- Worcester Polytechnic Institute and the Polytechnic of Namibia for making our experience in Namibia and this project possible.

AUTHORSHIP PAGE

Each member of the group contributed equally to the production of this report and to the projects overall completion, which includes but is not limited to the collection, processing, and analysis of data and information.

TABLE OF CONTENTS

Abstract i

Executive Summary ii

Acknowledgments viii

Authorship Page ix

Table of Contents x

Table of Figures xiii

List of Tables xv

List of Acronyms xvi

Chapter 1: Introduction 17

Chapter 2: Literature Review 20

2.1 Site Description 20

2.2 Desert Research Foundation of Namibia 23

2.3 Basin Management Committees 24

2.4 Water Policy 26

2.5 Water Systems and Supply 28

2.6 Establishing a Water Quality Baseline 29

2.7 Integrated Water Resource Management 31

2.7.1 Swaziland Case Study 33

Chapter 3: Methodology 37

3.1 Establishing a Baseline 37

3.2 Community Development of Solutions 39

3.3 Data Collection and Analysis 40

3.4 Project Plan 40

Chapter 4: Results and Analysis 41

4.1 Water Infrastructure 41

4.1.1 Nico-Nord 43
4.1.2 Doring Draai 43
4.1.3 Nico 44
4.1.4 Laurencia Pos 46
4.1.5 Laurencia 46
4.1.6 Gründorn (South) 47
4.1.7 Gründorn (North) 48
4.1.8 Diamont Kop 49
4.2 Water Quality 51
4.2.1 Field Tests 51
4.2.2 Analytical Laboratories Results 52
4.3 Social Baseline 54
4.4 Testing Equipment Analysis 57
4.4.1 Testing Strips 57
4.2.2 Colorimeter 58
4.5 General Analysis of Baseline Assessment 60
4.6 Educational Workshops 60
4.7 Pilot Study 61
Chapter 5: Conclusions and Recommendations 64
5.1 Water Quality 64
5.2 Colorimeter 65
5.3 Infrastructure 66
5.4 Community 66
5.5 Pilot Study 67
5.5.1 Otji-Toilet 67
5.5.2 Ion Exchange Filters 68
5.5.3 Calcium Hypochlorite 68
5.6 Sustainability 69
5.7 Farms Requiring Special Attention 69
5.7.1 Gründorn (South) 70
5.7.2 Diamont Kop 70

5.8 Summary 71

References 72

Appendix A – Component Evaluation Form 77

Appendix B – Community Questionnaire 78

Appendix C – Water Testing Parameter 81

Appendix D- Analytical Laboratory Services Quotations 82

Appendix E – Chemical Testing 83

Appendix F- Field Test Results 84

Appendix G – Analytical Labs Chemical Results 88

Appendix H- Analytical Labs Bacteriological Results 97

Appendix I: Ion Exchange Filter Specifications 101

Appendix J: Otji-Toilet Self Builder Manual 103

Appendix K: Ion Exchange Filter Quotation 116

Appendix L- Dry Sanitation 118

Apendix M: Otji-Toilet Quotation 125

TABLE OF FIGURES

Figure 1: Average Annual Rainfall in Namibia 21
Figure 2: Regions in Namibia 22
Figure 3: The Bucket System 23
Figure 4: Excerpt From the Water Resources Management Act of 2004 25
Figure 5: Map of Namibia 26
Figure 6: Global Water Partnership IWRM Framework 33
Figure 7: (Left) Nitrite/Nitrate Testing Strips 39
Figure 8: (Right) Hach 890 Colorimeter 39
Figure 9: Location of Farms 41
Figure 10: (Left) A Windmill Powered Borehole Locatacted at Doring Draai 42
Figure 11: (Right) An Elevated, 10,000 L Water Tank and Reservoir at Doring Draai 42
Figure 12: (Left) Borehole Base Shows Signs of Rusting and Leaking 44
Figure 13: (Right) Water Tanks and Pipes in Good Condition 44
Figure 14: Rubber Pipes That Supply Household Taps Are in Poor Condition and Require Patching 44
Figure 15: (Left) Solar Powered Borehole At Nico is in New Condition 45
Figure 16: (Right) Livestock in Vicinity of Infrastructure 45
Figure 17: (Left) Rubber Piping Above Ground, Although Appears in Good condition 45
Figure 18: (Right) A Reservoir Dam No Longer in Use 45
Figure 19 A and B: Edges of the Resevoir Show Signs of Cracking and Pipes are Rusting 46
Figure 20: (Left) Exposed Rubber Piping is in Good Condition 46
Figure 21: (Right) Small Leak in the Resevoir 46
Figure 22: (Left) Windmill Powered Borehole in Center of Community 47
Figure 23: (Right) Poor Pipe Conditions Beneath Storage Tanks 47
Figure 24: (Left) A Leaking Pipe from a Storage Tank is Patched 47
Figure 25: (Right) Reservoir in Excellent Condition 47
Figure 26: Piping is Poorly Repaired From the Second Reservoir 48
Figure 27A and 27B: Successful Repairs to the Second Reservoir 48
Figure 28: (Left) Rusty Pipes 48
Figure 29: (Right) Livestock Feces Near the Borehole 48

Figure 30A and 30B: Temporary Solutions to Leaky Pipes....................49
Figure 31: (Left) Reservoirs in Good Condition....................49
Figure 32: (Right) Severe Biological Growth in the Exposed Reservoirs....................49
Figure 33: (Left) Cracked Base of the Borehole....................50
Figure 34: (Right) Biological Growth Along the Leaks in the Dam....................50
Figure 35: (Left) Direct Fecal Contamination into Dam....................50
Figure 36: (Right) Poor Pipe Conditions....................50
Figure 37: Concrete of Livestock Trough is in Poor Condition....................50
Figure 38: Analytical Labs Nitrate Results....................53
Figure 39: Analytical Labs Total Hardness Results....................53
Figure 40: Community at Doring Draai....................54
Figure 41: Community Discussion at Gründorn (South)....................55
Figure 42: (Left) Mr. George Breaks Ground for Construction of his Toilet....................62
Figure 43: (Right) Community Members and DRFN Staff Measure Dimensions for the Foundation....................62
Figure 44: (Left) Community Members Discuss Construction Plans....................62
Figure 45: (Right) Mr. George Lays First Row of Bricks....................62
Figure 46: (Left) Mr. George and the Local Mason Lay Bricks....................62
Figure 47: (Right) Community Members Observe the Construction Process....................62
Figure 48: (Left) Mr. George Added a Horizontal Support into the Design....................63
Figure 49: (Right) Community Members Place Concrete Floor Slab....................63
Figure 50: (Left) Toilet House Walls Being Built....................63
Figure 51: (Right) Construction of Toilet House Walls Continues....................63
Figure 52: (Left) Roof Support is Added....................63
Figure 53: (Right) Completed Otji-Toilet....................63
Figure 54: Existing Sanitation Systems....................118
Figure 55: EcoSan Triple Win....................119
Figure 56A and B: UDS Complete Construction Design and Urine Diversion System....................120
Figure 57: Otji-Toilet....................122
Figure 58: Double Chamber Toilet....................123
Figure 59: Jo Jo Toilet....................124

LIST OF TABLES

Table 1: Common Testing Methods and Outputs 30
Table 2: Summary of NamWater Guidelines 30
Table 3: Water Quality Group Description 30
Table 4: Overall Farm Classifications 54
Table 5: Comparison of Nitrate Strip Results with Analytical Labs 58
Table 6: Comparison of Nitrate Results with Analytical Labs 58
Table 7: Comparison of Fluoride Results with Analytical Labs 59
Table 8: Comparison of Iron Results with Analytical Labs 59
Table 9: Comparison of Sulfate Results with Analytical Labs 59

LIST OF ACRONYMS

BMC- Basin Management Committees

CBM- Community Based Management

DRFN- The Desert Research Foundation of Namibia

DRWS- Directorate of Rural Water Supply

DWSSC- Directorate of Water Supply and Sanitation Coordination

E-CAP- *Sustainable use of Namibia's natural resources: contributing towards* ***enhancing the capacity*** *of future decision makers* project

GIS- Geographic Information System

GWP- The Global Water Partnership

HTH- Calcium Hypochlorite

IWRM- Integrated Water Resource Management

L- Liter

MAWF- Ministry of Agriculture, Water, and Forestry

N $-Namibian Dollar

NGOs- Non-Governmental Organizations

OFRB- Orange Fish River Basin

ORASECOM- The Orange-Senqu River Commission

SFDF- Swaziland Farmer Development Foundation

SZWP- Swaziland Water Partnership

TDS- Total Dissolved Solids

CHAPTER 1: INTRODUCTION

The single most essential resource to sustain human life is potable water, yet an estimated one billion people living in developing countries do not have this vital resource (The United Nations, 2011). Lack of clean water generally stems from a nation's inability to properly manage water that is present in a given region (Wall, Mezak, Gray, & Careau, 2008). Management issues include lack of communication, poor maintenance, limited water education, insufficient funds, and resource preservation. Water management has become a large-scale problem brought to the attention of the United Nations as well as other non-governmental organizations (NGOs). Management solutions are necessary for communities to grow and develop. Namibia is one of many countries improving water management strategies in its rural areas.

Having gained independence just twenty-one years ago, Namibia is a developing nation. It is a land of vast disparity mainly due to the lack of resources and isolation of certain regions. The lifestyles of those living in Windhoek, the capital, are comparable to that of a modern city; running water, electricity, and internet are all available. The rural regions are quite different. They have been slower to develop and often lack reliable electricity and clean water. The Orange Fish River Basin (OFRB), located in southern Namibia, is one region that requires attention. The living conditions are harsh and drinking water is subject to contamination. Since Namibia is a desert climate, it is arid with sparse and irregular rainfall. Therefore, communities rely mainly on ground water. The challenges the communities face with managing the scarce water supply, however, has led to a variety of problems and health concerns (U.S. Central Intelligence Agency, 2011).

The Desert Research Foundation of Namibia (DRFN) is an organization aspiring to end technological and resource inequality in rural areas. The DRFN's vision is of "a Namibia in which people manage the environment for sustainable livelihoods" (Desert Research Foundation of Namibia, 2011c). They plan to accomplish this through the "Sustainable use of Namibia's natural resources: contributing toward **enhancing the capacity** of future decision makers" project which is also referred to as the E-CAP project. The E-CAP project will establish and improve local communities' overall ability to develop sustainably.

The DRFN sponsored this project to evaluate rural communities facing these challenges. The project expanded on a study conducted on Odendaal farms located in the Hardap region. Our work included an extensive analysis of the communities, by establishing both the environmental and the social baseline concerning water and sanitation. Consequently, we focused on the second component of the E-CAP project: improving the water quality and sanitation management in rural Namibian communities (Desert Research Foundation of Namibia, 2011a).

A major challenge in many rural communities is pollution of the water supply. These isolated communities rely heavily on groundwater as their primary water source. Recent fieldwork identified that livestock and community impacts are the cause of pollution (Simataa, 2010). Community involvement is critical in establishing feasible water and sanitation management policies. Isolation in itself poses many problems to the communities and limits many potential solutions. Basic services such as transportation, communication, and electricity are severely limited in these communities (Kalauskas, Geddes, Ridley, & Diemand, 2010).

In a previous study completed in 2008, a team of researchers studied the Orange Fish River Basin (OFRB) and assessed a number of communities in several dimensions: water management, water use, sanitation methods, and cost recovery systems. The purpose was to suggest solutions for water and sanitation systems as well as to assess the potential success of the basin management approach. They concluded that many water issues were rooted in poor communication and found that the basin management approach was well suited for the area (Wall et al., 2008). However, this team was not able to implement any solutions. We evaluated reviews of current water and sanitation problems, and initiated a pilot study with DRFN.

Our first objective was to establish a water quality baseline. The baseline assessment included social, geographical, infrastructural, bacteriological, and chemical components. We used the results to identify problems involving water quality and sanitation. In addition to establishing a baseline, our objective was to investigate, develop, and pilot potential solutions to problems identified by community members and by our own observations and testing.

Community involvement and ownership was essential for successful implementation. To open the dialogue with community members we held educational workshops regarding water and sanitation. Rather than directly offering the community a solution, we encouraged them to participate in a discussion. Community participation in all phases of our project, including implementation, ensured that community members felt ownership.

Over the course of three field visits, we established a baseline, held community workshops, and initiated a DRFN pilot study. After identifying nitrate and bacteria as the most threatening contaminants, we researched applicable solutions. Through the community workshops we educated the residents on the hazards associated with the contaminants and discussed potential solutions culminating in implementation of a dry sanitation system. These results will contribute to improving the water and sanitation within the Odendaal farms and ultimately improve consumer health.

CHAPTER 2: LITERATURE REVIEW

The following chapter is a compilation of our preliminary research. We first give a geographic and demographic overview of the region. Next, we discuss water policy and acceptable standards of health. We describe what we have identified as an effective method of water management: the Integrated Water Resource Management (IWRM) approach. To conclude we analyze a case study that portrays the success of the IWRM approach in Southern Africa.

2.1 SITE DESCRIPTION

Namibia, a developing country located in southwestern Africa is directly bordered by South Africa, Angola, Botswana, and Zambia. The territorial area of Namibia is 824,292 square kilometers (318,177 square miles). Namibia has a dry desert climate and scarce water supply. In comparison, Pakistan, a country of similar size, has 25 times more surface water than that of Namibia. The lack of surface water and annual rainfall make water conservation essential for sustainability in rural Namibian communities (U.S. Central Intelligence Agency, 2011). Southern Namibia receives the least amount of annual rainfall in the country. As seen in Figure 1, the southern portion of Namibia accumulates less than 100 mm of rain per year (Directorate of Environmental Affairs, Ministry of Environment and Tourism, 2002).

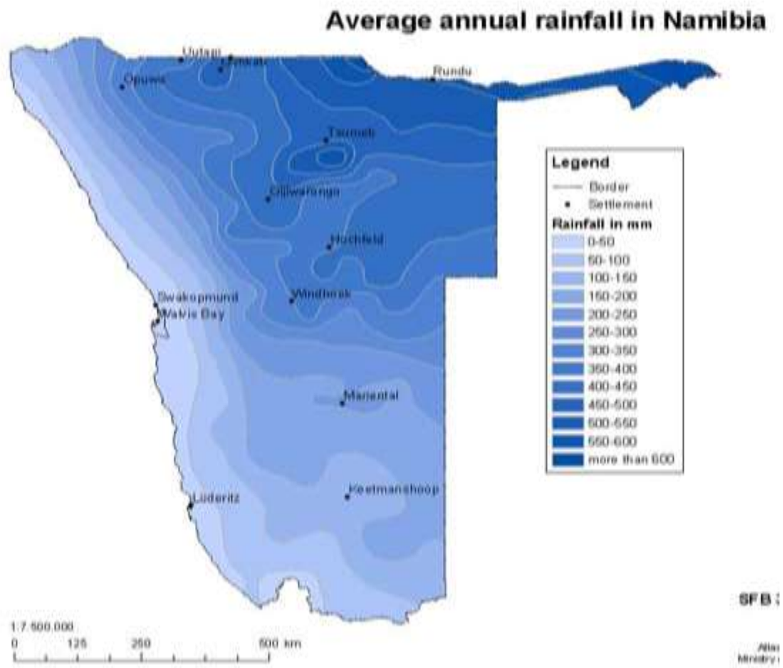

FIGURE 1: AVERAGE ANNUAL RAINFALL IN NAMIBIA (DIRECTORATE OF ENVIRONMENTAL AFFAIRS, MINISTRY OF ENVIRONMENT AND TOURISM, 2002)

The residents of southern Namibia are primarily farmers of Nama or Afrikaans descent. When Germany colonized Namibia in the late nineteenth and early twentieth century, the Nama faced genocide. German forces killed many indigenous people to assert control over the land and provide space for incoming Europeans. In the words of historian Jürgen Zimmerer, “The Germans pursued a campaign of annihilation that also targeted women and children” (Zimmerer, 2008). The Nama tribe was able to survive in spite of the German denial of food and clean water. The violence subsided in 1908, but the harsh feelings continued through to the new millennium and may still be present today (Zimmerer, 2008).

In 1962, the National Party of South Africa implemented the Odendaal Plan in what was formerly “South West Africa”, now Namibia (Forrest, 2008). The government purchased a large number of farms as part of the plan to ethnically segregate the country. Homesteads, called Odendaal farms, formed around water points in the region and can still be found today (Simataa, 2010). Many of these farms exist in the Hardap region of Namibia. As seen in Figure 2, the Hardap region is in the southern portion of Namibia. The Hardap region receives a low amount of rain each year, about 150 mm (Directorate of Environmental Affairs, Ministry of Environment and Tourism, 2002). A lack of water is a major problem in this region.

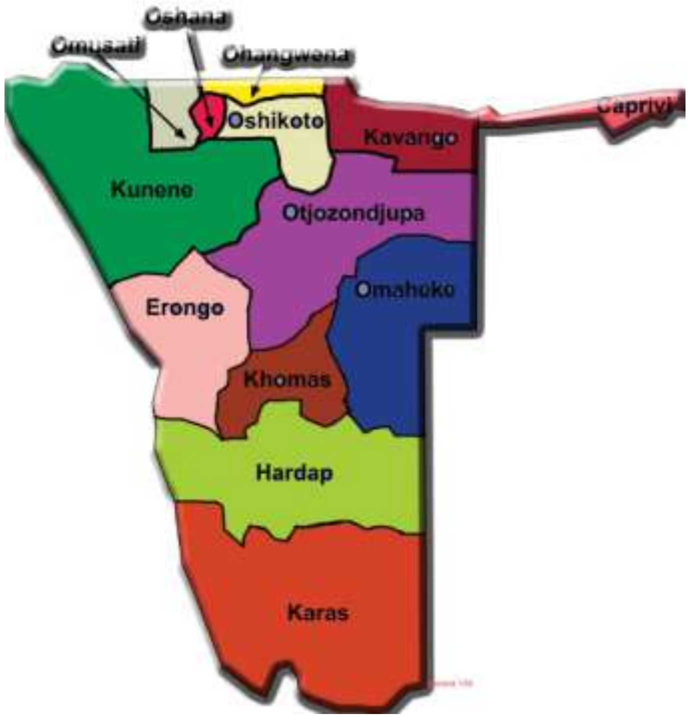

FIGURE 2: REGIONS IN NAMIBIA (NANTU, 2009)

The most common water source on an Odendaal farm is groundwater obtained from a borehole. Many of these were drilled in the 1970s and the government has been working to rehabilitate them. A major challenge in the rehabilitation process is the geographic isolation of these farms. The Directorate of Water Supply and Sanitation Coordination (DWSSC), a sub-department of the Ministry of Agriculture, Water, and Farming (MAWF), oversees the water supply and is responsible for all major borehole repairs. While community members finance basic repairs, the DWSSC operates solely on government funding for major restorations.

The principal concern on Odendaal farms is ground water pollution. Preliminary reports suspect contamination is a result of open human and livestock defecation (Wall et al., 2008). Often the most common sanitation practice is the "bush" or "bucket" system shown in Figure 3. The primary occupation of residents on these farms is livestock farming. These sanitation practices in combination with an abundance of livestock contribute to nitrate pollution and increase the risk of bacterial contamination.

FIGURE 3: THE BUCKET SYSTEM

2.2 DESERT RESEARCH FOUNDATION OF NAMIBIA

The Desert Research Foundation of Namibia (DRFN) is a non-governmental organization dedicated to the advancement of Namibia in the areas of water, energy, and land development. The DRFN, created in 1990, helps organize and distribute information gathered regarding life in harsh environments such as deserts, forests, and plains. In 1995, the DRFN built a main office in Windhoek, where they coordinate projects and reports. The DRFN supports heavily researched projects and encourages an "understanding of the environment for sustainable livelihoods and development" (Desert Research Foundation of Namibia, 2011b). The DRFN has three main focuses, land, energy, and water.

We worked on a water related project: The *sustainable use of Namibia's natural resources: contributing towards* ***enhancing the capacity*** *of future decision makers* (E-CAP). The DRFN designed the E-CAP project to work with Namibians in select communities to identify and manage problems in their water and sanitation systems. The E-CAP project consists of four components:

1. Capacity building of incipient national and regional level decision makers
2. Targeted support to rural decision makers to improve their own water and sanitation management
3. Team support to local authorities to enhance water and sanitation management
4. Environmental updates to Namibian Parliamentarians

We focused on the second component of the E-CAP project. An important aspect of this directive is community involvement.

2.3 BASIN MANAGEMENT COMMITTEES

Namibia recognizes a basin as the fundamental 'unit' to which they should assign a water management committee (Amakali, 2003). The term basin generally refers to the area that supplies and drains into a river; synonyms include watershed or catchment. In the case of many Namibian farms, however, the groundwater supply defines the boundaries of the basin, including the water, soil, vegetation, and wildlife.

Committees that oversee basins are thus responsible for maintaining the environmental health; they ensure that human activity does not negatively impact the quality or health of the basin system. Therefore, it is logical that the people who live within the communities of a basin are responsible for its management. Consequently, Community Based Management (CBM) is a supported and effective approach to maintaining health within rural water systems (see the Swaziland case study for more details, below).

In order to implement an effective CBM strategy, the Water Resources Management Bill has proposed to establish Basin Management Committees (BMC) (Amakali, 2003). These committees would provide communication between government and community to promote the health of the basin environment. The following excerpt from the Water Resources Management Act of 2004 details the functional responsibilities of a BMC:

No.3357 Government Gazette 23 December 2004 15

Act No. 24, 2004 **WATER RESOURCES MANAGEMENT ACT, 2004**

Functions of basin management committee

13. The functions of a basin management committee are -

(a) to protect, develop, conserve, manage and control water resources within its water management area;

(b) to promote community participation in the protection, use, development, conservation, management and control of water resources in its water management area through education and other appropriate activities;

(c) to prepare a water resources plan for the basin which plan must be submitted to the Minister for consideration when developing the Master Plan in terms of section 23;

(d) to make recommendations regarding the issuance or cancellation of licences and permits under this Act;

(e) to promote community self-reliance, including the recovery of costs for the operation and maintenance of waterworks;

(f) to facilitate the establishment of an operational system and maintenance system of waterworks and the accessing of technical support for water management institutions within its water management area;

(g) to monitor and report on the effectiveness of policies and action in achieving sustainable management of water resources in its water management area;

(h) to collect, manage and share such data as are necessary to properly manage the basin in coordination with the Water Resources Management Agency;

(i) to develop a water research agenda, together with the Water Resources Management Agency, appropriate to the needs of water management institutions and water users within its water management area;

(j) to help resolve conflicts relating to water resources in its water management area; and

(k) to perform any such additional functions as the Minister may direct under section 9 or assign under section 10.

FIGURE 4: EXCERPT FROM THE WATER RESOURCES MANAGEMENT ACT OF 2004 (REPUBLIC OF NAMIBIA OFFICE OF THE PRIME MINISTER, 2004)

Major basin management committees already exist in the Iishana sub-basin, the Fish basin, and the Kuiseb basin, but as noted by the DRFN, "water scarcity has prompted an increasing need to bring about more efficient use and management of water and related natural resources" (Seely, 2008). BMC are composed of the stakeholders from a diverse variety of backgrounds. Included among the stakeholders are community residents, government officials, members that work for the water supplier (NamWater), and members of related ministries (Agriculture, Water, and Development). It is critical for the success of the committee that the stakeholders first develop a common vision. This first step will develop a sense of commitment among all stakeholders. For many the decisions they make will directly affect the quality of their own water and community health, strengthening personal commitment. However, committee action will not directly impact all members, and therefore all stakeholders must establish a strong commitment through a shared vision. In the case of the Kuiseb BMC, it took three years to establish this kind of relationship between stakeholders (Seely, 2008).

2.4 WATER POLICY

This section discusses current policies relevant to the Fish River. We considered both Namibian and international water policies because the Fish River is a tributary of the Orange River, as shown in Figure 5.

FIGURE 5: MAP OF NAMIBIA

The Orange River is considered international water because it provides water for Botswana, Namibia, South Africa, and Lesotho. The primary international policy states that no country shall damage any international water source as well as its surrounding ecosystems. The 1997 United Nations Convention on the Law of Non-Navigational Uses of International Watercourses clearly defined the policies and expectations of international waters. General guidelines were defined to emphasize that countries work together. This convention also focused on determining whether a country, previously lacking a reliable water source, can draw from an international watercourse if it is going to negatively impact another country's existing water system. The debate considered whether a country should have access to water, or if countries with previously established systems had priority. Some argued that equality was important and by favoring existing water systems, the use by developing nations would be severely limited. This issue is particularly important when considering Namibia. In the case of the Orange River, South Africa already greatly draws on it for its water system. However, the language at the convention favors the idea of allowing all countries access to water (McCaffrey, 2001).

Some disputes have arisen over who has rights to the Orange River Basin. The Orange River is technically located in South Africa, however they agreed with Namibia to move the border to the halfway point in the river. This change has yet to occur. Nevertheless, the four countries have formed an international agency, the Orange-Senqu River Commission (ORASECOM), to ensure good communication and to oversee the implementation of integrated water resource management plans throughout the Orange River Basin (Hiddema and Erasmus, 2007).

As a recently independent nation, Namibia faces many challenges. Perhaps one of the biggest challenges is determining a water policy that is fair, efficient, and maintainable. The MAWF oversees national water policy with the South African Water Act of 1956 as the foundation for Namibia's policy. The Water Act of 1956 states that the community members need to purify water and replace it as closely as possible to the original source. This act goes on to say that, if there is difficulty following these regulations "the applicant may apply for an exemption" (Namibia Water Corporation Ltd., 2006a). This act also discussed water testing. The government tests water in three different categories of determinants, including those with "aesthetic/physical implications, inorganic determinants, and bacteriological determinants" (Namibia Water Corporation Ltd., 2006a). Water quality is divided into four categories:

excellent quality, *acceptable quality*, *low health risk*, and *high health risks*. *Low health risk* does not require immediate action. By law, the government immediately needs to address *high health risk* water. The guidelines in the Water Act of 1956 also divide water into four categories based on bacteria content. The groups are *very safe*, *suitable*, *bacteriological risk*, and *unsuitable*. Both the *bacteriological risk* and *unsuitable* categories require immediate care. According to this act, population size determines the frequency of testing. At a minimum, water needs to be tested every three months (Namibia Water Corporation Ltd., 2006a).

In 1993, Namibia created the Directorate of Rural Water Supply (DRWS), which is now known as DWSSC. The primary objective of the DWSSC is to make water available to rural communities and enable them to maintain their systems (Ministry of Agriculture, Water & Forestry, 2010). Early DWSSC policies emphasized community involvement. Communities were encouraged to be directly involved in establishing and managing infrastructure. In addition, the government and other organizations introduced communities to cost recovery to justify monthly water fees. Lastly, when determining water system changes, the government needs to consider financial limitations of the community to ensure that the community can afford the improvements (Namibia Water Corporation Ltd., 2006b).

The Namibian Government commercialized bulk water supply in December of 1997. They created Namibia Water Corporation Ltd (NamWater) to provide water to businesses, cities, towns, and occasionally the DWSSC. Cost recovery is the biggest challenge facing NamWater. Their goal is to provide affordable water to all. However, expenses for equipment repairs make this difficult. NamWater understands the importance of water to a developing nation and strives for ensuring safe, clean, water throughout Namibia (Namibia Water Corporation Ltd., 2006b).

2.5 WATER SYSTEMS AND SUPPLY

In Namibia, the majority of potable water comes from groundwater. Typically, one to two percent of rainfall replenishes groundwater used by the community. Since Namibia has such a dry climate, rainfall is not a reliable source. NamWater has already been working in the Hardap region of Namibia to supply water. However, there are still parts of the region that do not have access to clean water (Namibia Water Corporation Ltd., 2005).

In rural areas boreholes provide water for the community. Since groundwater in boreholes does not go through a treatment process, cleanliness of water is a major concern.

Dangerous health risks are common, and increased nitrate levels in water are of particular interest. These increased levels can lead to methemologlobinemia. Bacterial contamination in water can also present many health risks. While in some areas, NamWater operates water treatment plants; financially these are not sustainable solutions on Odendaal farms. Rural communities need to find a way to test and maintain their own water supply.

In rural communities, a water point committee maintains the borehole. Typically, two to five households rely on one borehole. These households form a water point committee. One person is the overseer and receives leadership training. This person serves as the liaison between the DWSSC and the community. Another community member is selected as the caretaker. He or she is responsible for all minor repairs to the borehole. Each household using the borehole is responsible for N $10 a month to fund the minor repairs.

The practices of people and government directly affect water quality. To ensure quality water, the government and people should establish regular communications to immediately address any broken pipes or leaks. A disconnect between the people and government often results in poor management of water and is wasteful for the community. Education of rural community members is a critical component in the solution of Namibia's water problems.

2.6 ESTABLISHING A WATER QUALITY BASELINE

To establish a baseline, several testing methods are available to determine the concentration of common water impurities and properties of interest. The DRFN has previously measured total dissolved solids (TDS), pH, nitrate (NO_3), nitrite (NO_2), phosphate (PO_4), and ammonia (NH_4) concentrations (Simataa, 2010). The DRFN tests for these specific water properties because in high concentration they can contaminate water sources. Given the proper equipment, these measurements are easily obtainable. Table 1 outlines the testing methods previously used by the DRFN.

TABLE 1: COMMON TESTING METHODS AND OUTPUTS

Test	Testing Method	Method Output
TDS	Digital TDS meter	Quantitative dissolved salt quantity
pH	pH indicator strip	Approximate quantitative pH
PO_4	Phosphate reagent	Qualitative
NO_3	*Aquachek* test strip	Approximate quantitative nitrate conc.
NH_4	*Quantofix* ammonium strips	Semi-quantitative ammonium conc.

While these testing devices are simple, they are unavailable in many rural communities (Simataa, 2010). This means that the DRFN either needs to bring the testing supplies with them from Windhoek or they must collect samples for professional lab analysis. To establish a baseline for water quality, it is important that the tests provide accurate, quantitative results. Qualitative testing does not provide clear-cut evidence regarding water safety. Table 2 provides a summary of the guideline values for these standards according to NamWater (Namibia Water Corporation Ltd., 2006a). The quantities outlined in Table 2 are divided into categories A through D. The categories each correspond to a level of quality suggested by NamWater. Table 3 describes these categories, below.

TABLE 2: SUMMARY OF NAMWATER GUIDELINES

Parameters	Unit	A	B	C	D
TDS (Conductivity)	mS/m25 ^{o}C	150	300	400	400
pH	No Unit	6.0 – 9.0	5.5 – 9.5	4.0 – 11.0	< 4.0 >11.0
PO_4		Not Available	Not Available	Not Available	Not Available
NO_3	mg/L	10	20	40	> 40
NH_4	mg/L	1	2	4	> 4

TABLE 3: WATER QUALITY GROUP DESCRIPTION

Group	Description
A	Water with excellent quality
B	Water with good quality
C	Water with low health risk
D	Water with high health risk, or water unfit for human consumption

The absence of baseline water quality information in rural communities can be attributed to the nonexistence of testing facilities and shortage of communal testing materials (Simataa, 2010). Chemical testing equipment can be difficult to acquire in rural areas, as communication is limited and specialized equipment is not commonly available. Therefore, the DRFN brings its own testing equipment.

2.7 INTEGRATED WATER RESOURCE MANAGEMENT

In the arid Namibian climate, water is a scarce resource that requires careful management. Water resource management is a complex and ongoing process that involves multiple components: water allocation, river basin planning, stakeholder participation, pollution control, monitoring, information management, economic management, and financial management. For successful water management all components must be addressed. The Global Water Partnership (GWP) is an organization working to create a "water secure world" (Global Water Partnership, 2010c). The GWP based their organization developmental plans on the Dublin and Rio Statements (1992), the agreements of the Millennium Assembly (2000), and on the outcomes of the World Summit on Sustainable Development (2002). These worldwide conferences created the foundation of the Integrated Water Resource Management (IWRM) plan (Global Water Partnership, 2010c).

Governments of many countries have developed and are implementing national IWRM plans. Its objective is "the coordinated development and management of water, land and related resources in order to maximize economic and social welfare without compromising the sustainability of ecosystems and the environment" (Global Water Partnership, 2010b). In the case of Namibia, pollution enters the groundwater due to local habits. The water problems that exist in most rural communities result from a multitude of causes involving social and economic factors. Unlike sector-by-sector and top-down management styles, IWRM is a "cross-sectoral policy" that acknowledges integral components of water management (Global Water Partnership, 2010d).

Five basic principles established at the World Summit in Rio de Janeiro comprise the IWRM strategy. The first principle defines fresh water as a limited resource that is critical for the sustenance of life, development, and environment. People use water for a diverse selection of purposes and functions; therefore, it calls for an integrated management strategy. The second principle states that all water participants including users, planners, and policy-makers should be involved in the development and management of water. Active participation on all levels will allow for long-term consensus that will benefit the community. The third principle identifies women as key players in the provision, management, and safeguarding of water. In many societies, women do not have the same amount of power as men, yet are the primary users of water for domestic purposes. Therefore, women need to be involved in decisions regarding water. Principle four acknowledges water as having social and economic value. This principle puts emphasis on the vital and basic right of every human being to have access to reasonably priced, clean water, and sanitation. To successfully manage water, consideration of the economic value is important. Water, when considered as an economic good, will encourage people to use it in an efficient and equitable manner. Namibia has struggled to achieve this principle due to an abundance of nonpermanent housing from which water companies are unable to collect water tariffs (Wall et al., 2008). The last principle restates IWRM as a means to efficiently manage and sustain the use of water. It emphasizes water as an integral resource that involves the ecosystem, social factors, and economic influence (Global Water Partnership, 2010a).

Of the main principles, economic efficiency, social equity, and ecological sustainability are the essential components for implementation. These main principles optimize water use, ensure that all classes of people have an equal opportunity and opinion in water services, and improve environmental availability of water. Figure 6, below, shows the relationship and interdependence between these objectives as the three main pillars of IRWM: “the enabling environment”, “the institutional roles”, and “the management instruments.” The pillars of IRWM represent governing legislation and regulation in place for stakeholders, capabilities of stakeholders, and management strategies for regulation, monitoring, and economic optimization (Assaf, 2010).

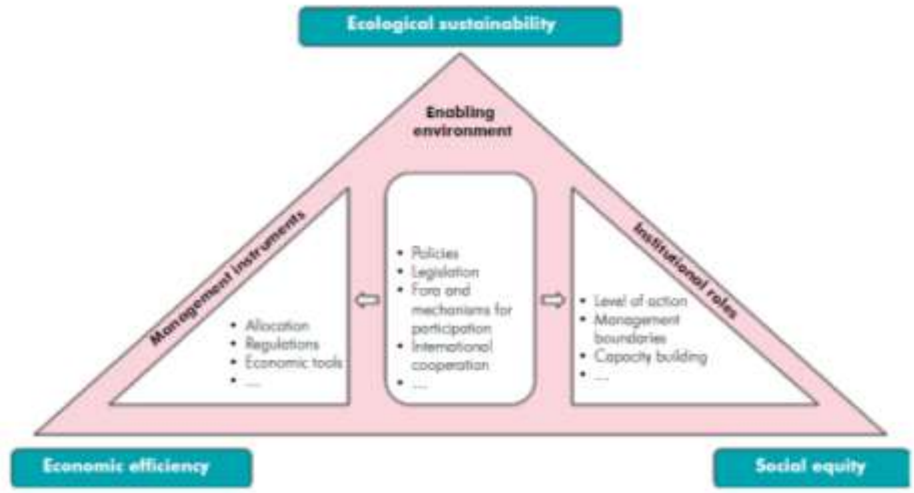

FIGURE 6: GLOBAL WATER PARTNERSHIP IWRM FRAMEWORK (ASSAF, 2010)

The people inhabiting the southern region of Africa recognize that water plays a central role in their livelihoods. The arid climate calls for a strict and determined effort to implement water policies that create positive socio-economic effects. IWRM principles implemented over the past ten years, triggered positive reform. The major challenge identified by critical papers is consensus between various stakeholders. Many argue that political incentive is necessary for a democratic consensus between current livelihood and preservation for future generations. The IWRM strategy uses a Habermasian communicative rationality to be successful. Habermas's philosophy states that each player in the situation must be able to put aside individual motives for a rationally communicative goal (Habermas, 1984).

IWRM has conducted studies all over the world with variable success. With each case study that they have performed, the GWP notes conclusions and future recommendations for later application to potential implementations. The GWP has conducted a dozen case studies in southern Africa with overall success. The next section has been adapted from a case study conducted by the GWP in KaLanga, Swaziland (Global Water Partnership, Swaziland Water Partnership, 2008).

2.7.1 SWAZILAND CASE STUDY

Four years after the 2002 World Summit on Sustainable Development, the government of Swaziland formed a partnership with GWP called the Swaziland Water Partnership (SZWP). The GWP identified KaLanga, Swaziland as an applicable candidate that would benefit from IWRM. With a community of about 9,600 residents, the community depends on the

Makhondvolwane (Mvutjini) reservoir/earth dam. The supply of water is directly proportional to annual rainfall and therefore limited. In 1973, the Rural Water Resources Branch made an effort to supply clean water to the community and later transferred the project to the Swaziland Water Services Corporation. Over this time period, a pumping station, pipes for irrigation, and balancing dams with electrical power supplied 23% of households with water. However, the whole operation collapsed when the Swaziland Water Services Corporation gave control to the KaLanga people after suffering from a lack of funding. The project was unsuccessful due to insufficient knowledge of the existing water system. Increasing drought and lack of maintenance has significantly decreased the quantity of water in the dam. Humans and livestock pollute water by drinking directly from the dam. Moreover, tourists come to the dam for recreational swimming and camping, often leaving the site unclean. Diarrhea occurs in the community and surveys show that 39% of the people sought treatment for water related illnesses in the past year. Water quality tests revealed coliform counts between 650-1980 per 100 mL; the national standard states coliform counts should not exceed 10 per 100 mL. The impact of human and livestock contamination reveals how the KaLanga water dam lacks cohesive water management and has become heavily polluted as a result.

At the beginning of the project, the community hosted a meeting to discuss water management issues and possible solutions. The community elected seven members to serve as contact points for the SZWP project office. The project ran according to IWRM principles and aimed to develop the Mvutjini dam and optimize its benefits. The project constructed drinking troughs for livestock, sanitation facilities, laundry areas, showers, and latrines. The effort repaired irrigation infrastructure of the dam for agricultural purposes. The creation of standpipes for evaluation of water quality and drilling boreholes at suitable sites improved water portability. Capacity building increased training on issues and institutional management. The project provided a low-level bridge across the dam to allow access to the opposing side of the dam.

During the launch of the IWRM project, the “enabling environment” played a significant role in the success of the project. Several water-related ministries, media, private sectors, and youth became involved in the community. Involvement on many levels promoted and enhanced the understanding of the importance of IWRM. The project received $270,000 USD from the Swaziland government and a grant from the GWP to improve domestic resources and increase the ability to implement plans. Local organizations sent several smaller contributions. SZWP not only helped with planning and building, but also helped community members learn to access sources of funding and taught them how to draft letters and proposals to solicit financial support. Community members decided to implement a fee for use of water from boreholes and for tourist use of the dam facility. These fees will defer costs of maintenance and operation.

At the beginning of the project, SZWP and implementing partners met with major community stakeholders. The community was able to form an institution that led the project progress. The institution had several tasks including directing capacity building, drafting a constitution, detailing work plans, setting time frames, and starting a maintenance fund. A multi-sector project advisory team comprised of government officials, water user groups, private sector, and academics, provided guidance for the project. Both committees reported to the community as a whole. To improve project support, implementing partners from organizations were included. Establishing clear roles of each agent at the start of the project evaded conflict. For example, the Swaziland Farmer Development Foundation (SFDF) provided support and guidance on issues involving farming, gardening, and livestock production. Lastly, GWP representatives trained all community members on IWRM concepts in an effort to encourage positive practices in the future.

Management tools used in the KaLanga project determined the range of environmental and socio-economic elements to evaluate. A collection of hydrological, physiographic, demographic, and socio-economic data formed a Geographic Information System (GIS). The GIS helps manage decision-making and evaluate water supply and sanitation. Furthermore, a baseline created at the beginning of the study informed community members about the scope of the problem. This baseline is kept on file for future comparison. Community members explored solutions to water and sanitation issues and created a "wish list". Executive committee members prioritized the wish list considering feasibility, time constraints, and financial restrictions. To establish benchmarks and ways to measure progress, the community created a project monitoring and evaluating plan. GWP representatives taught conflict resolution techniques throughout the process of IWRM. They also highly encouraged youth involvement. These management tools help to foster a community spirit and directly involve them in developing improvements.

Two years after the KaLanga project was completed, the community and other organizations involved succeeded in installing boreholes, homestead water harvesters, livestock drinking troughs, homestead toilets, and fencing around the dam. At the completion of the project, GWP representatives made several future recommendations. They state that a clear definition of roles and responsibilities helps to maximize skills, resources, and knowledge of the participants. Although experts are important in the project, this case study suggests that earlier involvement of the community and local authorities is important to ensure project acceptance and ownership by community members. Conflict resolution and leadership training is important for community members so they have the tools necessary to persevere through conflicts posed by their peers or committee members.

The initial goals in the project were ambitious. In a project of this scale, those involved need to recognize that challenges will arise and therefore the project should start with small goals for learning purposes. If those involved learn from challenges in a small project they can apply their experience to larger scale projects. Training and meetings provide a strong foundation for the community to discuss, plan, and resolve potential conflicts. (Global Water Partnership, Swaziland Water Partnership, 2008).

The KaLanga case study confronts many of the same problems observed in rural Namibia. IWRM is concurrent with E-CAP principles stated by the DRFN because of the high emphasis on community involvement. Following the three pillars - the enabling environment, the institutional framework, and the management instruments - will help carve the path to water and sanitation improvement. Similar to KaLanga, rural Namibia also faces drought, pollution of water sources, and lack of resource management. Providing baseline education will encourage awareness of the need for improvement among the community. Involving stakeholders to create an enabling environment will also provide the community with the means to conduct the project. Furthermore, creating committees or institutions will ensure that monitoring progress occurs not only during the process but also after the completion of improvements. Teaching the community management skills will make the process smoother as well as provide the community with valuable tools for the future. The strategy presented in this case study combines resources to aid the community and help them develop solutions regarding water and sanitation issues. Community involvement will ensure the long-term success of the project. The IWRM approach is a compatible and successful method for initiating and enacting water and sanitation improvements in rural Namibia.

CHAPTER 3: METHODOLOGY

Our goal was to contribute to the improvement of water quality and sanitation on eight Odendaal farms located in the Hardap region of Namibia shown in . We accomplished this goal by meeting the following objectives:

1. Determine levels of water contaminants and properties present in the drinking water, and consequential health concerns
2. Observe and record social perceptions of water and sanitation practices
3. Investigate and record the physical state of water infrastructure
4. Investigate environmental and geographical impacts on water quality
5. Involve community in discussion of development of water and sanitation solutions
6. Propose solutions to improve overall water and sanitation
7. Pilot applicable solutions to be monitored by the DRFN

Chapter three outlines how we achieved these objectives, and is organized into two dimensions. The first dimension established a baseline through observation, water testing, and interviewing in the community. The second integrated the community with plans for development of solutions through meetings with community leaders, directorates, and ministries. We worked with the DWSSC and the DRFN to develop findings and recommendations. We piloted our recommendations to be monitored by the DRFN to guide future interventions by the E-CAP project.

3.1 ESTABLISHING A BASELINE

Our first objective was to establish a baseline for the region. We established a baseline by gathering information from the following sources:

1. Physical landscape
2. Infrastructure
3. Water quality
4. Social habits
5. Social perceptions

The first component of the baseline involved an evaluation of the physical landscape and infrastructure. We considered where the houses were located in relationship to the water, where the livestock were kept in relationship to the borehole, and how the humans and livestock interacted with the water source. The next component reviewed the practices that influence the cleanliness of the existing water system. We assessed the current sanitation technology and practices and their impacts on the water. Lastly, the baseline assessment included testing of the chemical and bacteriological quality of drinking water.

To complete our objectives, we needed an understanding of the physical layout of each farm and the current condition of the infrastructure. The infrastructure assessment included noting GPS way-point data, making visual evaluations, and taking photographs. With guidance from the DWSSC and the DRFN, we visually inspected the infrastructure. We inventoried and assessed key water and sanitation structures such as reservoirs, boreholes, and water tanks. We surveyed the condition of the infrastructure and recorded our observations in an evaluation form, which detailed any information that we found relevant. Lastly, we photographed important infrastructural features for future reference (see Appendix A – Component Evaluation Form, p. 77). We compiled the data to create a map of the infrastructure. We annotated all data to correspond with its sampling location.

Part of the baseline assessment was to understand current practices of the community and their impacts on the water quality. We conducted interviews that posed questions regarding where and how waste is disposed, as well as where and for which purposes the community members collect water (see Appendix B – Community Questionnaire, p. 78). It was also important to record precautions taken to prevent livestock from drinking or defecating directly into the water supply. During interviews, we recorded responses on the community questionnaire.

Establishing a water quality baseline required chemical analyses of local water sources for which we developed a protocol with the DRFN. This entailed conducting standardized tests (digital probing, paper indicators, and colorimetric) for water pH, total dissolved solids (TDS), nitrate/nitrite, iron, sulfate, and fluoride. We worked with the DRFN to prioritize testing based on health concerns (see Appendix C – Water Testing Parameter, p. 81). Water testing supplies for field evaluation were bought from Aqua Services & Engineering. Field Supplies included a Hach conductivity meter, Nitrate/Nitrite testing stripes, pH testing strips, and the Hach DR/890 colorimeter. The testing equipment can be seen in the figures below. Analytical Labs provided water collection bottles for transportation of the samples to the lab for bacterial and chemical analysis (see Appendix D - Analytical Laboratory Services Quotations, p. 82 for testing details).

We recorded testing data in a table (see Appendix E – Chemical Testing, p. 83) and compared data for each site against the acceptable health standards of NamWater Ltd., the World Health Organization, and the US Environmental Protection Agency to determine the quality of the water in the community.

FIGURE 7: (LEFT) NITRITE/NITRATE TESTING STRIPS
FIGURE 8: (RIGHT) HACH 890 COLORIMETER

3.2 COMMUNITY DEVELOPMENT OF SOLUTIONS

After completing a rapid assessment of the community baseline, we brought all findings to Windhoek for evaluation. We compiled the results from interviewing, mapping, and water testing, so that our team and the DRFN staff and DWSSC could review these factors. The exact organization and compilation of results was determined on site under the guidance of the DRFN. We used literature available at the DRFN and MAWF as they have an extensive archival collection available to draw conclusions based on our findings. In addition, we met and discussed previous solutions to similar problems with the DRFN.

We planned a second field expedition, which brought our team together with local leaders and officials in these farming communities. We invited local leaders and officials to the discussion based on recommendations from the DRFN and the DWSSC. We presented our findings and discussed realistic solutions with the community leaders. The fundamental principal of E-CAP component II emphasizes the importance of community involvement in finding solutions for water and sanitation issues. Meetings with local leaders and officials facilitated collaboration to review findings and observations uncovered in baseline evaluations. At these educational workshops we exchanged advice and ideas to guide the discussion to a plausible solution.

3.3 DATA COLLECTION AND ANALYSIS

At the conclusion of our project, we completed three field expeditions at the farmland communities in Hardap. The first trip involved infrastructure mapping, water quality assessment, observations of community habits, and interviews of residents. The visit determined the water and sanitation baseline for the community. From the data, we made recommendations for community collaboration on our second visit. Per request of the DRFN, we assessed the accuracy of the testing equipment we used. We conducted a T-Test on the colorimeter results to determine the level of variance between Analytical Lab results and the colorimeter. We completed a visual comparative analysis for the testing strips. We could not conduct a statistical analysis on these results because the testing strips give a range and not a specific number.

The second trip served as the foundation to begin implementation. We gathered community opinions on immediate treatment and preventive solutions. Potential pilot studies were discussed to gauge community interest. Through this discussion we determined an optimal pilot site. To conclude our project we compiled all findings collected for the baseline and provided the DRFN with a report that outlined and summarized all recommendations.

3.4 PROJECT PLAN

Upon arrival in Windhoek, we spent the first two weeks working in conjunction with the DRFN and DWSSC to prepare for our field visit. During this time, we contacted the professional laboratories to obtain testing equipment. We also contacted representatives of the DWSSC to inform them of our plans and invite them to join us. In the third week, we visited the eight farms in Hardap and conducted water samples, geographical assessments, informal interviews, and community observations. We returned to Windhoek for the following week to analyze data and discuss solutions. In the fifth week, we returned to the community and presented findings to the local leaders and residents. Following the second field expedition, we returned to the DRFN for a week and began planning the implementation phase. The seventh week we spent in the field beginning the pilot study of our recommendations. In the eighth week, we completed a final analysis, made recommendations, and concluded the project.

CHAPTER 4: RESULTS AND ANALYSIS

The results of our fieldwork on the Odendaal Farms are presented in this chapter. We divided our baseline assessment into three sections: water infrastructure, water quality, and social baseline. In each section we present results for the eight farms we surveyed. Baseline data includes infrastructural component evaluations, chemical analyses, and interview responses. In our preliminary field visit, we evaluated eight farms: Nico-Noord, Doring Draai, Nico, Laurencia Pos, Laurencia, Gründorn (South), Gründorn (North), and Diamont Kop. The locations of these farms are shown in .Additionally we analyzed the accuracy of the testing equipment we used. Lastly, we outlined the educational workshops conducted and the pilot study that followed.

FIGURE 9: LOCATION OF FARMS

4.1 WATER INFRASTRUCTURE

All of the Odendaal farms exhibit the same general infrastructure; each consists of a borehole (either windmill or solar powered), 10,000-liter water tanks, concrete reservoirs, livestock troughs, and taps. In addition to these major infrastructural components, we thoroughly evaluated piping within the system. We surveyed the system on each farm and were able to compare and contrast the condition of these components, taking note of geography and environmental conditions that made each site unique. Figure 10 and Figure 11are some photographic examples of the assessment.

FIGURE 10: (LEFT) A WINDMILL POWERED BOREHOLE LOCATACTED AT DORING DRAAI
FIGURE 11: (RIGHT) AN ELEVATED, 10,000 L WATER TANK AND RESERVOIR AT DORING DRAAI

Visual evaluations showed that a majority of the water infrastructure is functional although occasional maintenance is necessary. To mitigate these maintenance problems, each community (typically small groups of neighboring farmers) appoints a member as a volunteer caretaker. This person receives general training from the DWSSC on basic maintenance of water infrastructure. The caretaker is responsible for addressing minor repairs to the boreholes and water system such as broken pipes or leaks. The community funds minor repairs, with each household responsible for paying N$10,00 (approximately $1.50 USD) per month for use of the borehole (although payment is not strongly enforced). The DWSSC takes responsibility for major repairs such as broken windmills, sunken boreholes, or malfunctioning solar panels. The caretaker requests these major repairs from the DWSSC office in Gibeon; if approved, the request is forwarded to Mariental, the capital of the Hardap region. Typically the DWSSC then orders the parts from Windhoek. Due to this lengthy process, repairs take at least a month. If a borehole is out of commission those community members must travel to the next nearest borehole to obtain water. Another constraint in the repair process is the shortage of governmental funding. Often more boreholes need rehabilitation than the budget allows for. Repairs that the government cannot fund are postponed to the following budget year.

Our objective in making detailed infrastructural evaluations for each farm was to be able to draw conclusions through comparison. In many cases, we found that the farms had similar geographical and environmental conditions, and accordingly suffered the same issues. The single most prevalent infrastructural issue was leaking pipes. Through our observations, we concluded that the wear of the pipes was primarily due to exposure to livestock and poor maintenance. Damage from the livestock occurred because they walked directly over the pipes. Neglect of maintenance is not due to a lack of community effort but to a shortage of education and funding. Another common problem was the poor condition of reservoirs, which we found with many holes and in need of cleaning, problems that we attributed to old age and lack of community maintenance. Our detailed infrastructure evaluations are summarized in the following subsections, organized by farm.

4.1.1 NICO-NORD

Nico-Noord consists of three households that are supplied water through a solar powered borehole. The farm owner and caretaker, Sarah Bock, has lived at Nico-Noord since the 70s, and is very involved in water management within the surrounding Odendaal farms. Relative to other farms, her infrastructure is well kept and in excellent condition. In addition to her household system (faucet tap in the kitchen and bathroom), the campground on her property has two flush toilets, showers, and a tap. The septic system is periodically pumped and disposed of at a location away from the house. Sarah also is the only owner in the region (to our knowledge) with a biogas digester; however the device is currently out of commission due to a broken pipe. Overall, we found the water supply infrastructure on Nico-Noord to be above average; not only were all components in good operable condition, but the sanitation facilities are more advanced than others found within the region.

4.1.2 DORING DRAAI

Doring Draai is a community of four households supported by a single windmill-powered borehole. Our first observation upon arrival was that the livestock pen was located directly above and around the borehole. The borehole itself is functional but shows signs of rusting and leaking. Two 10,000 L tanks are in good condition, as well as all steel piping and fixtures. Aboveground rubber piping (that supplied household taps) shows some signs of wear, and community members have attempted to reinforce leaking areas. One household is equipped with a new flush toilet, though has no strategy for pumping the septic tank. Figure 12, Figure 13, and Figure 14 capture some of the infrastructural points at Doring Draai, including the minor leak and pipe issues.

FIGURE 12: (LEFT) BOREHOLE BASE SHOWS SIGNS OF RUSTING AND LEAKING
FIGURE 13: (RIGHT) WATER TANKS AND PIPES IN GOOD CONDITION

FIGURE 14: RUBBER PIPES THAT SUPPLY HOUSEHOLD TAPS ARE IN POOR CONDITION AND REQUIRE PATCHING

4.1.3 NICO

Two boreholes supply the Nico farm with water. Wind powers one borehole while the other is solar powered. The DWSSC rehabilitated the solar borehole in 2010, and we found its components to be in excellent condition. A small fence surrounds the borehole, preventing potential damage from livestock (as shown in Figure 15). The livestock were in the vicinity of reservoir tanks and dam, though appeared to have no impact on these structures, shown in Figure 16. Taps extend from this borehole through aboveground, rubber piping that we also found to be in relatively new condition (Figure 17). Two 10,000 L tanks served as a reservoir, essentially replacing a circular reservoir dam that formerly stored water from this source (Figure 18).

FIGURE 15: (LEFT) SOLAR POWERED BOREHOLE AT NICO IS IN NEW CONDITION
FIGURE 16: (RIGHT) LIVESTOCK IN VICINITY OF INFRASTRUCTURE

FIGURE 17: (LEFT) RUBBER PIPING ABOVE GROUND, ALTHOUGH APPEARS IN GOOD CONDITION
FIGURE 18: (RIGHT) A RESERVOIR DAM NO LONGER IN USE

The windmill-powered borehole supplies water to a second reservoir dam, which is in functional but in poor condition. We found numerous cracks in the concrete and metal pipes are rusted, shown in Figure 19 A and B. It is notable that no livestock grazed in the vicinity of the borehole or the reservoir and that this is the preferred drinking water source of the residents.

FIGURE 19 A AND B: EDGES OF THE RESEVOIR SHOW SIGNS OF CRACKING AND PIPES ARE RUSTING

4.1.4 LAURENCIA POS

All infrastructural components at Laurencia Pos are in good working condition. Only two households reside on this relatively isolated farm. We observed few livestock, which may account for the condition of the water system, especially the exposed piping, which we found in excellent condition (Figure 20). The windmill-powered borehole supplies water to two elevated 10,000 L tanks that are in good condition. The reservoir is operational, though we observed some small leaks through the corrugated steel bracing shown in Figure 21. The concrete livestock trough is in excellent condition.

FIGURE 20: (LEFT) EXPOSED RUBBER PIPING IS IN GOOD CONDITION
FIGURE 21: (RIGHT) SMALL LEAK IN THE RESEVOIR

4.1.5 LAURENCIA

No infrastructural evaluations were conducted at this site.

4.1.6 GRÜNDORN (SOUTH)

Gründorn (South) was the largest community we surveyed, with 18 households. Two windmill-powered boreholes supply the southern Gründorn community, though community members typically only use the closer of the two. The first borehole is located in the center of the community, surrounded by a church, households, and most importantly, an overflowing pit latrine. This borehole is shown in Figure 22. We found the tanks for this borehole to be in overall good condition; however the corresponding piping is in need of maintenance as evidenced by Figure 23 and Figure 24. In several areas the community had patched the piping with rubber. The reservoir in Figure 25 appeared new and showed no signs of wear.

FIGURE 22: (LEFT) WINDMILL POWERED BOREHOLE IN CENTER OF COMMUNITY
FIGURE 23: (RIGHT) POOR PIPE CONDITIONS BENEATH STORAGE TANKS

FIGURE 24: (LEFT) A LEAKING PIPE FROM A STORAGE TANK IS PATCHED
FIGURE 25: (RIGHT) RESERVOIR IN EXCELLENT CONDITION

We observed the same piping issue at the second reservoir. The community members had successfully patched the reservoir, yet the long, unprotected piping had many leaks. Figure 26 and Figure 27 capture these repairs.

FIGURE 26: PIPING IS POORLY REPAIRED FROM THE SECOND RESERVOIR

FIGURE 27A AND 27B: SUCCESSFUL REPAIRS TO THE SECOND RESERVOIR

4.1.7 GRÜNDORN (NORTH)

The northern Gründorn community is very widespread, composed of six homes. The single, windmill-powered borehole is relatively far from the site of the reservoirs and tanks. The borehole is in functional condition, though it is rusty and the pipes leak (see Figure 28). By our observation of tracks and feces, it appeared that livestock roamed in the direct vicinity of the borehole shown in Figure 29.

FIGURE 28: (LEFT) RUSTY PIPES

FIGURE 29: (RIGHT) LIVESTOCK FECES NEAR THE BOREHOLE

Figure 30 shows that community members had attempted to repair the leaking pipes without success. The borehole supplies water to two 10,000 L tanks in addition to two large reservoirs. From a structural analysis, shown in Figure 31 and Figure 32, these components are all in good condition but the reservoir interior is highly contaminated with biological growth.

FIGURE 30A AND 30B: TEMPORARY SOLUTIONS TO LEAKY PIPES

FIGURE 31: (LEFT) RESERVOIRS IN GOOD CONDITION

FIGURE 32: (RIGHT) SEVERE BIOLOGICAL GROWTH IN THE EXPOSED RESERVOIRS

4.1.8 DIAMONT KOP

We found the farm at Diamont Kop in a unique situation; the borehole water quality was so poor that NamWater extended a pipeline to supply drinking water. While this pipeline did provide the family with suitable water, it is expensive (around N$9 per m^3). We fear that to avoid cost, the family may be using the dangerous water from the borehole. Only one household resides on this farm, and we did not observe many livestock. The windmill-powered borehole is cracked at the base (Figure 33), yet still supplies water to a reservoir in poor structural condition. We found several leaks in the reservoir walls, and contamination by fecal matter and biological growth was evident, shown in Figure 34 and Figure 35. Additionally, the pipe to the dam was extremely rusted (Figure 36). As evidenced by Figure 37, the trough was structurally functional but in poor condition.


FIGURE 33: (LEFT) CRACKED BASE OF THE BOREHOLE

FIGURE 34: (RIGHT) BIOLOGICAL GROWTH ALONG THE LEAKS IN THE DAM


FIGURE 35: (LEFT) DIRECT FECAL CONTAMINATION INTO DAM

FIGURE 36: (RIGHT) POOR PIPE CONDITIONS

FIGURE 37: CONCRETE OF LIVESTOCK TROUGH IS IN POOR CONDITION

4.2 WATER QUALITY

Two different sets of water quality tests were completed. We conducted the first set of tests on site, at the farms and the campground. These included tests for basic parameters. Analytical Laboratories performed the second set of tests. We collected the water and brought the samples to the lab for chemical and bacteriological analysis.

4.2.1 FIELD TESTS

Water quality testing in the field consisted of measurements of TDS, pH, nitrite, nitrate, fluoride, iron, and sulfate. TDS (total dissolved solids) is the level of conductivity, which overall can show the general quality of water. The pH value represents the level of acidity, which if too high can damage the water supply infrastructure. Nitrate, nitrite, and fluoride are ions that can be detrimental to health. Iron and sulfate are ions that may lead to deterioration of infrastructure, promote bacterial growth, and may impact the aesthetic quality of water.

We identified some common trends in the testing results for each farm. All farms had alarmingly high nitrate readings ranging over 20 ppm, however only three testing locations showed any indication of nitrite on the testing strips. None of the locations indicating nitrite contamination are used for human consumption. Sulfate readings conducted using the colorimeter showed readings over 100 mg/L of sulfate in most of the testing locations. Unfortunately many of the sulfate tests hit the colorimeters limit of 160 mg/L. We further diluted the water with deionized water in order to obtain a reading, however this decreases the accuracy of the reading. It was still within the acceptable range. The pH was within the neutral range (between 6 and 8) at every location. The iron testing results showed high levels in a few locations but the majority were within normal range. The full results can be seen in Appendix F - Field Test Results, p.84.

Overall the water quality is similar on each farm. We found high levels of nitrates at every location, excluding the NamWater tap at Diamont Kop. These levels are alarming as nitrates are dangerous to health, particularly in infants. Nitrates can cause methemologlobinemia, which is more commonly known as “blue baby syndrome.” This occurs when nitrates are naturally reduced to nitrite in the infant’s stomach. The nitrite reduces the oxygen carrying capacity of the blood and if untreated can lead to death. When we compared our results with previous testing by the DRFN, we found the levels have increased (Simataa, 2010). Rain can cause nitrates from the waste to enter into the water supply. This year's excessive rain may have caused the increase in nitrates (Smit, 2011). We found no presence of nitrite at the majority of sites. However, we did find levels of nitrite at Diamont Kop, Laurencia, and Gründorn (North). The nitrite levels at Diamont Kop and the trough at Gründorn (North) exceeded the acceptable standards guideline; they both reached the limit of 3 ppm. Nitrite pollution can also occur from open defecation of humans and livestock. In this case the nitrite was likely produced by a reaction that converts nitrate into nitrite. The levels of fluoride and sulfate were within the range of acceptable water quality. This is interesting as we expected high fluoride levels to be the cause of the widespread tooth mottling among the communities. The majority of farms had acceptable levels of iron, however, we found high levels in some locations. The only major concern was with the high levels of nitrate in the drinking water. These levels must be lowered to avoid potential health risks.

4.2.2 ANALYTICAL LABORATORIES RESULTS

We received two different sets of results for each farm from the lab. The chemical results were fairly similar to those we got in the field. As we suspected the biggest concern is the nitrate levels. The total hardness is also of concern. This is a common problem with borehole water from the south. It can lead to calcification but poses no health risks. The other parameters were not of any concern. Figure 38 and Figure 39 show the results of the two concerning factors for all farms. Full results can be seen in Appendix G – Analytical Labs Chemical Results, p. 88 The bacteriological results showed that there were some farms that had a bacteria problem (full bacteriological results can be found in Appendix H - Analytical Labs Bacteriological Results p. 97). Table 4 shows the overall classifications for each farm based on chemical results and bacteriological. It also includes a brief description of what the rating means.

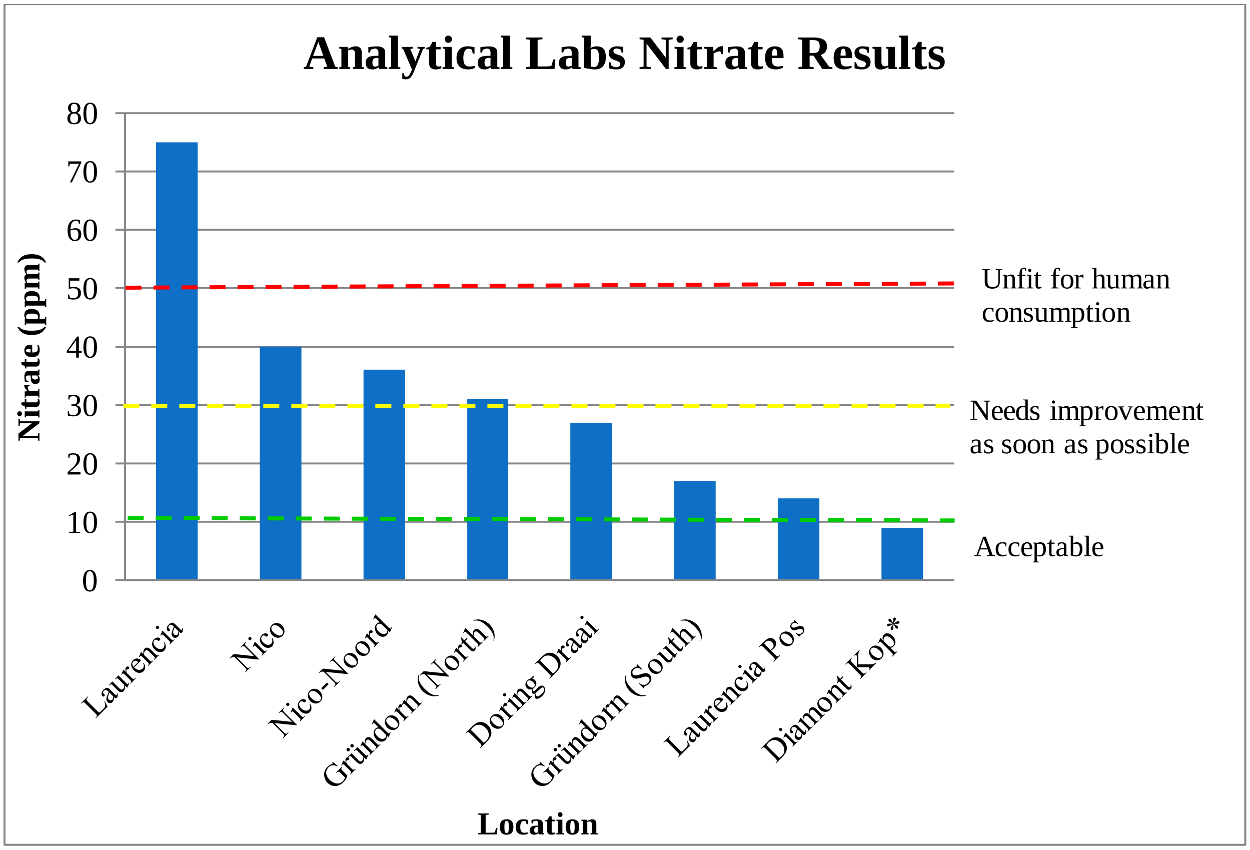

FIGURE 38: ANALYTICAL LABS NITRATE RESULTS

*Diamont Kop results are based on NamWater water not borehole water

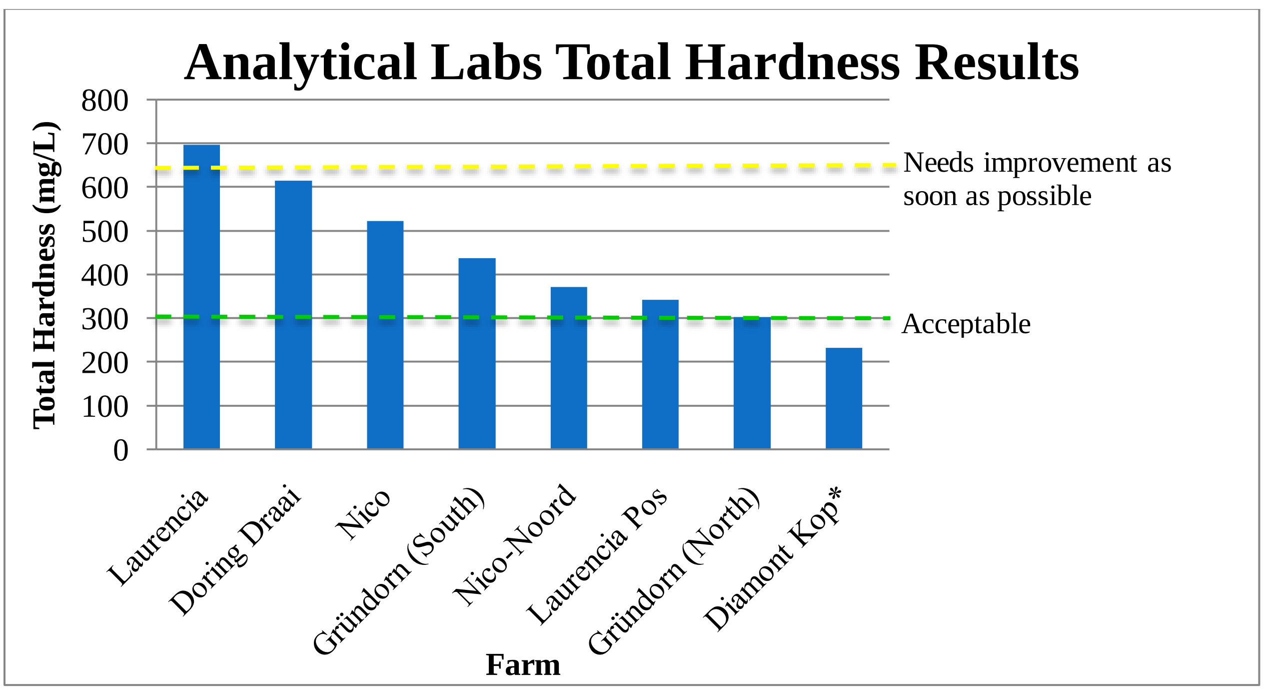

FIGURE 39: ANALYTICAL LABS TOTAL HARDNESS RESULTS

*Diamont Kop results are based on NamWater water not borehole water

TABLE 4: OVERALL FARM CLASSIFICATIONS

Farm	Chemical Classification	Bacteriological Classification	Description of Classification
Nico	C	C	Low Health Risk
Laurencia	D	C	Immediate Action Needed
Nico-Noord	C	C	Low Health Risk
Laurencia Pos	B	D	Immediate Action Needed
Gründorn (South)	B	B	Acceptable
Gründorn (North)	C	B	Low Health Risk
Diamond Kop	B	B	Acceptable
Doring Draai	C	B	Low Health Risk

4.3 SOCIAL BASELINE

The social baseline was determined from our interviews conducted on four of the farms, Nico, Laurencia Pos, Doring Draai, and Gründorn (South). At Nico, we interviewed Mr. George who has lived there since 2005. He is responsible for minor repairs and received general training from the DWSSC. We also met with Ms. Magrieda at Laurencia Pos. She has been a resident since 1999. As chairperson of the Water Point Committee, she has had leadership training from the DWSSC. At Doring Draai, we talked to three people: Mr. Kwoopr, a resident since 2008; Ms. Albertz, a resident since 2009; and Mr. Marcus, a resident since 2003. The interview format there can be seen below in Figure 40.

FIGURE 40: COMMUNITY AT DORING DRAAI

These individuals are all members of the Water Point Committee and take care of minor borehole issues as volunteers. Although there were training sessions, the interviewees were not residents at the time of the training. The interview at Gründorn (South) started with two people, Ms. Gabriela and Mr. Joseph; both residents since 1992. However, as the interview continued, more residents joined and added their thoughts and opinions (see Figure 41).

FIGURE 41: COMMUNITY DISCUSSION AT GRÜNDORN (SOUTH)

Ms. Gabriela held a position on the former Water Point Committee and Mr. Joseph is the current caretaker. He received training on basic maintenance such as minor leak repairs.

Residents from three of the four farms (Nico, Laurencia Pos, and Doring Draai) said the amount of water was never a problem; they had enough water for everyday activities. The primary uses of water are human consumption, cooking, bathing, laundry, and livestock. Community members often reuse wastewater for agricultural purposes. Ms. Albertz, at Doring Draai, stated that her water pressure was low. Her house sat on higher ground than the borehole, so the water had to be pumped uphill to reach her house. She also said that she would like to be able to use more water for her garden. At Gründorn (South), they said they have experienced shortages of water. Although they have two boreholes, one is only used for livestock because the water is of lesser quality. On days with minimal wind, the demand of the 18 households exceeds the amount of water available via the windmill pump. In addition, members of a nearby town, Asop, occasionally come to collect water from the borehole. Another contributing factor to water shortage is the lack of rainfall this year in the region. Normally, the community harvests rainwater, but this year rainwater collection was low.

Overall, the residents thought the quality of water was good. On three of the four farms, Nico, Laurencia Pos, and Gründorn (South), the residents were satisfied. However, at Nico and Gründorn (South), each farm has two boreholes, one of the boreholes had higher quality water than the other. Unfortunately at Nico, the borehole with lesser quality water was rehabilitated recently instead of the preferred borehole due to a lack of communication between the community and the DWSSC. The government began rehabilitation before the community was able to submit a letter explaining the differences in water quality. The only health concerns mentioned at these three farms were made by Mr. George at Nico, and Ms. Albertz at Doring Draai. Mr. George said that according to a dentist, consumption of their water causes teeth to crack and become brittle, probably due to high levels of fluoride. This is a common problem for the entire southern region. At Doring Draai, the community also had some concerns regarding water quality. Ms. Albertz said that children under five often experience vomiting and diarrhea especially during October and November. All the children in the area experience the same symptoms. They live too far away from each other for it to be a contagious disease. The only commonality is water. The community boils water for the infants, but when the infants reach a certain age they stop. Infants who consumed boiled water did not experience the vomiting or diarrhea. These findings suggest a possible bacteriological contamination. On all farms, the residents have not experienced a change in the quality of water over time.

Sanitation methods on all farms were relatively similar. For human waste, the majority of people used the bucket system or the bush. However, the wealthier houses did have flush toilets. Nico and Doring Draai each have one house with a flush toilet. The flush toilet systems have no way to be emptied. There is not a waste water treatment center or a company that pumps septic systems in the area. Therefore, when these systems become full, the waste is released into the field. Laurencia Pos did not have any flush systems and Gründorn (South) has two pit latrines. The pit latrines were full and could not be used any more, which is concerning to us due to their close proximity to the borehole. There were supposed to be two additional pit latrines built in Gründorn (South) but they were never completed. Everybody interviewed said they would prefer flush toilets to their current sanitation system.

As far as other waste generated, the responses were all very similar. The communities generate the same type of waste as people living in towns. This includes items like plastic bags, tin cans, plastic bottles, batteries, and so forth. Each household collects all of the waste and burns it. All farms except Laurencia Pos burn everything including batteries. Ms. Magrieda said she burned everything except the batteries because of their explosive nature.

The biggest challenge at Nico for Mr. George is the lack of a tap in his yard. He has to walk 50 meters to get water and uses a wheelbarrow to transport the water from the tap to his house. Ms. Magrieda said the biggest challenge at Laurencia Pos is the lack of water for her garden. It is difficult to get water from the reservoir to her garden. She has talked to the DWSSC, but needs an additional pipe. At Doring Draai, residents vocalized a concern for the future. The community is afraid that there will be a shortage of water if everyone has a flush toilet and garden. The biggest challenge at Gründorn (South) is that there is only one borehole for 18 households. The water level of the tank is low on days without a lot of wind.

4.4 TESTING EQUIPMENT ANALYSIS

As stated in our methodology, part of our water quality assessment was to compare and evaluate the accuracy and precision of the testing equipment. While in the field we used two different testing tools; testing strips and a colorimeter. We conducted a comparative analysis of the field testing results and Analytical Labs results from the house tap of each farm. For some parameters we conducted a T-Test in order to evaluate the amount of variance between the samples. In a T-Test a null hypothesis is stated. Based on the p-value given in the T-Test the null hypothesis is either rejected or not rejected; the data can be declared significantly different or significantly similar.

4.4.1 TESTING STRIPS

On each farm testing strips were used to take measurements of nitrate, nitrite, and pH. For nitrite and pH the comparative analysis was 100% similar. There were no discrepancies in the results between field testing and Analytical Labs; nitrite readings were below .1 mg/L and pH was neutral in all cases. The nitrate readings varied slightly between testing methods (see Table 5 for results). Comparatively the testing strips were accurate, but lacked precision. Since the testing strips could only read as 1, 5, 10, 20, or 50 mg/L, we had to make estimations when recording the nitrate concentration.

TABLE 5: COMPARISON OF NITRATE STRIP RESULTS WITH ANALYTICAL LABS

Nitrate		
Farm	Chemical (ppm)	Analytical Labs (mg/L)
Nico-Noord	20-50	36
Doring Draai	20-50	27
Nico	20-50	40
Laurencia-Pos	20	14
Laurencia	50	75
Gründorn (South)	20	17
Gründorn (North)	20-50	31
Diamont Kop	10	9

4.2.2 COLORIMETER

Using the colorimeter we conducted nitrate, sulfate, iron, and fluoride testing. To assess the accuracy of the colorimeter we conducted a T-Test on the sulfate, iron, and fluoride results. Table 6 - Table 8 shows the results of field testing and Analytical Labs as well as the T-Test p value. The p value represents the amount of variance between the two sets of data. In most cases a T-Test with a p value under .05 is considered statistically similar. Considering this value only the fluoride test is statistically similar. The nitrate and iron colorimeter results are not considered statistically similar to the results from Analytical Labs.

TABLE 6: COMPARISON OF NITRATE RESULTS WITH ANALYTICAL LABS

Nitrate		
Farm	Chemical (mg/L)	Analytical Labs (mg/L)
Nico- Noord	18.4	36
Doring Draai	17.8	27
Nico	11.5	40
Gründorn (South)	11.9	17
T- Test		0.061

TABLE 7: COMPARISON OF FLUORIDE RESULTS WITH ANALYTICAL LABS

Fluoride		
Farm	Chemical (mg/L)	Analytical Labs (mg/L)
Nico-Noord	1.1	0.9
Doring Draai	0.9	0.7
Nico	0.2	0.5
Laurencia-Pos	1.2	0.4
Laurencia	1.2	0.9
Gründorn (South)	1.4	1.1
Gründorn (North)	2	1.6
Diamont Kop	0.7	0.5
T- Test		0.044

TABLE 8: COMPARISON OF IRON RESULTS WITH ANALYTICAL LABS

Iron		
Farm	Chemical (mg/L)	Analytical Labs (mg/L)
Nico- Noord	0.01	0.01
Doring Draai	0.1	0.02
Nico	0.09	0.05
Laurencia- Pos	0.02	0.08
Laurencia	0.02	0.02
Gründorn (South)	1.9	0.06
Gründorn (North)	0.11	0.02
Diamont Kop	0.04	0.02
T- Test		0.31

We could not conduct a T-test on the data from sulfate testing because the machine could not read a value higher than 80 mg/l. In order to obtain high values we had to dilute the sample with deionized water. The more diluted the sample became the less accurate the reading was. Table 9 depicts the results of the colorimeter beside the results of Analytical Labs.

TABLE 9: COMPARISON OF SULFATE RESULTS WITH ANALYTICAL LABS

Sulfate		
Farm	Chemical (mg/L)	Analytical Labs (mg/L)
Nico- Noord	140	121
Doring Draai	152	117
Nico	Limit: 160	140
Laurencia- Pos	148	55
Laurencia	148	243
Gründorn (South)	Limit: 160	308
Gründorn (North)	Limit: 160	238
Diamont Kop	Limit: 160	157

4.5 GENERAL ANALYSIS OF BASELINE ASSESSMENT

From our infrastructural observations, water testing, and interviews conducted in our first field visit we have identified a few common problems caused by economic and environmental conditions. The first problem is high levels of nitrate, which we attributed to open defecation of livestock and people over extensive time. Environmental conditions intensify the problem. In most cases, animal corrals are at higher elevations than boreholes causing nitrates to seep into the ground and flow (with the rest of the groundwater) into the borehole.

The lack of human sanitation systems adds to contamination. Due to monetary constraints, the majority of people cannot afford any sanitation systems. As a result, residents use the bush or bucket system. One community has pit latrines, which is environmentally unsound because the feces remain in the ground causing nitrate contamination. Pit latrines can also potentially lead to bacteriological issues.

The lack of maintenance of the minor infrastructure was common, and primarily resulted in broken and/or leaking pipes. Not only does this waste water, but it also exposes water to further contamination. Finances were the major contributing factor to the lack of repairs. Community members are responsible for minor upkeep of infrastructure, and an account provides funding for minor maintenance. Every month each household is expected to pay N$10 to the community account for water usage. Currently, a lack of enforcement leads to many households not complying. Therefore, money for repairs is not necessarily available.

4.6 EDUCATIONAL WORKSHOPS

In our second field visit we conducted two educational workshops to present our preliminary observations and stimulate a discussion amongst the communities. We prepared a poster to present our findings to the communities. The first workshop we conducted at Gründorn (South) focused on the problems with their current sanitation system. They have two overflowing pit latrines in close proximity to the borehole. The community members had no prior knowledge of dry sanitation methods but were receptive to the idea. During our discussion community members mentioned that they had experienced diarrhea, nausea, vomiting, and stomach cramps. This contradicted our first field visit as they said they had not experienced any water related health issues. We believe the community was unaware that these symptoms could be attributed to poor water. The community was optimistic about piloting the solutions (Otji-Toilet and ion exchange filter) we presented.

Our second educational workshop was held at Doring Draai and members from the surrounding farms were present. At this workshop we emphasized the importance of controlling livestock defecation in the vicinity of the borehole. The community members understood and seemed willing to begin changing their habits. We also introduced the concept of dry sanitation and although they had no knowledge of these systems they agreed dry sanitation would be beneficial. The communities were enthusiastic to learn how to properly construct Otji-Toilets.

Overall the educational workshops were well received. The communities gained valuable information to prevent further contamination of their water sources. There was a positive attitude towards community-involved implementation.

4.7 PILOT STUDY

We piloted the first Otji-Toilet in this study at the home of Mr. George located on the Nico Farm. We selected him to pilot the toilet for his enthusiasm to test the system, and his willingness to learn and share his experience with the surrounding community. Additionally, his household was of ideal size to test a single system. We made Mr. George responsible for its maintenance and he was actively involved in the construction of the toilet. The construction of the toilet followed the steps outlined in the Otji-Toilet manual (see Appendix J - Otji-Toilet Self Builder Manual, p. 103).

The most important component to successful implementation was community involvement in the building process. Involvement ensures that the community becomes personally invested in the success of the pilot study. While members of the DRFN participated, Mr. George primarily conducted construction. Members of neighboring communities were also heavily involved. A local mason was present throughout the construction process providing guidance. Mr. George even incorporated personal variation into the system design, further demonstrating his investment in the pilot. He inserted a metal pipe as an horizontal support to the floor plate. Community-integrated implementation of the Otji-Toilet system was highly successful. The process can be seen in the figures below.

FIGURE 42: (LEFT) MR. GEORGE BREAKS GROUND FOR CONSTRUCTION OF HIS TOILET
FIGURE 43: (RIGHT) COMMUNITY MEMBERS AND DRFN STAFF MEASURE DIMENSIONS FOR THE FOUNDATION

FIGURE 44: (LEFT) COMMUNITY MEMBERS DISCUSS CONSTRUCTION PLANS
FIGURE 45: (RIGHT) MR. GEORGE LAYS FIRST ROW OF BRICKS

FIGURE 46: (LEFT) MR. GEORGE AND THE LOCAL MASON LAY BRICKS
FIGURE 47: (RIGHT) COMMUNITY MEMBERS OBSERVE THE CONSTRUCTION PROCESS

FIGURE 48: (LEFT) MR. GEORGE ADDED A HORIZONTAL SUPPORT INTO THE DESIGN

FIGURE 49: (RIGHT) COMMUNITY MEMBERS PLACE CONCRETE FLOOR SLAB

FIGURE 50: (LEFT) TOILET HOUSE WALLS BEING BUILT

FIGURE 51: (RIGHT) CONSTRUCTION OF TOILET HOUSE WALLS CONTINUES

FIGURE 52: (LEFT) ROOF SUPPORT IS ADDED

FIGURE 53: (RIGHT) COMPLETED OTJI-TOILET

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

After several field visits, meetings with officials and experts, and our own research, we have developed the following guidelines to help improve overall water quality and sanitation systems on Odendaal farms in the arid farm regions. These include suggestions on water quality and infrastructure.

5.1 WATER QUALITY

The water quality results showed alarming levels of nitrate contamination. Through our research, we were able to associate high levels of nitrate with open defecation of both livestock and humans. To overcome this issue both short term and long-term solutions are necessary. **The most feasible short-term solution is for taps used for human consumption to be fitted with an ion exchange filtration system** (see Appendix K-). To minimize replacement costs water taken from taps fitted with the filtration system must only be for human consumption. In most cases, an additional tap could be installed so the family will have the option of filtered or unfiltered water. This can most efficiently be achieved through the addition of a t-junction. The filter will be attached only on one side; the side that is solely used for drinking water. In addition, the filters need to be cleaned once every six months. **We recommend that the DWSSC take care of the maintenance to ensure the filters are changed correctly**. This will lead to a longer life span of the filter and ensure removal of nitrates.

As mentioned previously, both short term and long term solutions are necessary to improve groundwater contamination. In order to lower the amount of nitrates in the groundwater, farmers need to prevent their animals from defecating in the vicinity of the borehole. **The first recommended change to the configuration of farms is to place troughs further away from boreholes**. Currently, the majority of farms have livestock troughs directly on top of the boreholes or only a few meters away. This leads to animals defecating directly on top of, or in close proximity to boreholes. **Another change that we recommend is to move animal corrals**. On most farms, corrals (where the animals are kept at night) are close to the borehole. In addition, corrals are typically at a higher elevation than the borehole. This means that nitrate from animal feces seeps into the ground and is carried downhill (with the other groundwater) into the borehole water. The corrals should be far away from the borehole and if possible at the same elevation to avoid further contamination. **Lastly, we recommend installing**

strong fencing around the immediate area of the borehole. This will prevent animals from destroying exposed infrastructure and defecating in the immediate vicinity of the borehole. The only solution is time and prevention of further contamination so that these changes will lead to quality improvements in the future.

The current sanitation systems are also adding to the nitrate problems. **We recommend the implementation of dry sanitation systems**. A variety of dry sanitation methods are available as described in Appendix L - Dry Sanitation, p.118. We installed an Otji-Toilet in the Nico community as a pilot project. **We recommend regular quarterly inspection to ensure the system is running properly**. Assuming positive results from the pilot study in Nico, **we recommend the installation of the Otji-Toilets on all farms**. These toilets are currently the best option because Namibia manufactures them, they require the least amount of maintenance, they do not require water, and they are the least expensive. Reduction of human and animal feces directly near the borehole should prevent further nitrate contamination of water

5.2 COLORIMETER

Based on comparative analysis of testing equipment we have developed several recommendations. **We recommend continued use of the nitrate/nitrite and pH strips**. Since NamWater suggests that nitrate is below 10 mg/L, we believe that the testing strips are of adequate accuracy to determine if nitrate levels are of concern. Also, NamWater guidelines state that any sign of nitrite in the water is of health concern. Therefore the nitrite testing strip will serve to identify any trace of nitrite in the water. Healthy water should have a neutral pH reading. The test strips can sufficiently differentiate between acidic, neutral, and basic. Due to discrepancies in comparative testing **we do not recommend purchasing the colorimeter**. Based on T-Test results we do not believe the colorimeter provides accurate enough results to be used instead of professional chemical testing. Also the limitation of the sulfate test is not suitable for water testing purposes in the Hardap region. **We recommend continued chemical testing through a professional lab** as there tests are more extensive and accurate.

5.3 INFRASTRUCTURE

Overall, the large pieces of infrastructure were in functional condition; it was the smaller pieces that were of concern. **We recommend in future rehabilitation or installation of boreholes, the DWSSC uses more durable materials for piping.** This will prevent further water contamination. The water is exposed to the environment and animals where the pipes are broken. Also, leaking pipes are wasteful and water is a scarce resource on these farms. **We recommend that the DWSSC conduct periodic inspections of the infrastructure** to ensure that the integrity of the structure is maintained.

5.4 COMMUNITY

The social component of the baseline highlighted community concerns and desires. Information gathered at interviews revealed that select community members had received some training concerning infrastructural maintenance. However this training was not received frequently enough. **We recommend that the DWSSC give annual standardized training to Water Point Committee members**.

The DWSSC was present throughout each of our field visits. Their purpose was to guide and provide additional information for us as we conducted our methodology in the field. **We recommend more extensive involvement of the DWSSC in educating the communities on water and sanitation**. Communities need to be routinely reminded of methods of water contamination prevention. We found that people frequently move; therefore information workshops could be held on a yearly basis. Regular visits to the farms will improve the communication between the community and government. The DWSSC will be better informed on maintenance and water quality issues related to the borehole.

The second field visit served not only to educate people on water quality but also to gauge community interest in implementation of a pilot study. As stated in the IWRM approach, community involvement is essential for the success of a project. **We recommend that community members be present and involved in all phases of implementation.** The community members must feel ownership and responsibility regarding the project. Involvement in all steps of the process will ensure that community members feel this ownership and responsibility. Meetings were informal and community members were encouraged to contribute. Community members seemed very interested in our suggestions and enthusiastic about being involved in implementation. The community enthusiasm regarding implementation makes us confident that community members will put forth their best effort to ensure that the pilot study succeeds.

5.5 PILOT STUDY

Implementation of pilot solutions for E-CAP component II has two components, physical solutions, and their respective monitoring strategies. We constructed a single Otji-Toilet at the conclusion of this report. This toilet was the first implemented solution in a series of pilots the DRFN will fund through the E-CAP project, supported by the Finnish government. In addition to the Otji-Toilet, two other physical solutions will be tested as part of the initial pilot study: ion exchange filters and calcium hypochlorite powder. The ultimate goal in piloting these systems is to gauge their success and demand within rural communities. If successful, the DRFN can provide strongly founded recommendations to rural decision makers. In this section we describe the details regarding each solution in the context of the Odendaal farms, and suggest guidelines for evaluating the success of each.

5.5.1 OTJI-TOILET

In addition to the first Otji-Toilet at Mr. George's house, the DRFN intends to install more as part of this study. To promote success, they must carefully consider the personal investment of each recipient and the placement of each system. Recipients should demonstrate motivation to use and build the system to ensure commitment. It is also critical that those receiving toilets are actively involved in the building process to instill a sense of ownership and responsibility. **We advise that multiple communities receive pilot toilets to assess any variation in success**. Lastly, each system must be limited to serving less than 10 people; if overused the system will fail. Through educational workshops, communities should be informed that the pilot is to be studied, and encouraged to share their thoughts regarding the system.

To effectively gauge the success of the Otji-Toilet pilots, **we recommend the DRFN establishes a user-integrated monitoring system to directly assess each system every three months**. This could include an inspection of the structure, and an interview with the appointed owner. The DRFN could specifically address the owners' challenges with their system, and if necessary, offer further instruction. Challenges may include damage, insufficient maintenance, or infrequent use of the system. All community members and family could be invited to share their experiences with the system as well.

5.5.2 ION EXCHANGE FILTERS

As a short-term solution to high nitrate levels, **we recommend the DRFN will install ion exchange filters on select taps among the Odendaal farms**. When choosing the locations of pilot filters we suggest the DRFN consider two parameters. Communities, which exhibit the highest levels of nitrate contamination, could be given priority. Families with young children and babies could be prioritized, as these parties are most susceptible to poisoning. By these guidelines, the pilot filters will benefit at-risk communities the most effectively. Similar to the Otji-Toilet, recipients should demonstrate commitment to maintaining the system, and if possible, be involved in its installation.

We recommend the DRFN develops a user-integrated monitoring system and conducts informal interviews to obtain user feedback on the system approximately every three months. To maximize the lifespan of filters, household taps must be fitted with a T-junction, to enable users the option to bypass the filter. Water for all purposes other than human consumption will bypass the filter. In addition, two water meters will be installed with the filters: one for filtered water, the other for unfiltered. The meters will evaluate family water consumption to provide the DRFN with quantitative field data to guide future studies. Those who receive pilot filters will be required weekly to test and record the nitrate levels to ensure its safety, and to indicate resin functionality.

5.5.3 CALCIUM HYPOCHLORITE

Calcium hypochlorite powder will effectively eliminate biological contamination within the affected communities. **The DRFN can provide communities with powder, and give instruction for daily administration**. Community members can integrate chlorine treatment into a daily routine, simply adding a scoop each day. The volume of powder required could be determined under the guidance of either Analytical Laboratories, or Aqua Services Inc, who were consulted throughout this study.

The DRFN could test treated water periodically (about every three months) and conduct informal interviews with users. Interviews should specifically include questions regarding health and user satisfaction. **We suggest that communities with significant biological contamination be given priority during the pilot study**.

5.6 SUSTAINABILITY

The DRFN will pay for the installation of all pilots through grant funding provided by the Finish Government. **We recommend that every household at the farms we visited receive an Otji-Toilet**. Families could be encouraged to save money to help pay for the toilet. This will help the family take ownership of the toilet, ensuring that maintenance will be completed. Maintenance is the responsibility of the family. **The DRFN could hold a meeting with the DWSSC and MAWF to discuss funding**. At this meeting the DRFN will present the results from all the pilot studies to encourage the MAWF to sponsor the continued implementation. By law the government is required to immediately attend to water of "D" quality and they are supposed to attend to "C" quality water as soon as possible (Namibia Water Corporation Ltd., 2006a).

After the pilot studies are completed, the maintenance of the filters will be the responsibility of the DWSSC. In order to ensure the filters last as long as possible and they are properly removing nitrates, **we recommend the DWSSC create a position to maintain the filters**. Depending on the results of the pilot study, the frequency of maintenance will be determined.

The MAWF should also fund bacteriological testing of the water. By law, this should be done every three months (Namibia Water Corporation Ltd., 2006a). This will continue to monitor the effectiveness of the chlorination. In addition, it will prevent residents from ingesting harmful water.

5.7 FARMS REQUIRING SPECIAL ATTENTION

Throughout our field expeditions, we found two farms, Gründorn (South) and Diamont Kop, which require special attention. The major concern we had at Gründorn (South) was the current pit latrine situation. The pit latrines were overflowing and in the direct vicinity of the borehole. They were the only community we visited that had pit latrines. Diamont Kop requires special attention because the borehole water is already known to be unfit for human consumption. However, access to the borehole has not been restricted so there is a possibility that families are still using and drinking the water. This section describes a few farm specific solutions.

5.7.1 GRÜNDORN (SOUTH)

The overflowing pit latrines at Gründorn (South) are a pressing concern. Due to their close proximity to the borehole, we fear that if left untreated these pit latrines will further contaminate the water. The waste must be removed in order to ensure that the water is not negatively impacted. Initially we planned to use a honey sucker to remove the waste. A honey sucker is a machine used to vacuum and clean septic tanks. Normally this would be effective; however, the community has been compressing the waste when the pit becomes too full. This has compacted the waste, which means a honey sucker is no longer a viable solution. The only option is to dig the pit latrines out either using heavy machinery or shoveling them out by hand. **We recommend the pit latrines be emptied and sealed as soon as possible to prevent contamination.**

5.7.2 DIAMONT KOP

Diamont Kop requires immediate attention. The community receives clean water from NamWater because previously the water was found to be unfit for human consumption. We used test strips to assess the quality of the water and found it was still in extremely poor condition. A new family has recently moved into the area and there is a strong possibility that they are drinking from the contaminated borehole. Due to the expenses of NamWater, we fear the family may be using the borehole. **We suggest that community members be educated on the potential dangers of drinking contaminated water**. The DRFN can accomplish this by holding an informational conference with the community, similar to the educational workshops we held in other communities. **We also recommend that the DRFN collect water samples from the borehole for both chemical and bacteriological lab tests**. This will determine what could be done with the borehole. Depending on the results, we have two different recommendations. **If the water is salvageable the quality can be improved using the nitrate filters and chlorination**. **Otherwise, access to the borehole should be eliminated**.

5.8 SUMMARY

In conclusion the major outstanding issues on Odendaal farms are nitrate and bacteriological contamination in the groundwater. We attribute the contamination to improper management of biological waste. We recommend:

1. Relocation of Livestock
2. Installation of Dry Sanitation Systems
3. Installation of Nitrate Ion Exchange Filters
4. Chlorination Treatment
5. Development of Routine Water Testing

Successful implementation of these recommendations will reduce groundwater contamination in both the short and long term for these communities. These recommendations have been presented to the communities, DWSSC, and DRFN to promote a collaborative effort. All parties were positive about the suggestion and enthusiastic about beginning implementation.

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APPENDIX A – COMPONENT EVALUATION FORM

Number/ Image #(s)		**Approximate Age**	
Component		**Location**	
		Material	
Condition		**Repairs Needed**	
		Evident Environmental Factors	

APPENDIX B – COMMUNITY QUESTIONNAIRE

Farm:	ID#:	Age:	Gender: M F
Length of residency:	Household size:	Living Accommodations:	

1. How did you come to live here?

   i. From where?

   ii. Why?

2. Do you live here permanently or do you only come here on weekends?

   i. Who owns the place?

3. Are you a member of the Water Point Committee?

   i. Have you had any training from the Water Point Committee? Explain.

4. Where do you collect water?

5. How much water do you use in a day?

   i. What do you use it for?

6. How often do you collect water?

7. For how many people do you collect water? Expand a bit on usage of water

8. How far must you walk to obtain water?

9. What are your thoughts on the quality of water?

10. What was the water quality like when you first moved here?

11. What do you think led to the water quality changes, if any?

12. How does the amount of water available this year compare to previous years?

13. How do you dispose of dirty or used water? __________ __________ __________
14. Do you use any sanitation facilities or sanitation methods? If yes describe them. __________ __________ __________ __________ __________ __________
15. What sanitation system would you prefer? __________ __________
16. Who is responsible for the maintenance of the water supply infrastructure? __________ __________ i. How often does it receive maintenance? __________ __________
17. Have you/or any of your family members experienced any water-related health concerns? If so, when and what were they? __________ __________ __________ __________
18. What is the biggest challenge you face with the current water situation? __________ __________ __________ __________
19. What kind of waste do you generate? __________ __________ __________ i. How do you dispose of other waste (trash or garbage)? __________ __________ __________ __________

APPENDIX C – WATER TESTING PARAMETER

Property/Contaminant	Health Risks/Source
pH	Poor levels can lead to corrosion and further contaminate water Naturally and industrially produced
TDS (conductivity)	Can cause scaling in water pipes due to chemical build-up Naturally and industrially produced
Alkalinity	Affects corrosion rate
Chloride	Poor taste, can be corrosive
Fluoride	Bone disease, mottled teeth
Nitrate	Blue baby syndrome, methaemoglobinaemia Due to sewage contamination or agricultural runoff
Nitrite	Blue baby syndrome, methaemoglobinaemia Due to sewage contamination or agricultural runoff
Sulfate	Causes corrosion, laxative effect, poor taste
Sodium	Poor taste
Potassium	Poor taste
Magnesium	Causes Hardness, Scum formation
Calcium	Causes Hardness, Scum formation
Manganese	Stains sanitary ware and laundry, cause deposits, poor taste
Iron	Oxidized deposits (rust), discoloration, promotes bacteria growth, staining. Occurs naturally in ground water
Coliform	Indicates presence of other harmful bacteria. Diarrhea, vomiting, nausea. Usually from human/animal fecal waste
Benzene ?	Anemia, carcinogen Can come from leaking fuels, landfills
Toluene ?	Carcinogen. Causes nervous system, kidney, liver problems Can come from leaking fuels
Cryptosporidium	Gastrointestinal illness, vomiting, diarrhea, cramps From human and animal waste
Giardia Lamblia	Gastrointestinal illness, vomiting, diarrhea, cramps From human and animal waste
Arsenic	Skin damage, Circulatory system complications, cancer Erosion of deposits

APPENDIX D - ANALYTICAL LABORATORY SERVICES QUOTATIONS

ANALYTICAL LABORATORY SERVICES cc
P.O. Box 86782 Eros, Windhoek, Namibia
Tel (061) 210132 Fax (061) 210058 e-mail analab@mweb.com.na

Quotation # Q110319

To: **Desert Research Foundation Namibia**

Date: 18-Mar-11

Your Ref : Water analysis

Attn: **Ms. F. Simataa**

e-mail : **faith.simataa@drfn.org.na** **18-Mar-11**

	Qty	Type of analysis / operation	Charge N$
1	1	Heterotropic plate count	164.00
2	1	Coliform group presumptive, 10 tube MPN	130.00
3	1	* Coliform confirmation following the above test	65.00
4	1	* E. coli confirmation following the above test	65.00

ANALYTICAL LABORATORY SERVICES cc
P.O. Box 86782 Eros, Windhoek, Namibia
Tel (061) 210132 Fax (061) 210058 e-mail analab@mweb.com.na

Quotation # Q110304

To: **Desert Research Foundation of Namibia**
P.O. Box 20232
Windhoek

Date: 8-Mar-11

Your Ref : Water analysis

Attn: **Mr. P. Klintenberg**

8-Mar-11

	Qty	Type of analysis / operation	Charge N$
1	1	Standard water test incl. the following parameters: pH, electrical conductivity, turbidity, alkalinity, hardness, chloride, fluoride, nitrite, nitrate, sulphate, sodium, potassium, magnesium, calcium, manganese, iron	534.78

APPENDIX E – CHEMICAL TESTING

Site:	Picture #
Source:	Date:
Property/Contaminant	**Value**
pH	
TDS (conductivity)	
Fluoride	
Nitrate	
Nitrite	
Sulfate	
Iron	

Site:	Picture #
Source:	Date:
Property/Contaminant	**Value**
pH	
TDS (conductivity)	
Fluoride	
Nitrate	
Nitrite	
Sulfate	
Iron	

Site:	Picture #
Source:	Date:
Property/Contaminant	**Value**
pH	
TDS (conductivity)	
Fluoride	
Nitrate	
Nitrite	
Sulfate	
Iron	

Site:	Picture #
Source:	Date:
Property/Contaminant	**Value**
pH	
TDS (conductivity)	
Fluoride	
Nitrate	
Nitrite	
Sulfate	
Iron	

APPENDIX F - FIELD TEST RESULTS

Field Test Results for Nico-Noord					
Property/Contaminant	**NamWater Guidelines**	**Trough**	**House Tap**	**Water Tank**	**Garden Tap**
pH	5.5-9.5	Neutral	Neutral	Neutral	Neutral
TDS [conductivity] (µS/cm)	300 mS/m	1431	1578	1501	1689
Nitrate [test strips] (ppm)	-	20-50	20-50	20-50	10-20
Nitrate [colorimeter] (mg/L)	20	-	18.4	-	-
Nitrite (ppm)		0	0	0	0
Fluoride (mg/L)	2.0	-	1.1	-	-
Sulfate (mg/L)	600	128	140	132	Limit: 160
Iron (mg/L)	.01	0.01	0.01	0.11	0.01

Field Test Results for Doring Draai						
Property/Contaminant	**NamWater Guidelines**	**Borehole**	**Water Tank Tap**	**House Tap A**	**House Tap M**	**House Tap K**
pH	5.5-9.5	Neutral	Neutral	Neutral	Neutral	Neutral
TDS [conductivity] (µS/cm)	300 mS/m	-	1845	1974	1920	1796
Nitrate [test strips] (ppm)	-	20-50	20-50	20-50	20-50	20-50
Nitrate [colorimeter] (mg/L)	20	-	-	17.8	17.8	-
Nitrite (ppm)		0	0	0	0	0
Fluoride	2.0	-	-	0.9	-	-
Sulfate (mg/L)	600	-	Limit: 160	152	144	Limit: 160
Iron (mg/L)	.01	-	0.02	0.10	0.09	0.08

Field Test Results for Nico			
Property/Contaminant	**NamWater Guidelines**	**Solar Tank Tap**	**Windmill Tap**
pH	5.5-9.5	Neutral	Neutral
TDS [conductivity] (µS/cm)	300 mS/m	1763	1168
Nitrate [test strips] (ppm)	-	20-50	20-50
Nitrate [colorimeter] (mg/L)	20	11.5	-
Nitrite (ppm)		0	0
Fluoride	2.0	0.2	-
Sulfate (mg/L)	600	Limit: 160	58
Iron (mg/L)	.01	0.09	0.05

Field Test Results for Laurencia Pos				
Property/Contaminant	**NamWater Guidelines**	**Water Tank**	**House Tap**	**Old Solar Tap**
pH	5.5-9.5	Neutral	Neutral	Neutral
TDS [conductivity] (µS/cm)	300 mS/m	1018	1015	Limit: 1999
Nitrate [test strips] (ppm)	-	20	20	Limit: 50
Nitrate [colorimeter] (mg/L)	20	-	-	-
Nitrite (ppm)		0	0	1
Fluoride	2.0	-	0.4	-
Sulfate (mg/L)	600	66	68	Limit: 160
Iron (mg/L)	.01	0.36	0.03	0.03

Field Test Results for Laurencia		
Property/Contaminant	**NamWater Guidelines**	**House Tap**
pH	5.5-9.5	Neutral
TDS [conductivity] (μS/cm)	300 mS/m	Limit: 1999
Nitrate [test strips] (ppm)	-	Limit: 50
Nitrate [colorimeter] (mg/L)	20	-
Nitrite (ppm)		0
Fluoride	2.0	1.2
Sulfate (mg/L)	600	148
Iron (mg/L)	.01	0.02

Field Test Results for Gründorn (South)			
Property/Contaminant	**NamWater Guidelines**	**Water Tank**	**Livestock Tap**
pH	5.5-9.5	Neutral	Neutral
TDS [conductivity] (μS/cm)	300 mS/m	1822	Limit: 1999
Nitrate [test strips] (ppm)	-	20	20
Nitrate [colorimeter] (mg/L)	20	11.9	-
Nitrite (ppm)		0	0
Fluoride	2.0	1.4	-
Sulfate (mg/L)	600	Limit: 160	Limit: 160
Iron (mg/L)	.01	1.9	0.07

Field Test Results for Gründorn (North)				
Property/Contaminant	**NamWater Guidelines**	**Trough**	**House Tap**	**Borehole**
pH	5.5-9.5	Neutral/Basic	Neutral	Acidic/Neutral
TDS [conductivity] (µS/cm)	300 mS/m	1858	1830	-
Nitrate [test strips] (ppm)	-	20	20-50	20-50
Nitrate [colorimeter] (mg/L)	20	-	-	-
Nitrite (ppm)		Limit: 3	0	0
Fluoride	2.0	-	2.0	-
Sulfate (mg/L)	600	Limit: 160	Limit: 160	-
Iron (mg/L)	.01	0.02	0.11	-

Field Test Results for Diamont Kop				
Property/Contaminant	**NamWater Guidelines**	**NamWater Tap**	**Livestock Tap**	**Reservoir**
pH	5.5-9.5	Neutral	Neutral	Neutral
TDS [conductivity] (µS/cm)	300 mS/m	1271	Limit: 1999	-
Nitrate [test strips] (ppm)	-	10	Limit: 50	Limit: 50
Nitrate [colorimeter] (mg/L)	20	-	-	-
Nitrite (ppm)		0	0.15	Limit: 3
Fluoride	2.0	0.7	-	-
Sulfate (mg/L)	600	Limit: 160	Limit: 160	-
Iron (mg/L)	.01	0.04	0.18	-

APPENDIX G – ANALYTICAL LABS CHEMICAL RESULTS

ANALYTICAL LABORATORY SERVICES cc

P.O. Box 86782 Eros, Windhoek, Namibia
Tel (061) 210132 Fax (061) 210058 e-mail analab@mweb.com.na

TEST REPORT

To: **Desert Research Foundation Namibia**
P.O.Box 20232
Widnhoek

Date received: **31-Mar-11**
Date required:
Date completed: **14-Apr-11**

Attn: Mr. P. Klintenberg

e-mail: patrik.klintenberg@drfn.org.na

Your Reference: 1000002623
Lab Reference: I110431

Sample details	Nico
Location of sampling point	-
Description of sampling point	-
Date of sampling	-
Time of sampling	-
Test item number	I110431/5

Parameter	Value	Units	Classification	Recommended maximum limits: Human consumption Group A	Group B	Group C	Livestock watering
pH	7.8		A	6-9	5.5-9.5	4-11	
Electrical Conductivity	181.9	mS/m	B	150	300	400	
Turbidity	0.50	NTU	A	1	5	10	
Total Dissolved Solids (calc.)	1219	mg/l					6000
P-Alkalinity as $CaCO_3$	0	mg/l					
Total Alkalinity as $CaCO_3$	472	mg/l					
Total Hardness as $CaCO_3$	522	mg/l	B	300	650	1300	
Ca-Hardness as $CaCO_3$	357	mg/l	A	375	500	1000	2500
Mg-Hardness as $CaCO_3$	165	mg/l	A	290	420	840	2057
Chloride as Cl^-	185	mg/l	A	250	600	1200	1500-3000
Fluoride as F^-	0.5	mg/l	A	1.5	2.0	3.0	2.0-6.0
Sulphate as SO_4^{2-}	140	mg/l	A	200	600	1200	1000
Nitrate as N	40	mg/l	C	10	20	40	100
Nitrite as N	<0.1	mg/l					10
Sodium as Na	197	mg/l	B	100	400	800	2000
Potassium as K	1.4	mg/l	A	200	400	800	
Magnesium as Mg	40	mg/l	A	70	100	200	500
Calcium as Ca	143	mg/l	A	150	200	400	1000
Manganese as Mn	0.01	mg/l	A	0.05	1.0	2.0	10
Iron as Fe	0.05	mg/l	A	0.1	1.0	2.0	10
Stability pH, at 25°C	6.7						
Langelier Index	1.1	scaling		>0=scaling, <0=corrosive, 0=stable			
Ryznar Index	5.6	scaling		<6.5=scaling, >7.5=corrosive, ≥6.5 and ≤7.5=stable			
Corrosivity ratio	0.9	increasing corrosive tendency		Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency			

Remark: Overall classification of water, considering only constituents that have been tested for:
Group C, low risk water

Interpretation based on guidelines for the evaluation of drinking water for human consumption, DWA, Namibia, July 1991

S. Rügheimer
Laboratory Manager

ANALYTICAL LABORATORY SERVICES cc

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TEST REPORT

To: **Desert Research Foundation Namibia**
P.O.Box 20232
Widnhoek

Date received: 31-Mar-11
Date required:
Date completed: 14-Apr-11

Attn: Mr. P. Klintenberg

e-mail: patrik.klintenberg@drfn.org.na

Your Reference: 1000002623
Lab Reference: I110431

Sample details	LOR
Location of sampling point	-
Description of sampling point	-
Date of sampling	-
Time of sampling	-
Test item number	I110431/6

Parameter	Value	Units	Classification	Recommended maximum limits Human consumption Group A	Group B	Group C	Livestock watering
p H	7.5		A	6-9	5.5-9.5	4-11	
Electrical Conductivity	291	mS/m	B	150	300	400	
Turbidity	0.25	NTU	A	1	5	10	
Total Dissolved Solids (calc.)	1950	mg/l					6000
P-Alkalinity as $CaCO_3$	0	mg/l					
Total Alkalinity as $CaCO_3$	431	mg/l					
Total Hardness as $CaCO_3$	697	mg/l	C	300	650	1300	
Ca-Hardness as $CaCO_3$	474	mg/l	B	375	500	1000	2500
Mg-Hardness as $CaCO_3$	222	mg/l	A	290	420	840	2057
Chloride as Cl^-	426	mg/l	B	250	600	1200	1500-3000
Fluoride as F^-	0.9	mg/l	A	1.5	2.0	3.0	2.0-6.0
Sulphate as SO_4^{2-}	243	mg/l	B	200	600	1200	1000
Nitrate as N	75	mg/l	D	10	20	40	100
Nitrite as N	<0.1	mg/l					10
Sodium as Na	350	mg/l	B	100	400	800	2000
Potassium as K	2.2	mg/l	A	200	400	800	
Magnesium as Mg	54	mg/l	A	70	100	200	500
Calcium as Ca	190	mg/l	B	150	200	400	1000
Manganese as Mn	<0.01	mg/l	A	0.05	1.0	2.0	10
Iron as Fe	0.02	mg/l	A	0.1	1.0	2.0	10
Stability pH, at 25°C	6.6						
Langelier Index	0.9	scaling		>0=scaling, <0=corrosive, 0=stable			
Ryznar Index	5.7	scaling		<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable			
Corrosivity ratio	2.0	increasing corrosive tendency		Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency			

Remark: Overall classification of water, considering only constituents that have been tested for:
Group D, high risk water, unsuitable for human consumption

Interpretation based on guidelines for the evaluation of drinking water for human consumption, DWA, Namibia, July 1991

S. Rügheimer
Laboratory Manager

ANALYTICAL LABORATORY SERVICES cc

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TEST REPORT

To: **Desert Research Foundation Namibia**
P.O.Box 20232
Widnhoek

Date received: 31-Mar-11
Date required:
Date completed: 14-Apr-11

Attn: Mr. P. Klintenberg

e-mail: patrik.klintenberg@drfn.org.na

Your Reference: 1000002623
Lab Reference: I110431

Sample details	N Nord
Location of sampling point	-
Description of sampling point	-
Date of sampling	-
Time of sampling	-
Test item number	I110431/7

Parameter	Value	Units	Classification	Recommended maximum limits – Human consumption: Group A	Group B	Group C	Livestock watering
pH	7.6		A	6-9	5.5-9.5	4-11	
Electrical Conductivity	161.2	mS/m	B	150	300	400	
Turbidity	0.10	NTU	A	1	5	10	
Total Dissolved Solids (calc.)	1080	mg/l					6000
P-Alkalinity as $CaCO_3$	0	mg/l					
Total Alkalinity as $CaCO_3$	477	mg/l					
Total Hardness as $CaCO_3$	372	mg/l	B	300	650	1300	
Ca-Hardness as $CaCO_3$	257	mg/l	A	375	500	1000	2500
Mg-Hardness as $CaCO_3$	115	mg/l	A	290	420	840	2057
Chloride as Cl^-	131	mg/l	A	250	600	1200	1500-3000
Fluoride as F^-	0.9	mg/l	A	1.5	2.0	3.0	2.0-6.0
Sulphate as SO_4^{2-}	121	mg/l	A	200	600	1200	1000
Nitrate as N	36	mg/l	C	10	20	40	100
Nitrite as N	<0.1	mg/l					10
Sodium as Na	220	mg/l	B	100	400	800	2000
Potassium as K	1.5	mg/l	A	200	400	800	
Magnesium as Mg	28	mg/l	A	70	100	200	500
Calcium as Ca	103	mg/l	A	150	200	400	1000
Manganese as Mn	<0.01	mg/l	A	0.05	1.0	2.0	10
Iron as Fe	0.01	mg/l	A	0.1	1.0	2.0	10
Stability pH, at 25°C	6.8						
Langelier Index	0.8	scaling		>0=scaling, <0=corrosive, 0=stable			
Ryznar Index	6.0	scaling		<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable			
Corrosivity ratio	0.7	increasing corrosive tendency		Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency			

Remark: Overall classification of water, considering only constituents that have been tested for:
Group C, low risk water

Interpretation based on guidelines for the evaluation of drinking water for human consumption, DWA, Namibia, July 1991

S. Rügheimer
Laboratory Manager

ANALYTICAL LABORATORY SERVICES cc

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TEST REPORT

To: **Desert Research Foundation Namibia**
P.O.Box 20232
Widnhoek

Date received: 31-Mar-11
Date required:
Date completed: 14-Apr-11

Attn: Mr. P. Klintenberg

e-mail: patrik.klintenberg@drfn.org.na

Your Reference: 1000002623
Lab Reference: I110431

Sample details	L Pos
Location of sampling point	-
Description of sampling point	-
Date of sampling	-
Time of sampling	-
Test item number	I110431/8

				Recommended maximum limits			
				Human consumption			Livestock
Parameter	Value	Units	Classification	Group A	Group B	Group C	watering
pH	7.9		A	6-9	5.5-9.5	4-11	
Electrical Conductivity	91.1	mS/m	A	150	300	400	
Turbidity	0.60	NTU	A	1	5	10	
Total Dissolved Solids (calc.)	610	mg/l					6000
P-Alkalinity as $CaCO_3$	0	mg/l					
Total Alkalinity as $CaCO_3$	339	mg/l					
Total Hardness as $CaCO_3$	342	mg/l	B	300	650	1300	
Ca-Hardness as $CaCO_3$	177	mg/l	A	375	500	1000	2500
Mg-Hardness as $CaCO_3$	165	mg/l	A	290	420	840	2057
Chloride as Cl^-	52	mg/l	A	250	600	1200	1500-3000
Fluoride as F^-	0.4	mg/l	A	1.5	2.0	3.0	2.0-6.0
Sulphate as SO_4^{2-}	55	mg/l	A	200	600	1200	1000
Nitrate as N	14	mg/l	B	10	20	40	100
Nitrite as N	<0.1	mg/l					10
Sodium as Na	68	mg/l	A	100	400	800	2000
Potassium as K	1.9	mg/l	A	200	400	800	
Magnesium as Mg	40	mg/l	A	70	100	200	500
Calcium as Ca	71	mg/l	A	150	200	400	1000
Manganese as Mn	0.01	mg/l	A	0.05	1.0	2.0	10
Iron as Fe	0.08	mg/l	A	0.1	1.0	2.0	10
Stability pH, at 25°C	7.1						
Langelier Index	0.8	scaling		>0=scaling, <0=corrosive, 0=stable			
Ryznar Index	6.3	scaling		<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable			
Corrosivity ratio	0.4	increasing corrosive tendency		Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency			

Remark: Overall classification of water, considering only constituents that have been tested for:
Group B, good quality water

Interpretation based on guidelines for the evaluation of drinking water for human consumption, DWA, Namibia, July 1991

S. Rügheimer
Laboratory Manager

ANALYTICAL LABORATORY SERVICES cc

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TEST REPORT

To: **Desert Research Foundation Namibia**
P.O.Box 20232
Widnhoek

Date received: 31-Mar-11
Date required:
Date completed: 14-Apr-11

Attn: Mr. P. Klintenberg

e-mail: patrik.klintenberg@drfn.org.na

Your Reference: 1000002623
Lab Reference: I110431

Sample details	GR 1
Location of sampling point	-
Description of sampling point	-
Date of sampling	-
Time of sampling	-
Test item number	I110431/1

Parameter	Value	Units	Classification	Recommended maximum limits Human consumption Group A	Group B	Group C	Livestock watering
p H	7.8		A	6-9	5.5-9.5	4-11	
Electrical Conductivity	206	mS/m	B	150	300	400	
Turbidity	1.6	NTU	B	1	5	10	
Total Dissolved Solids (calc.)	1380	mg/l					6000
P-Alkalinity as $CaCO_3$	0	mg/l					
Total Alkalinity as $CaCO_3$	541	mg/l					
Total Hardness as $CaCO_3$	437	mg/l	B	300	650	1300	
Ca-Hardness as $CaCO_3$	322	mg/l	A	375	500	1000	2500
Mg-Hardness as $CaCO_3$	115	mg/l	A	290	420	840	2057
Chloride as Cl^-	192	mg/l	A	250	600	1200	1500-3000
Fluoride as F^-	1.1	mg/l	A	1.5	2.0	3.0	2.0-6.0
Sulphate as SO_4^{2-}	308	mg/l	B	200	600	1200	1000
Nitrate as N	17	mg/l	B	10	20	40	100
Nitrite as N	<0.1	mg/l					10
Sodium as Na	299	mg/l	B	100	400	800	2000
Potassium as K	0.96	mg/l	A	200	400	800	
Magnesium as Mg	28	mg/l	A	70	100	200	500
Calcium as Ca	129	mg/l	A	150	200	400	1000
Manganese as Mn	<0.01	mg/l	A	0.05	1.0	2.0	10
Iron as Fe	0.06	mg/l	A	0.1	1.0	2.0	10
Stability pH, at 25°C	6.7						
Langelier Index	1.1	scaling		>0=scaling, <0=corrosive, 0=stable			
Ryznar Index	5.5	scaling		<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable			
Corrosivity ratio	1.1	increasing corrosive tendency		Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency			

Remark: Overall classification of water, considering only constituents that have been tested for:
Group B, good quality water

Interpretation based on guidelines for the evaluation of drinking water for human consumption, DWA, Namibia, July 1991

S. Rügheimer
Laboratory Manager

ANALYTICAL LABORATORY SERVICES cc

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TEST REPORT

To: **Desert Research Foundation Namibia**
P.O.Box 20232
Widnhoek

Date received: **31-Mar-11**
Date required:
Date completed: **14-Apr-11**

Attn: Mr. P. Klintenberg

e-mail: **patrik.klintenberg@drfn.org.na**

Your Reference: 1000002623
Lab Reference: **I110431**

Sample details	GR 2
Location of sampling point	-
Description of sampling point	-
Date of sampling	-
Time of sampling	-
Test item number	I110431/2

Parameter	Value	Units	Classification	Recommended maximum limits: Human consumption Group A	Group B	Group C	Livestock watering
p H	8.3		A	6-9	5.5-9.5	4-11	
Electrical Conductivity	203	mS/m	B	150	300	400	
Turbidity	0.15	NTU	A	1	5	10	
Total Dissolved Solids (calc.)	1360	mg/l					6000
P-Alkalinity as $CaCO_3$	0	mg/l					
Total Alkalinity as $CaCO_3$	489	mg/l					
Total Hardness as $CaCO_3$	303	mg/l	B	300	650	1300	
Ca-Hardness as $CaCO_3$	200	mg/l	A	375	500	1000	2500
Mg-Hardness as $CaCO_3$	103	mg/l	A	290	420	840	2057
Chloride as Cl^-	202	mg/l	A	250	600	1200	1500-3000
Fluoride as F^-	1.6	mg/l	B	1.5	2.0	3.0	2.0-6.0
Sulphate as SO_4^{2-}	238	mg/l	B	200	600	1200	1000
Nitrate as N	31	mg/l	C	10	20	40	100
Nitrite as N	<0.1	mg/l					10
Sodium as Na	336	mg/l	B	100	400	800	2000
Potassium as K	1.2	mg/l	A	200	400	800	
Magnesium as Mg	25	mg/l	A	70	100	200	500
Calcium as Ca	80	mg/l	A	150	200	400	1000
Manganese as Mn	<0.01	mg/l	A	0.05	1.0	2.0	10
Iron as Fe	0.02	mg/l	A	0.1	1.0	2.0	10
Stability pH, at 25°C	6.9						
Langelier Index	1.4	scaling		>0=scaling, <0=corrosive, 0=stable			
Ryznar Index	5.5	scaling		<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable			
Corrosivity ratio	1.1	increasing corrosive tendency		Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency			

Remark: Overall classification of water, considering only constituents that have been tested for:
Group C, low risk water

Interpretation based on guidelines for the evaluation of drinking water for human consumption, DWA, Namibia, July 1991

S. Rügheimer
Laboratory Manager

ANALYTICAL LABORATORY SERVICES cc

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TEST REPORT

To: **Desert Research Foundation Namibia**
P.O.Box 20232
Widnhoek

Date received: 31-Mar-11
Date required:
Date completed: 14-Apr-11

Attn: Mr. P. Klintenberg

e-mail: patrik.klintenberg@drfn.org.na

Your Reference: 1000002623
Lab Reference: I110431

Sample details	D.K.
Location of sampling point	-
Description of sampling point	-
Date of sampling	-
Time of sampling	16:00
Test item number	I110431/3

Parameter	Value	Units	Classification	Recommended maximum limits – Human consumption Group A	Group B	Group C	Livestock watering
p H	8.1		A	6-9	5.5-9.5	4-11	
Electrical Conductivity	128.5	mS/m	A	150	300	400	
Turbidity	0.10	NTU	A	1	5	10	
Total Dissolved Solids (calc.)	861	mg/l					6000
P-Alkalinity as $CaCO_3$	0	mg/l					
Total Alkalinity as $CaCO_3$	334	mg/l					
Total Hardness as $CaCO_3$	232	mg/l	A	300	650	1300	
Ca-Hardness as $CaCO_3$	150	mg/l	A	375	500	1000	2500
Mg-Hardness as $CaCO_3$	82	mg/l	A	290	420	840	2057
Chloride as Cl^-	128	mg/l	A	250	600	1200	1500-3000
Fluoride as F^-	0.5	mg/l	A	1.5	2.0	3.0	2.0-6.0
Sulphate as SO_4^{2-}	157	mg/l	A	200	600	1200	1000
Nitrate as N	9.0	mg/l	A	10	20	40	100
Nitrite as N	<0.1	mg/l					10
Sodium as Na	194	mg/l	B	100	400	800	2000
Potassium as K	2.9	mg/l	A	200	400	800	
Magnesium as Mg	20	mg/l	A	70	100	200	500
Calcium as Ca	60	mg/l	A	150	200	400	1000
Manganese as Mn	<0.01	mg/l	A	0.05	1.0	2.0	10
Iron as Fe	0.02	mg/l	A	0.1	1.0	2.0	10
Stability pH, at 25°C	7.2						
Langelier Index	0.9	scaling		>0=scaling, <0=corrosive, 0=stable			
Ryznar Index	6.3	scaling		<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable			
Corrosivity ratio	1.0	increasing corrosive tendency		Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency			

Remark: Overall classification of water, considering only constituents that have been tested for:
Group B, good quality water

Interpretation based on guidelines for the evaluation of drinking water for human consumption, DWA, Namibia, July 1991

S. Rügheimer
Laboratory Manager

ANALYTICAL LABORATORY SERVICES cc

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TEST REPORT

To: **Desert Research Foundation Namibia**
P.O.Box 20232
Widnhoek

Date received: 31-Mar-11
Date required:
Date completed: 14-Apr-11

Attn: Mr. P. Klintenberg

e-mail: patrik.klintenberg@drfn.org.na

Your Reference: 1000002623
Lab Reference: I110431

Sample details	D. Draai
Location of sampling point	-
Description of sampling point	-
Date of sampling	-
Time of sampling	-
Test item number	I110431/4

				Recommended maximum limits			
				Human consumption			Livestock
Parameter	Value	Units	Classification	Group A	Group B	Group C	watering
p H	7.5		A	6-9	5.5-9.5	4-11	
Electrical Conductivity	201	mS/m	B	150	300	400	
Turbidity	0.40	NTU	A	1	5	10	
Total Dissolved Solids (calc.)	1347	mg/l					6000
P-Alkalinity as $CaCO_3$	0	mg/l					
Total Alkalinity as $CaCO_3$	426	mg/l					
Total Hardness as $CaCO_3$	615	mg/l	B	300	650	1300	
Ca-Hardness as $CaCO_3$	429	mg/l	B	375	500	1000	2500
Mg-Hardness as $CaCO_3$	185	mg/l	A	290	420	840	2057
Chloride as Cl^-	313	mg/l	B	250	600	1200	1500-3000
Fluoride as F^-	0.7	mg/l	A	1.5	2.0	3.0	2.0-6.0
Sulphate as SO_4^{2-}	117	mg/l	A	200	600	1200	1000
Nitrate as N	27	mg/l	C	10	20	40	100
Nitrite as N	<0.1	mg/l					10
Sodium as Na	193	mg/l	B	100	400	800	2000
Potassium as K	1.3	mg/l	A	200	400	800	
Magnesium as Mg	45	mg/l	A	70	100	200	500
Calcium as Ca	172	mg/l	B	150	200	400	1000
Manganese as Mn	0.01	mg/l	A	0.05	1.0	2.0	10
Iron as Fe	0.02	mg/l	A	0.1	1.0	2.0	10
Stability pH, at 25°C	6.7						
Langelier Index	0.8	scaling		>0=scaling, <0=corrosive, 0=stable			
Ryznar Index	5.8	scaling		<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable			
Corrosivity ratio	1.3	increasing corrosive tendency		Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency			

Remark: Overall classification of water, considering only constituents that have been tested for:
Group C, low risk water

Interpretation based on guidelines for the evaluation of drinking water for human consumption, DWA, Namibia, July 1991

S. Rügheimer
Laboratory Manager

ANALYTICAL LABORATORY SERVICES cc
P.O. Box 86782 Eros, Windhoek, Namibia
Tel (061) 210132 Fax (061) 210058 e-mail analab@mweb.com.na

Assessment of water quality for human consumption

For practical reasons, the guidelines are divided into four groups.
The highest group assigned to any of the constituents determines the classification of the water as a whole.
Group A: excellent quality water
Group B: good quality water
Group C: low risk water
Group D: high risk or water unsuitable for human consumption

Ideally water should be either Group A or Group B. If water is classified as Group C, the situation is not yet critical, but attention should be given to those constituents over the Group B limit. If however, the water is classified as Group D urgent and immediate attention is required to reduce the levels of the problem constituents in the water to suitable levels.

Naturally occurring chemicals that are of health significance in drinking water
Fluoride: Exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis.
0-1.0 mg/L fluoride: no adverse health effects or tooth damage occurs

Chemicals from agricultural activities that are of health significance in drinking water
Nitrate and nitrite: In water it has been associated with methaemoglobinaemia, especially in bottle-fed infants
>20 mg/L nitrate as N: methemoglobinaemia occurs in infants. Occurrence of mucous membrane irritation in adults

Some of the naturally occurring chemicals which occur in drinking water at concentrations below those at which toxic effects may occur.
Chloride: high concentrations of chloride give a salty taste to water. Concentrations in excess of 250 mg/l are increasingly likely to be detected by taste.
Hardness: Depending on the interaction of other factors, such as, pH and alkalinity, water with a hardness above approximately 200 ppm may cause scale deposition in the pipe work and tanks. On heating, hard waters form deposits of calcium carbonate scale.
pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200ppm.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250ppm.
Magnesium: The average taste threshold for magnesium is about 70ppm
Total dissolved solids: The palatability of water with a TDS level of less than 600ppm is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000ppm.

APPENDIX H - ANALYTICAL LABS BACTERIOLOGICAL RESULTS

ANALYTICAL LABORATORY SERVICES

P.O. Box 86782 Eros, Windhoek, Namibia

Tel (061) 210132 Fax (061) 210058 email analab@mweb.com.na

TEST REPORT

To: Desert Research Foundation Namibia

P.O. Box 20232

Windhoek

Date received: 31-Mar-11

Date required:

Date completed: 05-Apr-11

Att. Mr P. Klintenberg

Your Reference: 1000002623

Lab. Reference: I110431

Type of Sample(s)

Water

Samples Received

Eight sample received on the 31/03/2011 and tested on the 01/04/2011

Sampling was done by the client on the 31/03/2011 in the afternoon

The samples were collected in a sterile glass bottles supplied by Analytical Laboratory Services and kept at refrigeration temperature prior to analyses.

Test(s) Required

Heterotrophic Plate Count

Total coliform and E. coil: Most Probable Number Technique

Test Method(s) used

ISO 6222:1999

Heterotrophic plate count to estimate the total number of viable heterotrophic bacteria

Cfu/ml

Spread plate method

Plate count agar, 35°C/48h

Enumeration of coliform group bacteria in potable water

Most probable number per 100ml

Multiple tube fermentation technique, (10 tubes)

Lauryl tryptose broth (presumptive), 37°C/24-48h

Brilliant green bile broth (confirmed), 37°C/24-48h

Enumeration of E. coli in potable water

Most probable number per 100ml

Multiple tube fermentation technique, (10 tubes)

Lauryl tryptose broth (presumptive), 37°C/24-48h

Lauryl tryptose MUG broth (confirmed), 44.5°C/24-48h

Duration of Test(s)

01/04/2011–05/04/2011

Results

Test / Identification	Heterotrophic Plate Count, cfu/ml	Coliformgroup, MPN/100ml	E. coli, MPN/100ml
1. N. Nord	100	>23	2
2. Niro	370	23	1
3. Lor	460	23	1
4. D. Draai	180	n/d	n/d
5. L. Pos	90 000	4	4
6. GR 1	120	2	n/d
7. GR 2, 9:45	160	n/d	n/d
8. D.K.	12 estimated	4	n/d

cfu/ml = Colony forming units per ml

n/d = not detected by the method specified

MPN/100ml = Most probable number per 100ml; this number is based on certain probability formulas and is an estimate of the mean density of E. coli in the sample

Overall classification of the water considering parameters that have been tested for:

N. Nord: Group C, water with a risk factor which requires rectification
Nico: Group C, water with a risk factor, which requires rectification
LOR: Group C, water with a risk factor which requires rectification
D. Draai: Group B, microbiologically still suitable for human consumption
L. Pos: Group D, unsuitable for human consumption
GR 1: Group B, microbiologically still suitable for human consumption
Gr 2: Group B, microbiologically still suitable for human consumption
D.K.: Group B, microbiologically still suitable for human consumption

To consider water as very safe for human consumption (Group A) the total plate count shall not exceed 100cfu/ml, coliform and E. coli shall be absent in 100ml in 95% of the samples.

Consider inadequate the results of the examination of a single sample from a given source. When possible, base evaluation of water quality on the examination of a series of samples collected over a known and protracted period of time.

If the guideline values are exceeded, a second sample taken from the same source should be analysed as soon as possible.

The heterotrophic plate count is an analytical method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water the better maintained the water system is.

Increases of heterotrophic plate counts due to re-growth in tanks and in plumbing do not indicate necessarily the existence of a health risk, as long as the entry water meets acceptable microbial water quality norms and contamination from outside is prevented. Appropriate maintenance of these devices is required for aesthetic reasons.

Coliform bacteria are commonly found in the environment (e.g. soil or vegetation) and are generally harmless. If only total coliform bacteria are detected, the source is probably environmental. Fecal contamination is not likely. However, if environmental contamination can enter the system, there may also be a way for pathogens to enter the system. Therefore it is important to find the source and resolve the problem

Strictly speaking fecal indicators (more specifically *E. coli*) only indicates fecal pollution by warm-blooded animals or humans, which implies the potential presence of waterborne pathogens. Fecal pollution does, of course, also have aesthetic implications for drinking water.

Examination of routine bacteriological samples cannot be regarded as providing complete information concerning water quality. For example, bacterial indicators may not adequately reflect the risk of contracting viral or parasitic infections.

____

S. Rügheimer

Laboratory Manager

Nitrate removal and Softening Combined in One vessel.

Recommended Resin choice

Cation exchange resin Anion exchange resin
Amberlite SR1L Na Amberlite PWA5 or
Imac HP555

Above resins are authorized in Europe for the treatment of drinking water.

Amberlite PWA5 & Imac HP555 are nitrate-selective resins. Conventional anion exchangers are not suitable for this application, as in case of overrunning the unit, a nitrate concentration higher than that in the feed could be produced. This is not possible with Amberlite PWA5/Imac HP555, which bind nitrate more tightly than other anions.

System choice

The resins **cannot be used in a stratified bed** or in two separate columns, as the high calcium or sulphate or bicarbonate concentration produced during regeneration could result in precipitation. This risk is much reduced when the resins are used in a mixed bed.
It is recommended to operate the unit beyond the nitrate breakthrough to displace some of the sulphate from the resin and thus reduce the risk of precipitation.

Setting resin volumes

The respective volume of cation and anion resin depends on the hardness and nitrate concentrations in the water to be treated. For a good understanding of the relationship: because the cation resin has approximately 4 times more operating capacity than the anion resin, you need only 25% of it if the hardness/nitrate ratio is equal to 1 (theoretically only 20%). Note also that this mixed bed has no upper or lower limit of one component, because it is never separated, unlike in mixed beds in demineralization (those should have a C:A resin proportion roughly between 35:65 and 65:35%).

Regeneration conditions

Once again, this mixed bed is not separated before regeneration. Therefore it should not be backwashed unless suspended solids have accumulated on the resin bed surface. In this case **it must be re-mixed after backwash.**

A relatively high regeneration velocity is required to reduce the risk of precipitation, which, if occurring, will take place outside of the unit. Co-flow regeneration is not recommended, as its efficiency is not good and large peaks of hardness, nitrate or sulphate are observed at the beginning of the following cycle.

In short, we recommend a reverse flow regeneration of the resins in the mixed state. The quantity of regenerant should be at least 120 g NaCl per litre of resin, in a 6% solution, at a flow rate of 6 bed volumes per hour. For example 125 g NaCl per litre of resin at 6% (about 62.5 g NaCl per litre of regenerant solution) represents 2 bed volumes (m3 of solution per m3 of resin). At 6BV/h, the regenerant injection would take only 20 minutes.

If conventional softening (Amberlite Ir120Na) and a standard strong base anion resin such as Amberlite IRA402Cl are used in this application, and the resins are not operated as a mixed bed, precipitation of calcium/magnesium sulphate/carbonate could form within the resin bed or around areas of low flow, like strainers etc.

These deposits can be partially removed from the resin and the vessels by periodic cleaning with a strong acid such as 10% HCl.

Frequency of cleaning will depend upon usage but we suggest monitoring of pressure drops and service flows and if any uncalculated changes occur, cleaning must be carried out.

The resin will probably have to be removed from the columns, acid cleaned and then returned to service. At this time the collector systems will be inspected and also cleaned if required. Topping up of the resins can also be carried if required as some losses could occur during this procedure.

APPENDIX J - OTJI-TOILET SELF BUILDER MANUAL

The Otji-Toilet self builder manual

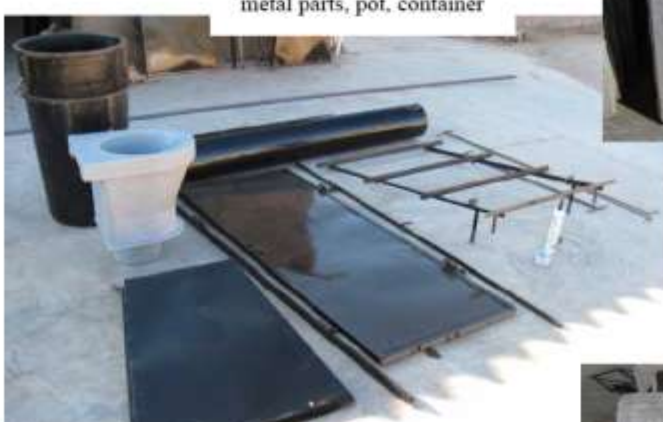
The Clay House Project Otjiwarongo

The Otji-Toilet self builder set

Your self builder set consists of following material

1 Lid box with following parts
  a) frame
  b) lid with bolts
1 ventilation pipe
1 door
1 door frame with following parts
  a) 1 angle iron 40 x 40 x 3 mm with hinges
  b) 1 angle iron 25 x 25 x 3 mm without hinges
1 welded steel roof structure
1 foundation steel ring (4 round steel— 2 long, 2 short parts)
2 perforated 90 l plastic container
1 Toilet Pot
2 concrete side plates
2 concrete dry plates (700x700)
1 concrete floor plate (850x750)
15 roof tiles (cool tiles)
1 silicon, wire, 2 long 2 short screws
- 4 nuts, 2 angle iron pieces

dry plate



metal parts, pot, container

side plate

floor plate

silikon, wire, screws, angel iron, nuts

roof tiles

Congratulation — you decided to build your Otji-Toilet by yourself. A good solution as well for you and for the environment, because the Otji-Toilet is an environment friendly ecosan toilet.
This brochure will help to finish the building job successfully.

The CHP-Team wishes you many success and always fresh air in your self built Otji-Toilet.

How to build your Otji-Toilet

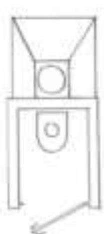
For a builder it is not difficult to build an Otji-Toilet. All you need is the construction plan, the Otji-Toilet self builder set you bought at the Clay House Project and following additional materials:

480 super bricks
3 bags cement
0,6 m sieved sand
5 litre paint of your choice

and the usual building tools like digging spate, tape measure, brick trowel, plastering trowel, hammer, wheel barrow, screw driver, fencing plier, straight edge, block brush and last but not least a spirit level.
If no super bricks are available, you can use any other cement bricks, but make sure that all measurements are being kept.

And you have to know how to face the lid box of your toilet exactly to the North.

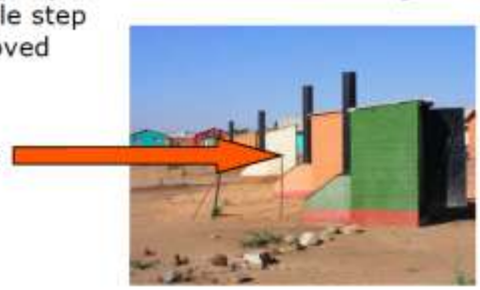
Without facing the lid box to the north your Otji-Toilet will not work properly. For a well functioning Otji-Toilet it is essential to find the right direction. Furthermore the place for the lid box must be shadowless to get the whole day full sun. Only under these conditions you will have an odourless functioning Otji-Toilet.



Before you start to dig the hole for the toilet, please make sure that all the toilet parts you have received are complete and the additional material is available as well.

The following pages show each single step which is necessary to build a proper functioning and long lasting Otji-Toilet. Please don't change the construction because every single step has its own importance and is approved through our long experience.

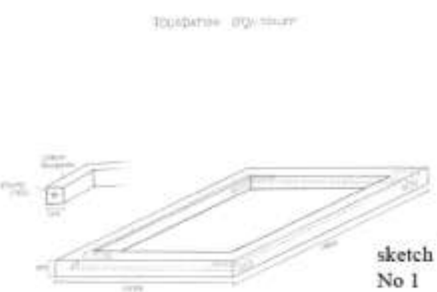
lid box strictly north



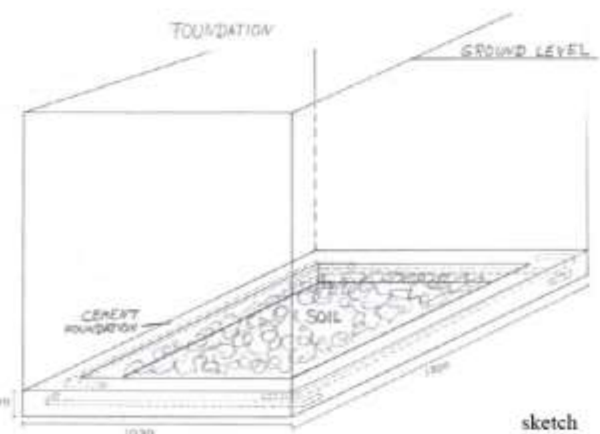
1. In the beginning is a hole

The hole what you dig is 1.100 mm deep, 1.070 mm wide and 1.800 mm long. If your underground is too rocky, the depth of the hole can be reduced. In that case the toilet floor should be raised just as much above ground level in order to get enough depth.

2. Laying the foundation



sketch No 1



sketch No 2

The concrete foundation will be reinforced with the round steel you received together with the Otji-Toilet self builder set. This reinforced foundation has to carry the whole weight of the toilet house and will prevent the walls from cracks. It is important to level the foundation exactly to get a straight toilet house.
As a preparation for the concrete foundation dig a square channel of 150 mm depth and 150 mm wide on the ground of the hole.

3. Building the tank

The walls of the underground tank can be build out of super bricks or any other bricks which are available. Just make sure that you keep the inside measurements shown in the construction plan. The walls must reach one brick over ground level.

4. Setting the floor-plate

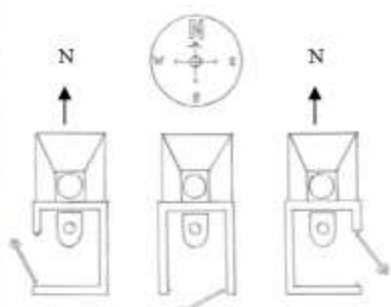
sketch
No 3

After building the tank, the floor-plate must be set in cement. Put mortar underneeth and add mortar to the side of the plate.

5. Building the toilet house

The building of the toilet house starts at the back side of the floor plate and goes than in direction to the front of the house. The wall of the toilet house is being built on the floor plate, but exeeds to the front plate (south).This side wall has outside a length of 1.200 mm and is extended over the floor plate. Therefore a small foundation should be laid in front. Normally the toilet door opens to the south, but you can change the design if needed.

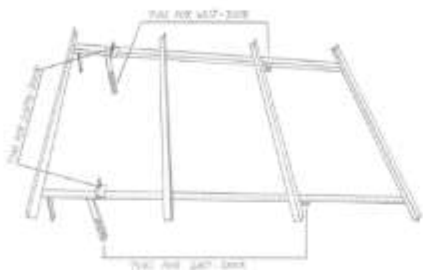
add foundation



sketch
No 4

6. Installing the roof structure

As soon as the toilet house is finished, the roof structure is laid on the walls and fixed with mortar. The roof structure provides pins for doors in any direction. The following sketch shows what pin has to be used for what direction of door (to the south, to the east, to the west).
Once the tiles are fixed with wire at the roof structure the gap between roof and wall can be filled with mortar. By that way the roof gets its stability as well.



sketch
No 5

7. Fixing the cool tiles

The cool tiles are being laid starting from the north lid box side—left hand. Each tile has a pin which you hang at the angle iron. The wire fixed to each concrete pin must be tied to the angle iron.

8. Installing the door frame

The door frame contents of two angle iron which must be connected to the pins of the roof structure. See on sketch 3 which pins should be used depending on the direction the door faces.
Each frame has to be concreted into the bottom.

south door
roof

south door
floor

9. Add cement slap

As the floor plate does not cover the whole inside space, add a 100 mm cement slap.

addede cement slap

10. Building the lid box

When the toilet house is completely finished the lid box is being installed.
At first hold the steel frame without the lid at the backside of the toilet house. Put the side plates straight on the tank wall and lean them to the box (you need two people). The box has on each side two pins which prevent the side plates to fall down into the tank, an other two pins are at the upper side of the box. Mark where the upper pins touch the wall, remove the lid box and the side plates and knock a small slit into the wall, where the upper pins of the lid box can enter.
Now bring the box with the pins into the slit and lean at the same time the side plates to the box. Fix the side plates with cement mortar. After that you have to fill the gap between lid box and the tank with bricks and mortar.






11. Installing the ventilation pipe

Put the ventilation pipe over the hole on the top of the lid box. Fix it with wire at the roof structure and use the silicon to seal it on the lid box to make it air– and waterproof. Seal as well small gaps between lid box and side plates to prevent any air circulation at the box. Big gaps you have closed with mortar.

12. Fixing the door

Hang the door into the hinges. Through the special formed hinges the door closes automatically.

13. Fixing the toilet pot

The toilet pot has to be fixed on the floor plate with two screws and the nuts belonging to it. Do it with two people, one on the top and one inside the tank. You have received two short pieces of a iron which can be used as washer..

14. Putting the drying plates into the tank

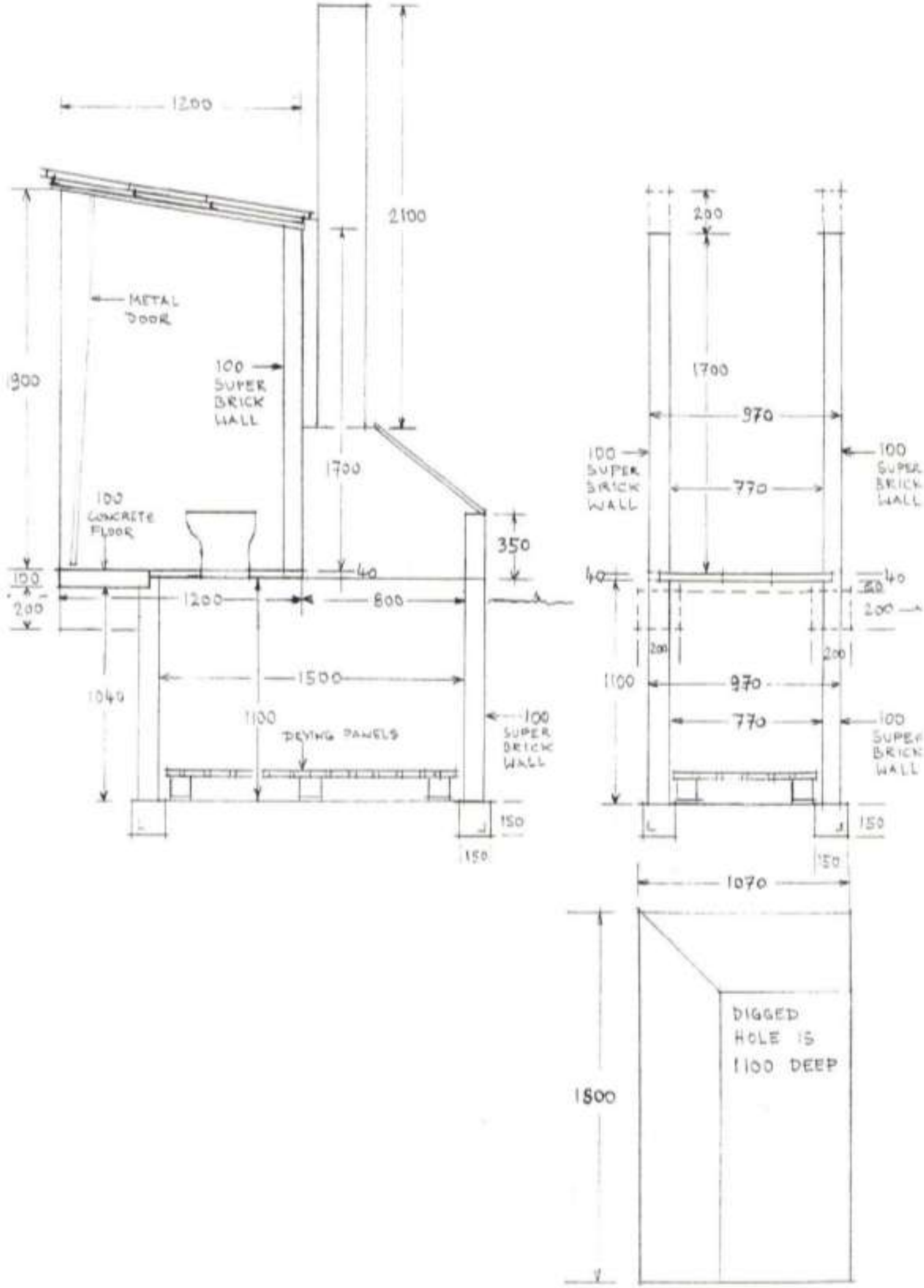
Before you put the drying panels into the tank, the bottom of the tank has to be cleaned from mortar which has fallen down during the building process. This is important to ensure good infiltration once functioning. Now put some bricks as sockets for the drying plates at the ground of the tank.
Place the plates on the bricks and as last step put the plastic containers onto the drying plates (don't throw the containers down on the plates because the plates could brake).

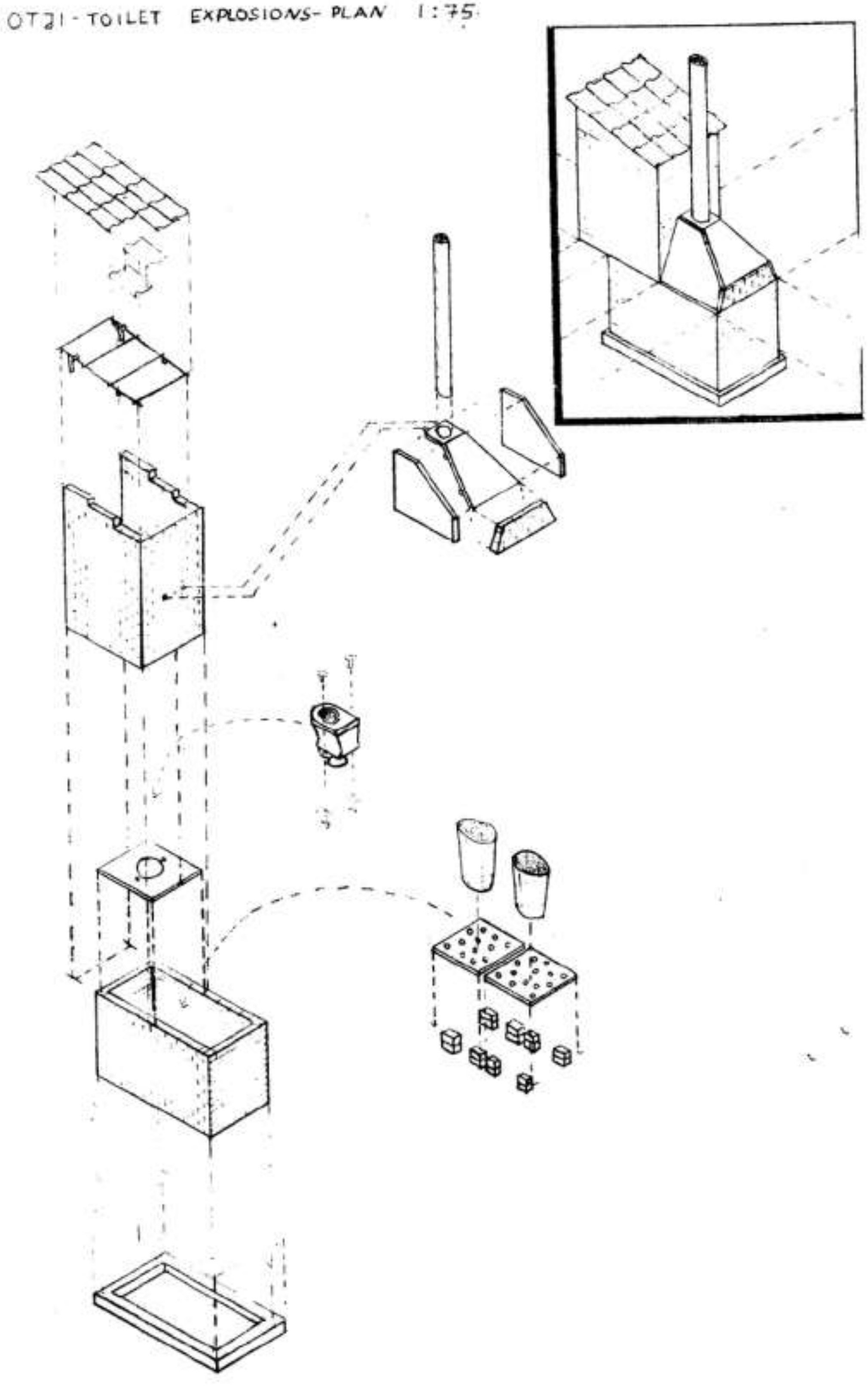
15. Sit down and enjoy

16. How to maintain the Otji-Toilet

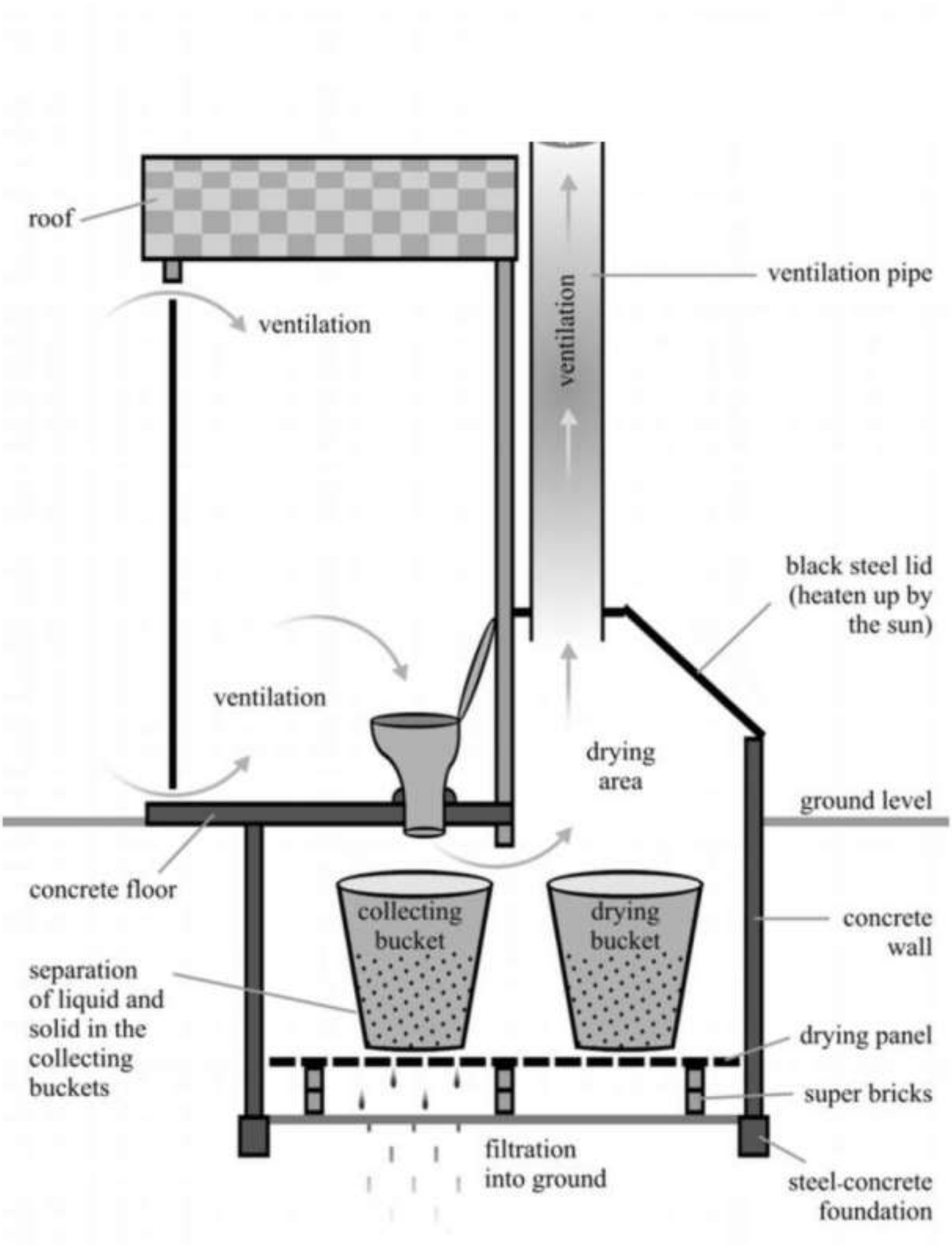
Usually the Otji-Toilet needs maintenance only twice a year. If you have more then 10 people using the toilet, please check every 4 month whether the container for the droppings is full or not. Move the full container with a steel hook to the back side of the tank, where the droppings can dry for half a year. Replace the full container with the empty container. Once the second container is full you have to remove the first container with the dried droppings and to empty it, than you exchange the both containers again.
The toilet pot has to be cleaned occasionally with a brush and a little bit of water. That's all.

CONSTRUCTION PLAN M 1:25
UPDATE: 19/09/05




OTJI-TOILET EXPLOSIONS-PLAN 1:75

Otji-Toilet function plan



The CHP is a namibian non-profit organisation with a Trust board. The „NAMIBIAN CLAY HOUSE DEVELOPMENT PROJECT TRUST“ is registered since 1991, with Nr. T6/92

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APPENDIX K - ION EXCHANGE FILTER QUOTATION

AQUA SERVICES & ENGINEERING (PTY) LTD

QUOTATION

April 21, 2011

TO:	**DESSERT RESEARCH FOUNDATION OF NAMIBIA**
ATT:	**DR. PATRIK KLINTENBERG**
TEL:	061 – 377 500
E-MAIL:	PATRIK.KLINTENBERG@GMAIL.COM

FROM:	**DR. THOMAS HONER**
OUR REF.:	Q 04-085-DRFN
PAGES:	1 OF 2

SUBJECT: NITRATE REMOVAL - SOFTENING

Dear Dr. Klintenberg,

We have the pleasure in quoting you as requested:

1.	5 off 10" Filter Housing	@ N$ 448.00 / ea	**N$ 2,240.00**
2.	5 off 10" Filter Cartridge	@ N$ 195.00 / ea	**N$ 975.00**
3.	5 off Mixed Bed Ion Exchange Resin, app. 500 – 600 ml each	@ N$ 35.00 /ea	**N$ 175.00**
4.	1 off Salt, 40 kg	@ N$ 0.867 / kg	**N$ 34.68**

Please note:

Delivery	: 1 – 3 Weeks
Price	: **excl. VAT; excl. Transport (ex Windhoek)**
Valid	: 30 Days

Aqua Services & Engineering (Pty) Ltd
Reg. No.: 93/196
Northern Industrial Area
Windhoek, Namibia
P.O. Box 20714
Windhoek, Namibia

VAT No.: 0052681-01-5
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Directors:
C.D. Stöck (MD)
Dr. G.G. Lempen
Dr. G.E. Rencken
A.M. Gisclon (French)
A.C. Thomas (Non-exec)

VEOLIA WATER
Solutions & Technologies

AQUA SERVICES & ENGINEERING (PTY) LTD

Please note that the quotation is subject to raw material prices, manufacturing costs and the exchange rate (1 US$ = 7.10 N$; 21.04.2011). The proposal is subject to ASE's General Terms of Sale. Available on request.

Please do not hesitate to contact the undersigned should you have any questions or require more information.

Yours faithfully
For Aqua Services & Engineering (Pty) Ltd

Dr. Thomas Honer
Process Chemist
Cell: +264 81 433 4329
thomas.honer@ase.com.na

APPENDIX L - DRY SANITATION

In the rural regions of Namibia waste management is a challenging issue. For people living in these areas a flush toilet is not a practical or affordable option. Therefore many use the bucket, bush, or pit latrines as a means of sanitation. This form of sanitation is inexpensive, but dangerous to the environment. Fecal matter on or in the ground is likely to contaminate the groundwater resulting in bacteria or nitrate contamination. Figure 54 shows the wide variety of sanitation options used around the world. There are two main factors that need to be considered when sanitation systems are being discussed. The first factor is transport. Transport means that the waste is moved from one point to another while no transport means that waste does not move. The second consideration is water. A water system requires running water while systems that are in the no water category are completely dry. Since water is a limited resource in rural areas, a sanitation method that requires no transportation and no water is preferable (Wienecke 2011).

	Transport	**No Transport**
Water	Flush toilets shared Flush toilets not shared Flush toilet connected to septic or holding tank Vacuum sewer	DEWATS Enviro Flush Biogas digester
No Water	Pail toilets Buckets	**Dry sanitation** **VIP** **UDS (Ecosan)** **Bush** **Pit / Long drop**

FIGURE 54: EXISTING SANITATION SYSTEMS (WIENECKE 2011)

Dry sanitation is a form of human waste disposal that requires no water or transportation. Dry sanitation is often a preferred use of sanitation because it is economical, environmentally friendly, and hygienic. The two major forms of dry sanitation are dehydration and compost. A dehydrating toilet involves the separation of urine and feces, in most systems urine is either diverted or evaporated while feces are dehydrated through solar radiation and evaporation. The drying process is expedited by adding lime, ash, or soil after each use. The addition of these materials also increases the pH of the material to prevent bacterial growth. In a composting toilet urine and feces are not separated, but collected together and broken down by bacteria. The byproduct of a composting toilet makes excellent fertilizer. In both methods airflow is essential to assist the dehydration process and reduce odors. Compared to other no water and no transportation sanitation methods such as the bush and pit latrines, dry sanitation methods are preferred. Dry sanitation protects the groundwater, is environmentally friendly, and is more hygienic (Kaczala 2006).

The concept behind dry sanitation is the ecological sanitation (ecosan) system. The basic principle of ecosan is the "utilization of available resources and saving water: closing the nutrient and water cycles with as little loss of material, nutrients, and energy as possible" (GTZ 2011). This entails recycling human waste back into the environment by preserving the nutrients while reducing the potentially toxic effects of open defecation. If executed properly, dry sanitation can improve health by preventing the contamination of ground water with harmful pathogens. Also dry sanitation can increase the recycling nutrients if the byproduct is used as fertilizer or by a biogas digester for electricity. Another positive attribute of the ecosan system is the conservation of resources such as water and eliminated need to transport waste. Figure 55 visually summarizes the positive effects of the ecosan system (GTZ 2011).

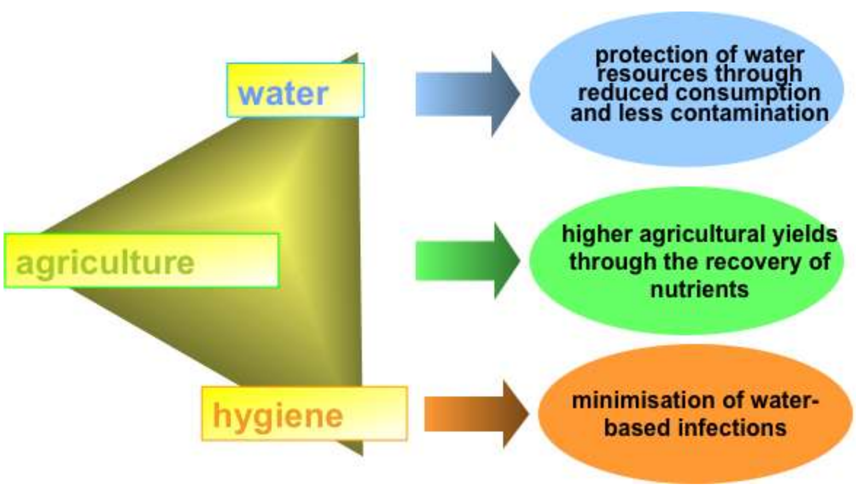

FIGURE 55: ECOSAN TRIPLE WIN (WIENECKE 2011)

The remainder of Appendix L describes different dry sanitation options in detail.

Urinary Diversion System:

A Urinary Diversion System (UDS) is a dry sanitation method in which the urine is diverted away from other waste. The urine is usually directed back into the ground because urine contains natural nutrients such as nitrogen, phosphorus, and potassium, promoting the growth of plants. The dried feces can be used for a similar purpose and will increase the water retention in the soil. The byproduct is an excellent source of energy. Both urine and dried feces can be used as feed for a biogas digester to create gas or electricity. This system is considered cost effective and estimated to be about N$ 1,000.

Mariental is the first site in Namibia to install a UDS toilet. The design was manufactured in Germany and imported to Namibia. Two UDS toilets were installed by a German UDS manufacturer and funded by the GTZ. Figure 56A depicts the basic design of the UDS. The builders first dug a pit to provide space for the composting bag and urine bottle. A urine bottle is not necessary; alternatively piping can be installed to direct urine to water a garden or other purposes. Next a concrete pedestal was built above the pit for placement of the toilet. Inside the toilet bowl is the UDS seen in Figure 56B. The builder then constructed a housing unit around the toilet and a ventilation shaft connected to the pit so that composting material receives airflow. The housing unit should also provide ventilation to increase airflow into the pit and reduce the potential for odors.

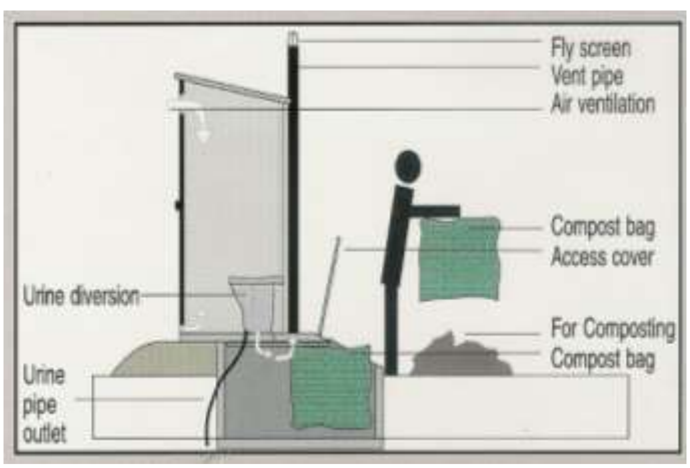

FIGURE 56A AND B: UDS COMPLETE CONSTRUCTION DESIGN AND URINE DIVERSION SYSTEM (WIENECKE 2011)

In order for this system to be sustainable, some maintenance is required. A community member or hired worker should empty the composting bag and urine bottle to prevent overflowing. Occasional cleaning of the toilet will prevent odors and provides appropriate sanitation. An alteration to the design will be the addition of male urinals since the current system requires the male to sit down on the toilet (Wienecke 2008).

Solar Powered:

In addition to the two UDS systems installed in Mariental, two solar-powered units were installed. Compared to the UDS, the solar unit is easier to construct and maintain since there is no pit in the design. The disadvantage of this design lies in the increased cost. The design used in Mariental costs about N$ 7,400. The builder installed a housing unit around a plastic toilet with an internal basket with small holes in the bottom. All waste is collected in the basket. The basket is above a heated base, powered by the solar unit, so that liquid that falls to the bottom of the basket evaporates. To prevent odors the builders installed a solar powered fan to properly aerate the basket.

This system requires minimal maintenance. A designated person in the community should occasionally rake the materials in the basket so that dried and shredded materials will fall into the collection tray below. This same person should regularly empty the collection tray. The frequency of maintenance depends on the number of uses in a given time period. As stated above, the remains can be burned or used for composting purposes. Also the solar unit's battery requires replacement every couple of years (Wienecke 2008). Solar batteries are readily available but are costly to replace.

Otji-Toilet:

The simplest dehydration design is the Otji-toilet. Although this design is simple, this system is just as effective as other sanitation systems. The Clay House Project developed the design of the Otji-toilet in Otjiwarongo, Namibia. See Figure 57 for the design implemented in Aranos. The advantage of using this toilet design in Namibia is that parts are made in Namibia thus importation is not required. The parts for installation are priced as N$ 4,000 plus any labor costs.

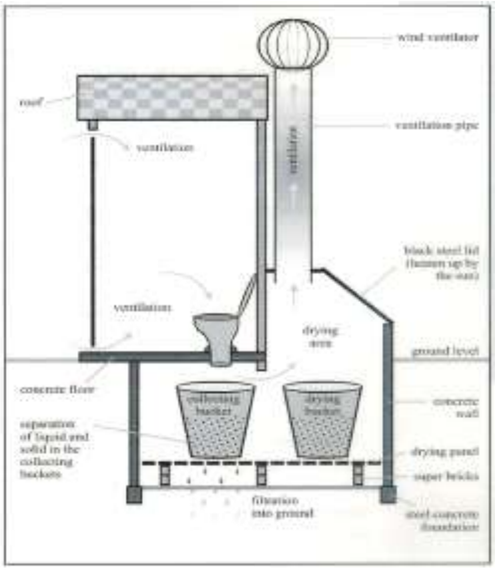

FIGURE 57: OTJI-TOILET (WIENECKE 2011)

A pilot study was conducted in Aranos, Namibia with the Otji-toilet. The Aranos project used local labor and materials to construct the toilet. Beneath the toilet, builders dug a 1.5 meter pit for two cubic meter tanks. A perforated bin sits above a porous panel. All waste resides in the bin, but excess liquid will fall though the porous materials and back into the soil. This is not a contamination concern as very little falls through. A ventilation shaft provides airflow in the chamber to expedite the dehydration process. The pit contains both a collecting bin and a drying bin. A black lid on the backside of the toilet allows for access to the interior portion of the toilet and also helps heat the collecting to bin to assist in the dehydration process. Initially the municipality installed eighteen toilets. Due to the success of the project they later installed forty more toilets.

This system requires minimal maintenance. A member of the community or employee is tasked with switching the collecting bin with the drying bin once the collecting bin is full. The collecting bin then becomes the drying bin. He or she can access the pit of the toilet through the back lid and can conduct this task using a hook or a stick. After approximately four to six months the material in the drying bin should be completely dehydrated. The material in the drying bin can either be burned or used in a biogas digester.

Double Chamber Toilet:

The double chamber toilet is similar in conceptual design to the Otji-Toilet, see Figure 58. This toilet has two chambers however at any point in time only one of the chambers is in use. When the first chamber is full, the toilet is relocated to be above the second chamber. The toilet is light-weight and is moved by hand. Following relocation of the toilet, the hole above the filled chamber is closed with a plug. After several months, the waste has dried and the chamber can be emptied and disposed of similarly to the Otji-toilet. The disadvantage of this approach is the amount of maintenance required to move the toilet to second chamber. The cost of materials and installation is unknown.

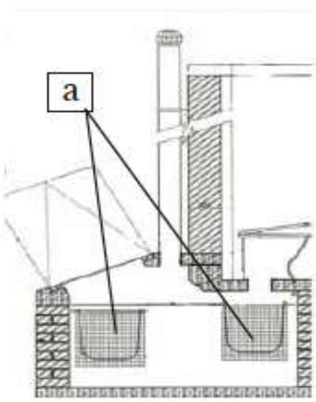

FIGURE 58: DOUBLE CHAMBER TOILET (WIENECKE 2011)

Jo Jo Toilet:

The Jo Jo Toilet is another example of a dehydration toilet. The cost for the materials to make the Jo Jo toilet is around N$ 3,000. The dehydration process in the toilet happens over a period of 25 days. Figure 59 depicts a schematic of the toilet. Waste enters the toilet and goes down a vertical shoot to the beginning of a helical shoot conveyer. Each time the toilet lid is opened or closed a mechanism will rotate the helical shoot, pushing waste further down the shoot. About midway down the conveyer is a ventilation shaft in which air can circulate. By the end of the 25-day process the waste should be odorless and dehydrated. The only maintenance this product requires is the emptying of the collection bag at the end of the shoot. Compared to other dry sanitation products this design is more complex due to the conveyer mechanism. Therefore it has a higher chance of breaking and requiring further repairs.

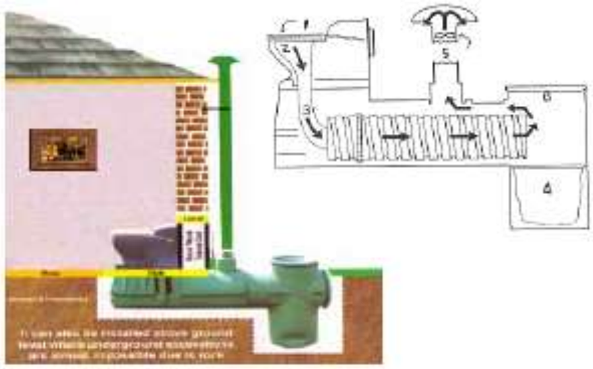

FIGURE 59: JO JO TOILET(WIENECKE 2011)

APENDIX M - OTJI-TOILET QUOTATION

Prices since 01.01.2011

excl Urine-Diversion-

System

units		price/unit	N$
1	Lid box	610.00	610.00
1	ventilation pipe	271.00	271.00
1	Door	561.00	561.00
1	door frame	207.00	207.00
1	steel roof structure	286.00	286.00
1	foundation steel ring	207.00	207.00
15	roof tiles (cool tiles)	6.00	90.00
1	toilet bowl (pit-pot)	546.25	546.25
2	perforated 90l container	225.00	450.00
2	side plates	98.67	197.34
2	dry plates 70 x 70	78.43	156.86
1	floor plate	138.00	138.00
1	silicon, wire, etc.	48.00	48.00
480	Superbricks	2.00	
3	cement bag	80.00	
0.6	Sand m^3	160.00	
5	paint l	58.00	
	Materials		**3,768.45**