Evaluation of Microbial Drinking Water Quality and Related Health Impacts in Thoomba Ka Goliya, Rajasthan, India

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Abstract

Diarrhea is the second leading cause of death world wide among children under the age of five [1]. In rural India, where living conditions are still below poverty line, the sanitation and hygiene facilities along with drinking water quality are often sub optimal which exacerbate the risk of contracting water related diseases such as diarrhea and dysentry. In a village setting such as Thoomba Ka Goliya, which is situated in the Thar desert of the drought prone region of Marwar in Rajasthan, water scarcity is a grave problem due to scanty and erratic rainfall. Hence, the incidences and frequency of contracting diarrhea among these rural communities living within these drought prone and water critical zones is especially exacerbated.

Sand dams are hydraulic retention structures that are built across ephemeral riverbeds in arid and semi arid dryland regions. This ancient technology can store large volumes of rainwater affording ample water supply to the rural people during the long, harsh and dry summers. Furthermore, the quality of water is improved through the process of natural sand filtration. The purpose of this study is to understand the extent to which sand dams can contribute to minimizing the risk of contracting diarrhea and improving health.

For this purpose, a quantitative method in the form of a water analysis has been employed to test the microbial quality of water from the sand dam. In addition, this has been complemented by a qualitative method which entails conducting household and expert interviews to better understand and clarify the research question. Two approaches have been used in this process: phenomenolgoical and participatory research action.

The results of the research study indicate that since the construction of the sand dam in the village, a significant reduction in the incidences of diarrhea along with improved physical health has been observed among the rural population in the village.

In summary, the study findings have moderately supported the study hypothesis. However, some of the implications of the outcomes also call on further research in the field. This study has paved the way for the need for more advanced quantitative research to be carried out on issues pertinent to the links between the practicality of sand dams and rural health. What is more, it also calls upon strengthening alliances between community leaders, stakeholds, policy makers, NGOs, private public partnerships, small and medium sized enterprises and other concerned government bodies so as to be able to better understand the causes for diarrhea and ill health, which are mutually inclusive. Further, what needs to be factored in is an understanding on how these causes can be prevented and consequently, what remedial measures need to be considered to facilitate this. This includes, but is not limited to, addressing, social issues such as illiteracy, empowering women and fostering building capacity on topics pertinent to health education and health awareness.

List of Abbreviations

JBF – Jal Bhagirathi Foundation

WASH – Water Sanitation and Hygiene

GLR – Ground Level Reservoir

PHED – Public Health and Engineering Department

TBC – Total Bacterial Count

PAR – Participatory Action Research

CFU – Colony Forming Units

TW – Tubewell

HH – Household

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1 Introduction

Human health and the environment are inextricably linked. Water insecurity is one of the gravest challenges faced by millions living in the rural communities in India. The availability and access of clean drinking water are critical issues that most water stressed regions in developing countries are faced with today. The incidences of water related diseases are constantly on the rise as a result thereof.

Diarrhea is the second leading cause of death in the world in children under five years and the third most common cause of childhood mortality in India, responsible for 13% of deaths within the same age group. Even though the number of deaths has declined through the intervention of various vaccination programmes, the proportional mortality attributed to diarrhea remains significantly high [1]. Diarrhea is also known to be the underlying cause for malnutrition in children affecting their mental and somatic health [2]. The cause for endemic diarrhea however, is not explicitly a function of water quality but also its volumetric abundance [3]. Accordingly, the quality of water along with the problems relative to water scarcity need to be considered in order to effectively address diarrhea.

The drylands of Marwar region in western Rajasthan located in the Thar desert in India, is the most densely populated arid land in the world. The word "Marwar" has its roots from the Sanskrit word "Maruwar" which means Land of Death referring to the harsh environment characterized by drought and scanty and erratic rainfall [4]. Consequently, the water availability and supply are unable to meet the water demand of the rural communities in Marwar.

Clean water supply that is free of pathogens such as faecal matter is a key determinant of public health. Water for drinking and domestic purposes are inadequate and the amount of water for sanitation and hygienic practices such as hand washing and bathing are trifling. Diarrhea is therefore, especially exacerbated in these areas. Diarrhea, particularly when persistent, is known to have severe health impacts on young children, the elderly and people with impaired immune systems. It can cause dehydration and malnutrition which could be life threatening [5].

Rainwater is an especially valuable resource in water stressed areas of the world such as Rajasthan, India which is prone to drought and falls in a zone of extreme water scarcity [6]. Due to numerous factors attributed to, inter alia, pollution of ground and surface water, groundwater drawback, increase in demand for water, population projections, rise in land pressure and the daunting implications of climate change and variability, the practice of harvesting rainwater in areas where water is a scarce commodity, is not a need any longer, but a must.

The groundwater dam is a traditional rainwater harvesting tool whose purpose is to capture and store rainwater, thereby, securing its availability through the long dry periods. The stored rainwater is used for irrigation, feeding cattle, domestic purposes and even drinking. The sand accumulated in the dam over a period of time, affords a natural filtration process, whereby water that is abstracted from this system is clean and free from pathogens.

The geographical focus of this thesis is a small village by the name of Thoomba Ka Goliya located in Marwar of the Jalore district in the sate of Rajasthan in India. Thoomba Ka Goliya has a population of 704 people is located in the Jalore district of Marwar, Rajasthan. The Marwar region is subject to extreme temperatures with exceptionally low annual rainfall ranging from 100 500mm [6]. Marwar, located in the Thar desert one the most densely populated arid zones in the world and has had the worst water crisis particulary relative to drinking water [7]. After the construction of a sand dam in the village in March 2014, ca. 100 wells have been recharged as a result of which the quality of water has significantly improved. Despite this, water scarcity is still a challenge in these regions. Furthermore, the sanitation and hygiene facilities in the village are sub par which only exacerbate the freqeuncy and degree of contracting water related diseases, particularly diarrhea.

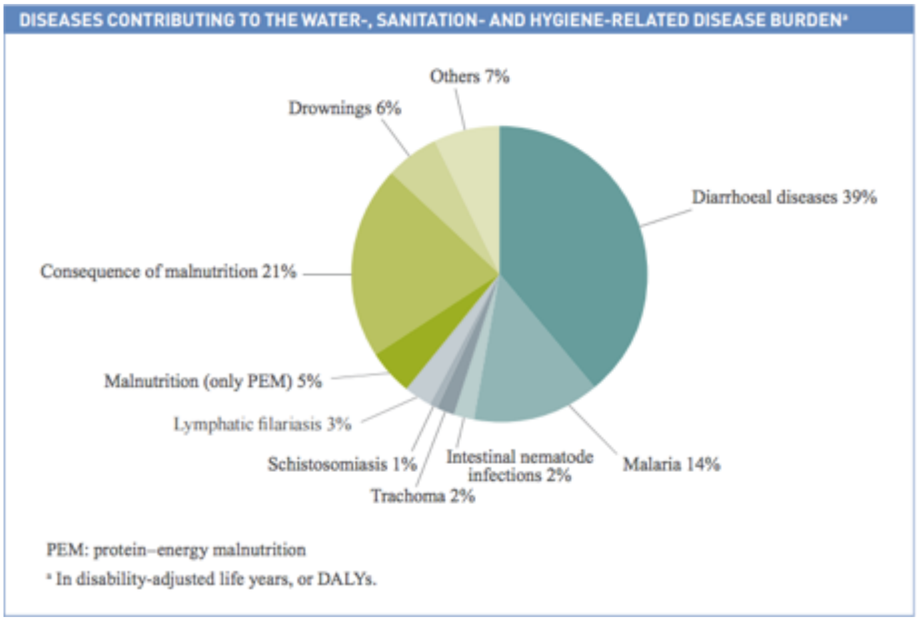
This master thesis attempts to explore the current situation relative to the microbial water quality from the sand dam at Thoomba Ka Goliya and to what extent this may have impacted the lives and health of the locals using this water for drinking and domestic purposes. This has been carried out through a water analysis as well as expert and household interviews, which have been elaborately explained in the "Methodology" section of this thesis.

2 Background

2.1 Water and health

World wide, approximately 1.8 billion people have access to only a drinking water source that is contaminated with faeces. Diseases like diarrhea, dysentry, polio, hepatitis A, cholera and typhoid are all associated with poor sanitation practices and contaminated water. Each year, over 500.000 deaths are attributed to diarrhea from drinking contaminated water [8]. According to the WHO "Diseases related to contamination of drinking water constitute a major burden on human health. Interventions to improve the quality of drinking water provide significant benefits to health." [9 p2]

Around 10 % of the total global burden of diseases could be prevented by improving the quality of drinking water along with sanitation and hygiene [10 p7]. Some of the other Water Sanitation and Hygiene (WASH) related diseases which are known to have deleterious effects on human health are malnutrition, which is generally attributed to repeated episodes of diarrhea, intestinal nematode infections, lymphatic filariasis, schistosomiasis, trachoma, malaria, drowning and other quantifiable diseases [10]. WHO quantifies burden of disease using the disability adjusted life years (DALYs) or quality adjusted life years (QALYs). These units afford a metric system to quantify the life years lost owing to disease. Diarrheal diseases account for the highest percentage i.e. almost 40%, relative to burden of diseases (see figure 1).

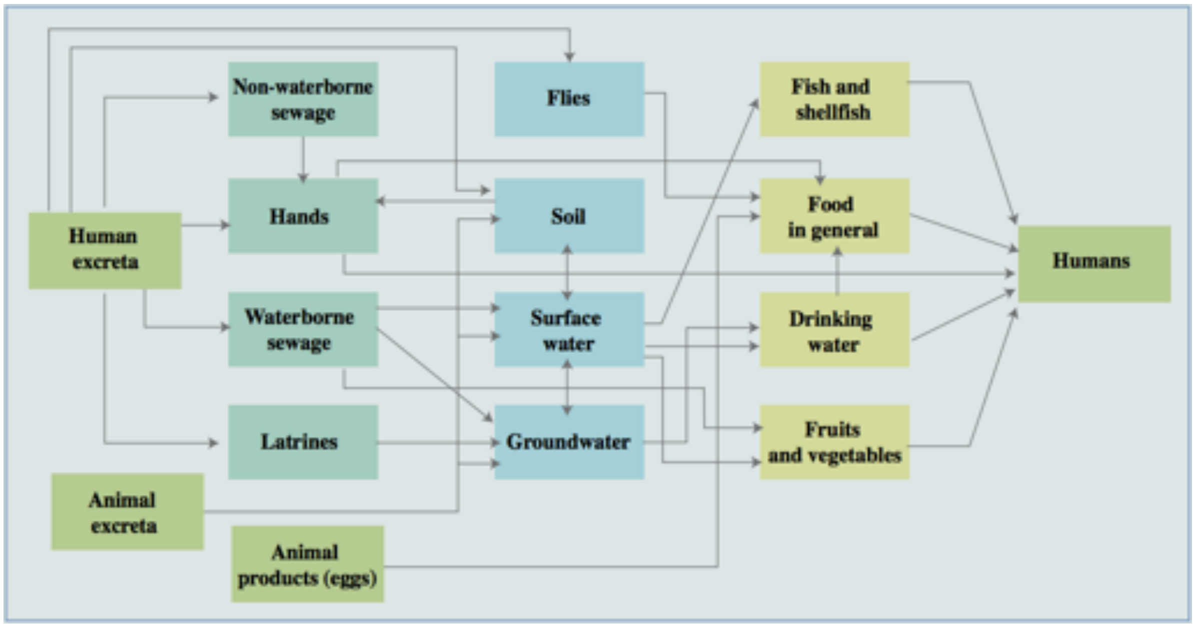


F gure 1: WASH re ated d sease burden. [10 p11]

2.2 Diarrhea

The WHO defines diarrhea as “the passage of loose or liquid stools more frequently than is normal for the individual. It is primarily a symptom of gastrointestinal infection. Depending on the type of infection, the diarrhea may be watery (for example in cholera) or passed with blood (in dysentery for example)” [5]. It lasts several days and depletes the body of essential fluids and salts that are necessary to survive. People who die from diarrhea, actually die from dehydration due to loss of essential fluids from the body.

The cause of diarrhea is due to an infection in the gastrointestinal tract caused by a host of bacteria, viruses and parasitic organisms, which are mostly spread by water that is contaminated with human or animal excreta (including birds). These organisms can be transmitted through water, food, from person to person or poor hygiene and sanitation practices [5]. Figure 2 depicts the various transmission paths of how faeces can come into contact with food and drinking water consumed by humans.



F gure 2: Faeca -ora transm ss on pathways [10 p7]

Diarrheal infections are exacerbated in water stressed areas where there is a dearth of water for healthy sanitation practices and clean water for drinking and cooking. In developing countries, the two most common microbes causing diarrhea are Rotavirus and *Escherichia Coli*. [10]

This thesis focuses on evaluating the microbial quality of water. Rapid tests for analysing water have been conducted on site to check for presence and level of colony counts of bacteria through the use of dipslides. The procedure of the tests and explanation for why specifically these parameters have been used as indicators has been explained in the methodology section.

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2.3 Point-sources of drinking water

A direct correlation exists between diarrheal health risks and the point source of drinking water [11 p8]. According to the Joint Monitoring Programme for Water Supply, an improved drinking water source is defined as one that is protected from outside contamination, in particular, from faecal matter [11]. Although access to an improved water supply does not unequivocally imply that it is free from contaminants and therefore, suitable for domestic purposes or drinking. But a shift of water supply from an unimproved to an improved source reflects a proportional reduction in the risks associated with diarrhea [11].

Thoomba Ka Goliya has an **improved supply of drinking water**. Although the households do not have taps, water for drinking and cooking is collected from the village GLR (see figure 10 for image of GLR) which now, after construction of the sand dam has a continuous supply of running water througout the year. This GLR is walking distance from every household in the village. Even though the water may be free of pathogens at the source, factors such as unclean utensils for fetching water, storage of water for long periods of time, unhygienic surroundings where the water is stored and other unsanitary practices while handling water may allow entry of pathogens leading to the usage of contaminated water.

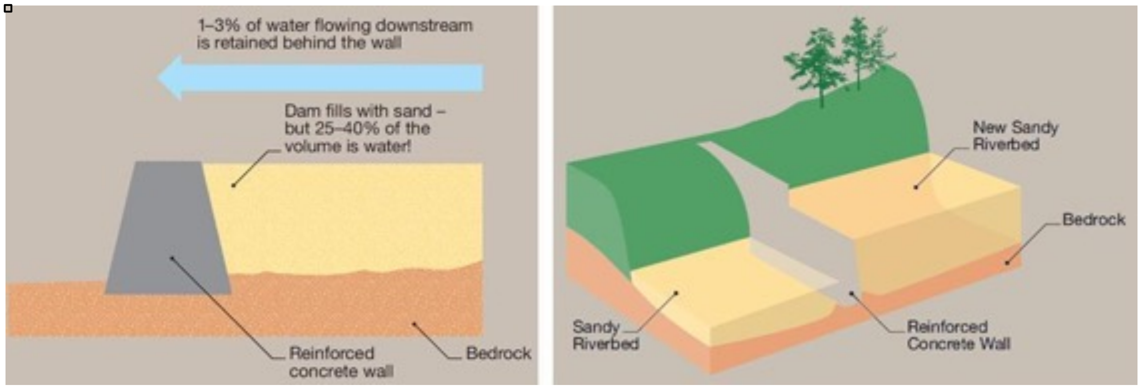
2.4 Groundwater dams

Sand dams and subsurface dams are both clustered under the umbrella term known as groundwater dams. Both these dams store rainwater under the ground.

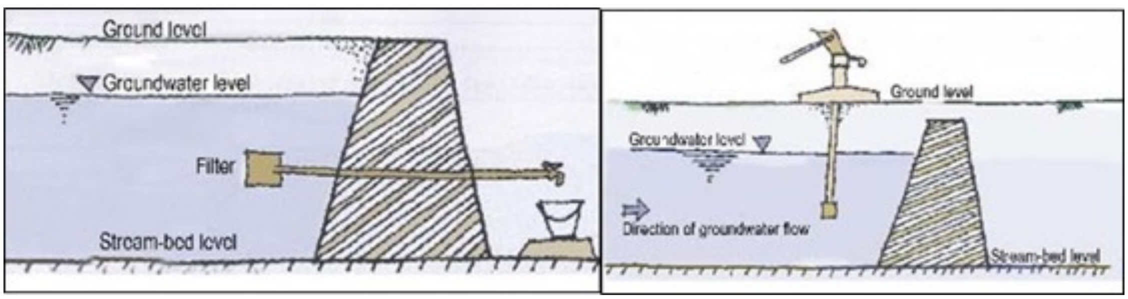
A sand dam (see figure 3), also commonly referred to as sand storage dam, is a hydraulic retention structure. It is built above the ground and into the riverbed of an ephemeral river. The sand accumulates upstream of the dam during the rainy season, with the result that additional groundwater storage capacity is created as water is stored within the pores of the sand.

Subsurface dams (see figure 4) on the other hand block the groundwater flow of an already existing aquifer and stores water below the ground level. It is built completely below the ground and is visible as a plain river bed when viewed from the surface. However, some of the disadvantages of subsurface dams are that they may obstruct natural groundwater flow and as a result exhaust groundwater from the downstream side of the dam. [12]

Sand dams and subsurface dams are similar technologies with the common purpose of storing large volumes of water to compensate for the long dry periods in arid and semi arid regions across the globe such as sub Saharan Africa and Rajasthan, India. A sand storage dam, because it is built over the surface is generally able to store larger volumes of water (with proper siting over 6000 m^3 is possible [12]). 25 – 40% of the volume of the dam is rainwater. The best sites for the construction of such dams are where the soil comprises of sand and gravel, with either rock or a clay (an impermeable) layer at the bottom so that there exists a medium that does not allow water to seep or percolate through it.



F gure 3: Left - Schemat c cross-sect on of a sand dam. R ght - Sand accumu ates unt the dam s comp ete y fu of sand up to the sp way (.e. the he ght of the dam). [12]



F gure 4 :Left - Ou tet p pe w th tap. R ght - Cross sect on of a subsurface dam w th a hand pump for water extract on. [12]

The technology of sand dams dates back to 9000 B.C [12]. Sand dams are deemed a sustainable rainwater harvesting solution in many arid and semi arid regions in sub Saharan Africa. The Guardian quoted “Sand dams voted best water solution in water crisis debate” [13]. According to the pioneers and expert builders of sand dams across the globe namely Excellent Development, sand dams are one of the most cost effective methods of conserving rainwater. Some of the factors relative to sustainability of groundwater dams are:

Economical

Excellent Development is an organisation that has established itself as expert builders of sand dams in sub Saharan Africa and Rajasthan. It has also supported buidling the sand dam in Thoomba Ka Goliya. According to Excellent Development, sand dams are cheap and easy to build. They have a life span of about fifty years and are able to store huge volumes of water that help bridge the water demand through the long dry season and hence securing enough food throughout the year. In addition, through community input and participation in building the sand dams, the concept of sustainability is reinforced since the communities are the owner and have partake in its maintainance. [14]

Ecological

Through a natural aquifer recharge of rainwater, the water table rises and reverses desertification. This increases the land fertility all around the area of the dam, affording higher crop yields and also increases biodiversity. In addition, through increased growth of flora, carbon emissions are reduced which in turn helps mitigate climate change. [14]

Technology

Since the sand reservoir in the dam is covered with sand, the water is protected against evaporation and contamination. Natural sand filtration of water is afforded by the sand dam which yields pathogen free water which is potable. Clean water quality is known to minimize diarrheal diseases and improve helath. Although the design is simple and inexpensive, it still requires expert technical assisstance, since there are several factors such as gradient, relative to the location, of where the dam can be built. In addition, parameters such as an impermeable layer of clay on the must be taken into account while building the dam. [14]

Social

Through increased crop productivity owing to increased water availability from the sand dams, farmers have more income. This income supports education and literacy among the communities. Of all the states in India, Rajasthan has one of the lowest literacy rates in the states among males and females with 67.06% [14 p110]whereas amongst females, the state ranks last in all of India with 52.66% [14 p111]. With higher earnings, parents can afford to send thier children to school. It also enhances the social connectedness among the communities, which is a key health determinant, since less time is spent in walking hours to collect water. The time can now be spent on recreational activities.

2.5 The Jal Bhagirathi Foundation (JBF)

Thoomba Ka Goliya is situated within the Thar desert in Marwar. In order to address the severe water crisis in the Thar Desert, stakeholders from the different regions in the Thar mandated the formation of the JBF for this purpose. As a consequence, the JBF was formed as a public trust 2002 in Jodhpur, Rajasthan. Their mission is to alleviate water scarcity to provide the rural communities in Marwar with adequate drinking water. Their focus is on leveraging traditional knowledge and using appropriate cost effective technology to harness water. In addition, they are also committed to promoting education and capacity building in the region though networking and advocacy. [15]

2.6 Sand dam at Thoomba ka Goliya

The sand dam at Thoomba Ka Goliya is a community owned dam. The “Jal Sabha” or Water Users´Association is a village level forum established to discuss issues and problems in the villages related to water. It also then seeks solutions towards resolving these challenges and asserting prioritites. The “Jal Parishad” or the “Water Forum” is a higher body and a division level set up. It comprises of relevant stakeholders such as water experts from diverse resource institutions, members from the Jal sabha and nominated members by the JBF. This body is responsible for reviewing and sanctioning projects and proposals submitted by the Jal Sabhas.

F gure 5: Memor a rock w th on the s de of the sand dam w th symbo s of the donors and parnters nvo ved n the project.

The building of the sand dam at Thoomba ka Goliya has been one such project which was granted sanctions with the goal of contributing towards resolving some of the water challenges faced by the rurals living there. The sand dam was completed on the 8th of March 2014 in collaboration with JBF, Excellent Development and Africa Sand Dam Foundation. It has also partly been funded by the European Union. The total grant received for this project was 17.77.621 Rupees of which 14.82.505 Rupees was donated by the European Union and 2.95.036 Rupees was the amount received from community contributions. The sand dam is located at a distance of approximately 2.5 kms from the Thoomba ka Goliya village (see figure 9 for screenshot of Thoomba ka Goliya on Google earth). The GPS coordinates of the exact location of the sand dam and the corresponding distances of the sand dam from the two tubewells from where samples for the water analysis were taken, as well as the GLR can be seen in Table 2.

The dimensions of the sand dam located at Thoomba ka Goliya are as follows:

The length of the wall is 51 meters, the width is ca. 1.05 m and the depth of the wall below ground level measures to 6.2 meters whereas the height above is 0.6 meters. One can also see a step built in the wall on either side which is the crest. The height of this is 0.5 meters. For a picture of the Thoomba Ka Goliya sand dam, see figure 7 below. More detailed and precise dimensions of the sand dam can be viewed in the technical drawings which are attached in the appendix section of this thesis.

F gure 6: P cture of sand dam taken from the downstream s de at Thoomba Ka Go ya. Image taken by author 22.03.2017.

F gure 7: Screenshot of Thoobma Ka Go ya sand dam and correspond ng d stances from the tubewe s, ma n GLR and the Thoomba ka Go ya v   age. Taken on Goog e Earth Pro, Apr   2017.

Way-point	GPS Coordinate	Approx. distance from dam in meters
Village Thoomba Ka Goliya	N 25 35 5.33 E 72 48 52.66	2500
Sand Dam Location	N25°34'36.26" E72°50'11.11"	0
22 (1st Tube Well)	N 25 34.709 E 72 50.402	400
23 (2nd Tube Well)	N 25 34.690 E 72 50.272	200
24 (Main GLR)	N 25 34.580 E 72 50.163	70

Tab e 1: GPS co-ord nates and approx mate d stances of tube we s, GLR and v   age from sand dam. Created by the author 14.03.2017

2.7 Water supply and distribution network in Thoomba Ka Goliya

Since the construction of this community owned dam, the returns have been tremendous not just financially but also in terms of health. The sand dam built in the village was initiated as a pilot project primarily to enhance irrigation, contributing to food security and alleviating poverty. However, after the success of this dam, several dams have been built in and around the Jalore district in Marwar.

F gure 8: Tubewe 2 – WayPo nt 23. Thoomba Ka Go ya. Water techn c an open ng tubewe for co ect on of water samp e. Image taken by the author 22.03.2017

According to the local water technician from the Public Health and Engineering Department (PHED). PHED is the government water utility supplying water to the entire state of Rajasthan. There exist over 100 tubewells in the entire village. A tubewell (see figure 8) is similar to a water well, however, in the case of a tubewell, as the name suggests, a stainless steel tube or pipe with a diameter ranging from approx. 10 20 cm is bored into the earth to the depth of the water table to abstract water. In the village of Thoomba Ka Goliya, the depth of the tubewells vary, but most of them are within the range between 200 300 ft. The deeper tubewells are sometimes also referred to as “borewells”. An electric pump is generally used to lift the water that is commonly used for irrigation.

The primary source of water in the village is underground water that is drawn from various tubewells. According to the water technician from the PHED, since the construction of the sand dam, the water table has risen significantly, affording a greater availability of water around the area. However, the exact increase in the volume of water has not been measured up until now. The direct benefits have been reaped by the riparian households living closest to the dam, i.e. at a distance of approx. 200 – 300 m. The peripheral impacts of the dam however, have been perceived upto a radial distance of maximum 2.5 to 3 kilometers from the sand dam. According to anecdotal evidence provided by the villagers and the key informants, not only has the volumetric abundance of water around the area notably increased, but further, the quality of water has drastically improved. This of course has been attributed to the construction of the sand dam that is able to capture and store water within the pores of the sand affording a continuous supply of water through the long dry spells.

There exist a total of three tubewells around the sand dam that connect to the main or central GLR (see figure 9 for an image of the main/ central GLR). However, water samples were collected only from two tubewells since the third one was defunct and has therefore, also, not been pinned on the Google Earth map screenshot of the Thoomba ka Goliya map (see figure 7).

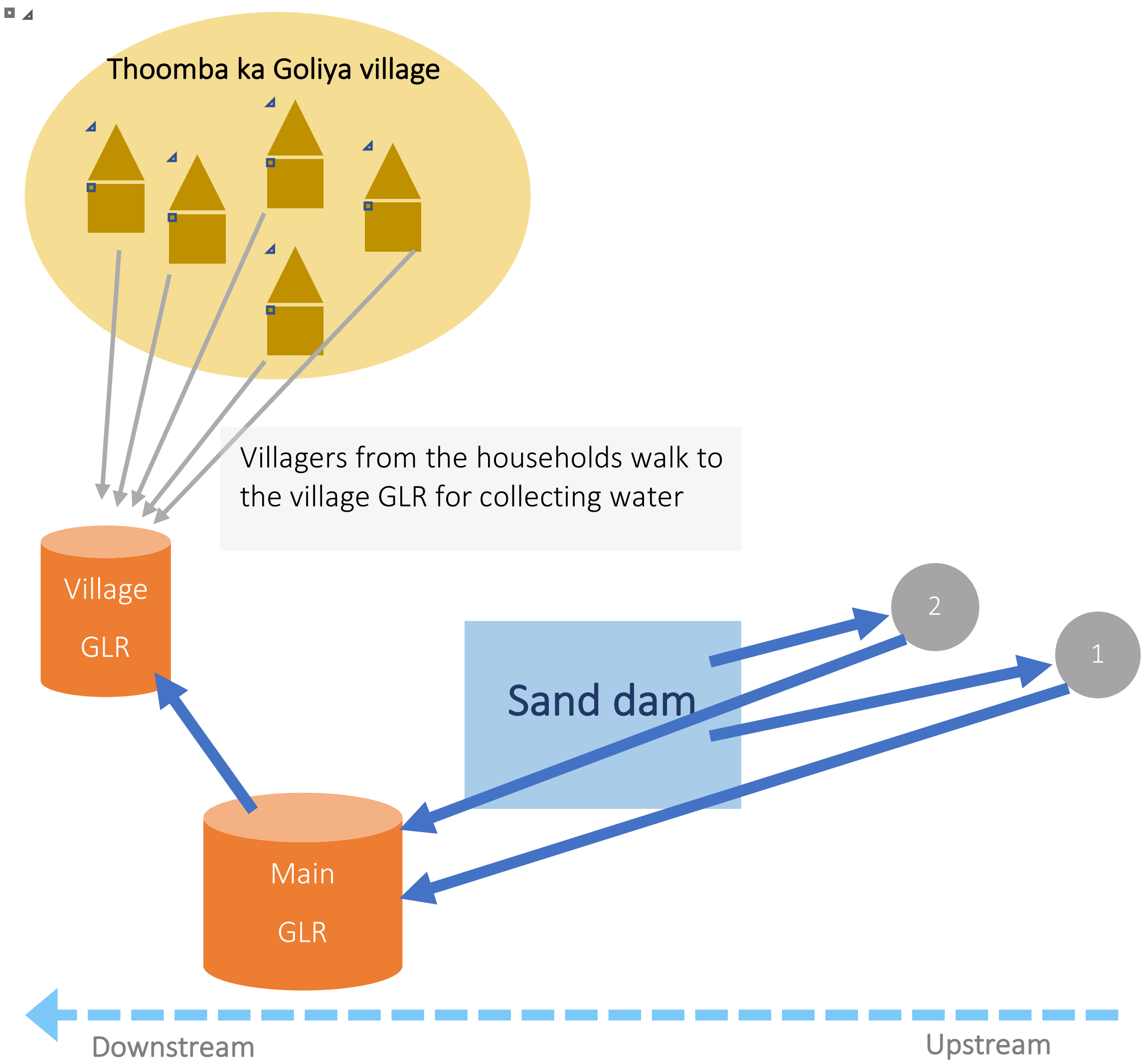
F gure 9: Ma n/ Centra GLR Thoomba Ka Go ya ocated near sand dam. Image taken by the author 22.03.2017.

The main GLR in turn supplies water to the entire village and around, carrying water to the smaller village GLRs (see figure 10 for an image of a village GLR). Thoomba Ka Goliya village, located at a distance of approximately 2.5 km from the sand dam has also reaped the benefits of the dam its since the underground pipes from the village GLR are connected to the main GLR situated near the sand dam (see figure 11 for water supply and distribution network from the sand dam). The water from the village GLR is used primarily for drinking and cooking. Essentially, the water collected in the main GLR is a mixture of underground water and rainwater i.e. stored water from the sand dam. The capacities of the main and village GLRs are 160 and 40m^3 resepectively (see table 2).

F gure 10: Image of v age GLR at Thoomba ka Go ya. Image taken by the author 22.03.2017.

GLR	Approx. capacity in m^3	Approx. distance in meters From sand dam
Central/Main GLR	160	70
Village GLR	40	2500

Tab e 2: Capac ty and d stance of GLRs from sand dam. Created by the author 12.04.2017.



F gure 11: I ustrat on of the water p pe ne supp y and d str but on network from the sand dam n Thoomba Ka Go ya. Created by the author 12.06.2017.

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Direction of pipline flow of water

Tubewells 1 and 2

3 Aims and Objectives

The goal of this research is to contribute to a higher understanding of the extent to which, groundwater dams may lead to improved health and minimized incidences of diarrhea, both of which are mutually inclusive, in Thoomba ka Goliya, Rajasthan.

The use of groundwater dams maybe seen as a sustainable solution for addressing water scarcity in Marwar, affording a higher quantity of water throughout the year due to the large storage capacity of sand dams, for healthier sanitation practices as well as improved microbial quality of drinking water among rural communities. The latter occurs due to the natural mechanisms involved in subsurface filtration of sand afforded by the sand dam. Furthermore, groundwater dams could be seen as a potential improved source of drinking water that could contribute to minimizing diarrheal risk and thereby improving health among the rural communities in Marwar.

In order to be able to quantify, to a certain degree, the quality of drinking water from the sand dam in Thoomba ka Goliya, a total of eleven tests have been carried out. In addition, to assess the health of the household relative to the quality of water, an expert interview with the local naturopath (Ayurvedic doctor) and seven household interviews were carried out.

Expert opinions and qualitative household interviews have been complemented with quantitative data i.e. a water analysis to augment the scientific rigour of the study. Patient surveys could not be carried out since no medical records relative to diarrhea or any other illness exist in any of the primary health care centres or commnity health centres situated in and near to the village. Hence, qualitative data has been used in the form of interviews to evaluate if the lives of the locals have improved in terms of health and wellbeing.

3.1 Water analysis

As aforementioned, a total of eleven tests were carried out. Ten water tests were conducted in situ, to measure the colonies of microbial pathogens present in water. Of the ten samples, three water samples were taken different point sources which referred to as control points, from the village drinking water system. These were from the main GLR and the two connecting tubewells. The other seven samples were taken from different households in the village where also interviews with the families were conducted.

In addition, in order to evaluate the microbial quality of water purely from the sand dam, a hole was excavated to abstract water. However, since it was the dry season, the dam did not yield any water at that depth. The sediment was laden with moisture and therefore, a sample of this was taken to check for microbial pathogens. This test was not carried out in situ.

3.2 Qualitative interviews

3.2.1 Household interviews

Seven household interviews were carried out with the locals living close to the sand dam in Thoomba ka Goliya. A phenomenological approach with participatory research action has been used for data collection and analysis.

3.2.2 Expert interview

Further, an expert interview has been carried out with the Ayurvedic doctor at the nearest local health centre in the nearby village in "Bhadrajun" which is approximately four kilometers from

Thoomba Ka Goliya. In principle, a general physician (allopathic doctor) and a naturopathic doctor are available for attending to the patients and treating their ailments in said village. However, on the day of the interview, only the ayurvedic doctor was present. It should be noted that in India, Ayurveda is an approved form of indigenous medicine by the ministry of AYUSH (The Department of Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homoeopathy). Its science and practice are also well accepted in India.[16]

As previously stated, since there were no available medical records of patients at the primary health care centres or nearby hospitals, it was challenging to acquire quantative data relative to the number of patients contracting diarrheal diseases. Hence, an expert interview with the local doctor was alternatively considered.

4 Methodology

The following sections describe in detail the methods that have been used to materialise the study outcomes. In order to be able to quantify to what extent groundwater dams may contribute to a minimised risk of diarrheal diseaes and consequently lead to improved rural health, the intial steps taken were finding suitable methods that would best answer the research question. Many hours of research were put this. In addition, conscious efforts were made towards the methods not only being in alignment with each other and the rest of the thesis, but also in a way that they eventually converge toward answering the common research question. The selected methods endeavour to afford a semblence of **methodological congruency**. The concept of methodological congruency, advanced by Morse and Richards illuminates the interconnectedness and interrelatedness of all the components encompassed in the research. I.e. the research questions, the objectives and the methods used appear as one cohesive whole rather than incoherent pieces of data or fragemented parts [17, p.185].

In the light of the answering the research question, several factors relative to procurement and availability of data were taken into account. These included analyses of the microbial quality of water abstracted from the groundwater dam and as well as stored drinking water from the households. This was to determine and verify the microbial safety and quality of the water and to check if it is deemed fit for drinking as per the WHO guidelines for drinking water quality. Due to the unavailability of any form of quantitaive data regarding the number of diarrheal cases in the village resulting from the water, this research calls on an approach that is effectively able to measure or at best estimate the cases of diarrhea and health conditions of the people before and after the construction and the sand dam. Through logical inference, depending on the frequency of diarrheal cases **before** and **after** the construction of the dam, one may deduce whether this is the result of improved microbial water quality and/or increased water quantity along with other WASH related practices.

Also, what has been factored in are that the selected methods befit the characteristics of the phenomena under study, whilst affording a systematic means of answering the research question at hand. Hence, a qualitative study in the form of household interviews and an expert interview has also been included as part of the research methodology. This would incorporate part of the solution to the research question in the way that it would provide a means of understanding the lives and health conditions of the rural people at Thoomba Ka Goliya. Since diarrhea does not result exclusively from **water** but also stems from **food** and **unsanitary** and **unhygenic living environment**, It would also help provide more detail to better understand the other sources of possible microbial contamination affecting health and causing diarrhea.

Mixed methods is the broader term used to describe qualitative and quantitative studies used in a research area, as has been done in the passage above where these methods have been used to answer the research question. According to Cresswell, it is **an emerging research approach** in the social and health sciences that involves combining both **statistical trends** and **stories** to study human and social problems [18]. The fundamental assumption here is that the investigator combines quantitative evidence along with qualitative data in order to provide a better and clearer understanding of the research problem than just one by itself.

Similarly, in the context of this research, the stories derived from two qualitative theoretical models, namely, **phenomenological and participatory action research approach** (qualitative) along with a water anaysis (quantitative) have been used together not so much to supplement or augment the quantitative data, but more, each method in a way has been used to complement the other in order to provide a greater understanding of the problem and hence arrive at appropriate and potential solutions for the issues that will be identified. It affords more details, anecdotes, variation and different perspectives to the given problem. Mixed methods also presents a means by which the research problems are negated by each of the research methods used. Quantitative data may not always be valid while qualitative data may not always reliable. Hence, when using mixed methods, the outcomes of the methods present with reliable and valid data, ensuring that the results are thorough and accurate.

The first method describes the process of the water analysis to check for presence of microbes. Information regarding where and how the analysis has been carried out has also been mentioned in the following section below. The second method used is a qualitative household survey as well as an expert interview.

Although the methodology used for this thesis did not present with any major challenges during the data collection phase, there were certain events that deviated from the original thesis proposal which have been explained in the following sections.

4.1 Method 1 - Water analysis

To facilitate the process of sampling during the water analysis, three additional people apart from the researcher were present:

- Water technician from the PHED Mr. Kapoora Ramji
- Member of the rural water committee at Thoomba Ka Goliya, who is also the key informant and field coordinator – Mr. Mahavirsinghji
- Engineer and expert of sand dams from JBF, interpreter and field coordinator – Mr. Mohit Kumar

Before the field trip to Thoomba Ka Goliya, contacts were established with JBF who had built the groundwater dam. JBF inturn assigned the key informant to do a process of purposeful sampling for the water analysis. This comprised of identifying and then purposefully selecting 12 households in the area that had a direct pipeline connection to the main GLR where the groundwater dam was located. This was successfully done by the key informant, however, a day before the field trip, a demise had taken place in the village and most of the village memebers were obliged to attend the funeral. Consequently, this research afforded only 7 water samples taken from the households, 2 water samples from the tubewells that are closest to the sand dam and 1 water sample from the main GLR. In addition, one sample of the sediment was also taken. The analysis for the presence of microbial pathogens for the sediment sample however was carried out in a laboratory. The procedures used for sampling have been illuminated below in the following sections of this document.

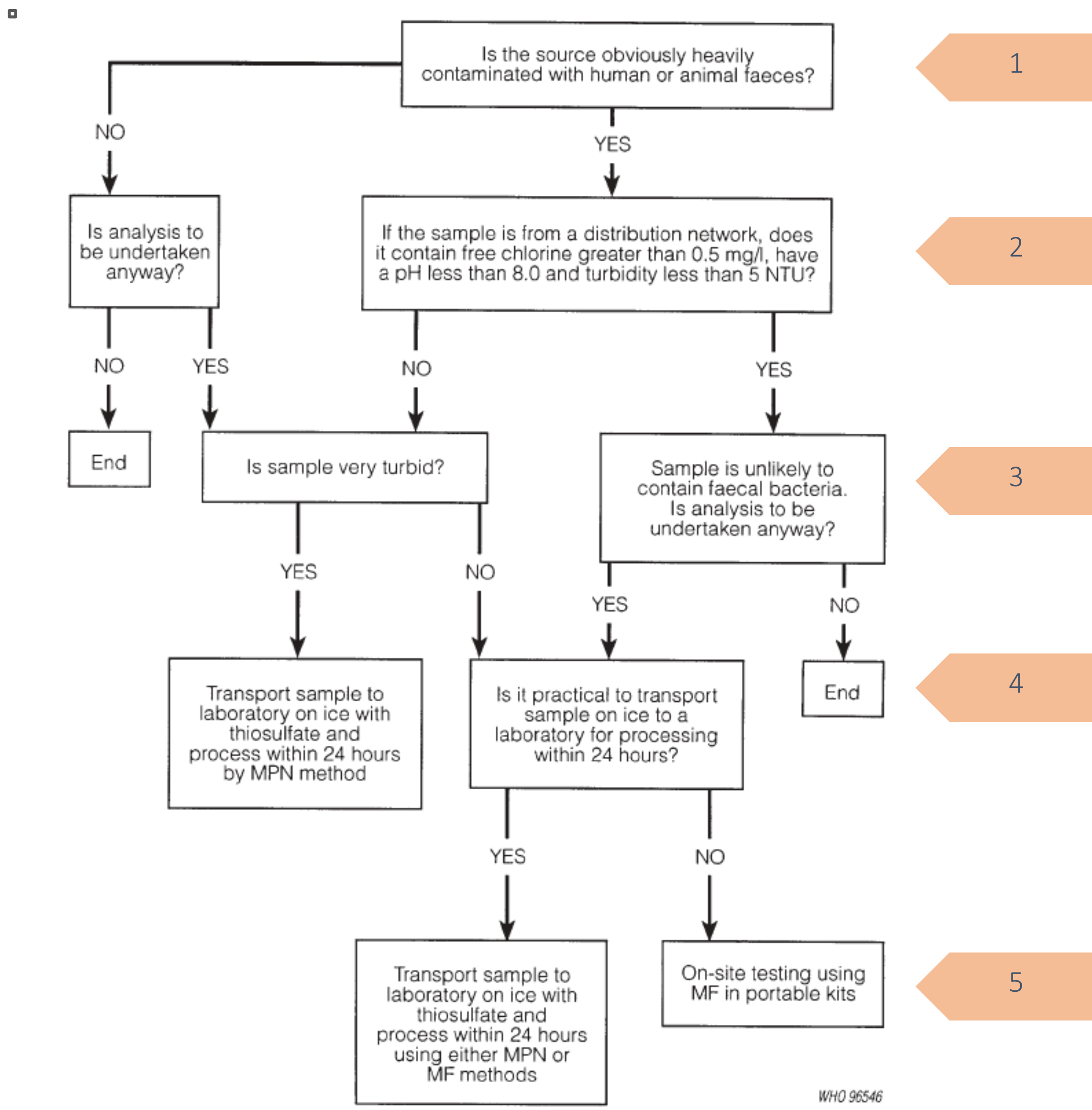
4.1.1 Materials and Methods

Rapid tests or on site tests were used in the field to to determine the quantity (colonies) of microbial pathogens present in the water. For each of the analyses conducted, one test was carried out to check for the presence of all speicies of aerobic bacteria via TBC (total bacterial count/ml) and the second was carried out specifically to measure the colonies of *E. coli* (*E. coli*/ ml), respectively. As aforementioned, the analysis for the sediment however, was carried out in a laboratory in Ahmedabad, Gujarat (approx. 8 hours south from Thoomba ka Goliya).

As per the guidelines for drinking water quality by the WHO, the main analytical methods used to isolate indicator organisms are membrane filtration (MF), multiple tube method (MT) and presence absence tests [19 p60   p66]. The former two tests require the use of incubators and other equipment which is less cost effective as opposed to the latter presence absence tests. However presence absence tests, as the name suggests, are only used to test for the presence or absence of the organism sought. These are not quantitative tests and should in principle be used primarily in those areas where the expected results test negative for microbes. Since India is a country where the presence of microbial pathogens in water is common, it is not recommended to use this technology for a water analysis. Therefore, such tests are rendered inadequate especially in rural areas where faecal contamination is common.

However, there exists other methods or technologies which have not been mentioned in the WHO guidelines that are also now commonly used to test water in rural areas. For example, dipslides or dipsticks are a slightly more technologically, sophisticated and improved versions of the presence absence tests since they can measure the degree of contamination by either counting the number of colonies that appear on the slide or by measuring the density of colonies formed by comparing the density of the formed colonies on the slides with a density chart provided with the sampling kit. For this thesis, the water tests have been carried out on site in the natural setting and the dipslide technology has been used. The details of the product technology used for this analysis has been clearly elucidated in section 4.1.3 where facts relative to the quality management systems and certifications have been mentioned.

It should also be mentioned that although one of the factors that affected the choice for selection of this technology was the cost, a serious cost benefit analysis was considered wherein the costs of the products versus the reliability of the tests were weighed. In addition, a decision making algorithm (see figure 12) as per recommendations by the WHO was also factored in and proved helpful in arriving at a decision for the choice of the most appropriate test kit to carry out the water analysis. Although the algorithm has not been used one to one and at various steps of the network, certain assumptions needed to be made since at this point of time during in the research, there was not enough information available regarding the sepcific questions in the boxes.



F gure 12: WHO dec s on-mak ng network for se ect on of method of water ana ys s [19 p64]. Adapted by the author to nd cate steps n the sequence.

At step 1, the obvious response to the question "is the source obviously heavily contaminated?" was "yes". At step 2, "If the sample is from a distribution network, does it contain free chlorine greater than 0.5mg/l, have a pH less than 8.0, and turbidity less than 5 NTU?", the assumed response for this was "yes" because the only information made available by the key informant over the phone was that the water was potable. At step 3 and step 4 the responses were “yes” and “no” respectively. At step 5, the outcome was “On site testing using Membrane Filtration method in portable kits”.

The costs beared for all the activities relative to this thesis were private. No financial support or grant was received from any organisation or individual. Costs incurred during the process of data collection included:

- Transportation from Jaipur (Rajasthan) – Thoomba Ka Goliya – Ahmedabad (Gujarat)
- Accomodation
- Food
- Equipment (Rapid bacterial test kit) to carry out water analysis

In the case of membrane filtration, through desktop research, it was found that it is not the kits per se that are expensive, but more the incubators in which the analytes need to be stored after sampling. As a result of all the above mentioned factors, the best alternative and the most feasaible choice of equipment for the conducting the water analysis was the the rapid bacterial testkit with dipslides produced by Rakiro Biotech Systems Pvt. Ltd.

4.1.2 Microbial Parameters

According to the WHO, the greatest public health risks relative to microbes in water are associated with ingestion of water that is contaminated with faeces from humans or animals (including birds). Human and animal excreta can be a source of pathogenic bacteria, viruses, protozoa and helminths. [9]

Figure 13 depicts cattle walking around the sand dam which is indicative of the possibilty of faecal droppings around the dam. Animal faecal droppings can be seen in Figure 14. Even though the image depicsts cattle walking downstream of the dam, it is very likely that cattle are also crossing the dam from the upstream side.

F gure 13: Catt e cross ng over the sand dam. Image taken by author 22.03.2017.

F gure 14: An ma faeces on downstream s de of the sand dam. Image taken by author 22.03.2017.

The WHO states " It is not practical, and there are insufficient data to set performance targets for all potentially waterborne pathogens, including bacteria, viruses, protozoa and helminths. A more practical approach is to identify reference pathogens that represent a group of pathogens, taking into account variations, characteristics, behaviours and suceptibilities of each group to different treatment processes. Typically, different **reference pathogens** will be identified to represent bacteria, viruses, protozoa and helminths." [9 p126].

The two Indicator organisms used to check for microbial pathogens are *E. coli* and TBC:

E. coli

E. coli has been used as one of the indicator organisms to test for levels of microbial pathogens. In agreement with the Indian Standard Drinking Water Specification [20] as well as the WHO, *E. coli* or thermotolerant coliform bacteria must not be detectable in any 100 ml sample (see table 3 below) [9]. In addition, if detected, immediate investigative action should be taken wherein a second water sample must be taken in order to determine the exact point source of pollution for remediation [9]. The count of thermotolerant coliforms is also an acceptable alternative indicator, although the most precise indicator of faecal pollution is *E. coli* which has been used in this water analysis [9].

Organisms	Guideline value
All water directly intended for drinking	
E. coli or thermotolerant coliform bacteria[b,c]	Must not be detectable in any 100-ml sample
Treated water entering the distribution system	
E. coli or thermotolerant coliform bacteria[b]	Must not be detectable in any 100-ml sample
Treated water in the distribution system	
E. coli or thermotolerant coliform bacteria[b]	Must not be detectable in any 100-ml sample

[a] Immediate investigative action must be taken if *E. coli* are detected.
[b] Although *E. coli* is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory tests must be carried out. Total coliform bacteria are not acceptable indicators of the sanitary quality of water supplies, particularly in tropical areas, where many bacteria of no sanitary significance occur in almost all untreated supplies.
[c] It is recognized that in the great majority of rural water supplies, especially in developing countries, faecal contamination is widespread. Especially under these conditions, medium-term targets for the progressive improvement of water supplies should be set.

Tab e 3: Taken from WHO Gu de ne va ues for ver f cat on of m crob a qua ty [9]

Total Bacterial Count (TBC)

Another aspect of assessing the quality of water is estimating the total number of bacteria present in the analyte. The total bacterial count is a non specific test that detects a broad range of bacteria that include pathogens, non pathogens and opportunistic pathogens [21]. These include coliforms as well. It is also commonly referred to as Standard Plate Count, Total Aerobic Plate Count or Heterotrophic Plate Count. “This parameter is most commonly used to measure the overall bacteriological quality of drinking water in public water utilities” [21]. It is a general indicator of poor microbial water quality.

According to the USEPA, Health Canada, WHO and several other countries´ guidelines, there are no specified tolerance levels for TBCs. However, an increase in the CFU count above baseline levels may be seen as undesirable [22]. Although the parameter of utmost importance to monitor faecal pollution is *E. coli*, the TBCs is a process indicator which is generally used as a secondary test to measure the efficiency of a distribution system from the quality of raw water. “It can be used in conjunction with monitoring for *E. coli*, total coliforms, turbidity and disinfectant residuals as part of a multi barrier approach to producing safe drinking water” [22].

Characteristic	U.S.	Canadian	EEC	WHO	Australian guideline
Fecal coliform (organisms per 100 ml)	0	0	0	0	0
Coliforms (organisms per 100 ml)	1	10	—	0	0 (95% of samples analyzed), remaining <10 per 100 ml
Total bacteria count (supplied for human consumption)					
37°C	—	—	10 per ml	—	—
22°C	—	—	10 per ml	—	—

Note: — = not specified.

Tab e 4: Taken from Water treatment process: s mp e opt ons, Standards for M crob o og ca Qua ty [23 p22]

In the past, TBCs were used as indicators particularly to measure efficacy of sand filters and in turn, used as indirect indicators for hygienic quality of water and water safety. Even today, they can be used to measure performance of filtration [21, p. 19]. A sudden rise in TBC levels may be indicative of faecal contamination but also suggestive of a change in the quality of raw water or regrowth of bacteria in a distribution system. However, gradual increases overtime is indicative of a decline in the quality of raw water. Further, high TBCs demonstrate conditions for bacterial regrowth which could, inter alia, lead to pipe corrosion, exacerbate slime which in turn could contribute to the water tasting foul and increasing the need for disinfectants. In addition, it could also give rise to the growth of secondary respiratory pathogens like Legionella. In principle, the TBC parameter is used as a marker of the aesthetic quality of water. [21]

In the light of this research study, TBCs have been used as an indicator organism primarily to check for the efficacy of sand filtration of the sand dam and the pipe distribution system. Although the water flowing through the system has not been treated or disinfected at any stage from source to the end user, it is interesting to find out at where in the distribution system, through identification of certain control points, possible contamination occurs. For instance, lower TBC levels at source could indicate effective filtration of water through the sand, however, higher TBC levels farther away from the source could imply contamination stemming from the pipeline system, such as pipe corrosion etc.

4.1.3 Rapid Bacterial Test Kit

Bactaslyde – Dipslides, produced by Rakiro Biotech systems Pvt. Ltd. were used for the tests. Bactaslyde ® dipslides [24] afford microbe detection using a presterilized slide which is coated with a special media on each side which is then used to measure the growth of a variety of bacteria and also yeasts and fungi. With the help of this dual media, two tests were able to be performed simultaneously. One side of the slide was used to measure the TBC and the other, *E. coli.*

Rakiro Biotech Systems Pvt. Ltd. has achieved the ISO 9001:2008 certification which is an international standard relative to quality management systems [25]. The standard affords a framework which efficiently manages the organisation and simultaneously lays a foundation that ensures a philosophy of constant improvement. The assessement is external and on going to ensure an element of sustainability. This can be applicabe to any kind of organisation and is based on 8 quality management principles namely: Customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, fact based decision making, mutually beneficial supplier relations. [25]

In addition, the products of the company have been certified by the State Public Health Laboratory (Pune), Bhabha Atomic Research Centre (BARC), Haffkine Institute for Training, Research and Testing, Italab, Raptakos Brett Test Laboratories and Geo Chem Lab [25].

4.1.4 Usage of dipslides

Slides were removed from the containers only when the samples were ready for testing. Before this, the slides remained closed and packed in their bottles.

4.1.4.1 Storage

The dipslides were purchased on 17th March 2017 and were manufactured on the 1st March 2017. Date of expiry for the products was 6 months from the date of manufacture. Upon purchase of the products and before actual usage, the slides were stored vertically in a cool and dry place.

4.1.4.2 Sampling

For each test, the slides were dipped into the water ensuring that the media surface was completely immersed into the water. For each test, the dipslides were immersed into the liquid for a duration of 25 seconds in a vertical position. The slides were then shaken off for any excess liquid for 3 4 seconds. Subsequently, the slides were put back into the transparent plastic tubes and closed tightly.

The sampling for the water analysis was carried out at 4 different areas:

Sand dam

F gure 15: Farmer excavat ng a ho e n the sand dam at Thoomba Ka Go ya for samp ng. Image taken by the author. 22.03.207

At the source, a hole 2.5 feet deep was excavated on the sand dam. This was approximately at a distance of 13 meters upstream from the centre of the spillway of the dam. The purpose of excavating the hole was to abstract water, to test exclusively for *E. coli.* However, since it was the dry season and consequently had a low water table, no water was to be found. Instead, a sample of moist sediment was taken and tested at a laboratory in Ahmedabad (Gujarat Laboratory, Shahibaug, Ahmedabad, Gujarat) since the field trip equipment consisting of rapid tests was inadequate to test for pathogens on solid surfaces.

In the laboratory, the methods used for testing the colony counts were IS: 5402 2012 for TBC and IS:5887 (P I) – 1976 (Reaff. 2005) for E. *Coli* count respectively. For the former, a horizontal method has been used by counting the number of colonies on the solid medium after anaerobic incubation at 30° C [26]. The principle for this procedure has been exlpained extensively in the Bureau of Indian Standards – Microbiology of food and animal feeding stuffs – Horizontal method for enumeration of micro organisms colony count technique at 30°C [26]. Likewise, for the latter, the methods and principles have been elaborated upon in the Indian Standard guidelines – Methods for detection of bacteria responsible for food poisoning [27].

Tubewells

For the tests that were carried out to test the water in the tubewells 1 and 2 (way point 22 and 23) respectively, located 400 and 200 m upstream from the dam respectively, the water was collected in sterile bottles (4x4x15 cm) ensuring the height of the bottle allowed for ample altitute, so that the entire length of the dipslide (8 cm) can be comfortably immersed into the liquid during the sampling stage (see figure 16). In addition, since the pumps to draw out water connected to the tubewells were not switched on at the time of sampling, both the tubewells were unscrewed slighty from the parts above the surface of the sand that allowed the water to flow through. This stream of water was allowed to flow for about a minute after which the sterile bottle was filled to the brim for sampling.

F gure 16: Samp e of water from tubewe 1 (WayPo nt 22) co ected nto a ster sed bott e for test ng. Image taken by the author. 22.03.2017.

It is also worth mentioning that the area around the tubewells and main GLR were also covered with animal droppings in certain parts. Since the tubewells are located on the upstream side of the sand dam, this of course contributes to the overall quality of undergroundwater in and around the sand dam.

F gure 17: Tubewe 1 – area covered w th am na faeces. Image taken by the author 22.03.2017.

F gure 18: Areas surround ng the tubewe s covered w th an ma faeces. Image taken by the author 22.03.2017.

Main GLR

A GLR is similar to a storage tank at ground level. The capacity of this tank is approximately 160 m^3 and is situated at a distance of ca. 70 meters from the sand dam. The tank is managed and owned by the PHED, the state government body responsible for supplying water to the state of Rajasthan. This GLR is connected to the village GLR from where water is collected by all the households in the village. For the test from the main GLR, the water was accessed from the top of the GLR with the help of a rope and bucket. This was because at the time of sampling, according to the water technician, this was the only way to obtain water as the faucets attached to the GLR were defunct. A clean bucket was used to draw out the water and the dipslide was immersed directly into the full bucket for sampling.

Similar to the areas surrounding the tubewells, the area around the main GLR was also covered with animal droppings.

Households

According to the village water committee, the water technician from the PHED as well as through anecdotal evidence of the villagers in Thoomba ka Goliya, the impact of the sand dam relative to an increase in water yield and quality, has been reflected only upto a radial distance of 3 to 3.5 kilometers from the point of the sand dam.

Consequently, samples were taken from 7 households located at a distance of less than 3 kilometers from the sand dam. The first 2 households were located at a distance of approximately 200 – 300 m away from the sand dam whose impact has been tremendous. The other 5 samples were taken from the main village, located at a distance of 2.5 kilometers from the sand dam. At the time of visiting the village, only 7 samples from 7 different households could be taken since it was the harvesting season, and most members from the village were out in the fields. Also, as aforementioned, there had been a death in the village and many of the villagers were attending the funeral.

The process of sampling was the same for all households. A glass of drinking water was offered in a clean glass by the respective member from the household being interviewed. A sample was taken directly from this glass. The water was not drunk by the researcher. The dipslide was immersed into the glass and then stored away in vertically in a box for incubation.

F gure 19: Stee g ass from a househo d from wh ch a water samp e was taken to check for m crob a pathogens. Image taken by the author 22.03.2017.

4.1.4.3 Labelling

Each of the tests were labelled with details of the date, time and place of sampling and then kept aside in the tubes vertically for incubation (see figure 20)

F gure 20: A abe ed d ps de n ts ster zed conta ner. Image taken by the author 22.03.2017.

4.1.4.4 Incubation

The slides were kept in an upright position and left to incubate for 12 – 18 hours at room temperature as per the instructions of the user´s manual for the Bactaslyde dipslides. During the time of sampling, the outside temperatures ranged from 30°C to 32°C , whilst indoors, the temperatures ranged between 26°C – 30° C. Generally, colonies which are noticeable with the naked eye start to appear within 18 – 24 hours of incubation. As per the standard operating procedures of the test however, the growth of bacteria is also contingent upon various factors such as the species of bacteria and their growth phase inter alia. Consequently, the time taken for the colonies to manifest may be slow due to a slower growth rate of the bacteria.

In this case, pictures of the manifested colonies for each test were taken 19 hours and 30 hours after sampling and labelling, respectively.

4.1.4.5 Interpretation of results

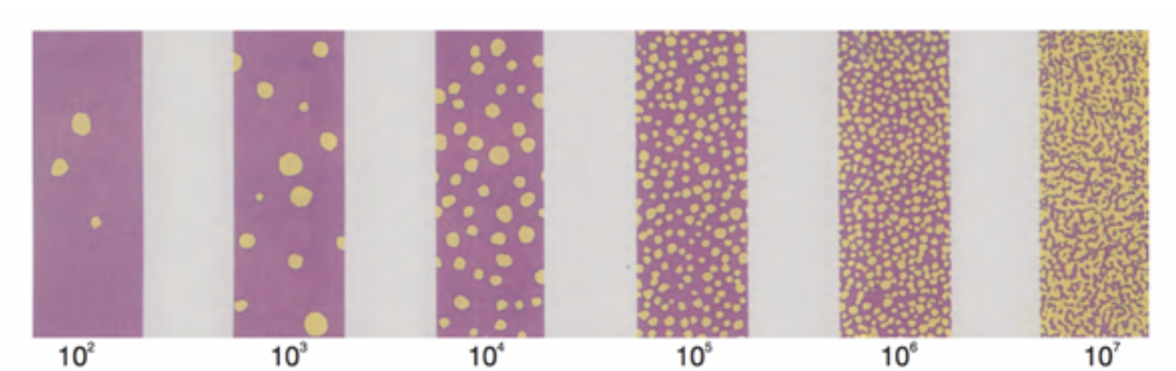
Subsequent to the incubation phase, the density of the bacterial colonies that appeared on the media surfaces of each test was compared with the density charts provided with the product user´s manual.

The coated media on either side of the slides comprises of water – 95.5%, Agar 2.0%, Peptone 1.5%, Yeast Extract 0.5%, Dextrose 0.25%, Chloride 0.25%, Food colour 0.004%.

The yellow coloured medium is used for detection of TBC (Total Bacterial Count) and the violet coloured medium for detection of *E. coli.*

<u>Test for *E. coli*</u>

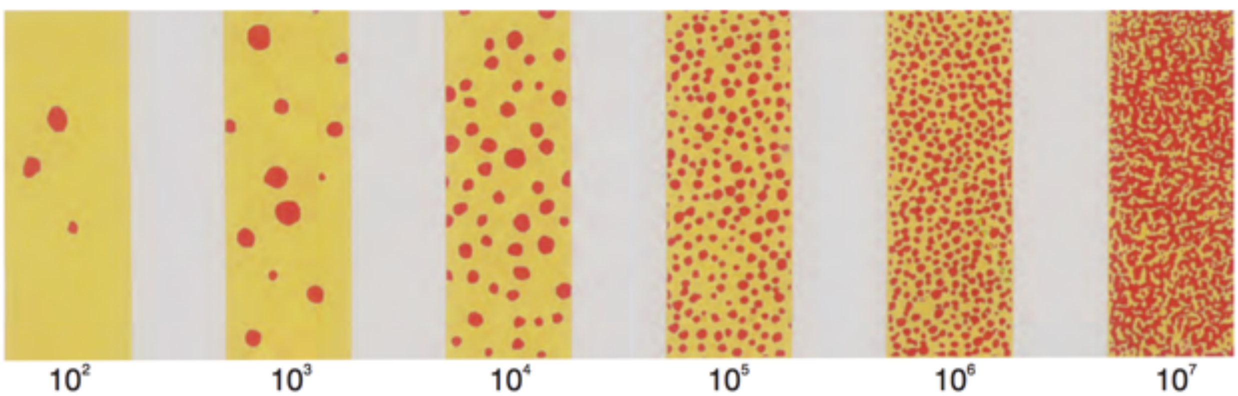
In Figure 21, the colonies of *E. coli* bacteria on the surface media appear as yellow spots. Even one colony represents a count of 10^2. If there is no colony on the surface media, this represents a count of less than 10^2.



F gure 21: Bactas yde Dens ty Chart for *E. coli/ml*. [28]

Test for Total Bacterial Count (TBC)

Colonies of all species of aerobic bacteria appear as red spots on the surface media (see figure 22. As per the user´s manual instructions for the Bactaslyde TBC test, manifestation of colourless colonies must also be accounted for. In addition, the size of the colonies is not to be given much significance since it the density which is to be measured. Similar to the *E. coli* test, even one colony represents a count of 10^2. If there is no colony on the surface media, this represents a count of less than 10^2.



F gure 22: Bactas yde Dens ty Chart for Tota Bacter a Count/m [28]

4.1.4.6 Disposal of used slides

Following the water test, the slides were carefully handled since they contained microorganisms. After the second reading of the water tests i.e. where pictures were taken after 30 hours post incubation, the slides were immediately desinfected and subsequently incinerated.

4.2 Method 2 - Household and expert Interviews

4.2.1 Household interviews

A qualitative research design has been used as the second method since the research question attempts to understand how and to what degree, the quality of drinking water from the sand dam used by the rural people in Thoomba Ka Goliya, has affected their heath. In particular, it seeks to understand if the risk of diarrhea has been minimized after the construction of the sand dam.

4.2.1.1 Research Design

The theoretical model primarily used, based on what has been logically requried by the research question, is participatory action research. A hallmark of this kind of research is that there is a **blending** of the demarcation between the **reseacher and the participant** [29]. Each may take on the other´s role during different phases involved in the research study. In this kind of an approach, there exists no ownership of the research and its more like a collective collaboration between participant and the researcher. Additionally, there is no unified or consolidated methodology for implementing participatory action research. The general framework is that one would have one or more researchers travelling to a community and engaging with the members, selecting participants from the community for interviews, discussing problems that palgue the community and thereafter coming up with a number of potential remedies and implementing those solutions.[29]

A few other tenets of such a theoretical modes are collective commitment, inclusion of the self in a collective reflection, **mutual benefit** and **alliance building** [29]. In essence it encapsulates an immersive community based research programme where the researcher not only helps to engage the participants in problem solving but also becomes part of the process. This however, is not a model wherein it is the obligation of the researcher to alleviate the social and moral problems. Instead of a collectivist approach to problem solving is used where, problem solving is taken on as a shared responsibility. It's a two way process and the collective approach becomes a shared responsibility. Everyone is immersed in the problem solving and discussion process and collectively a solution is arrived at [29].

Also the problem cannot be fully understood by the resarcher alone unless the participants are engaged. Therefore, **critical diaglogue** was also established with the participants where they were engaged in not only dialogue, but also proactively helping in activities pertinent to the research to arrive at a solution. For instance, they helped excavate a hole in the sand dam, to take sediment samples. In addition, they were very helpful and cooperative when it came to taking samples from the main GLR. Further, a bucket and a rope were arranged for by a few of the community members. The participants that were chosen for the interviews were able to explicate the problem and other issues around the water quality before and after the construction fo the dam and how this affects their health. However, since their standards as well as expectation relative to topics such as lifestyle, health and cleaniness are very low, it was not only challenging to elicit from them solutions for how health can be improved, but more how they define health and their understanding of what it is to be healthy and to live in clean and hygienic surroundings. The key informant was also a core part of the research process in the way that he provided the necessary background information for the research and was very supportive in organising in the field trip. Meals for the researcher were also provided by the community. A close rapport was establilshed with the participants, the key informants and villagers who helped excavate the hole in the sand and the water technician. It felt as though the researcher was accepted as part of the clan and of course, they understand that she was also here to support them in her own way i.e. through the research project.

Additionally, according to this approach, the participants provide the complexity of the issue or problem. When using this kind of an approach, the researcher must believe that the participants are keen enough to understand the problem and in turn, the participants must establish trust that the resarcher genuinely cares and is there to help and not provide advice or recommendations and suggestions. This is also known as alliance building. Further, such a project should be mutually beneficial to both parties. This rapport was established with the participants, however, the researcher´s expectation regarding the responses was higher than what was actually achieved. The questions were answered adequately, but the answers lacked **depth**. Moreover, the relationship was symbiotic in nature where each party has a win win and is benefited and supported by the other. There was an expectation also from the participants that through the interviews, conclusions would be reached that would in someway help ameriolate their lives.

Besides that, there is an influence of a phenomenological approach that is carried out with regard to certain phases within the study such as data collection and interviews. This comprises an emerging qualitative approach that is used to study the specific phenomenon as lived and experienced by the target group i.e. members of the rural community of Thoomba Ka Goliya who drink water sourced from the sand dam. The preliminary and also subsequent research plans have constantly been subject to change especially after entering the field. During the data collection phases, many a time, certain questions were omitted taking into account the degree of openness/friendliness and knowledge of the participant. Of course, questions were also posed ad hoc sometimes, i.e. questions that were not part of the prepared questionnaire. The researcher has attempted to constantly be flexible, sensitive to the situation and surrounding and of course creative and ready to improvise. These are also some of the characteristics of an emergent design in research.

The research attemps to explore the essence of these experiences. An important characteristic that has been considered in the study is the that the participants´ meaning has been given prominence, whilst a conscious attempt has been made to filter out the biases, preconceived notions or interpretations of the researcher.

“A phenomenological study describes the common meaning for several individuals of their lived experiences of a concept or a phenomenon” [30, p.76]. So in this study, the overarching research question is “What is the experience of health of the rural communities at Thoomba Ka Goliya after construction of a sand dam?” Health is linked to the lives of the people and the common denominator in the context of this study is the sand dam. More specifically, how the lives of the rural communities, and consequently, their health have been affected by the sand dam. What is more, health is something that is experienced subjectively and relatively differently for every individual. Since the determinants of health along with the physical and social also include the emotional or mental aspect, the researcher endeavoured to incorporate this by selecting a qualitative phenomenological approach along with PAR affording the study more comprehensiveness. This is a descriptive account of a person´s lived experience. A hallmark of such an appraoch is locating and extrapolating the universal essence of the phenomenon or the lived experience [30]. And this essence, is fundamentally an emotional and visceral one. It includes “what” was experienced and “how” it was experienced. In the context of this study, living in conditions of extreme water scarcity which exacerbate poverty and disease is the common phenomenon relative to “what” was experienced by the participants for which all them have different subjective and descriptive accounts to tell. These accounts talk about the “how”. This approach was selected for the exact reason that emotions that include “how” descriptive accounts cannot be quantified or likewise be answered through closed ended survey questionnaires.

The interviews were carried out within a natural setting. Each participant´s household was visited by three people: The researcher, the key informant and the interpreter. It should perhaps be mentioned at this stage that although the researcher is of am of Indian origin and has been born and brought up in India and speaks fluent Hindi, it was still very challenging to understand the local dialect of Marwari. The participants could clearly understand what was being asked to them in Hindi, however, the responses were given in a dialect of Marwari which was incomprehensible to the researcher. Therefore, an interpreter was part of the group of interviewers who helped interpret the participants responses primarily from Marwari to Hindi/English.

As aforementioned, the thesis proposal intented to interview at least 12 participants/ households from the village and subsequently take water samples (see appendix for research proposal). The key informant had also arranged for this and had liaised before hand with the respective households that used water from the village GLR (which is sourced from the sand dam) to give interviews.

In addition, there was also an expert interview that took place with the local village doctor at Thoomba Ka Goliya. Since at the time of the interview, the results and findings of the water analysis and household interviews were not known, questions were asked ad hoc based also on some of the anticipated responses of a few household interviews. The expert interview was carried out prior to the household interviews.

The qualitative research methods also focus on rigorous data collection procedures. The collection of data in open, semi structured and in depth one on one interviews affords effective qualitative analyses of the content in a natural setting. Whilst conducting the interviews, a dialogical approach has been emphasized upon throughout the study with the interviewer only steering the conversation whilst holding the back seat and allowing the participant to speak. However, due to the participatory element of the PAR approach used as part of the theoretical model, open discussions were also carried out on how issues pertinent to the research question could be resolved. Suggestions were made and ideas were brought to the table by the researcher and key informant. However, these discussions were not recorded as part of the interviews, since the focus has been kept on the participant and the respective responses to the questions from the questionnaire.

In the light of the data analysis, the approach is characteristic of an emergent and flexible design. Both deductive as well as inductive approaches are used. The former includes creating broad categories or themes from detailed interpretations or more commonly referred to as the bottom up approach. The latter concerns looking for evidence in the data to support the built themes.

4.2.1.2 Role of Researcher

The researcher is a student of the Hamburg University of Applied Sciences studying towards attaining a Master´s degree in Health Sciences. In the light of this study programme, each student is required to submit a Master thesis on a topic of his/her choice.

The researcher has always had an emotional connection towards pressing issues that are so rampant in her part of the country where she lives, i.e. India. Basic civic amenities relative to issues such as sanitation, hygiene and most importantly, clean and safe potable water, which are a given in most countries, yet a luxury in other parts of the world, is a fact not easy to fathom. This sheer iniquitous discrepancy is primarily what lead her to pursue not only a Master´s degree which focused on the environmental aspects affecting health, but it was also her personal aspiration to be able to find a topic for her theisis that she is passionate about and which affords her the opportunity of being able to contribute in her own way that is meaningful.

Writing on a research topic in the field of rural development relative to the microbial water quality and simultaneously bringing me into direct contact with the local people at Thoomba Ka Goliya has been an eye opening experience. As the researcher is Indian, one would assume that seeing poverty everyday is part and parcel of living in a developing country. However, this unortunately, is based on a false premise. Having lived in urban India, within a social system that has embedded in it, a very discreet caste sytem, it is not commonplace for everyone to come into direct contact with people from the rural areas and more so, to see first hand their homes from the inside and then begin to understand their way of life. What life means to them and their definitions of health, wealth, success and happiness are very different from our own understanding of the meanings we have assigned to these words.

For the researcher, it was daunting to observe how some households still do not have electricity. Since Rajasthan is located in the Western part of India that is primarily desert and barren, it is not uncommon, that the temperatures soar upto 48 degrees celcius in summer. Yet not a fan or a refridgerator to store food is to be seen anywhere in the households.

However, in the light of this research, whilst interviewing the participants and having spent time with them afforded the researcher perhaps only a fraction of insight into the lives they lead. Yet, she is overcome with a multitude of feelings. First and foremost a deep sense of sympathy and empathy was felt towards the people. Undoubtedly, they live a life that is at poverty line if not below. Their possessions are few and despite that, their perceived sense satisfaction does not go unnoticed. In addition, there is also a certain sense of resentment that is evoked during observing the rural plight, at the social construct and of the political and economic system. These farmers belong to perhaps one of the most hard working professions, and yet what they earn is very meagre. Even their expectations of their needs for instance, on what health is, are quite low as will be explained in the "Results" section of this document. This sheer disparity and imbalance between input and output is often challenging to grasp. All the same, a conscious attempt of bracketing has been made in the study where the researcher has attempted to keep she interpretations of stories told as close to the meanings derived by the experiences of the participants.

4.2.1.3 Data Collection

A series of activities are involved by the qualitative researcher in the process of collecting data. A strategy of purposeful sampling of participants was employed for this study in order to best inform the researcher about the central problem under examination. Subsequently, the venue/site as to where the interviews would be conducted was decided upon. Since, in addition to the interviews, water samples to carry out the water analysis also needed to be taken, homes/ household visits was decided upon.

According to Creswell, the number of participants for a phenomenological study should range between 3 and 10 [30]. In this study however, the total sample size is 7. The researcher conducted one on one interviews with the participants based on 6 sets of mixed questions that comprised of open as well as closed ended questions. The questionnaire for the interview was devised following telephonic discussions with the key informant and JBF about having an idea of the water and health situation in the village . After producing the first draft, several modifications were made to it after subsequent discussions with the first and second supervisor before the final version was produced (see attached in the appendix under thesis proposal).

The interviews with the participants took on an average, not longer than one hour per participant. This was also due to the fact that all the information received by the participants or sometimes even questions asked by the researcher were interpreted from either hindi to Marathi or the other way round. Although the questionnaire was prepared in English, the questions were asked in Hindi and responses were given in a dialect of Marathi. The information was recorded using an audio recorder/ taping device. Subsequent to this, the interviews were transcribed by the researcher i.e. put into digital text into an MS word file and again, translations had to be made from Marathi/ Hindi into English. The transcripts for all the interviews have been produced in English. 43 % of the respondents were female and the remaining 4 of the 7 participants were male. It was predominantly the male participants who were more engaged and assertive while answering the questions. They also answered in more detail in comparison to the female respondents. The state of Rajasthan has one of the lowest literacy raters among women in the country [14 p111]. The key informant also informed the researcher that almost none of the women respondents were literate, as a result of which, the answers to most of the questions were more monosyllables or one liners. It was challenging to elicit from them minutiae relative to the questions for the research.

In addition to collecting data from the interviews, pictures of some of the households as well as the surroundings of the village were taken to get an idea of the conditions the members live in. This compelements the data collection from interviews affording better assimilation of data and prepaving the way for the data analysis.

Although no consent forms were officially signed by the participants, a verbal consent was given at the beginning of the interview where the researcher after explaining the purpose of the interview also asks if asking questions would be fine. In this way, their consents were given. What is more, most of the participants were illiterate rendering the use of a written form inadequate.

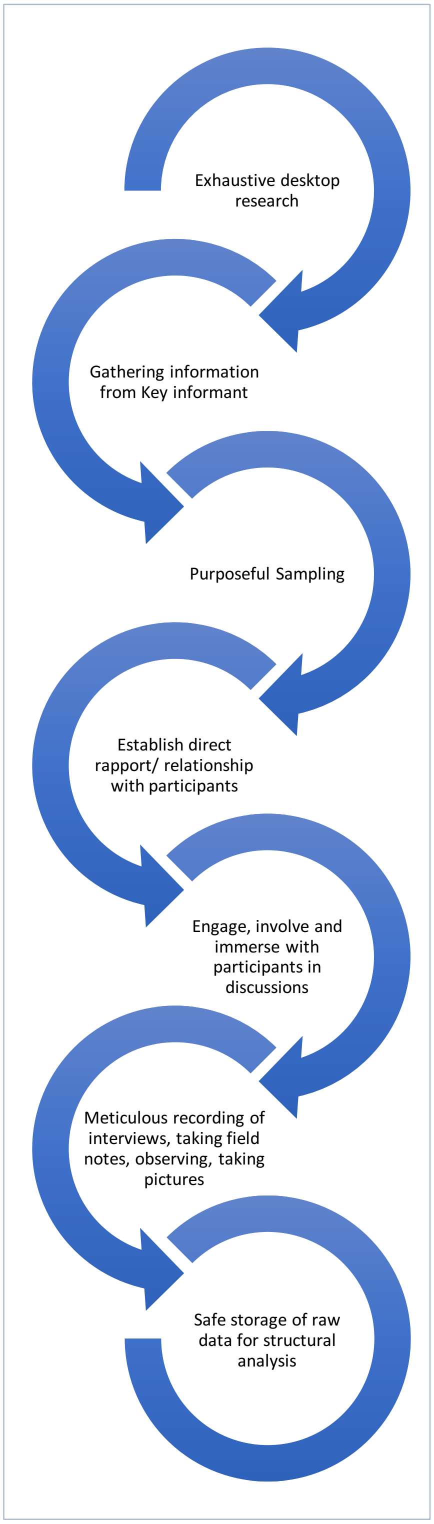


Figure 23: Phases involved in data collection. Created by the author 23.05.2017

As described in the figure below (Figure 20), the process of data collection involved a series of steps beginning with desktop research. A thorough literature research was done as a first step to acquire information about Thoomba Ka Goliya and the water situation in MarwarThis then brought me to JBF, the foundation that was involved in constructing and implementing sand dams in diverse regions in around Rajasthan. After liaising with them, contact details of the key informant and member of the water council were shared with.

The field trip was arranged with the key informant before visiting the village. It it perhaps relevant to note that all conversations relative to information being shared about the research, were primarily carried out over the phone via skype. Since the researcher was in Germany during the intial phases of the research, the planning phase was done there whilst the implementation was of course carried out on-site.

The key informant took the onus of purposefully selecting the participants for the interviews since it is not everyone in the village who had their drinking water supply from the sand dam. Subsequent to this phase, of course, there was a rapport that was established with the participant prior to interviewing them. A concious attempt has been to create an atmosphere where the participants feel comfortable with the researcher and also understand that the researcher is part of a process that may contribute to a form of empowerment and social change in the long run. For this, the intent of the resesarch study was explained during the introduction stage and before the interviews were carried out with them.

4.2.1.4 Data Analysis

Again, as aforementioned, both inductive as well as deductive processes have been used whilst analyzing the data for this study. The inductive process involved horizontalization of data which involves reading and familiarising onself with the interviews. Hereafter, each statement is then carefully analysed ensuring that each of them is given equal weightage and in the process, data that is nonoverlapping and nonrepetitive is achieved. Subsequently, a process of making sense of the raw data and organizing them into more general and broader perspectives called codes, themes or categories is carried out. Following this, the deductive processes encompass gathering evidence to support and corroborate the built themes and interpretations. It involved complex reasoning, continually switching between inductive as well as deductive approaches. According to Creswell, the process of analysis is a comprehensive and interconnected one that comprises of organizing data, conducting a preliminary read-through of the data i.e. familiarizing oneself with the data followed by coding and organizing themes of the data (inductive process), representing the data and lastly, interpreting them [30, p. 179]. The passages for which codes were assigned were carefully analysed and subsequently, all passages which represented a similar meaning were categorized under the same code.

A preliminary step to the data analysis process encompassed a thorough desktop and literature research to find out the factors responsible for influencing health in rural communities in developing nations. Literature from "Healthy Villages – A guide for communites and community health workers, WHO 2002 " [31] has been used a reference for gaining a deeper understanding of the aforesaid factors. This process served in the development of categories while coding. The software MAXQDA has been used to facilitate the process of data analysis.

4.2.1.5 Data Validation and Reliability

According to N.K. Denzin "Triangulation involves the conscious combination of quantitative and qualitative methodologies as a powerful solution to strengthen a research design where the logic is based on the fact that a single method can never adequately solve the problem of rival causal factors" [32]. It is a way of enhancing the confidence and credibility of research outcomes through corroboration of mutliple sources. Although Cresswell explains that no distinct method exists for a specific approach used in qualitatitve analsis, what is significant is degree of the emphasis laid on validation for the respective approach. Either way, Cresswell recommends the use of multiple validation strategies irrespective of the type of approach being used. [30, p. 250]

With regard to a qualitative study, there are no immaculate perceptions when it comes to triangulation. Every source has an element of the truth and there is no one absolute truth from one source. In this case, triangulation affords depth of vision when as it takes into consideration two or more perspectives about the same topic.

In the light of this thesis, triangulation has been carried out in the form of household interviews and an expert interview with the local naturopathic doctor to corroborate the reasons for health or lack of it, among the rural communities. Also, it has been used to further verify and substantiate if ill-health among the patients is a direct result attributable to the water quality and if there has been a reduction in the number of diahrreal cases since the construction of the dam. Furthermore, the preliminary data collected from the aforementioned interviews were discussed and corroborated in depth with the key informant during the field trip at Thoomba Ka Goliya.

Other key aspects relative to validation of data are peer reviewing or debriefing, and member checking inter alia [30]. However, in view of this study, these were not carried out due to lack of time. However, after submission of the master thesis, should the study if at all be published, it would inevitably undergo the rigorous process of external peer reviewing. The process of validation with regard to member checking, which is core as part of any qualitative research was also omitted due to lack of time. As a result of this, the participants were not afforded the opportunity to actually read the final results in order to validate the accuracy of the outcome or credibility of the interpretations. However, the findings will be shared with the foundation JBF who supported and facilitated the field trip at Thoomba Ka Goliya.

In quantitative research, reliability refers to the idea of replicability and repeatability of a study [33]. According to Dempsey and Dempsey [34], two aspects of reliability have been regarded as essential, namely, the accuracy of the data collected and the data collection instrument. To further elaborate this, the former addresses the challenge that the respondents may be resistant or even reluctant towards sharing information and instead give information that is dictated as acceptable or desirable according to the society/ environment they live in. The latter is in reference to the significance of an unbiased researcher in order to achieve reliability.

The first aspect has been addressed in the way that the anonymity of the respondents has been protected. Although during the process of conducting the interviews with the housewives who were primary respondents, responses were complemented by other family members e.g. the husbands who sometimes became the primary resondents, when there seemed to be a disagreement on information shared or a display of uncertainty by the primary participant. Even though this was an inevitable task i.e. to allow exclusively the primary respondent to answer all the questions, it was observed that more accurate and detailed data was obtained when there were more than one respondents in the family complementing the answers to the questions posed. That said, each individual family´s anonymity has been protected.

The second aspect relative to reliability has just as well been addressed factoring in “bracketing”, experience and high standards whilst interviewing and a process that involves systematic and rigorous data analysis. The researcher will try to give a description in detail of the themes and categories that emerged in the interviews. In addition, a correlation will be made with how these findings are connected to the aims of the study.

4.2.1.6 Transferability

Beyond Thoomba Ka Goliya, the results for this study could be useful in contributing to further construction of groundwater dams in arid and semi arid regions of Rajasthan where sand is bountiful and water is a scarce commodity. Naturally, this in contingent on many technical factors that support the construction of said dams such as the existence of ephemeral riverbed on which the dams can be built, account for specific gradient e.g. 2% and an impermeable bedrock, inter alia.

The factors that speak for the benefits of sand dams clearly outsweigh the disadvantages. Since sand dams are first and foremost proven to be cost - effective and have the capacity to sotore large volumes of water that helps secure water availabilty during the long dry harsh season and furthermore could contribute to a decrease in WASH related diseases, it is only logical that more of such sand dams be built in other areas in the Marwar region to combat water insecurity. JBF has reported that two such projects are already running where sand dams are being built in the Marwar region.

This study could contribute toward backing the health aspects related to sand dams and thereby further reinforcing the reasons for building more dams, should the results of this study reflect positive outcomes.

4.2.1.7 Ethical Issues

The background of the study was explained to the participants. The participation was of course voluntary and not remunerated. Therefore, the purpose of the study and also how the participant could perhaps gain from the study was brought to light. The principle of **reciprocity** [30] was consciously addressed in the study. Although the results depicted in this study might be irrelevant or inconclusive to many of the participants, since it does not essentially offer strategies for coping with the situation they are in, what might be helpful to them is to provide them with a synopsis of the benefits of sand dams and emphasize the importance of drinking clean and uncontaminated water. Further, it could contribute to an understanding of the connection between drinking clean water, hygenic sanition practices and improved health i.e. mental, physical and social, among these rural communities.

In addition, the anonymity of the participants has been respected and protected. The results have been presented with multiple perspectives and since the study is not part of any funding institution or financed by any stakeholders alike. Hence, there is no vested interested or motive in tampering with the data in order to sway the results in a particular direction.

4.2.2 Expert interview

In the light of the expert interview, questions posed to the Naturopathic doctor Dr. Shyam Singh Raj Purohit, were ad hoc. Due to unavailability of the doctor in the evening of the field trip, the expert interview, unfortunately, was conducted prior to the household interviews in the morning. However, since some of the illness occuring in the village could be anticipated based on literature research as well as reports from the key informant, questions were asked to him in an extempore manner based on the findings from the prior research. The questions primarily revolved around three subjects:

- What were the most predominamt diseases in the village before the sand dam was built?
- Have these reduced after the dam was built?
- Can these diseases be directly attributed to the quality of drinking water?

The duration of the interview lasted ca. 20 minutes with interruptions (by other patients). The doctor refused the use of a recording device to record any conversations as a result of which notes of the dialogue was made. In addition, like the locals of the village in Thoomba Ka Goliya, the doctor spoke in a dialect of Marwari which the researcher could not understand. Although he did speak some Hindi, he could not make himself understood in the language as a result of which, an interpreter was needed here too. Notes of the conversation were taken down in English. It appeared as though a lot of information and details were lost in the process of translation. The interpretor reported the use of a lot of medical jargon which he could not understand and hence, did not know how to interpret. The notes of the researcher have therefore attempted as best has been possible, to infer from what was being interpreted and her own limited medical knowledge to arrive at outcomes that seemed logical.

5 Results

5.1 Water analysis

This section presents the results of the water analysis that was carried out in situ with seven households, two tubewells and the main GLR on the 22.03.2017 at Thoomba ka Goliya, Rajasthan, India. The results of the sediment test have also been presented here which were carried out in the Gujarat laboratory in Ahmedababad.

According to the instructions of the user´s manual for the Bactaslyde – dipslides, the slides are to be kept in an upright position and left to incubate for ca. 12 – 18 hours at room temperature. As described in the methodology section of this study, the dipslides were left to incubate indoors at the recorded temperature ranging between 26°C – 30°C. Pictures of the dipslides were taken 19 and 30 hours after the sampling respectively.

The results presented within this section are those that have been taken after 19 hours of the sampling produre. The results taken after 30 hours have been presented in the appendix. In the pictures of the dipslides below, each dipslide has been compared with the density chart available with the Bactaslyde® package [28]. The number of spots on the media indicates the number of colonies and these are then compared with the density chart to arrive at an estimate of the number of Colony Forming Units present in the samples. The size of the colonies is insignificant.

Household 1

Figure 24 TBC – 10^3/ ml, *E. coli* – 10^6/ ml

Household 2

Figure 25: TBC – 10^5/ ml, *E. coli* – 10^5/ ml

Household 3

Figure 26: TBC – 10^3/ ml, *E. coli* – 10^2/ ml

Household 4

Figure 27: TBC – 10^5/ ml, *E. coli* – 10^6/ ml

Household 5

Figure 28: TBC – 10^6/ ml, *E. coli* – 10^7/ml

Household 6

Figure 29: TBC – 10^3/ ml, *E. coli* – 10^3/ ml

Household 7

Figure 30: TBC – 10^3/ ml, *E. coli* – 10^2/ ml

Main GLR

Figure 31: TBC – 10^2 / ml, *E. coli* – 10^2/ ml

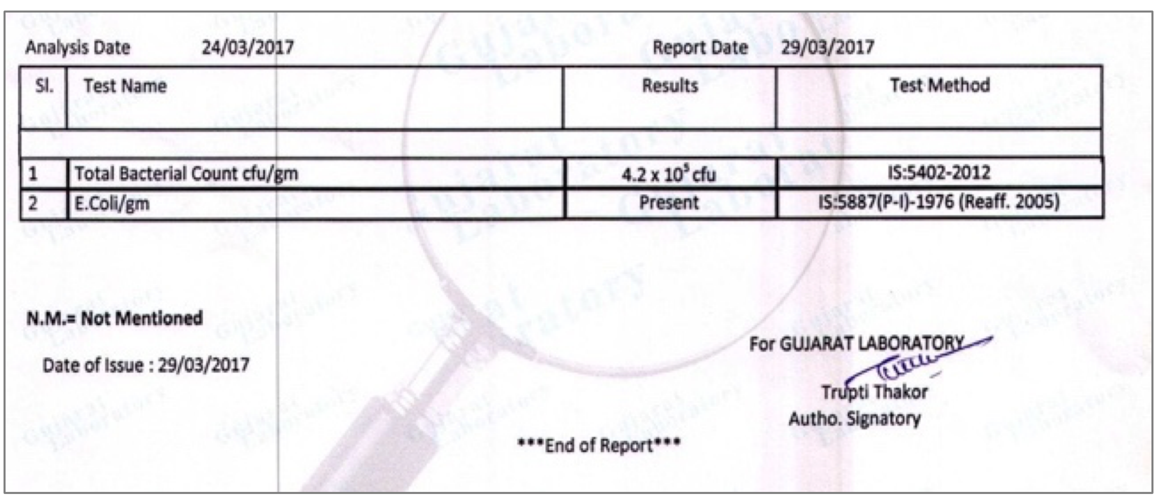
Tubewell 1 (WP 22)

Figure 32: TBC – $<10^2$/ ml, *E. coli* – $<10^2$/ ml

Tubewell 2 (WP 23)

Figure 33: TBC – $<10^2$/ ml, *E. coli* – $<10^2$/ ml

Test reports from sediment



Analysis Date 24/03/2017 Report Date 29/03/2017

Sl.	Test Name	Results	Test Method
1	Total Bacterial Count cfu/gm	4.2×10^5 cfu	IS:5402-2012
2	E.Coli/gm	Present	IS:5887(P-I)-1976 (Reaff. 2005)

N.M.= Not Mentioned

Date of Issue : 29/03/2017

For GUJARAT LABORATORY

Trupti Thakor

Autho. Signatory

End of Report

Figure 34: Sediment test results – detection of *E. coli* and TBC. Taken from full laboratory report attached in the appendix.

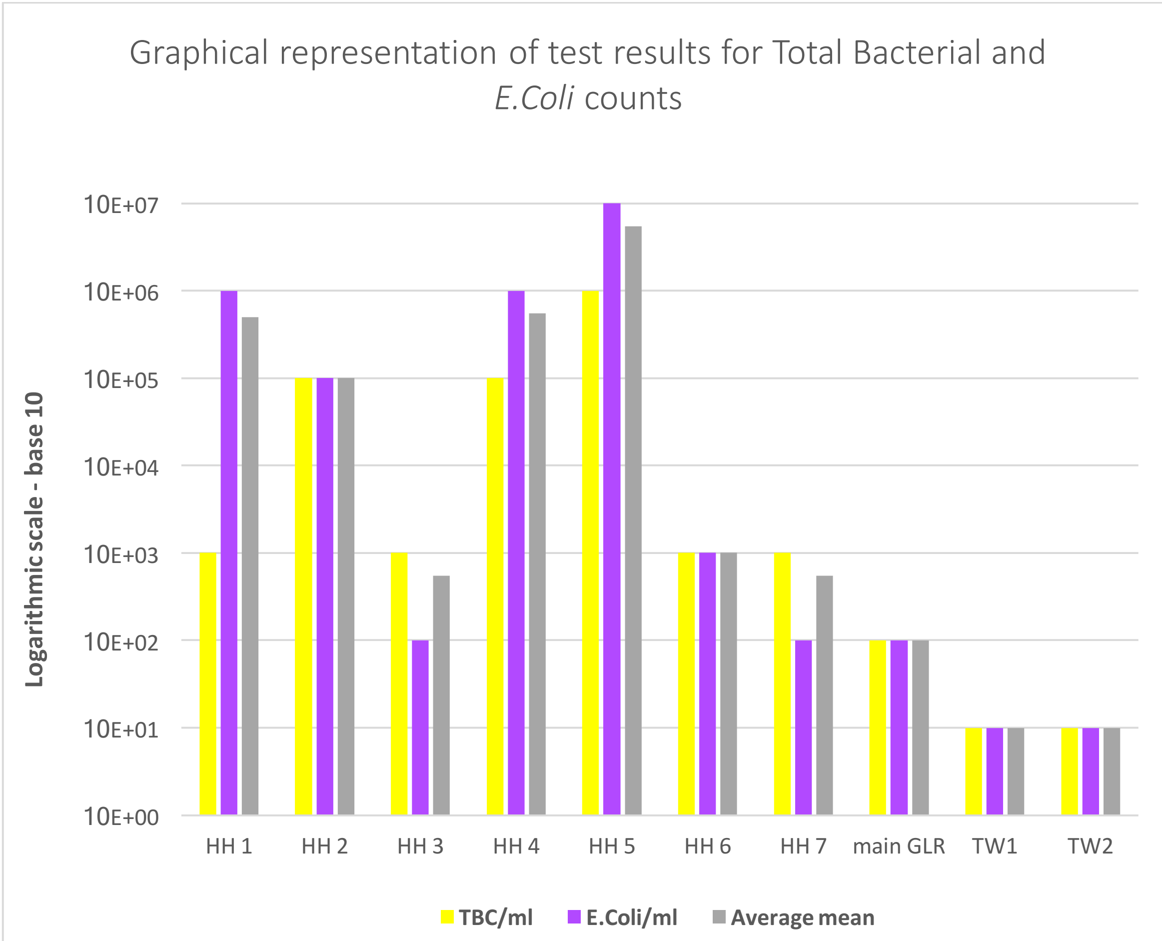


Figure 35: Column chart depicting test results for Total Bacterial, *E. coli* counts and their average means. Created by the author 01.09.2017.

The column chart above illustrates the *E. coli* and TBC counts/ml for the 7 households (HH), the main GLR and the 2 tubewells (TW1 and TW2) at Thoomba ka Goliya as on 22.03.2017.

In general, with the exception of household 1 where there is a 3 log difference in the TBC counts to that of *E. coli*, tests for *E. coli* along with TBC conducted for all the households depict similar counts with a difference of only 1 log for four out of seven households. I.e. for each sample taken, the counts for *E. coli* are relatively proportional to the TBC counts. In addition, no outlier values were measured in the tests. Together, this is indicative of **reliability** of the **equipment** used**, reliability** in **test procedures** whilst sample taking and **validity** of the **test findings.**

Both tubewells displayed a count of **less than 10^2/ml** for both ***E. coli* as well as TBC**. In the graph above, this has been represented as 10^1/ml on the Y-axis, although this may or not be entirely accurate. According to the Bactaslyde® water test kit, clear slides where no colonies have been isolated or can be detected with the naked eye will be interpreted as less than 100 CFUs/ml [28]. Evidence of the clear slides is exhibited in Figures 29 and 30 of this thesis. It can also be observed that the neighbouring **main GLR** has the **next lowest count** in juxtaposition with the two tubewells, with **100 CFU/ml or 10^2/ml for *E. coli* and TBC**. This could be attributed to the methods employed while collecting water for sampling (see section 4.1.4.1 for sampling) where possible contamination from the use of external props might have occurred (in this case, a bucket). Additionally, the contamination could also be from within the tank. The key informant informed the researcher that the tanks had not been cleaned in a year and this could lead to build up of bacteria and other organic matter inside of the tank.

All the households in comparison to the **tubewells and GLR** present with **significantly higher bacterial counts**. Through logical inference, it may be deduced that the water at source from the tubewells is not only free of faecal pathogens but what is more, from the TBC tests, one can assume that the efficacy of subsurface filtration performance of water through the sand, afforded by the many layers of sand accumulated on the dam, is of a very high quality. Furthermore, it is notable that despite the animal droppings found downstream and upstream of the dam near the tubewells (see figures 13 and 14 and figures 17 and 18 respectively), the water abstracted from the tubewells is absolutely pathogen free. This may be attributed to, inter alia, factors such as the depth of the dam which enhances filtration quality with increased magnitude of depth, the quality and physico chemical characteristics of sand, size of the sand grains, size of pores in the sand and surface charges of bacteria with regard to adsorption. While no faecal matter was to be seen directly over the dam, one cannot rule of presence of cattle crossing over the dam from time to time. From the TBC count, we can also deduce, that the general bacteriological quality of the water is high.

Although the test reports from the **sediment tested positive for *E. coli* and TBC** (see figure 34), it should be noted that the sediment was abstracted from the dam at a depth of only 2.5 feet (0.76 meters). While the total depth of the dam wall is ca. 6.2 meters, it is difficult to say upto what level the filtration of water through sand takes place. Eitherway, the sediment sample was taken at a depth which equated to just 12% of the entire depth of the dam wall, which is most likely also the depth at which the pipelines for the distribution system have been placed. Although the sediment may show presence of pathogens, the water abstracted from the layers below, as can be evidenced from the results from the tubewells, is relatively pathogen free.

The highest *E. coli* count is 10^7/ml for household 5 which is abysmal when compared to the either the national or International standards set by the Bureau of Indian Standards in the Drinking Water Specification or the WHO in the Guidelines for drinking water quality. Both guidelines state that for "for all water directly intended for drinking, the *E. coli* count **must not be detectable in a 100 ml sample**" (see table 3 [9]). In addition, "immediate investigative action must be taken if either *E. coli* or total coliforms are detected" [9]. For total coliform, the minimum action is **repeat sampling**. If the bacteria have been isolated in the repeat sample, immediate further investigative action must be undertaken to determine the cause [9]. Household 5 is also presented with the highest TBC count which is 10^6/ml which seems plausible given the high *E. coli* count demonstrated for the same household.

Overall, what is evident from the column chart above is that the water quality tested at source i.e. from the tubewells, demonstrates the lowest bacterial counts. And as one tests the water farther away from the source, microbial contamination seems to increase. This implies that contamination primarily occurs at the level of the end user. Conceivably, the untensils are not cleaned regularly or disinfected before refilling water. In addition, storage of water in the utensils over longer periods of time lead to a proliferation in bacterial levels. Further, the scoop or other tools or untensils used to draw out water from the main water utensil or earthern pot also play a role in the entry of pathogens through an external source. Uncovered water utensils is also a contributing factor to an increase in the level of bacteria since bacteria in and around the utensil can easily enter the water.

The indicator organism for testing the quality of the pipeline system is also commonly the TBC . In principle, the longer and more complex a pipeline network is along with an increased number of plumbing systems, the higher are the chances for contamination [23]. Relative to the water tests taken by the researcher, there has been no display of any steep rises in TBCs. A sudden rise in TBC count is indicative of faecal contamination while a gradual rise may be suggestive of conditions conducive for bacterial regrowth which could lead to pipe corrosion [21]. In the light of this study however, a one time water test was conducted, so it is difficult to say if there has been a rise or decrease in the levels of TBCs given the fact that there has been no temporal timeline for comparison of these values. However, from the graph, it is apparent that the counts for *E. coli* and TBC for the main GLR and the tubewells are equal. This is suggestive of a functional and well maintained pipeline distribution system that has been employed in the village to connect water from the sand dam to the village GLR from where water is collected.

5.2 Household interviews

The following section will afford the reader a deeper insight into the lives of the rural people. It will outline how their lives have been impacted by the sand dam and furthermore, how it may have contributed to reduced incidences of diarrhea and improved health.

The WHO postulates that “good health is not merely the absence of disease or infirmity; it is also a reflection of the social and mental well-being of people in a community.” [31 p7] Hence, all these factors must be addressed when considering the overall or general “health” of people.

For this, the most important factors impacting health have been acknowledged by the WHO as the following:

5.2.1 The Environment

The environment emcompasses the physical environment as well as the social environment. Both equally impact health in a significant way. A clean environment with clean surroundings and effective facilities available for sanitation, drinking water supply and hygiene, all contribute to physical and mental well-being in a positive way and help prevent spreading of diseases. It may also help reduce depression. [31 p9]

Communities within where discrimination exists for example against gender, religion, race, income and/or social status are known to have a higher propensity towards delveloping anxiety and other mental disorders. Communities that live in harmony with one and other are known to be healthier. [31 p9]

5.2.1.1 The awareness of individuals and communities about health (Capacity building)

When the root cause of the illness is not known to the people, they are unable to make decisions relative to investment of resources or time that foster or promote health. Hence it is absolutely fundamental that people are made aware of the causes of disease outbreaks and how these can be prevented. For intstance, personal hygiene, improved sanitation as well as improved drinking water facilities contribute to better health. It is imperative that the community members understand the close nexus that exists between health and improved WASH services. The government, NGOs, Small and Medium-sized enterprises (SMEs), community leaders and even practical and effective alliances between NGOs and SMEs or SMEs and the government are key in capacity building. [31 p9]

5.2.1.2 Personal hygiene

Equally important in maintaining health is personal hygiene. For instance, if injuries or minor burns and cuts are not treated properly, they could become infected leading to serious health problems. In addition, personal hygiene also encompasses bathing regulary, washing hands after defecation, wearing clean clothes etc. [31 p9]

5.2.1.3 Health care system

Everyone falls sick from time to time which needs medical attention. In particular infants, small childern and the elderly are the ones most vulnerable to falling ill. In all cases, the health outcome is related to availability and access of health care facilities nearby. It is therefore, essential that community leaders are engaged in lobbying to make these services available to the community members. [31 p9]

5.2.1.4 Disease

Diseases here have been categorized into faeco-oral and vector borne diseseases. The former are cause mainly when hands, food or water comes into contact with faeces and becomes contaminated with pathogens. When these pathogens are ingested by humans, it can lead to a myriad of serious diseases which include but are not limited to diarrhea, dysentry, cholera, typhoid and giardia. Some of these diseases are deadly and can be prevented with good quality of drinking water, clean domestic environments and healthy sanitation and hygiene practices such as handwashing. [31 p9]

The latter includes diseases that are spread by vectors such as mosquitoes, sandflies and snails. These of course are closely linked to the quality of the physical environment. Areas with dirty standing water e.g. formation of puddles from the rains or irrigation systems are perfect breeding grounds for mosquitoes. In addition "human behaviour as far as water contact patterns are concerned and socioeconomic status concerning the capacity to maintain a clean environment are also factors that contribute to spread of diseases. The risk of contracting vector borne diseases can be mitigated by employing procedures that can be incorporated into the daily community life such as keeping a clean home, cleaning the surrounding areas and modifying agricultural practices." [31 p10]

Elements of the above classification have been used and marginally adapted whilst forming codes, themes and categories during the phase of data analysis. However, as aforementioned in the data analysis section of this study, both inductive as well as deductive approaches have been used, making this an emergent design.

In the descriptive content analysis six main categories emerge: **"water scenario before contruction of the sand dam", "benefits of the sand dam", "disease", "health care system", "health awareness and capacity building" and "environment and health"**.

In order to better understand the lives of the people and derive from it the essence of how if has affected their lives and more importantly their health, it is important to comprehend how their lives were prior to the buidling of the the dam. A before and after story provides the reader with a clear comparison affording better discrimination for the analysis. This in essence is also one of the objectives of the study. In this section of the study, only two categories make a before and after comparitive analysis where the descriptive accounts of the respondents are **ancedotes of situations in the past**. These are "**water scenario before construction of the dam**" and "**disease**". All the other categories are descriptive accounts of the people in the **present**.

"Benefits of the dam" has been extracted from the transcripts to understand in detail the aspects, namely, "**water quality", "water quantity", "financial"**, that have been impacted by the dam and to what degree these aspects may have ehanced the lives of the rural communities. From the categorization based on the WHO, the category **"disease"** has been extracted which throws light on vector as well as faeco-oral diseases**.** Other categories derived, based on the WHO categorization are the **"health care system"** and **"health awareness and capacity building"**. The last category "environment and health" comprise of three codes, **"physical, mental and social", "sanitation and hygiene" and "water storage and treatment".** Figure 36 below presents the main themes and categories derived from the analysis.

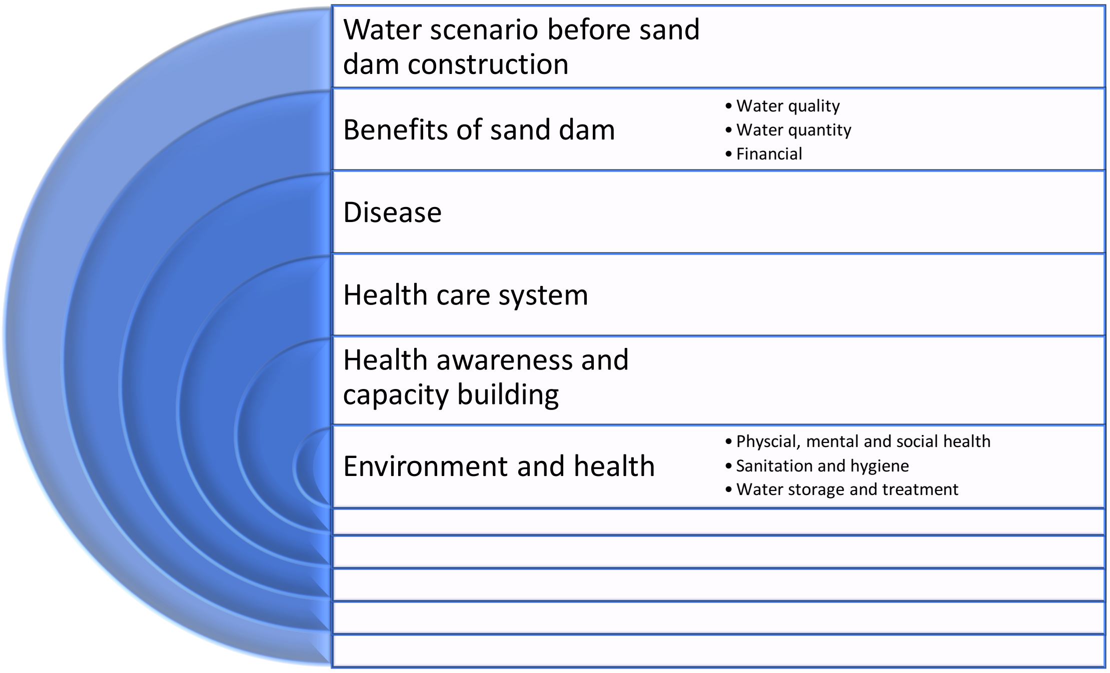


Figure 36: Categories and codes extracted from household interviews. Created by the author 22.09.2017

5.2.2 Water scenario before sand dam construction

The lives of the people before construction of the sand dam has been immensly impacted both socially as well as physically. All the respondents express the hardship of having to deal with times when there were very harsh weather conditions and no water. It almost seemed like an unimaginable period for most.

Water was available from the village GLR however, the supply was not continuous and did not nearly meet the water demand. Not only was the quality of water sub optimal and far from potable but also the volumes needed for everyday personal and domestic use were simply unavailable. During the long harsh summer months, when the water was hard, saline and unfit for drinking, the villagers were forced to resort to solutions such as buying water which only very few could afford or travelling on foot or with a bullock cart to nearby villages which were four to five kilometers away where water was fetched in earthen pots from surface and unimproved sources such as rivers and ponds. These sources are unprotected i.e. cattle may also defecate in and around the water body and drink water from the same sources. In addition, often people bathe and wash clothes in the same water. To fetch water from the nearby villages would take them atleast seven hours for a roundtrip.

During this time, the incidences of illnesses were at their peak. The majority of them experienced stomach related illnesses, while for the others (mostly elderly) it was ailments associated with the body pains and joint pains.

"It was very little. And not sweet. It did not taste good, it was very salty. Yet we had no choice but to drink it. Many children suffered many illnesses because of drinking the poor quality of water. Initially, we could only draw very little water for a few hours."
(Household 1, paragraph 7)

"There used to be a tubewell with water but the water was very salty. The water scarcity was very bad 15 years ago. We had to go to the other villages to get water from the water bodies there. When the water was too salty then we used to get a tanker of water. We had to buy the water. But mostly we used to go on a bullock cart to the nearby villages to get water."
(Household 2, paragraph 16)

"Earlier we had very less water. The water quality was very bad, we could not even make tea. The milk would tear in the water. It was extremely salty. Now the water is sweet all year round. And there is a lot of drinking water available now."
(Household 4, paragraph 2)

"We used to tie about ten earthen pots together, and we would start in the morning to fetch water and it would take us up until now (this time) to get the water. So, five hours or so. It would take sometimes even longer."
(Household 1, Paragraph 14)

"Yes, we were tensed about the situation. We used to go very far to fetch it. But now everything is fine. God has his way of taking care of all of us."
(Household 4, paragraph 69)

"We mostly had fever. And also stomach related problems."
(Household 5, paragraph 35)

"Back then we had many problems related to the joints."
(Household 3, paragraph 63)

Some of the participants also used a "before and after the dam construction comparison" to outline how drastically their lives changed for the better after construction of the dam.

"First we use to have a lot of stomach problems before the dam. Now no such problems. We used to have diarrhea and also sometimes vomiting."
(Household 6, paragraph 2 and 5)

"The water earlier used to be very heavy and salty. Now it is potable.
Since the construction of the sand dam, the water table has risen and we get sweet water."
(Household 5, paragraph 2)

"Mostly we were sick because of stomach problems. Now we don't get sick."
(Household 2, paragraph 18)

5.2.3 Benefits of the dam

5.2.3.1 Water Quality

All of the participants report a marked improvement in the quality of water since the construction of the sand dam in Thoomba ka Goliya. Consequently, they also state explicitly that the frequency of incidences of falling sick, mostly fever and diarrhea have significantly decreased. The water is now sweet and potable. One of the participants (Household 4) even quoted that on an average, the sickness of every family member has reduced to perhaps once a year.

"First the water used to be bad. Before we had very salty water and now its sweet. I've been here only since 15 years and now the water is good. I havent fallen sick since the sand dam has been built. When we fall sick we go to the health centre in Bhadrajun. Sometimes the nurse comes also gives us medicine. Before the construction of the dam we used to fall sick atleast once a month."
(Household 2, paragraph 53)

“Earlier we used to have pains related to the joints, now it has lessened”
(household 3, paragraph 6)

“Now the water is sweet all year round. And there is a lot of drinking water available now.”
(Household 4, paragraph 4)

“The families are now healthier because of the clean water from the sand dam. The water is sweet and tastes good. Earlier it used to be very salty and sometimes even dirty. Now it is good.”
(Household 6, paragraph 7)

“We used to earlier have loose motions and have problems with the stomach. And also, vomiting. The children used to vomit a lot. Now we are at peace since the sand dam has been built. It brings us good and sweet water.”
(Household 7, paragraph 4)

“Yes, it has (the quality of the water). We are all much healthier now that before the dam. We have clean water.”
(Household 7, paragraph 57)

The researcher also posed questions relative to the food to assess if possible contamination could not have also been due to the foods they were eating or whether the contamination could have been a result of storing away food for longer time periods, or storing it in unhygenic conditions. However, all of the respondents were very certain that all the illnesses were water related. The following statements below were in response to the question “How can you be sure that it is not the water that makes you sick and not the food? / what makes you say it is the water?”

“Because now the water has changed so our health conditions have also changed. They have become better. The food is the same. That has not changed. We eat the same kinds of foods.”
(Household 2, paragraph 61)

“Definitely, it is the water. The quality has now improved and earlier it used to taste very bad. Now the water tastes sweet and it is very clean. We also feel better now health wise.”
(Household 3, paragraph 8)

5.2.3.2 Water quantity

All of the farming is organic in Thoomba ka Goliya. Certain insecticides and pestices are used but these too are organic according to the key informant and anecdotal evidence. Cow dung is primarily used as manure.

Although a sand dam can store upto 25 – 40% of rainwater [12], the exact volume of water captured by the sand dam cannot be measured. Anecdotal evidence postulates that the water table has risen and this can be evidenced not only by the improved quality underground water but also a significant rise in the water table has been observed. The nearby tubewells to the dams have been recharged and there is a continuous supply of water which makes farming easier throughout the year. Consequently, this has afforded higher agricultural yields for the farmers and hence increased earnings. Higher incomes and better health are often correlated. In addition, it has also allows for more diverse farming in the way that the farmers are able to grow more variety of crops and fruits and vegetables which likewise contributes to improved health. Further, instead of buying vegetables for themselves, they are now finally able to grow them which saves them a lot of money.
They are now able to grow onions, tomatoes, garlic, spices such as chillies and cumin and fruits like Jamun and mango.

According to a case study carried out by JBF and Excellent Development [4], the key informant´s income in the year 2015 increased over 40% because he switched to growing vegetables and fruits from castor oil. Anecdotal evidence states that the sand dam has recharged atleast 100 tubewells located within close proximity to it. Further, the people of Thoomba ka Goliya claim that after the construction of the dam, the quality of the cotton crop, millet and cumin has improved considerably with a 50% increase in water availability in the village communitites.

"It has been very good the last few years since the sand dam has been built. This year we have more jeera yield. And also, lots of castor."
(Household 1, paragraph 59)

"Yes, we definitely now grow more vegetables. Also, more variety and different species. For example, we can grow Methi (Fenugreek) and chillies. Also, wheat now."
(Household 1, paragraph 61)

5.2.3.3 Financial

Due to higher agricultural productivity exhibited by the farmers in the village owing to the sand dam, the farmers have been able to earn more which has contributed to economic stability among the rural communities.

"When the yield is good and the climate is favorable and also there is abundant water, we all profit and we can all benefit financially. Also, there is more fodder for the cattle then and we don't have to buy so much food for them since we can grow it."
(Household 1, paragraph 63)

However, it is difficult to conclude if this has directly or indirectly contributed to improved health at this socio-economic level of living. Most of the money gained is either reinvested in the fields in the form of more effective technology or put aside for buying more land or for building reserves for medical expenses. However, none of the participants mentioned that they have used the money for better and/or higher education for their children or buying toilets or other household equipment such as refrigerators for safe storage of food.

5.2.4 Disease

Bronchitis and other problems related to the lungs, anaemia, acidity, body pain, fever, malaria, physical weakness, body stiffness (problems related to the joints), typhoid, diarrhea and vomiting were some of the health problems outlined by the respondents during the interviews.

The **most predominant** illnesses contracted in the village were those **related to the stomach**. **All seven participants** have, either themselves or other family members, at some point had problems related to the stomach. This presents with **diarrhea and vomiting.** In addition, all of the respondents claim that this had to do with the poor water quality.

"Mostly we were sick because of stomach problems. Now we don't get sick."
(Household 2, paragraph 18)

"We used to have a lot of stomach problems. Related to acidity and gas. We also used to have problems related to body pain and fever. I mostly had problems related to body pain and my wife and children with the stomach."
(Household 4, paragraph 33)

"We mostly get fever. And also stomach related problems. Mostly the younger people are falling ill. The children."
(Household 6, paragraph 20)

The **average frequency** with which they fall ill now had **significantly reduced** to just **one to two times a year** versus **six to seven times** before the sand dam construction. One of the participants (Household 2) even reported falling ill on an average, once every month (i.e. with stomach related disorders) before the time the dam was built.

The age groups that are most vulnerable to falling sick are the **children and the elderly**. Three out of seven (Households 2, 3 and 5) respondents reported that it was exclusively the elderly who fall ill more often compared to other age groups. Two of seven (Households 1 and 7) respondents claimed that both the elderly and the children were the most vulnerable to falling sick whereas the remaining two participants (Households 4 and 6) stated that it was mostly the children who were falling sick.

The second most common ailment next to **diarrhea** was **fever** (see figure 37). Although it is known that fever and diarrhea may comorbid, in the context of this analyis, they have been handled as two different physical grieviances since the participants have answered the questions in a manner that treats diarrhea and stomach related disorders as separate illnesses that are mutually exclusive and occur during different time intervals. Five of the seven participants maintained that alongside issues related to the stomach, fever has also been a general health problem of concern within the families. According to them, this is attributed to the exteme temperature differences.

"Sometimes we have vomiting and loose motions. Especially during the hot seasons. It's mainly due to heat and changes in the temperature. At night, it gets cool and during the day it is extremely hot. The body needs time to adjust."
(Household 3, paragraph 58)

In addition, the periods during which the families most often fall sick are the **summer and monsoon**. The monsoon period is also breeding time for mosquitoes and vector borne diseases such as malaria and fever comorbid. However, if the fever reported by all the households is an occurrence that is mutually exclusive from malaria is ambiguous. On an average, the reported recovery time for malaria is three to four days. Two respondents stated that 10 percent of the village population get malaria during the monsoons. The cases of malaria have remained the same before and after the sand dam construction. This may also be suggestive of the fact that the physical enviroment and living conditions of the people need to be improved.

"When it is hot and when it rains then we get sick."
(Household 7, paragraph 6)

"For the fever, it is mainly due to the change in weather. It happens especially during the monsoon and also during the malaria period when we have lots of mosquitoes. And also because of the changing season. Because of the temperature difference during the day and during the night. Regarding the stomach, it is certainly the water."
(Household 5, paragraph 38)

Furthermore, the majority of the elderly complained of fever and body pain and/or pain in the joints while the adults and children were the age groups with more stomach related disorders. The respondents maintained that the pain in the joints was also due to poor quality of water.

In the descriptive accounts with regard to the diseases contracted in the present, i.e. follwing the construction of the sand dam in the village, all the respondents reported that in addition to the signifiant decrease in the frequency of them falling sick, which is at the most one to two times a year or not at all, the diseases they now contract were still primarily **diarrhea followed by fever**.

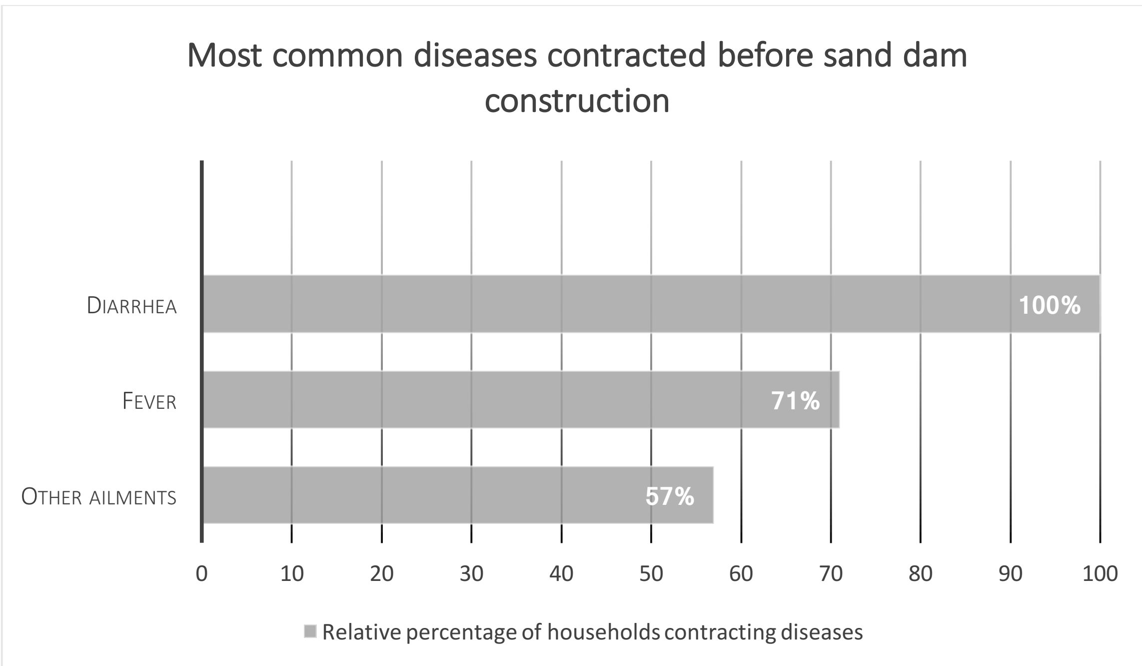


Figure 37: Representation of relative percentages of households contracting diseases before the construction of the dam. Diarrhea followed by fever are the two most common illnesses among the interviewed households. Created by the author 10.08.2017.

5.2.5 Health care system

The health care system in the village seems to be inadequate. As previously mentioned, the closest community health centre to Thoomba ka Goliya is located 4 kilometers away in the village of Bhadrajun. Most people avail of the public bus service for transport since they do not own their own vehicles. In the case of emergencies, there is no ambulance service available. What is more, the health centre that does not have an in patient facility. For this, one must go to a hospital nearby in Bhadrajun which is unaffordable for the rural people.

There is also a nurse who comes to Thoomba Ka Goliya two times a week for a couple of hours to treat patients. For the infants and children, there are Auxillary Nursing Midwives (ANMs) and General Nursing Midwives (GNMs) who visit the villages a few times a week to examine them. They are also responsible for administering the necessary vaccinations to the infants and children such as polio and DTP. However, what the other vaccines are, are not known since the parents of the children themselves are illiterate and not aware of the names of the vaccines or what they are for. However, the general village perception of the ANMs and GNMs is agreeable.

"Yes sometimes. They mostly provide medicines for children and they are good. They come to see if the children are healthy. When they are sick, they give them medicines."
(Household 1, paragraph 53)

5.2.6 Health awareness and Capacity building

As far as public health awareness goes, the local government sometimes arranges for workshop to be conducted in several villages in the district. However, most of the workshops related to capacity building on issues such as health awareness and women´s empowerment is managed by NGOs. Again, no one could give the researcher or the key informant any information regarding what the names of these NGOs are since they themselves were not aware. The general village consensus of the workshops was perceived as positive and useful. It is mostly the women and children who attend the workshops since the men need to work in the fields. It was reported that the workshops are organized three to four times a year. The duration of the workshop varies ranging from one to three days for a couple of hours every day.

"I went once or twice, but then I must work in the field so I can't be there all the days for so long. It is interesting. They talk about a lot of things like keeping everything well and clean and neat. And about personal hygiene and bacteria etc."
(Household 1 ,paragraph 73)

"Yes, we have workshops. The women come and present many topics related to health and vaccinations etc. They also talk about boiling water for children before drinking. Also, about how to treat injuries etc. i.e. disinfect them with something."
(Household 2, paragraph 79)

5.2.7 Environment and Health

5.2.7.1 Physical, mental and social health

The WHO defines health as "a state of complete mental, physcial and social well-being and not merely the absence of disease or infirmity" [31], The researcher has just as well endeavoured to elicit responses from the respondents that would describe more these three aspects of their lives. Unfortunately, the responses relative to the mental as well as social aspects were barely touched upon by the participants. It appeared that the participants were either resistant or shy to talk about it. According to the key informant however, apart from the fact that many people are just ignorant or oblivious to issues concerning mental health, for those who are aware or have experienced it first or second hand understand that there is often a stigma associated around it. Suicide has not been spoken about as it would be considered disrespectful in the context of an interview session to be asking questions of this nature. It was therefore, advised by the key informant that asking a question of this nature might lead to certain dissociation on the part of the respondents toward the researcher. Hence, all related questions have been avoided.

The physical aspects of health have been addressed in the previous sections under "Disease" where the respondents have talked about their general ailments and not just specifically outlined their physical problems related to water. Although through inference, it seems that most of their physical grieviances could be attributed to poor drinking water quality. The respondents maintain diarrhea and fever to be the most common ailments that the rural communities suffer from.

According to the WHO, **social determinants of health** are those "conditions in which people are born, grow, live, work and age" [35]. These are also the drivers for health inequities. Issues such as right to education, empowerment of women, gender equity and social exclusion can be clusetered under this point.

With regard to **education**, all of the respondents maintained that their children went to school. The key informant reported that it is common that the boy finish atleast tweleve years of education whereas the girls only go as far as class 8. The idea of the framework of this social construct within which the communities live, is that the men eventually will go on to get jobs and therefore, it is wiser to spend money on their educaton rather than the girl´s education. The girl however, will be married off into another family and around the average age of seventeen years and since she will be expected to stay at home and look after the children, investing in her education is not considered worthwhile. In general, the girls are considered to be a social liability in the way that they will eventually leave the family, so there exists a lack of interest in investing in her needs. What is more, the system of dowry is still very common and prominent in India. This is a traditional system that is still practiced among certain tribes and rural pepole where the parents of the girl child, at the time of marriage are obliged to pay large sums of money to the parents of the boy. Of course marriages are arranged by the parents. However, this topic has not been addressed in the framework of this research study. When asked by the researcher "Do you feel that you would have liked to study more so you could perhaps get a good job?", the respondent´s reply was very clear and obvious:

"No, I will get married." (respondent was a young girl)
(Household 2, paragraph 89)

"Yes, I am satisfied with my life. No, I don't want to change anything." (response to well-being, level of satisfaction and if they would have like to change something)
(Household 2, paragraph 87)

The social construct around education is one where the woman is expected to leave school after a certain age and stay at home learning to do domestic household tasks till she gets married. It appears that even though the option of studying further would exist, she would succumb to what is socially expected and accepted of othe girls her age. This would entail willingly dropping school as is the convention in society.

As observed by the researcher, clearly there is **discrimination of gender** among the society. Each gender has their own set of defined roles where the man goes out to work and women are expected to stay at home and look after the children and home. What is more, it appears that they are reluctant to step out of these roles for fear of how other family members or nieghbours might perceive of them. It is demonstrative of an extremely **traditional, rigid and conservative society.** Despite these issues, all of the respondents have held that they are allegedly relatively satisfied with their lives.

"Yes, I am very satisfied with my life. Yes, there are somethings I would like to change. But that is beyond my control. Whether I have it or not I am happy."
(Household 3, paragraph 106)

"Yes, I am satisfied. 8 out of 10." (Level of satisfaction on a scale of 1-10)
(Household 4, paragraph 60)

"Yes, I am content. I have food to eat, a roof over my head, and now good water to drink. What else could I want?"
(Household 5, paragraph 75)

The key informant reported that the neighbourhood is an amicable one and there is a sense of community among the people. Further, the sand dam is also owned by the community which portrays an understanding of the importance of community participation, involvement and connectedness among the rurals. These are factors that also promote and drive health in a positive way.

5.2.7.2 Sanitation and Hygiene

With regard to the household survey on the topic of **sanitation**, **two of seven** respondents which is less than 30% of the households interviewed, have **toilets** in their homes (see figure 38). Although the researcher did not actually visit any of the toilets or handwashing facilities due to reasons associated with cultural and social inappropriateness, the key informant informed that very basic **pit latrines** were used by the few who had them.

As part of the survey, questions were asked to every household member relative to **hygiene** and if the **hands were washed** before eating food for which **all seven** of the respondents replied **"yes"** (see figure 40). However, whilst conducting the interviews at their homes, no **sinks or soap** were to be seen. All the respondents also maintained that the hands were washed with soap. In addition, **all seven participants** stated that they **bathed everyday** (see figure 39).

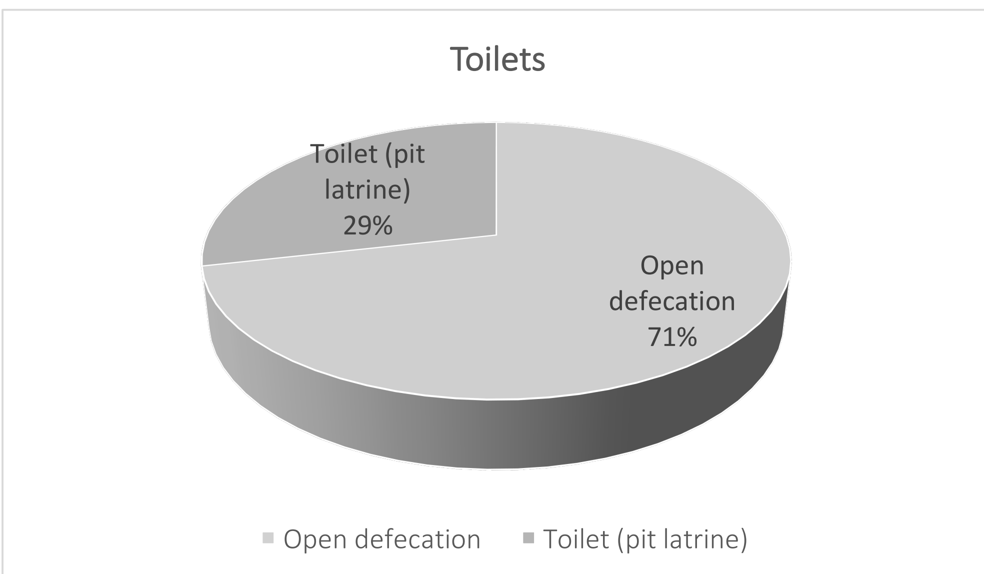


Figure 38: Illustration of number of respondents who own toilets versus those who openly defecate. Created by the author 08.10.2017

Figure 39: Illustration of number of households who state they wash hands before meals and bathe everyday versus those who do not. Created by the author 08.10.2017

Other issues with regard to **hygiene and transmission routes** are conerning **pets in the homes**, **milk consumption** and **meat consumption.** With regard to contracting diarrhea, all of the above mentioned points could possibly be factors contributing to stomach related ailments. For instance, the presence of pets at home makes it easier to come into direct contact with animal faeces and hence possible food or water contamination. There are several risks linked to raw milk consumption. According to the Centres for Disease Control and Prevention (CDC), raw milk because it has not been pasteurized can "carry germs such as *Brucella, Campylobacter, Cryptosporidium, E. coli, Listeria* and *Salmonella*, all of which present with serious health risks" and comorbid with diarrhea and vomiting [36]. Likewise **raw or undercooked meat** (including poultry, beef and sea foods) are known to contain germs such as *Clostridium perfringens*, that could have deleterious health effects that also comorbid with diarrhea and vomiting [37].

Only one of the interviewed participants possessed pets i.e. **two dogs**. The other **85 percent did not have any pets** however, they did occasionally feed the stray dogs that lived in the vicinity. The stray dogs do not enter the homes. In addition, **two participants** owned several **cows and**

buffaloes that lived close by (around 20 meters from the house). **All seven** participants reported that they **boiled the milk** before consumption. **Six of the seven** participants were **vegetarian** i.e. no meat consumtion.

All the results relative to sanitation and hygiene reflect that the only apparent open transmission routes of possible contamintion are those with **toilets** and **hand-washing**. Since the majority of the respondents do not own pets, are vegetarian and all of the them boil the milk before consumption, theoretically, these factors can be ruled out as potential sources of pathogens.

5.2.7.3 Water storage and treatment

The WHO postulates "Household Water Treatment and Safe storage (HWTS) is an important public health intervention to improve the quality of drinking water and reduce diarrheal disease" [38].

With the exception of one household, all the other households had small underground tanks for storage of water. This water however is not used for drinking since it is not clean. All drinking water is fetched from the nearby village GLR in small earthern or steel pots. The water in the underground tanks is bought from tanker trucks whose volumetric capacity is approximately 4000 litres. This is an expensive investment for most of the villagers but must be done since there is no other option available. The volume of an underground tank is ca. 12000 litres. The water from these tanks is used primarily for **washing clothes and bathing**. Two of the respondents even own a roof rainwater harvesting unit which the key informant informed was of relatively sophisticated technology that included a first flush system.

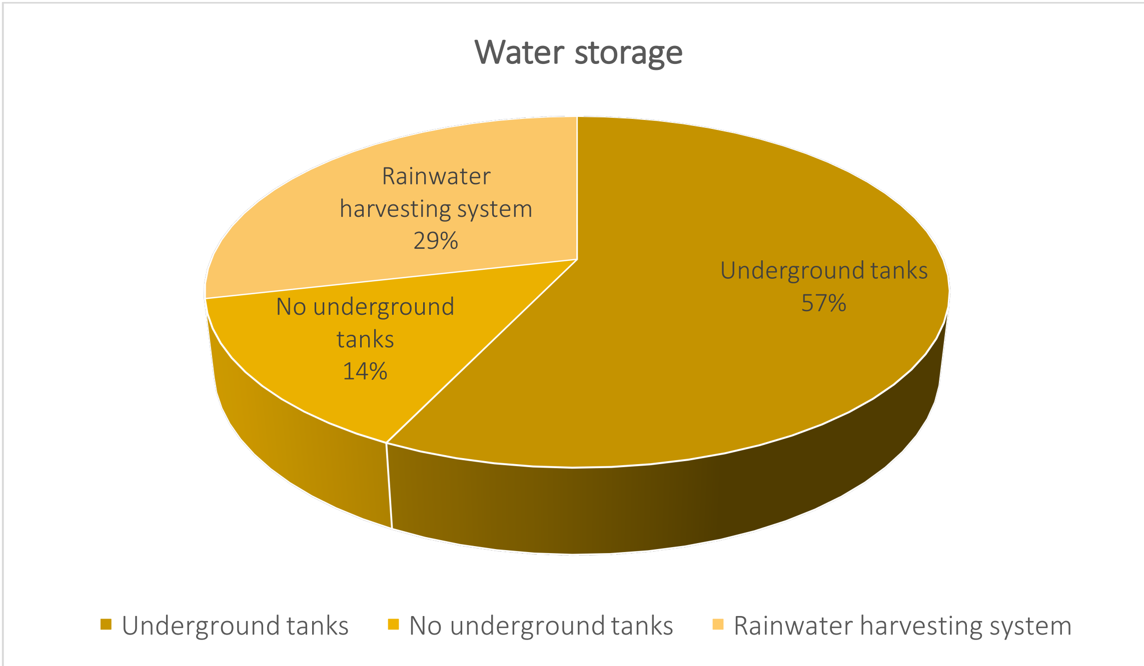


Figure 40: Illustration of number of households who own own undergrounds tanks versus those who do not and those with Rainwater harvesting systems. Created by the author 8.10.2017.

Four of the seven participants did **not treat** their water before drinking. One participant stated that he **sometimes used "alum"** to treat the water when it was turbid while two respondents reported they **always used alum** to treat the water before drinking it (see figure 41). Aluminum sulfate, also commonly referred to as "alum" is used for treating water especially in developing countries since it is inexpensive and easily available. The people in Thoomba Ka Goliya call it by its local name "Phitkari" which is a soft white stone and dissolves in the water which helps minimize turbidity through flocculation. [39, 40] Studies have reflected that alum is effective in reducing turbidity and hence chlorine demand is likewise reduced [39, 40]. However, no chlorine is used at any source or end-point to treat water in the village. The water supply from source (sand dam) to the village GLR is direct and does not undergo any treatment.

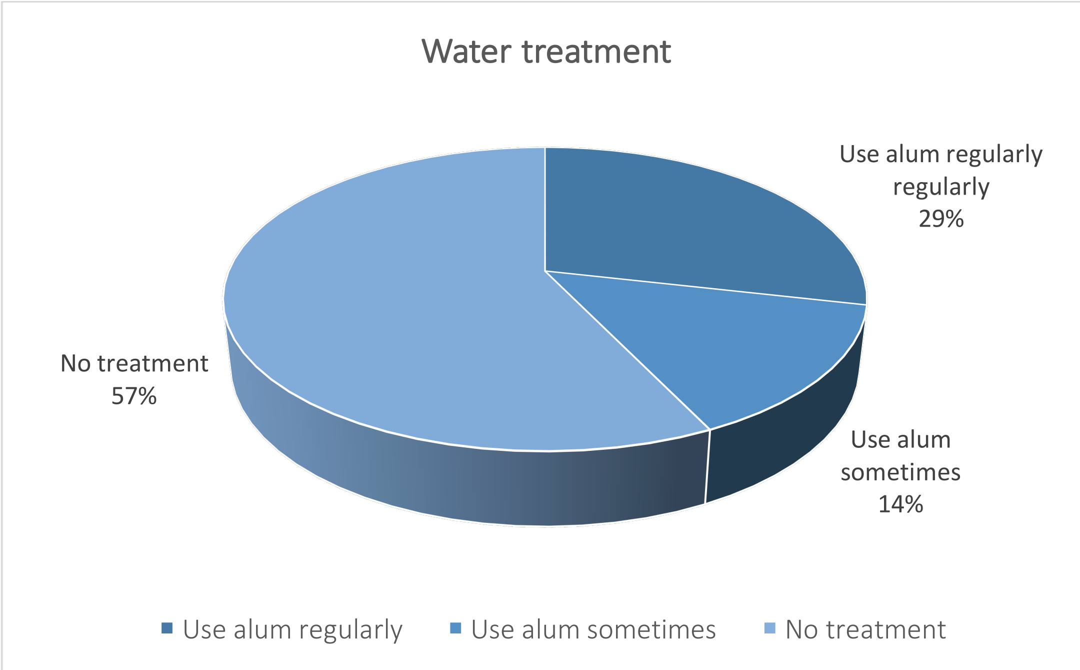


Figure 41: Illustration of number of households who treat water, who sometimes treat water and do not treat water before drinking. Created by the author 8.10.2017

5.2.8 Evaluation of WASH facilities available at Thoomba ka Goliya using indicators of the Joint Monitoring Progragmme for Water Supply and Sanitation (JMP)

According to the WHO, it is difficult to define precisely what the term "healthy" is with regard to overall health of a village. For the rural communities, this is contingent upon the "perception of the community members as to whether their village is a good place to live"[31 p2]. However, one of the key determinants that defines a healthy village is the rate of infectious diseases. "A village or rural community can be **considered healthy** when rates of **infectious diseases are low**" [31 p2]. This in turn is primarily contingent on the **WASH related facilities** that are available to the rural communities.

The JMP developed a five tier service ladder (see figure 42) in order to best evaluate and categorize the level of services for drinking water, sanitation and hygiene in rural areas. In addition, is also gives an explanation of what is understood by improved sources of drinking water as well as improved and/ or safely managed facilities concerning sanitation and hygiene.

The JMP, part of the WHO/ UNICEF is the custodian agency responsible for monitoring progress toward achieving of the Millenium Developmental Goals (MDGs). In the light of issues relative to water and sanitation, one of its goals (MDG 7), was to "Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation." [41]

In addition, one of the Sustainable Development Goals (SDG) target 6.1 calls for "achieving universal and equitable access to safe and affordable drinking water for all." This is measured by defining the percentage of population using an improved source of drinking water. This requires fulfilling the following criteria:

- "Water should be accessible on the premises
- Water should be available when needed
- Water supply should be free of faecal and priority chemical contamination." [42]

Based on the categorization by the JMP (see figure 41), the lowest rung for drinking water is directly from a surface water source such as a river, lake or pond and with regard to sanitation, open defecation is at the base of the ladder. It is assumed here that the lowest rung on the ladder as far as hygiene goes, is a state where no facilities are available for handwashing or bathing. Supposedly, mud or ash are used as agents for removing dirt.

The level above this include unimproved facilities for drinking water and sanitation with the assumption that no facility for handwashing exists on the premises or anyplace nearby. The next three higher tiers for the services are labelled "limited", "basic" and "safely managed" respectively. The "basic service" tier comprises an improved source of drinking water where the collection time for water is less than 30 minutes including queuing. Should it exceed 30 minutes

Figure 42: JMP classification of service ladders for drinking water, sanitation and hygiene. Adapted by the author for evaluation [41].

it will be tagged as a "limited service". As far as "basic services" for sanitation and hygiene go, there is access to improved facilities for defecation that is not shared between several households as compared to the "limited service", as well as access to a handwashing facility on the premises with soap and water. "Safely managed" services encompass the access of drinking water from an improved source which is available on the premises whenever needed and is free of contaminants. Sanitation facilities include a private toilet i.e. not shared with other households and where the excreta is safely disposed and treated.

A village or rural setting may not always necessarily be categorized under one specific tier for all the services rendered. It may be a combination of several tiers for different services as is the case in Thoomba ka Goliya. Figure 42 has been adapted by the author (outlined with blue squares) to evaluate and indicate the levels of different facilities at Thoomba ka Goliya with regard to drinking water, sanitation and hygiene.

Regarding the drinking water service at Thoomba Ka Goliya, since there are yet no taps in the households and the water must be collected from the village GLR, which is an improved source of drinking water (as it includes a piped water supply), based on the information and evaluation from the tests, one could classify the drinking water service as "basic". The collection time for water ranges between two to five minutes. This is less than 30 minutes and is free of faecal pathogens.

From the household surveys, it is clear that the concept of toilets is still fundamentally an unfamiliar concept and hence, nonexistent among the rural communities here. Most households do not have in-built toilets let alone having public toilets that are shared for everyones use. However, this is not regarded as a necessity by most household members. Despite government schemes that are currently operational to fund these toilets upto a certain percentage, the grants issued by the government to the community members for building toilets is pocketed and open defecation continues to be the normal practice here. Some households that do have toilets presumably use pit latrines without a slab or very basic hanging latrines.

Over 70 percent of the interviewed households do not possess toilets and defecate openly. Hence, it is expected that there is also no facility avaialble for handwashing. For those that do have a "limited" facility, there is no soap and water. Since none of the households have running tap water, it can be expected that there is close to **no handwashing** after defecation.

Although the time frame for acheiveing the SDG 6 global target is 2030 [41], clearly, with regard to WASH facilities, Thoomba Ka Goliya still has a long way to go. With regard to drinking water, the village is very close and just one rung away from reaching the SDG goal. On the contrary, with regard to sanitation and hygiene, several rungs still need to be climbed before the SDG target can be achieved. Open defecation and pit latrines are still the common practice and the next steps would be to look at taking measures towards improving the exisiting facilities and upgrading to limited if not basic levels of services. The same goes for the hygiene services. Facilities need to be improved on this front, where basic services, such as soap and water being made available to all village members on the premises is guaranteed.

5.3 Expert Interview

The naturopathic village doctor reported that the most predominant diseases in the village were diarrhea along with joint pains. This was due to the high level of micro nutrients in the water. In addition, he reported the presence of high levels of salt and fluoride in the water which in the long run are detrimental to health.

He stated, that the diarrhea is attributed to the high levels of microbes in the water and this is mainly because the villagers do not change the water daily. The same water is used over days and sometimes even weeks till the water in the containers (clay or steel pots) finishes. Only then do they go out and collect more water. They do not understand the link between diseases and dirty water because now their bodies are immune to it.

"They think that diarrhea is something that everyone gets every now and then and that is it normal. They don't understand that this can be prevented if they would change their water daily."

"The cases I mostly get are cases with chronic diarrhea. That would include typhoid, cholera, food poisoning and sometimes jaundice. I have been working in this health centre for almost ten years now and yes the most predominant disease is diarrhea. Sometimes they are adults but mostly children. They come only when the case is severe. By then the children are already weak and dehydrated completely."

Further, the doctor indicated, that joint pains or inflammation in the joints is another big problem and this also can be directly attributed to the water. Gout and arthritis are the main problems among the elderly.

"This again is because of very high levels of micro nutrients in the water. The body cannot break down the uric acid and it gets accumulated in their joints. This is very painful for them."

When asked whether the number of diarrheal cases had reduced since the dam had been constructed, his response was as follows:

"The sand dam has proved to be a big benefit for the villagers since the number of cases with diarrhea has reduced drastically. Earlier it used to be about 80 %. And today only 20 – 30 % of the patients I have, come for treatment of diarrhea. Still this can be eradicated completely if they would use a filter or treat the water and also change the water frequently."

With regard to water treatment and other measures to remove pathogens from water, he suggested that some villagers use potassium permanganate ($KMNO_4$) for treatment of their water that they store in the underground tanks. However, this does not suffice as turbidity and contaminants still exist in the water. Despite this, the water may be contaminated because they store the water in the tanks for very long periods. They should all buy water filters but these are sometimes costly for them. Even then, after filtering the water, one must change the water in the containers where they are stored. It is unlikely that the villagers would change the water frequently. He suggested alternatively, that they could boil the water before drinking but no one does this. He believes that this has to do with ignorance and also illiteracy among the villagers.

He also suggested that the way to remedy challenges linked to illiteracy and ignorance were to educate the women and organize more programmes related to health and awareness issues. Additionally, he also outlined the lack of government funding for public health programmes and building capacity for women. He indicated emphatically, that is it the government who must do more on the subject of education and for the peoples health.

"If the mother understands the links between germs and diseases, the knowledge will automatically pass down to the children. Today, the people in the village are bound to the long old age traditions of doing things exactly the way their ancestors did. Nothing has changed. Something has to change to bring about awareness of these issues."

In conclusion, the doctors closing sentence was as follows:

"Water from the sand dam is clean because of the sand filtration and one should build more sand dams in and around the region. Now they are building one in Mahinganiyo Ki Dhani also. This is good as it will benefit the people there."

5.4 Combined results from water tests, household survey and expert interview

Individual correlations between quantitative and qualitative results could not be effectively extrapolated since statistically no meaningful or **significant effects** were observed. The only apparent **intersecting correlations** that could be drawn between the individual qualitative and quantitative results were from those from the first, fifth and sixth household.

The members from HH1 are the only ones who eat meat and did not have underground tanks showed **significantly higher** bacterial counts and especially an even higher *E. coli* count (10^6/ ml) versus the TBC (10^3/ml) in their water test compared to the other households, aside from HH 5 who presented with the highest bacterial counts of all the households. Interestingly however, the incidences of illnesses reported by the household were **not significantly higher or lower** as compared to the other households who by contrast were vegetratian and did own underground tanks or rainwater harvesting units.

Interestingly, for the two households (HH5 and HH6) who did have toilets attached to their homes, HH5 presented with the highest bacterial counts for both *E. coli* as well as TBC counts, i.e. 10^7 and 10^6 respectively (see figure 35). HH 6 however was lower on the scale with 10^3 for both *E. coli* as well as TBC (see figure 35). Hence, it can be deduced from this study, given the small sample size, no significant correlation can be made between **unimproved** or **limited sanitation facilities** i.e. owning toilets (pit latrines) and **frequency** of contracting **diarrhea**. Both households´ common health complaints were related to frequent stomach problems and fever. The stomach problems were attributed to drinking contaminated water wheareas the fever was allegedly, due to changes in weather especially during the monsoon season. It is possible that the fever is also a result of malaria and/or other diseases which could comorbid. However, as stated previously, due to lack of medical knowledge, the respondents tend to treat malaria and fever as two mutually exclusive illnesses. With regard to treatment of water, household 5 "sometimes used alum" whereas household 6 "used alum regularly" to treat water.

These results from the household interviews are also moderately in line with the interview of the doctor. The doctor indicated the two predominant illnesses to be diarrhea followed by joint pains. However, the villagers suggested it was diarrhea followed by fever. The common denominator clearly remains **diarrhea.**

The overall current situation relative to the frequency of contracting diarrhea and suffering from other physical ailments such as body pains or fever has been reduced to an average of **one to two times** a year versus **six to seven times** a year before construction of the dam. This has been reported by all the respondents and evidently corroborated by the village doctor.

6 Discussion

In the following sections, the main study results and methodology will be discussed. Subsequently, potential limitations of the study will be outlined

The main findings of this study suggest that the sand dam in Thoomba Ka Goliya has contributed to a **significant reduction** in the **incidences of diarrhea** among the rural communities living there. With regard to **health**, from the qualitative interviews, there appears to have been a marked **improvement** in the **physical health** of the people in the village owing to a reduced risk in contracting water related diseases. This could be attributed to the improved quality of water from the sand dam. However, concerning an improvement in the **mental and social** aspects of health, the findings have been **inconclusive**. Hence, in view of this study, the outcomes have **moderately supported** the **hypothesis**: Sand dams are a sustainable solution in contributing to a minimized risk of diarrhea and improving health.

To recapitulate, **mixed methods** has been used in this study, where a quantitative method (water analysis) complements a qualitative method (household and expert interviews) to augment the clarification of the research problem and tackle it with evidence from two angles. A schematic diagram has been used to depict the process of the study from the start to the end and summarize the main findings of the thesis and to what extent they support the hypothesis (see figure 43)

As part of the **quantitative method,** a water analysis has been carried out to measure the levels of bacteria in the drinking water. The indicator organisms used are *E. coli* and TBC. In addition to measuring the levels of bacteria at the household levels, water tests have also been carried out at source, i.e. a test of the sediment from the sand dam, water tests from the two tubewells closest to the dam and the main GLR. As previously stated, the analysis of water at the different control points in the water distribution systems affords for an accurate account of where exactly along the network, possible contamination occurs.

In the **qualitative study**, two theoretical models have been used namely, the PAR and the phenomenological approach. This has been done to best answer the research question: To what extent can groundwater dams reduce the incidences of diarrhea and improve health in the village?

As stated previously, a significant reduction in the number and frequency of diarrheal cases among the villagers has been seen after construction of the sand dam. This has been reported not only by the participants first hand through the household interviews but also corroborated by the naturopathic doctor working in the health centre in the nearby village of Bhadrajun. In addition, the quantitative results have been used to buttress the results from the interviews. The results from the water analysis reflect that the water tests carried out at the household level reveal the highest bacterial counts (10^7/ ml) for *E. coli*, wheareas the water from both the tubewells show very low to no bacterial counts (< 10^2/ ml) for both *E. coli* and TBC. This implies that the sand dam yields water that is relatively pathogen free and hence could be rendered potable based on national as well as international standards for quality of drinking water. Further, the sand dam is known to store large quantities of water, as a result of which not only has the micro climate around the area changed making the arid land green and fertile, but even more, it is suggested that the sand dam has afforded the recharge of about 100 tubewells located in and around the village. This has been evidenced by the tremendous increase in agricultural productivity reported by the farmers, key informant and Excellent Development [4].

Despite the volumetric abundance of water that the sand dam can yield, the findings of this study show that the water from the dam, aside from drinking, has only been used for agricultural purposes. The WASH facilities in the village remain sub optimal and are not in alignment with the SDG goals (see figure 42). Although the drinking water source from where water is collected is an improved source (basic), the sanitation services remain unimproved where open defecation is still the common practice for the majority of the villagers. In this study, over 70% of the participants still defecate in the open. Further, with regard to hygiene, “limited” to “no facilities” exist for practices such as handwashing. This is suggestive of a severe economic scarcity of water related equipment and infrastructure in the village. However, despite these inadequacies, the reduction in the incidences of diarrhea after construction of the sand dam has been significant.

It is evident that sanitation and hygiene are important indicators of public health. Even for 29% of households (HH5) that did own toilets on their premises, the water tests for one of those households reflected the highest bacterial counts compared to the other households. Inspite of the high counts, the household did not report their ailments to be any more or less severe or even more frequent as opposed to the other households. This of course may be contingent on many factors such as immunity. Either way, as stated previously, despite the sub par conditions of the WASH facilities, the sand dam has proved to reduce the incidences of diarrhea.

By contrast however, according to a study by G.S. Kumar et al., if the sanitation conditions remain poor within an area, any efforts made towards improving the quality of drinking water quality may have very little impact regardless of the amount of contamination [43]. In addition, if a single transmission pathway is enough to cause diarrheal disease, then isolated solutions and single-pathway solutions are insufficient to address the problem. The more cohesive solution would be to integrate interventions that are able to eliminate all pathways causing disease [43].

Further, the findings of the study also suggest that the impact of improved water quality has been most beneficial for households living with good sanitary conditions, however, statistically, the effect has been most significant when sanitation conditions are measured at **community level** rather than at household level where the effect is not significant. Therefore, improvements in water quality in a community with poor sanitation conditions are insufficient and would have no effect on improving the incidences of diarrhea. On the other hand, in communities with better sanitation facilities, a reduction in the concentrations of faecal coliforms by two order of magnitude is expected to decrease diarrhea by 40%. And affording households with facilities that manage excreta disposal would contribute to a 42% reduction of diarrheal cases, whereas eliminating excreta around the house (adequate sanitation services) would lead to a 30% reduction [43]. Hand-washing as a single intervention can likewise reduce diarrhea by 30% [44].

The results indicate that along with improvements in the quality of water, sanitation, hygiene also need to be addressed in order to comprehensively reduce the incidences of diarrhea. [43] In view of this study, relative to the evaluation of WASH services (see section 5.2.8), perhaps a more elaborate quantitative survey needs to be carried out with larger sample sizes and as stated by G.S. Kumar et al., the evaluation should be carried out on the community level to produce any significant effect.

On the subject of handwashing and bathing, the responses were all positive. However, it seems that the identified weakness here is with regard to the interview questionnaire. The researcher has attempted to address the sensitivity on the subject of handwashing after defecation. Consequently, the question asked endeavoured to circumvent the topic of the practice of "handwashing after defecation" and generalise it by asking the question: "Are there any social rituals that are practiced in the family before eating meals such as praying or handwashing?". Likewise, unfortunately, the most obvious response to this was that all of them washed their hands before eating. The answers were based on what is seen as socially acceptable. Whether or not this really happens is questionable since no facilities such as sinks or even soap were to be seen in the homes. Hence, the figures pertinent to the topic of sanitation and hygiene could be renedered inadequate and not factual. Similarly, for the topic related to bathing. The question posed here was a direct yes/ no question, for which the obvious response was "yes".

As aforementioned, on the issue of attempting to gauge the situation relative to mental health to be able to gain an understanding of the overall health of the individual, it was brought to the researcher's attention, the sensitivily and taboo attached to the topic of mental health. Due to the participants lack of knowledge and awareness on the subject of inter alia, education and health, questions relative to social health were primarily based on the researchers observations and anecdotal evidence reported by the key informant. Owing to the rigidity of the social sturcture, the respondents even failed to understand the link between health and education. As a result of this, the research hypothesis relative to "health" has only moderately supported by the research results related to social and mental health since they have not be adequately addressed.

With regard to the household water treatment, the findings revealed that almost 60 % of the households do not treat their water at all before drinking. Those who do, use alum. The chemical term for this is aluminum sulfate. There are however, certain disadvantages linked to using alum. For instance, there is no way to exactly ascertain the dosage which according to the CDC "vary unpredictably" [39]. Furthermore, in a study by L. Telemovie, experimental evidence shows that there exists a plausible link between the use of aluminum and neurodegenerative disorders such as Alzheimers disease [45]. Although alum is a cheap source of treating water, it is perhaps best avoided since the long term implications of the use of such a chemical may produce deleterious health effects.

The quantitative findings of this study are in alignment with other studies conducted in this area, relative to microbial water quality abstracted from sand dams. This may be indicative of a certain degree of validity and reliability pertaining to the quantitative methods and findings. The findings in the light of this study reveal that the sand dam yields relatively clean pathogen free and potable water based on samples taken from the nearby tubewells. Similarly, in a study by O. Avis, from the London School of Hygience and Tropical Medicine, a water analysis of 29 sand dams in Makueni county, Kenya was carried out. Water samples were taken from all these dams in Makueni and the indicator organism used here was Thermotolerant coliforms (TTCs). According to his findings, “83% of the sand dams stored safe drinking water according to the WHO standards. 17% presented with very low risk.” [46].

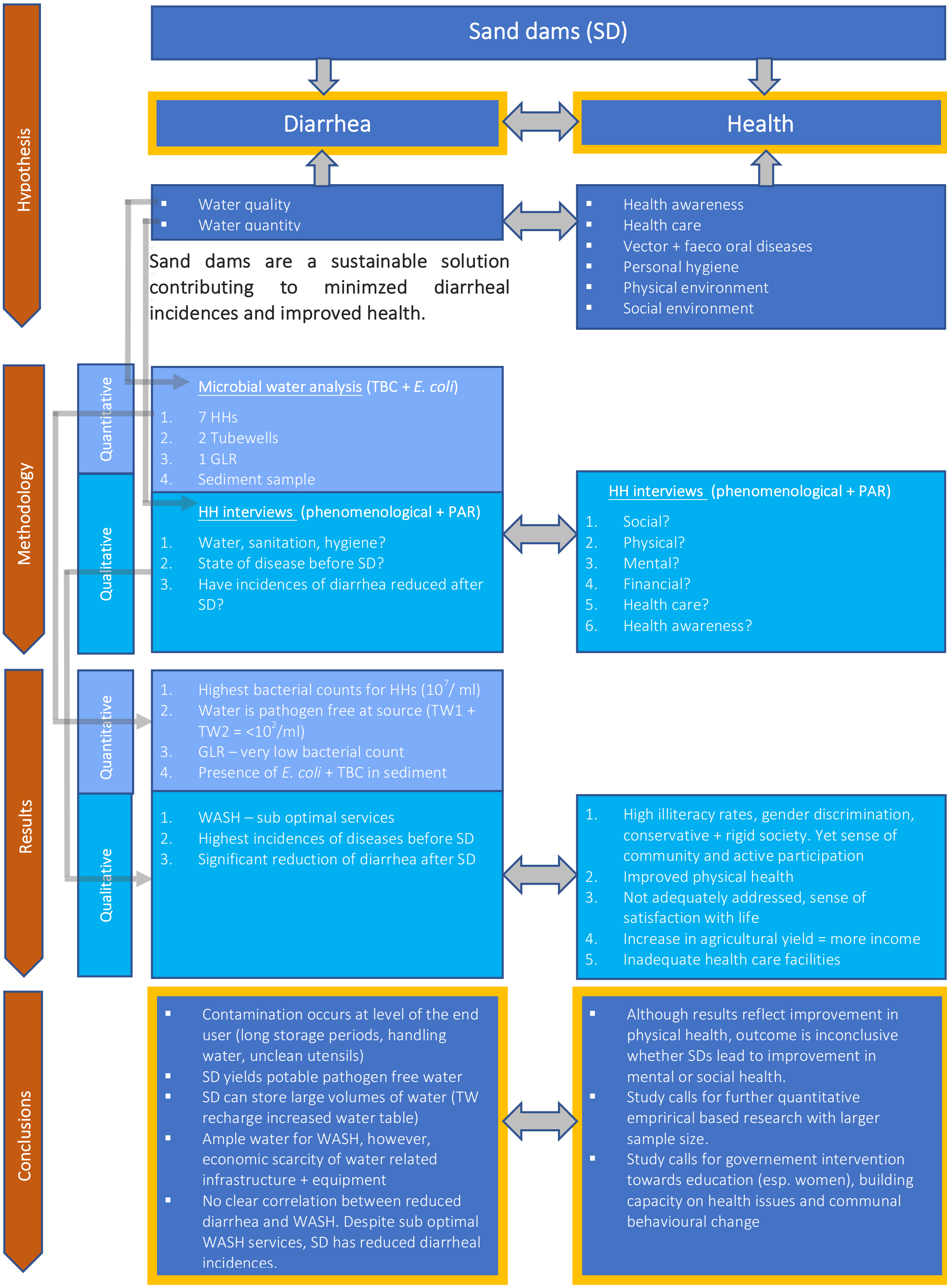


Figure 43: Schematic diagramm of research process. Created by the author. 07.10.2017

6.1 Limitations

The research study presented with several limitations in its journey from the thesis proposal to generation of the end results. These weakness have been discussed in the following paragraphs.

Water testing kit – Use of dipslides

The quantitative analyis employed the use of dipslides for the water analysis. This was done using a decision-making algorithm designed by the WHO. Although a higher accuracy of the tests might have been achieved using the in situ membrane filtration method in portable kits. As aforestated, these kits are costly due to the prices of the included incubators along with the kits. As a result of this, the most feasible option employed for the purpose of this study was the in situ dipslides from Rakiro®.

Equipment breakdowns

It was also observed during the water analysis that there were many breakdowns with the water equipment due to which for instance, a water sample from the main GLR needed to be taken from the top of the tank with the help of a bucket and rope due to a defunctional faucet at the GLR. This may have also contributed to an invalid result of the bacterial count, since contamination from the bucket could have played a role in the results. In addition, although there were three tubewells neighbouring the sand dam, water samples were only taken from two due to a breakdown in the pump of the third tubewell. Sytematic and regular maintenance inspections are called for in such cases.

Questionnaire design and participant responses

With regard to the qualitative analysis conducted through household and expert interviews, the researcher has unfortunately not been very successful in gaining a deeper insight and understanding into the lives of people and how the rural communities perceive issues relative to mental and social aspects of health since the responses were far from those as were expected. The responses lacked gravity, variance and detail. This could also be attributed to a poorly designed questionnaire and/ or a small sample size. Perhaps not enough time was allocated toward alliance building within the framework of the PAR model as a result of which the perceived relationship established between respondent and interviewer was not one based on trust. Consequently, this could have contributed to not enough details being shared with the reseracher. Furthermore, extrapolating the universal essence of the lived experiences of the responsdents was hence made even more challenging.

Sample size

The sample size for this study was 7 households. The research proposal expected to interview 12 participants. However, due to a demise in the village , the villagers were obliged to attend the funeral as a result of which only 7 of the respondents were present at the time of the interviews. However, with regard to the phenomenological approach, Creswell suggests a sample size ranging from 3-10 is considered optimal [30]. Since the sample size used in this study falls within this range, it is considered acceptable. However, a larger sample size would have lead to increased variability of data and hence added a multi perspective dimension to the study which appears to be lacking in this study. In the light of a quantitative study however, the sample size is clearly inadequate.

Uniformity in sampling at various control points

The intention of excavating a hole in the sand dam was to abstract water for sampling. Instead, a sample of the sediment, which was laden with moisture, was taken because no water was found at the depth of 2.5 feet. The tests carried out for this was not in situ. The analysis for this was carried in Ahmedabad, Gujarat and further, for the *E. coli* test, only a presence/ absence test was done. No bacterial counts were achieved for *E. coli* although the TBC test did include a count. In addition, the methods used to carry out the test were different from the in situ dipslide tests. Consequently, the testing methods used at the various control points varied which could suggest incorrect and/or inaccurate interpretations of the overall results.

Furthermore, for sampling, four control points were located (see figure 43). These comprised of 7 households, 2 tubewells, 1 main GLR and 1 sediment sample from sand dam. However, no water test was carried out from the village GLR due to an inadeqate number of dipslides.

Qualitative expert interviews

As part of the research proposal, it was expected to interview at least 3 experts in the village. These included the water technician who is a representative and employee of the PHED in the district of Jalor, Mr. Kapoora Raj, the key informant, Mahavirsing and the village nurse or doctor working at the health centre in THoomba Ka Goliya.

As part of the "emergent design" model, the water technician and the key informant invitably became part of the research in the way that along the field trip, they continually kept clarifying questions that the researcher otherwise meant to ask them as part of the interview. Hence, no interviews were rendered necessary here.

The village nurse and doctor however, were both unavailable for interviews at the time of the field trip even though this was planned and organised by the key informant. An attempt was made to establish a telephone interview, however, this too did not turned out as planned.

Water quality parameters

The two indicator organisms used in this study were TBC and *E. coli*. TBC is primarily a process indicator i.e. to measure efficacy of a filtration system or a water distribution system. It is commonly used in conjunction with *E. coli*. A high TBC might be indicative of bacterial regrowth in a distribution network. *E. coli* on the other hand is the organism of utmost importance to monitor faecal pollution.

Previous water tests had been carried out in the village at certain control points, prior to the building of the dam, primarily for the tubewells. These test results for randomly selected tubewells were shared with the researcher (see appendix). Unfortunately, it is unkown which tubewells these results correspond to since at the time of sampling and/ or conducting the test analyses, the process of labelling was not carried through adequately. Whether the samples were taken from the same tubewells that were used in this study is unclear since the key informant was uninformed on this topic as well. It would have been interesting to be compare the results of the bacterial counts of the test taken before the dam was built with the results of this research study. However, no microbiological parameters were tested for in theses analyses. The parameters were solely related to the physicochemical properties (see appendix for water report of tubewells). In the water reports taken from the tubewells, some of the parameters tested for are pH, TDS, fluroride, nitrate, chloride and total hardness.

7 Conclusion and recommendations

In summary, the main findings of this study indicate that the sand dams contribute to a significant reduction in the incidences of diarrhea as well as improved physical health owing to a reduced risk in contracting water related illnesses from drinking clean water. The sand dam yields an improved quality of water that is relatively pathogen free and potable. Although it is clear that diarrheal cases have markedly decreased among the rural people, the finding relative to an improvement in the mental and social aspects of health have been inconclusive. Hence, the study outcomes have reasonably supported the premise that sand dams are a sustainable solution in contributing to a minimized risk of diarrhea and improving health.

Based on the outcomes of the study, the answer to the research question is that sand dams could be rendered a useful and sustainable tool in contributing to minimized incidences of diarrhea to the extent that it provides the rural people with **superior drinking water quality** and consequently, leads to **improved physical health.**

In view of this study, there has been no clear correlation between reduced incidences of diarrhea and water availability for sanitation and hygiene. Despite the increase in the level of the water table after construction of the sand dam, the water has primarily been used for farming for which the outcomes related to agricultural productivity have been tremendous. Although the numbers for diarrhea in the village may have significantly decreased, it still exists. Water related illnesses such as diarrhea are completely preventable given the right measures are taken to avoid diarrhea causing pathogens from entering the drinking water and food. However, the transmission routes through which these pathogens can be spread are numerous. Hence, it is fundamental that emphasis be laid on sanitation and hygiene services to takle the issue from all angles (i.e. WASH). Due to the economic scarcity of water related technology and equipment which include lack of government subventions, no measures have been taken to invest in equipment for basic sanitation and hygiene facilities. It is indispensable, that the government and policy makers understand the significance of the linkages between diarrhea and WASH facilites. This study calls upon policy makers to petition and subsequently propel and promulgate plans and schemes that make such facilities affordable. In addition, to avoid breakdowns and make these services sustainable, even after the installation of this equipment, what needs to be factored in is regular maintainence. Sustainability could be facilitated through through community ownership and participation.

Given that a certain level of improved facilities are available to the rural members, whether the facilities are used or not depends on, inter alia, behavioural factors, attitudes of rural members towards standard of living, investment and viewpoints towards health. Also, tradition and social construct play a role in morphing the mindsets and the mental outlook of the villagers. In addition, more often than not, when the facilities do not meet the optimal level of what is considered healthy or normal, it seems that the community members do not feel the need to invest or build external alliances for petitioning for improvements in the facilities. The impression is that the general mental attitude is to "make do with what is available".

It is not uncommon however, that despite governmental efforts made towards schemes that partially provide grants for building private toilets in rural homes, no toilets are built, and instead the money is pocketed by the rural people. Such attitudes call for a major communal behavioural change. Similar cases have also been observed in Thoomba Ka Goliya. This can be extremely challenging since it involves changing the perception of a community. For any outcome to be successful, it is vital that the community members not only understand the complex nexus between diarrhea, health, water and sanitation and hygiene in theory, but that they are also prepared to implement changes practically. The underlying problem here that needs to be addressed is **education**.

The state of Rajasthan has the lowest literacy rates among women in India [45]. In Thoomba Ka Goliya, on a average, the girls study till class 8 subsequent to which they are expected to stay home before they are married off. What is more, there exists a social conservative and traditional rigid structure along with gender inequalities which are also products of illiteracy. Consequently, the social as well as mental determinants of health in the village have not been conducive in promoting or improving health but rather has had an antithetical influence. It is therefore imperative, that first and foremost **primary education** be addressed. Government interventions should focus on children completing schooling upto at least class 12. Further, workshops and seminars that promote empowering women in society and building capacity of the women not just in areas relative to public health and health awareness but more towards general and basic education are key. Similarly, workshops relative to communal behavioural psychology could prove beneficial as well.

The community leaders should make efforts towards improving and **lobbying** externally for higher allocation of funds toward building more primary health care centres in the villages and investment in WASH related technology so as to improve community health. This however, can only be done when and if the inextricable links between water, sanitation, hygiene and health are fully understood by the rural communities. In order to understand this, **collaborations** with NGOs, government and public bodies, private public partnerships and small and medium sized enterprises should be strengthened to enable better lobbying for activities that hinge on building community capacity and health education.

With regard to the household interviews, despite the similarities, redundancies in the responses of participants which also lacked a certain depth in the told descriptive accounts, one of the outcomes and personal learnings has been that no matter how much or how little is conveyed through the household interviews, the researcher as a person who has not experienced that phenomenon first hand i.e. what it is to live in extreme water scarce and poverty stricken conditions, can never truly gain a full understanding of the experience as lived by the participant. This can only at best be an approximation of the researcher´s understanding toward the plight endured and experienced by them. In addition, at the end of the day, these are still perceptions of the people that the researcher has best attempted to universally extrapolate the essence of, devoid her own biases and preconceived notions. In order to gain more concrete and valid data, a solution could be to carry out a household survey based on the WHO questionnaires on health. This could include a quantitative survey with larger sample sizes. The population of Thoomba Ka Goliya is estimated to be over 700. For the study to present with a statistical significance**, larger sample sizes** could be used for achieving a higher statistical power.

In the light of the parameters used to measure water quality, other critical parameters should also be monitored and tested based on the medical ailments of the rural communitites. This would for instance, better help identify and isolate which chemical element or mineral in the water is responsible for said ailment. This would perhaps lead to more awareness among the rural people and prompt them to take measures to treat and/or filter their water despite the high initial costs involved in buying such technology. Along with microbial parameters, equally important are the the physicochemical parameters that play a role in health. For a comprehensive test of water quality, all the key physicochemical parameters should be tested for. These should then be compared with the national or international guideline values such as the WHO and subsequently, apporpriate remedial action should be taken for those parameters that exceed the guideline values. In the water reports for the tubewells, some of the parameters tested for are pH, TDS, fluroride, nitrate, chloride and total hardness. In addition, the WHO suggests including parameters such as lead, chromium, arsenic and pesticides that are also critical to health [19].

The results from the water analysis indicate that the water at source is relatively pathogen free and can be used for drinking. The microbial contamination takes place at the end point which is the consumer. This contamination is consequence of poor handling of water. All water containers should be clean before collection of water from the communal water point. Ideally, the WHO suggests the use of chlorine for disinfection, however, sand can also be used. [31 p32].

In addition, the top of the container should always be covered and the scoop used to draw out water should be celaned reguraly and stored in a clean place.

There exist cost effective and **feasible atlernatives** to buying a water filter that maybe too expensive for the rural peole, that have been recommended by the WHO such as “boiling, filtering, chlorination or leaving water to settle”[31 p30] before drinking. Filtering encompasses the use of canvas or candle filters while disinfection is done with the help of chlorine. This however should only be done of the water is clear and not turbid. Chlorine in turbid water produces byproducts that are harmful to health. For treating drinking water, the common practice is the use of alum which is linked to neurodegenerative disorders such as Alzheimer´s disease [45]. Other alternatives for the settling could be using powder from the seeds of Moringa Oleifera and Moringa stenopetala which can be sprinkled on the surface of the water. However, this does not remove all pathogens or turbidity. Therefore subsequent boiling of water before consumption should be considered.[31 p32]

In conclusion, as deduced from the results, the sand dam at Thoomba Ka Goliya has proved to be a boon to the farmers not just in terms of agricultural productivity but also in reducing diarrhea and consequently, improving physical health. This study could contribute to serving as practical material for stakeholders and health policy makers affording them a higher understanding of the myriad of benefits that are linked to groundwater dams. Through logical inference, this could contribute to more measures being taken towards construction of more sand dams in the rural drylands of Marwar and consequently, combating the harsh challenges linked to water scarcity in the region.

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Appendix

A) Research Proposal

Evaluation of microbial water quality and impacts of diarrhea in Thoomba Ka Goliya, India

Sand dams linked to improved health and minimized risk of diarrhea among rural population in Thoomba Ka Goliya, Marwar, Rajasthan, India

1. Abstract

Human health and the environment are inextricably linked. The availability and access of clean drinking water are grave issues that most developing countries are faced with today. The incidences of water related diseases are on the rise as a result thereof.

Diarrhea is the second leading cause of death in the world in children under 5 years and the third most common cause of childhood mortality in India, responsible for 13% of deaths within the same age group. Even though the number of deaths has declined through the intervention of various vaccination programmes, the proportional mortality attributed to diarrhea remains significantly high [1]. Diarrhea is also known to be the underlying cause for malnutrition in children affecting their mental and somatic health [2]. The cause for endemic diarrhea however, is not explicitly a function of water quality but also its volumetric abundance [3]. Accordingly, the quality of water along with the problems relative to water scarcity need to be considered in order to effectively address diarrhea.

The drylands of Marwar region in western Rajasthan located in the Thar desert in India, is the most densely populated arid land in the world. The word “Marwar” has its roots from the Sanskrit word “Maruwar” which means Land of Death referring to the harsh environment characterized by drought and scanty and erratic rainfall [4]. Consequently, the water availability and supply are unable to meet the water demand of the rural communities in Marwar. Clean water supply that is free of pathogens such as faecal matter is a key

determinant of public health. water for drinking and domestic purposes are inadequate and the amount of water for sanitation and hygienic practices such as hand washing and bathing are trifling. Diarrhea is therefore, especially exacerbated in these areas.

Rainwater is an especially valuable resource in water stressed areas of the world such as Rajasthan, India which is prone to drought and falls in a zone of extreme water scarcity [5]. The Marwar region is subject to extreme temperatures with extreme low annual rainfall of 100-500mm [5]. Due to numerous factors such as groundwater drawback, population projections and climate change, the practice of diverse rainwater harvesting techniques, especially in arid areas is becoming indispensable.

The groundwater dam is a traditional rainwater harvesting tool whose purpose is to capture and store rainwater, thereby, securing its availability through the long dry periods. The stored rainwater is used for irrigation, feeding cattle, domestic purposes and drinking.

Thoomba ka Goliya, a village with a population of 704 people is located in the Jalore district of Marwar, Rajasthan. After construction of a sand dam here in 2014, ca. 100 wells have been recharged and the quality of water has significantly improved. The villagers revealed - "Before the sand dam, we had very hard water. We are not even able to make tea. Now the quality of water is becoming good for irrigation and drinking." In addition, the members of the village council have reported decreased incidences of illnesses among children and adults. Water availability is reported to have increased by 50%. Further, case studies have reflected a 40% increase in income of farmers contributing to diverse farming practices which contribute to improved health, economic stability and poverty alleviation.

Similarly, sand dams have also been built in sub-Saharan Africa by the same charitable organization (Excellent Development) where the water has been tested and is safe for drinking. According to O. Avis who tested 29 sand dams in the Makueni County in Kenya for the presence of thermotolerant coliforms (TTCs), “83% of sand dams stored safe drinking water according to WHO standards. 17% presented very low risk” [6]. Furthermore, Excellent Development postulate “People using the water from sand dams report a dramatic reduction in water-borne diseases” [7].

2. Expected Results

The use of groundwater dams maybe seen as a sustainable solution for addressing water scarcity in Marwar, affording a higher quantity of water for healthier sanitation practices as well as improved quality of water for drinking among rural communities. Furthermore, groundwater dams could be seen as a potential improved source of drinking water that could contribute to minimizing diarrheal risk and improving health among the rural communities in Marwar.

3. Research Question

To what extent can the use of water from groundwater dams contribute to improved health and minimized incidences of diarrhea in Thoomba ka Goliya, Marwar, Rajasthan, India?

4. Goal

Goal of the research is to contribute to a higher understanding of the extent to which, groundwater dams may lead to improved health and minimized incidences of diarrhea in Thoomba ka Goliya. The sand dam built in the village was initiated as pilot project primarily to enhance irrigation, contributing to food security and alleviating poverty.

Since the construction of this community-owned dam, the returns have been tremendous not just financially but also in terms of health. This thesis could be especially useful for health policy makers affording them a higher understanding of the link between sand dams and health.

5. Geographical Focus

Qualitative Household surveys and expert interviews will be conducted among the rural communities in Thoomba ka Goliya, Marwar, Rajasthan, India, where the sand dam is located to find out how the water from the dam has benefited their lives leading to improved health (physical and mental and social) and contributing to reduced incidences of diarrhea.

6. Methodology

6.1 Water analysis

6.1.1 Rapid tests will be used on the site to test for presence of bacteria (total coliforms, specifically *E. coli*) with the help of rapid test kits to determine if water has pathogens

The water analysis will be carried out at 3 different locations:

- the source: i.e. a random spot on the sand dam or where the tubewell is located
- the storage tank
- samples will be collected from the taps of 6 out of 12 random households whilst carrying out the interviews

- Two Tubewells are located upstream of the dam which are the sources of water for almost all the households in the village. Since almost every household has a tap with running water, in the case where *E. coli* is detected in the water sample, it would be useful to identify the stage/source (i.e. sand dam - storage tank - pipes from tank to taps) from where the bacteria originates. Hence the water test at 3 different stages will be carried out.
-

6.2 Qualitative household survey (interviews)

At the household level, different storage containers or utensils maybe used e.g. earthen pots, steel containers or plastic jerry cans etc. Again, even in the case where bacteria have not been detected in the drinking water, it would be useful to identify other possible sources from where microbes might originate should the reported incidences of diarrhea still be high. E.g. food, animals, unhygienic sanitation practices etc. For this purpose, also household interviews will be carried out to identify and/ or rule out sources of pathogens.

So far, through desktop research and also telephonic conversations with members from the village of Thoomba ka Goliya, there are no available medical records from the primary health care centres or health communities situated in and around the village, that explicitly reflect the incidences of water borne diseases contracted by the patients of Thoomba ka Goliya.

However, through anecdotal evidence from the village council members and through case studies carried out by the Jal Bhagirathi Foundation (JBF) that helped construct the dam, improved health and a reduction in the incidences of water borne diseases subsequent to the construction of the dam have been significant.

Accordingly, a qualitative household survey will be carried out with 12 different families in the village. Questions will primarily be answered by the housewives (20^{th} – 22^{nd} March 2017). All household Interviews will be carried out in person and recorded for data collection and subsequently, for systematic coding and framework building. The software used will be MAXQDA

6.3 Qualitative expert interviews (still needs to be determined if via phone or in person)

In addition, a qualitative analysis will also be carried out by 3 experts in the village (22nd March – 23rd March)

- Mr. Kapoora Ravi – representative and employee of the Public Health and Engineering Department (PHED) in the district of Jalor
- Mr. Mahaveer Singh – Farmer and member of the village council
- Nurse/Doctor who works at the health centre in the village in Thoomba ka Goliya.

A few questions will be planned for each expert, however, here questions will take place in a more extempore manner. A group interview may also take place depending on the convenience and time availability of said experts. Interviews will be recorded for data collection and subsequently, for systematic coding and framework building. The software used will be MAXQDA

Questions for Household Interviews

1. General warm-up questions
    a. How has the construction of the dam benefited you and your family?
    b. How and where do you use the water?
    c. How are the communities that use water from the dam being supported in terms of capacity building relative to water management and its use? Also, regarding public health e.g. imparting knowledge regarding healthy sanitation practices?
    d. Who are these supporters? (NGOs, private, public utility)?

2. Point-source drinking water
    a. What are the other point-sources of drinking water currently used in the village? (improved or unimproved?) Which one(s) do you use?
    b. Which is the most preferred point-source for drinking water in the village today? What was it before the dam was built?

c. How would you describe the quality of water from the dam? How is it in comparison to the former point-source(s) that were being used?
d. Can the water be drunk directly from all the named point-sources including the sand da n(i.e. without subsequent treatment)?
e. How do you abstract water from the sand dam (tube well/ infiltration well/ scoop hole etc.)? (in case there is a household with no running water)

3. Factors affecting drinking water quality (in case there is a household with no running water)
    a. Time and distance to point source – How long does it take to fetch water from the sand dam (tubewell)? How far away is it?
    b. Transport and Storage - How is the water being carried from the site to the household? Where is it stored?
    c. For how long is this water used before water needs to be fetched again?
    d. Do you store rainwater? If yes, where and how? Is this water used for drinking or cooking?

4. Treatment
    a. What measures do you currently employ to treat the water before drinking?
    b. What do they cost?
    c. How often are these measures taken?

5. Sanitation, Hygiene, Transmission
    a. Do you have a ritual like saying a prayer or everyone washing their hands before eating a meal?
    b. Do you have a distribution of household work where the chores are shared? Who throws the garbage? Where is this disposed? Also, sweeping and bathroom

cleaning and washing clothes – who does this and how many times a week is this done?

c. Has the frequency of these practices increased since the implementation of the dam? → Is there more water available for these practices? Do you all bathe more often (e.g. in the summer when temperature sore upto 40 degrees) now that there is more water?
d. Consequently, have the water related sicknesses reduced in the family?
e. Do you have any house pets? Are there a lot of birds or insects, flies or mosquitoes coming into house? What do you do to prevent this?

6. Health
   a. Physical

      Food (questions to determine/rule out source of *E. coli* from food)

      - How many meals a day do you/the family eat? Is the family vegetarian? IF meat what kind? How far is the abattoir from you home? Is the meat fresh? How do you cook this? What are the foods you eat/ name a few dishes that are cooked? What is the dish most eaten? What is done with the left over food? How is it stored? (Refrigerator or just room temperature and covered)
      - Does the family drink milk? Is it cows milk? How is the milk drunk – does one boil it? Where does the milk come from? Is it also used for cooking?
      - What are the most common illnesses contracted in the family? Do you notice after eating a certain food/ dish, that you often get diarrhea? Of all the times you have had diarrhea - do you know / think they are water-borne/ water related or food borne?
      - Who are the members in the family that primarily contract these diseases?

- What do you do when you fall ill with stomach related problems like vomiting, specifically diarrhea?
- What is the frequency of these disorders (1x month?)? Have they reduced since the sand dam has been built?
- Are there any preventive measures being taken to mitigate the risk of these diseases?
- Would you say that the overall health of the family improved since the construction of the dam? How?

b. Social

- Are there any upcoming festivals in the village? Will you go there? Will you wear something new to the event? Where do you shop for clothes/ jewellery? How often do you/ the family go shopping? Do you shop more now (financial)? What are the things you usually buy when you go?
- Do you ever get bored? Do you go visiting other family members living close by or take a small vacation? Do you have more time for the family since the past 2 years/ construction of the dam? How is this time spent?
- Do all the children especially the girls in the family attend school?

c. Emotional

- How was the situation 2 years ago when the availability of water was scarce in the village? Were there times when there was no water for drinking? What did you do to get drinking water? (stress)

d. Financial

- How has the crop yield been this year for you/ your husband? Has the sand dam impacted farming and the family earnings?

- Do you save any money? How much of the earnings is invested in the household (40%) How is the money used? (e.g. 30% for food like buying more fruits and vegetables, 10 % for renovating or buying toilets, soap, buying a refrigerator, TV etc.?

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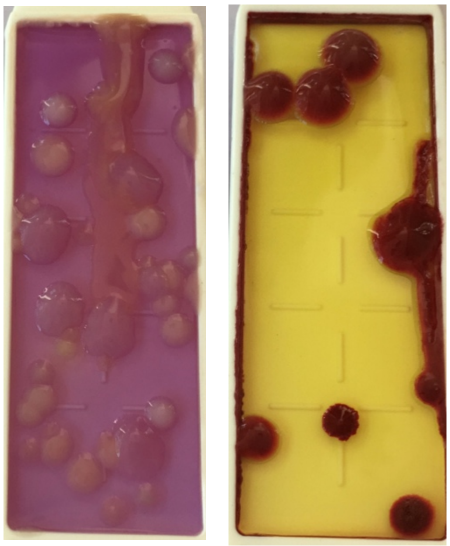
B) Resuts of water tests after 30 hours (counts/ ml)

HH 1



TBC – 10^4, *E. coli* – 10^3

HH 2

TBC – 10^5, *E. coli* – 10^5

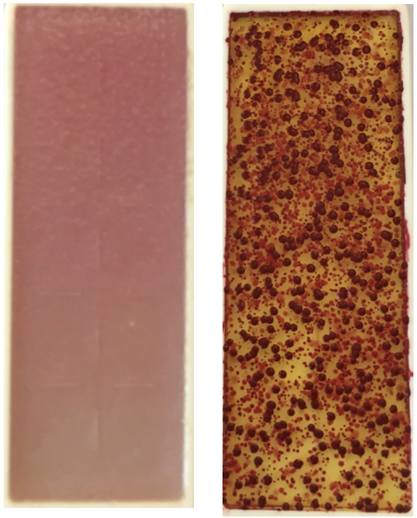
HH3

TBC – 10^5, *E. coli* – 10^3

HH4

TBC – 10^5, *E. coli* – 10^5

HH 5



TBC – 10^7, *E. coli* – 10^7

HH 6

TBC – 10^7, *E. coli* – 10^3

HH 7

TBC – 10^3, *E. coli* – 10^4

Main GLR

TBC – 10^7, *E. coli* – 10^3

Tubewell 1 (WP 22)

TBC – $<10^2$, *E. coli* – $<10^2$

Tubewell 2 (WP 23)

TBC – $<10^2$, *E. coli* – $<10^2$

C) Test report – Sediment sample from sand dam

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Web : www.gujaratlaboratory.com

TEST REPORT

Report No. GL/C./170324026

Sample Submitted By Macorganix
"SERENADE", Survey No:121, Sughad,
Behind Madhav Road, Near Koba Circle, Dist:
Gandhinagar-382424

Date of Receipt 24/03/2017
Reference No. NM

Batch No. NM
Mfg.Date NM
Exp.Date NM
Sample Qty.: 200 gm

Sample Described as Soil.

Mode of Packing Sample Packed in Plastic Container
Sample Condition Satisfactory
Marking -

Analysis Date 24/03/2017
Report Date 29/03/2017

Sl.	Test Name	Results	Test Method
1	Total Bacterial Count cfu/gm	4.2×10^5 cfu	IS:5402-2012
2	E.Coli/gm	Present	IS:5887(P-I)-1976 (Reaff. 2005)

N.M.= Not Mentioned

Date of Issue : 29/03/2017

For GUJARAT LABORATORY
[redacted]
Autho. Signatory

End of Report

Note :
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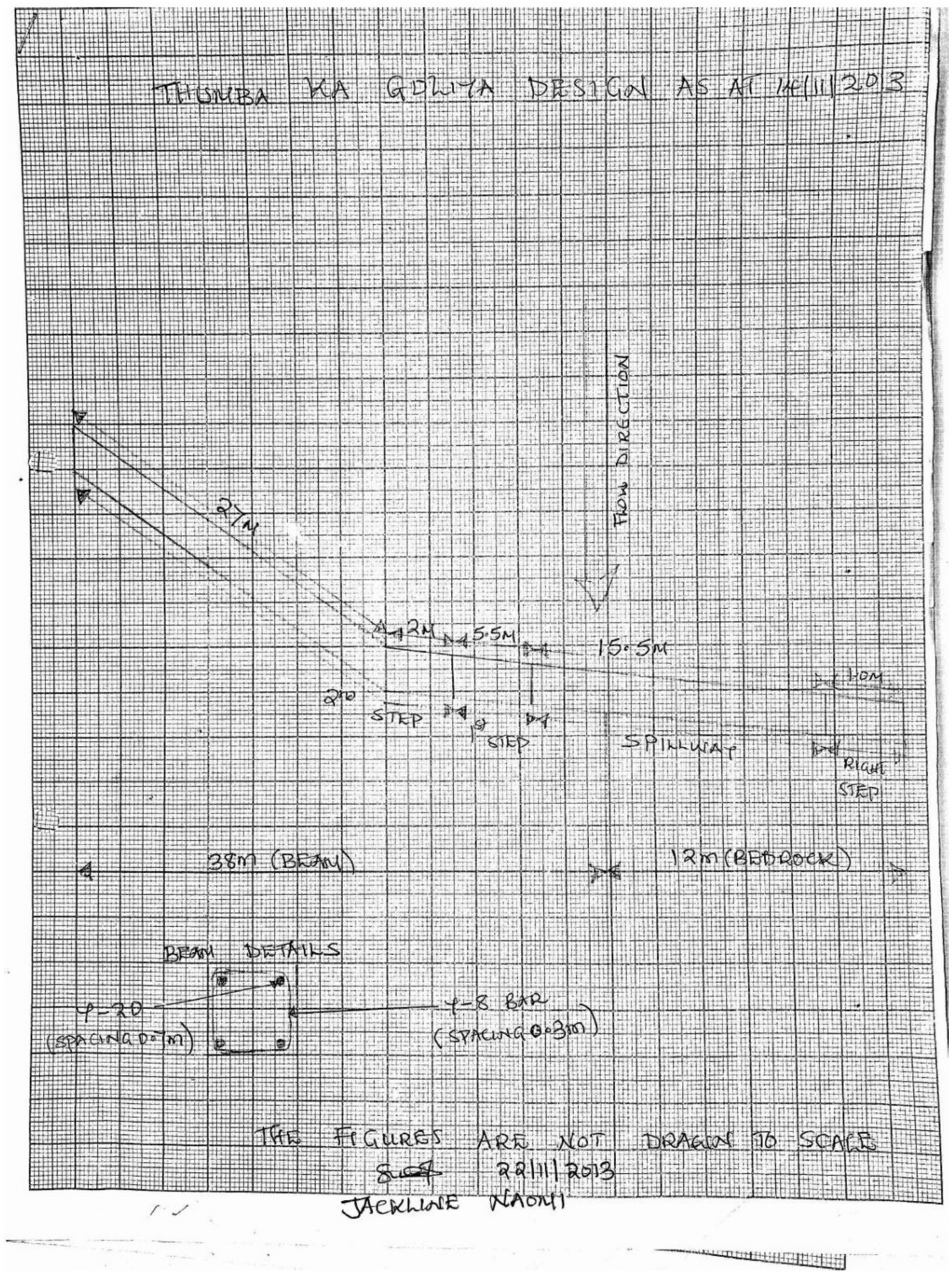
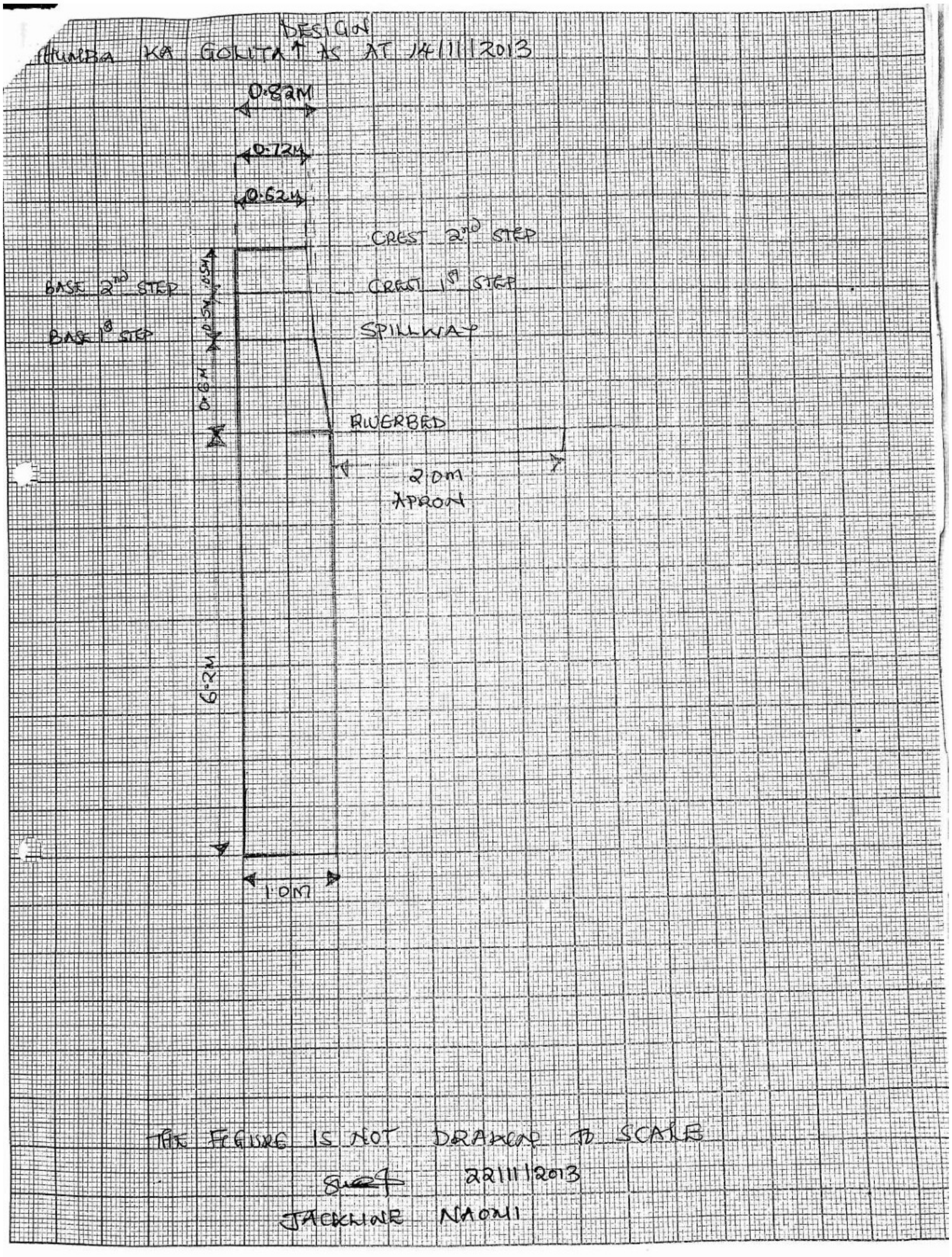
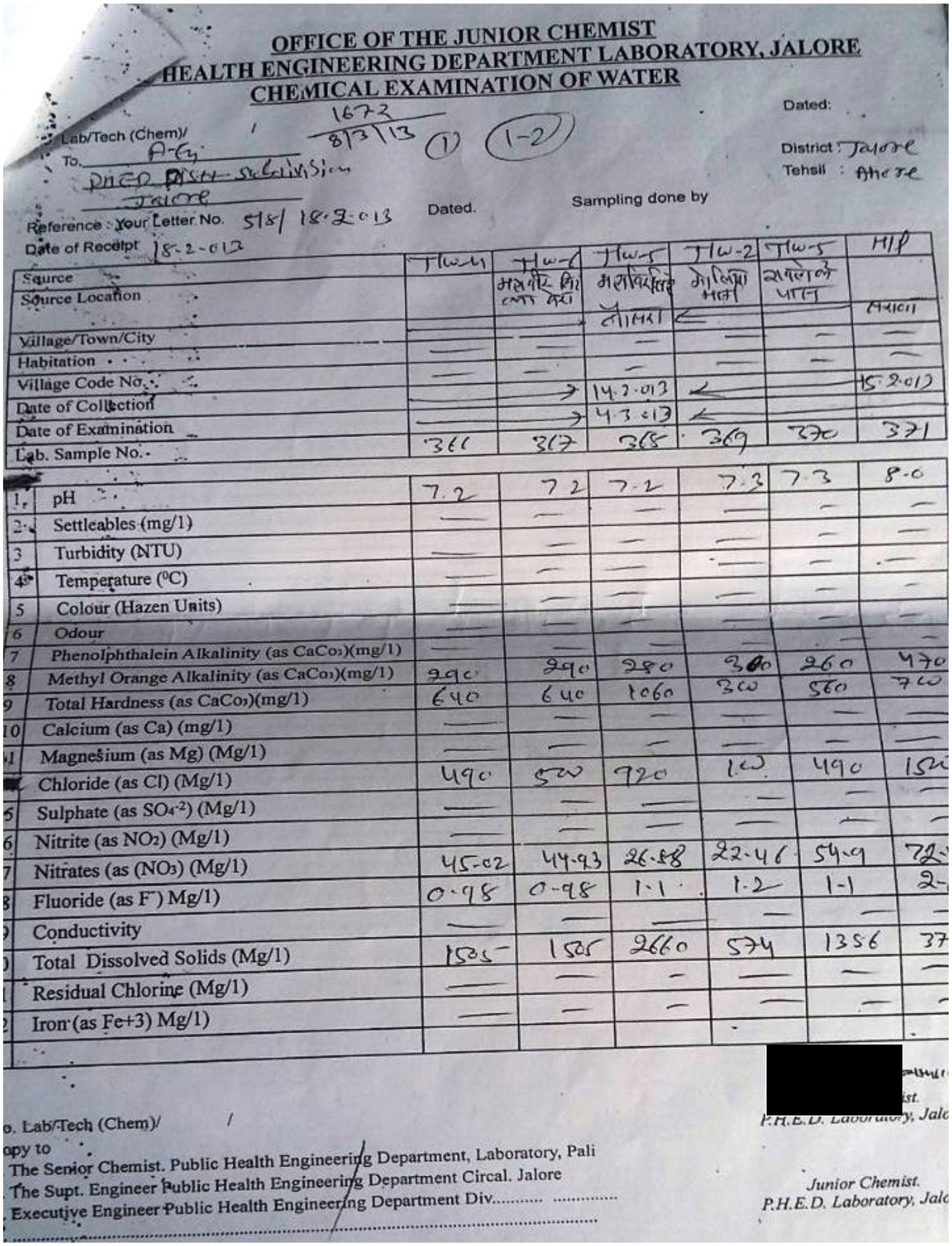
7. Perishable samples will be destroyed after testing, others after three weeks from the date of issue of the report, unless otherwise agreed with the customer. Also retain sample will not be returned unless otherwise agreed in writing.
8. The sample is accepted by us subject to our general conditions of services which is displayed at reception notice board & is also available on request. Attention is drawn to the limitation of liabilities; indemnification and jurisdictional issues etc defined therein.
9. Customer requested for the above test only.

D) Technical drawings – Sand dam Thoomba Ka Goliya




DESIGN
AS AT 14/11/2013
0.82M
0.72M
0.62M
CREST 2ND STEP
BASE 2ND STEP
CREST 1ST STEP
BASE 1ST STEP
SPILLWAY
0.5M
0.5M
0.6M
RIVERBED
2.0M
APRON
6.2M
1.0M
THE FIGURE IS NOT DRAWN TO SCALE
22/11/2013
JACKLINE NAOMI

E) Water report – Selected tubewells, Thoomba Ka Goliya



OFFICE OF THE JUNIOR CHEMIST
HEALTH ENGINEERING DEPARTMENT LABORATORY, JALORE
CHEMICAL EXAMINATION OF WATER

Lab/Tech (Chem)/ 1672 / 8/3/13 (1) (1-2) Dated:

To. A-G, PHED Distt- Subdivision Jalore District: Jalore Tehsil: Ahore

Reference: Your Letter No. 518/ 18.2.013 Dated. Sampling done by

Date of Receipt 18-2-013

	TW-4	TW-1	TW-5	TW-2	TW-5	H/P
Source		[illegible]	[illegible]	[illegible]	[illegible]	
Source Location			[illegible]			[illegible]
Village/Town/City	—	—	—	—	—	—
Habitation	—	—	—	—	—	—
Village Code No.	—	—	—			
Date of Collection	→	→	14.2.013	←		15.2.013
Date of Examination	→	→	4.3.013	←		
Lab. Sample No.	366	367	368	369	370	371
1. pH	7.2	7.2	7.2	7.3	7.3	8.0
2. Settleables (mg/1)	—	—	—	—	—	—
3 Turbidity (NTU)	—	—	—	—	—	—
4 Temperature (^0C)	—	—	—	—	—	—
5 Colour (Hazen Units)	—	—	—	—	—	—
6 Odour	—	—	—	—	—	—
7 Phenolphthalein Alkalinity (as $CaCo_3$)(mg/1)	—	—	—	—	—	—
8 Methyl Orange Alkalinity (as $CaCo_3$)(mg/1)	290	290	280	300	260	470
9 Total Hardness (as $CaCo_3$)(mg/1)	640	640	1060	300	560	700
10 Calcium (as Ca) (mg/1)	—	—	—	—	—	—
11 Magnesium (as Mg) (Mg/1)	—	—	—	—	—	—
Chloride (as Cl) (Mg/1)	490	520	920	100	490	15[illegible]
Sulphate (as SO_4^{-2}) (Mg/1)	—	—	—	—	—	—
Nitrite (as NO_2) (Mg/1)	—	—	—	—	—	—
Nitrates (as (NO_3)) (Mg/1)	45.02	44.93	26.58	22.46	54.9	72.[illegible]
Fluoride (as F^-) Mg/1)	0.98	0.98	1.1	1.2	1.1	2.[illegible]
Conductivity	—	—	—	—	—	—
Total Dissolved Solids (Mg/1)	1505	1505	2660	574	1356	37[illegible]
Residual Chlorine (Mg/1)	—	—	—	—	—	—
Iron (as Fe+3) Mg/1)	—	—	—		—	

[redacted] ...ist.
P.H.E.D. Laboratory, Jal...

No. Lab/Tech (Chem)/ /
Copy to
The Senior Chemist. Public Health Engineering Department, Laboratory, Pali
The Supt. Engineer Public Health Engineering Department Circal. Jalore
Executive Engineer Public Health Engineering Department Div........... ....

Junior Chemist.
P.H.E.D. Laboratory, Jal...

I hereby declare that I wrote this thesis without any assistance and used only the aids listed. Any material taken from other works, either as a quote or idea have been indicated under 'Sources'.

Date and Place:

Signature: