CRANFIELD UNIVERSITY

SCHOOL OF APPLIED SCIENCE

MSc THESIS

Academic Year 2008-2009

A MUKADAM

Drinking Water Quality and Treatment Practices in Pabal, India

Supervisor: J Webster

September 2009

This thesis is submitted in partial fulfilment of requirements for the degree of Master of Science

ABSTRACT

The drought prone, rural village of Pabal is an example of improved access to water through a piped water system, however at times the villagers are also recipients of a poor water quality supply. Prevailing illnesses of diarrhoea and gastro-intestinal diseases, especially during the monsoons result in 40-50 % of villager's income being spent on medical bills. This research project provided by Engineers Without Borders – UK and EngINdia aims to form an investigative study into the current water quality and treatment methods in Pabal. This was achieved by analysing water samples using the DelAgua Water Testing Kit for microbial pathogens (faecal origins) at different points in their distribution system as well as carrying out a social survey through 22 questionnaires and a few target interviews.

Results showed the reservoir water source to be highly contaminated but chlorination at the storage tank removed all traces of thermotolerant faecal coliforms. However all consumer points were also found to be contaminated as well as at the borehole hand-pump. Qualitative data collected through observations, sanitary surveys and the questionnaires provided possible reasons for contamination. The pipeline is in disrepair through lack of maintenance, pollutants and effluence (human and animal) are leached into groundwater and pipe supplies, as there are also no drainage or refuse systems in the village.

Most villagers are aware and practice basic health, sanitation and water treatment however some only treat once they fall ill. Water treatment is essential in Pabal at all times and should be implemented at a cost-effective household level. The villager's health may be safe guarded by utilising traditional methods such as cloth filtering, copper pot storage (anti-bacterial properties) in addition to chlorination. Further education and future water treatment designs based on bio-sand and UV filtering can be produced locally via the community involving educational centre Vigyan Ashram.

ACKNOWLEDGEMENTS

Firstly I would like to acknowledge and thank the staff at EWB - UK and EngINdia for providing me with a very interesting opportunity to carry out research in Pabal. I owe my deepest gratitude to my supervisors Dr. James Webster, Ms Alison Parker and to Mr. Melvin Leong, who have supported me through all stages of the thesis which I am very grateful for.

To all the staff and students at Vigyan Ashram thank you for accommodating my research and presence while staying in Pabal. Special mention goes to Kulkarni Sir, Anand Sir, Sonali Madam, Mr. Anil Joshi and Amma, for their support and help with all that I required. Mr. Ganesh Pingale without your time, patience and motorbike I would not have been able to collect and analyse my samples in time, thank you very much.

On a personal level I am indebted to my parents and brother for their love, support and encouragement especially throughout this year. I would also like to show my gratitude to Mr Sadiq Shabudin and my special friends and colleagues who have also shown their support, especially Tom Wilson for his company in Pabal.

Last but most defiantly not the least I would like to thank the Sarpanch of Pabal for his time, and all those lovely people I met, interviewed and spent time with in Pabal for being so welcoming and taking part in my research.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

1. INTRODUCTION

1.1 Water – Global Issue of Quantity

Water is a fundamental resource without which the Earth would not be able to sustain life as we currently know it. Freshwater is a finite resource most of which is 'locked away' in the icecaps of Antarctica, Greenland and in deep underground aquifers. Only 0.3% of the total freshwater reserves are usable, mainly accessible from rivers and lakes (Gleick, 1993).

The affluent growth of western human society with its technological advances means there are many issues and pressures (including conflicts) faced globally with regards to water supply, demand and management. These issues can be environmentally, economically, socially or even politically driven. In turn these have resulted in the formation of legislation at a global, regional and local level in order to control, monitor and protect this valuable resource. The Millennium Development Goals (MDGs) provide an internationally united set of development objectives to be achieved by 2015, in order to aid in the reduction of extreme poverty. The third target of the 7th goal aims to, '*Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation'* (MDG Report, 2008).

Climate change has affected the global hydrological cycle and has led to an intensification of extreme weather events, such as flooding, storms and droughts. For example the annually late monsoons in India have further dried out arid regions and created a drought situation in a quarter of the country (The Times of India, August 2009). The UN World Water Development Report 3 (2009) describes how overexploitation of aquatic ecosystems is an effect of acceptable water quality supplies being inaccessible. Water availability increases the potential for earning hence driving economic development. For example 69% of people living in areas of India without water for agricultural irrigation are poor, compared to 26% in irrigated areas (Bouguerra, 2006).

1.2 Drinking Water – Global Issue of Quality

The hydrological cycle is the natural process that drives the movement of water around the Earth. It is also the mechanism that has an effect on the quality of water as precipitation, evapotranspiration and groundwater seepage are all important processes to be considered when dealing with drinking water availability from a source. The rain and the water passing through the geology of an area have the ability to absorb different compounds both natural and manmade. For example the pesticide DDT (banned in most developed countries) has been detected in every stage of the water cycle, and was also the cause for the decimation of the songbirds in Rachel Carson's publication '*Silent Spring*' (Stauffer, (1998) and Carson, (1962)).

Crompton (1998) defines pollution as: *"a change in water quality which causes deleterious effects on the organism community or makes the aesthetic quality of the water unacceptable"*. Pollutants affecting water quality may come from point, non-point sources, or a combination of both. The following is a list of impurities that may be found in water: undissolved matter (floating liquids or solids), dissolved compounds (diameters below 10^{-9}m that sedimentation cannot remove), vegetable matter (i.e. algae), higher organisms (sized between 0.05-10mm and are harmless to human health) and pathogenic microorganisms (De Moel *et al*, 2006). Chemical contamination consists of gases such as CO_2 and SO_2, heavy metals and industrial chemicals found in the environment, that typically cause long-term health problems like arsenicosis and skeletal fluorosis. Waterborne pathogens can cause short-term diarrhoeal diseases such as cholera, bacillary dysentery and typhoid (WaterAid UK, 2009).

These impurities have to be regulated in order to achieve safe and acceptable drinking water standards. Global guidance and standards come in the form of the World Health Organization's (WHO) framework for safe drinking water (2004). It states that safe drinking water is, "water *with microbial, chemical and physical characteristics that meet WHO guidelines or national standards on drinking water quality*". The indicator for the MDGs is, "the *proportion of people* *using improved drinking water sources: household connection; public standpipe; borehole; protected dug well; protected spring; rainwater* "(WHO, 2009).

In the last 18 years around 1.6 billion people have gained access to safe drinking water however there are still 1 billion without safe drinking water and a further 2.5 billion without access to basic sanitation services (MDG Report, 2008). Many of these people are managing on as little as 10 litres of water a day for all their drinking, washing and cooking needs (WSSCC, 2008). According to Bouguerra (2006), a third of all deaths in the Third World is due to diarrhoea from drinking and contact with dirty water. Out of the 4 million children affected in the world, 1.5 million are from India.

1.3 Non-Governmental Organisations (NGOs) Affiliated With the Project

1.3.1 Engineers Without Borders – UK and EngINdia

The student-led charity organisation Engineers Without Borders UK (EWB-UK) provides both research and practical opportunities for engineers and students to assist in worldwide human development. Working with many other organisations and local NGOs they are able to facilitate projects such as the water treatment project in Pabal.

The EWB-UK associate EngINdia is a partnership of students from the University of Cambridge, the Massachusetts Institute of Technology (MIT) and the Indian Institute of Technology Bombay (IITB). The team carried out a research expedition in the summer of 2005, partly funded by the Royal Geographical Society (RGS) targeting the rural Indian village of Pabal. An assessment was made of the local community needs and available technologies, which resulted in a list of research areas for further development such as biogas generators, rain water harvesting, water testing and treatment.

1.3.2 Vigyan Ashram

A local Indian NGO founded in 1983 by Dr Srinath and Mrs. Mira Kalbag as a non-formal school for children that have dropped out of conventional education. It adopts a philosophy of '*Learning while doing'*. The comprehensive, year-long, vocational curriculum is targeted at rural school children of high-school age, also in-keeping with the meaning of the name of the school. "*The word 'Vigyan' is Sanskrit for science and it is an 'Ashram', to represent a value system based on simple living and high thinking''*, (Dr. Kalbag). Both male and female students cover four basic areas: Engineering, Energy and Environment, Agriculture and Animal Husbandry and Home and Health. As well as classroom, laboratory and field work the students are expected to raise Rs1000 of their tuition through various income generating activities. A working farm at the Ashram encourages the students to grow their own produce and learn to make vital economic decisions. Overall the students are taught how scientific and technical principles are applicable in a rural setting, giving them a boost in their self confidence and independent thinking.

This inspiring educational centre has produced many entrepreneurs who have gone on to open their own businesses in Pabal. Innovations include the design of an earthquake resistant, geodesic dome for human habitation ('the Pabal Dome'), a low cost tractor as well as low-cost LED-based light bulbs.

1.4 Pabal Village – An Indian Case Study

The village of Pabal, in Shirur taluka is situated in the Western district of the Maharashtra state of India. The closest town Rajgurunagar is 20kms away and the nearest city Pune is a further 70kms, lying over the basalt and granite geology of the Deccan Plateau (Maharashtra Guide, (2009)).

***Figure 1*: Shows the location of Pabal in the Maharashtra district**

(*Online source: Maps of India, 2006*)

The tropical monsoon climate found in Maharashtra is unevenly distributed and Pabal falls under one of the more drought prone regions of India. This is because it lies in the 'rain shadow' of the Sahyadhri Mountains (Western Ghats) that run parallel to the Konkan coast. Monsoons start in early June for a four month period after the high temperatures from March until May (Maharashtra Guide, (2009)).

The villagers of Pabal currently collect their water from either personal or shared boreholes or wells. The reservoir situated 2km away from Pabal and a storage tank on the hill allows water to be piped and running water to be accessed at public tap-stands and in some paying homes. However there is no formal system of water treatment and according to local doctors' diarrhoea and gastrointestinal diseases are common, as well as kidney stones. These problems are intensified during the monsoon season, as pathogens are washed into the water sources, resulting in up to 40-50% of the villager's income being spent on healthcare (Furminger *et al*, 2006).

1.5 Aim & Objectives of the EngINdia / EWB-UK Project

The **aim of the thesis** is:

A follow up on the EWB-UK baseline study into the current drinking water sources and treatment practices in Pabal, India, in order to provide appropriate solutions for improved personal health.

To achieve the aim, the following **thesis objectives** will need to be realized:

1. A microbiological assessment of the current water quality in Pabal at different points in the distribution system.
2. An assessment of the current water treatment practices.
3. An assessment of the current health and sanitation practices.
4. Recommendations for improvement using information gathered from the above objectives.

2. LITERATURE REVIEW

This chapter will review the role and effectiveness of Non-Governmental Organisations (NGOs) in development, as this project is associated and based on the cooperation and work carried out by a number of international and local NGOs i.e. EWB–UK, EngINdia and Vigyan Ashram. In order to provide essential background knowledge of the subject a review will then be carried out on the different aspects of water such as health, sanitation, pollution and treatment.

2.1 NGO's role in development and management

As globalisation occurs, there is a shift in power from public to private interest, which includes that of the NGOs. Fowler (2000) states that the NGOs have progressed from being "*ladles in the global soup kitchen', to a force for transformation in global politics and economics"*. This role change from a 'side utensil' to a more prominent figure has not come without failures, which can now be understood to have been due to a lack of cultural awareness, use of appropriate technology and/or community involvement in many initial development projects. This was effectively described in the following anecdote from Drangert (2004), quoted by La Frenierre and Dr. Szyliowicz (2008):

> *When development workers came to the Afar region they asked the indigenous people what priorities they had for development. The Chief of the Afar wanted schools for the children. The development worker walked around and asked: "Where is your toilet?"*
>
> *The Afars answered: "We do not need toilets, we shit in the bush."*
>
> *The foreigner emphasized how important it was to start with the toilet instead of the school. He also promised to build schools after the evaluation of the toilet. A pit latrine was dug and built to be used by the people.*

The development worker came back after a year for a follow-up and found the pit latrine had been used very little. He asked why.

The chief answered: "We farmers and uncivilized citizens are used to go out in the bush, enjoy the scenery and breathe the smell of the vegetation while defecating. When the civilized man came to us and asked us what priority we have, we answered – schools for our children. If you had started educating our children you might have succeeded to get people who can stand the smell of your pit latrine."

This sort of predicament can be overcome by taking on a problem-solving approach to development. Pearce (2000) goes on further to say: ''*the challenge for the future is not an intellectual one. More research is always needed, but we already know the principles of project success: engage with local realities. Take your time, experiment and learn, reduce vulnerability and risk, and always work on social and material development together….''.* La Frenierre (2000) recounts his personal experience with Engineers Without Borders in the successful construction of quick and inexpensive, small potable water systems in Ecuador, Thailand, and Laos. The system consisted of hand-built concrete spring-boxes, PVC pipes and UV resistant plastic water storage tanks. Training on maintenance and repair was provided to the locals to ensure sustainability of the projects.

It has also been noted that NGOs play an important role in the execution and development of projects, providing the skills, knowledge and expertise that a village community may require (Edwards and Fowler, 2002). However Pearce (2000), states that *"NGOs cannot and should not replace the state in 'promoting' development"*. It is therefore important that their role be a more supportive, advisory one, and their work should be carried out in conjunction with local governments or village authorities. Edwards and Sen (2002), discuss the issue of social change with regards to sustainable development. They argue that NGOs are *"explicitly values-based organisations"* therefore it is up to them to play the crucial role in supporting changes. Change can be a very difficult concept with regards to challenging or questioning traditional or habitual practices, but may be essential for the development of a project. It may also be a slow and gradual process or none at all, and acceptance will sometimes determine the success or failure of the project.

A report by Water and Environmental health at London and Loughborough (WELL) highlighted the importance of "*community participation, the role of women and community contributions and financing"* as being the key issues in development, based on their workshop on NGO experiences in the water and sanitation sector (Smout and Parry-Jones, 1999). Women and children generally carry the burden of water collection in developing countries therefore it is imperative to take into account gender issues when implementing new schemes and projects. However trying to include women in a village committee does not necessarily imply they will have an active or vocalised position, or will be involved in any decision making (Pearce, 2000).

The sense of ownership achieved through community participation in, for example, a water treatment system, should provide the motivation for future operation and maintenance of the system. The level of involvement and dedication of the community will be based on the perceived importance of the need for a better quality of water for each particular community. Most NGO water and sanitation projects utilise labour and local materials contributed by the community however some also collect financial contributions. Capacity building will then be required in money management, organisation and planning, with a high level of trust and transparency between the community, water committees and village leaders (Edwards and Fowler, 2002).

The role of the NGOs can also be one of facilitation of funds and aid that may be received in a country, by assisting local governments in distribution and allocation of money into projects. The Home Ministry of India controls their foreign funding and NGO sector by the Foreign Contribution Regulation Act (FCRA). It also provides local NGOs with a mandate for their work being carried out if they are able to provide their own funds, which in turn releases them from government surveillance (part of the FCRA), (Intervention India, 2003).

According to the Indian Government's National Rural Drinking Water Programme NGOs and Civil Society Organisations (CSOs) play a major role in community mobilisation as well as community assistance in the planning and management areas of their water supply schemes. Other activities of importance are: *''distribution of information, institutional building, engagement at a state level, technical support and monitoring''.* However in order for this to be sustainable there needs to be an institutionalisation of engagement whereby the NGOs and CSOs clarify their roles and objectives. The selection of CSOs must be dependent on skill and capability to ensure a fair process and they should be aware of their local situation. The CSO should also have access to sufficient resources to build on their capabilities allowing them to fulfil their responsibilities to uphold programmes on water and sanitation in rural areas (Rajiv Gandhi National Drinking Water Mission, 2009-2012).

2.2 Water and health

Those without any or limited access to clean water and sanitation in the world are severely affected in their health standards (WHO, 2009). According to Meier & Rauch (2000), there are annually 900 million cases of diarrhoeal diseases, which cause the death of more than 3 million children and other vulnerable sectors of the population in developing countries i.e. the very elderly and those with HIV/AIDS. It is also stated that more than half of the fatalities are preventable if only adequately clean water and sanitation were available. Providing access to sanitation and cleaner water in a village through a treatment system will not eradicate all diseases, but will be a very effective means of alleviating the human distress associated with loss of income and poor health (Biswas, 1997).

2.3 Water quality and pollution

Water is a means of transport therefore as explained in the introduction any compounds in contact with water will be transferred elsewhere. The concentrations of chemical and organic pollutants usually increase in concentration further downstream from a natural source. This is due to the water being in contact and collecting more contaminants along its course, especially while passing through an urbanised or agricultural area. These areas pose the risk of chemical and organic pollution. According to Rathore (2009) India is the third largest consumer of pesticides in the world (highest among the South Asian countries), and after China is the second largest manufacturer. Maharashtra and six other states accounted for almost 80% of the total consumption. Rathore then goes on to quote a study by the Planning Commission, Govt. of India, who estimated consumption levels in India to be 118,000 tons in 2000.

There has been an increase in awareness with regards to groundwater pollution, which is not as obvious as surface water pollution. An example of this was the installation of 4 million tube-wells in Bangladesh over the last 20 years to provide 95% of the population with pathogen-free water. However unknown at the time the waters were contaminated with (tasteless and odourless) arsenic, which today has left 20 million people exposed to serious health effects such as cancer (Gray, 2008). A similar problem is fluoride in water, which in excess can cause serious dental and skeletal deformities (66 million people affected in India and 10 million in China) (Gray, 2008). It should be noted that arsenic and fluoride are both naturally occurring compounds and are not anthropogenic contaminants.

Rainfall and weather also affect water quality especially rain therefore it is vital to take these factors into consideration when sampling and analysing water samples for contamination. According to Clapham (2004) the weather affects the quality of water in several different and independent ways:

- Heavy rainfall washes animal faeces, soil and detritus are washed into old, poorly designed and hence insufficiently protected wells, boreholes or open water sources. As lighter rain only wets the ground, the effects will not be as widespread.

- The heavier the rainfall, the faster the velocity at which microorganisms are flushed through the soil into the water supply, increasing their survival rate. It will also increase runoff and groundwater flow, picking up more faecal contamination along the way.

- The time of rains is also important, for example after the dry summer periods animal droppings will have accumulated on the ground. Initial rains may be highly contaminated with faecal bacteria, which will slowly lessen as autumn and winter passes onto spring. The presence of younger animals in spring also increases the Cryptosporidium content in droppings (as it prefers younger animals as well as humans).

Figure 2 shows the two options for drinking water. A community or individual may take route one and use an unprotected water source, running the health risks of drinking contaminated water. The second route is to treat water before drinking. However a study by the South Asian Network for Development and Environmental Economics (SADEE, 2004) states that although governments have attempted to supply treated water this has not been a universal achievement due to the financial investments required. The National Family Health Survey (NFHS) of India (1998-1999), found that 50% of all households consumed water without any purification methods. It was thought to be more through a lack of awareness than poverty, as 32% of the richer households failed to treat their drinking water.

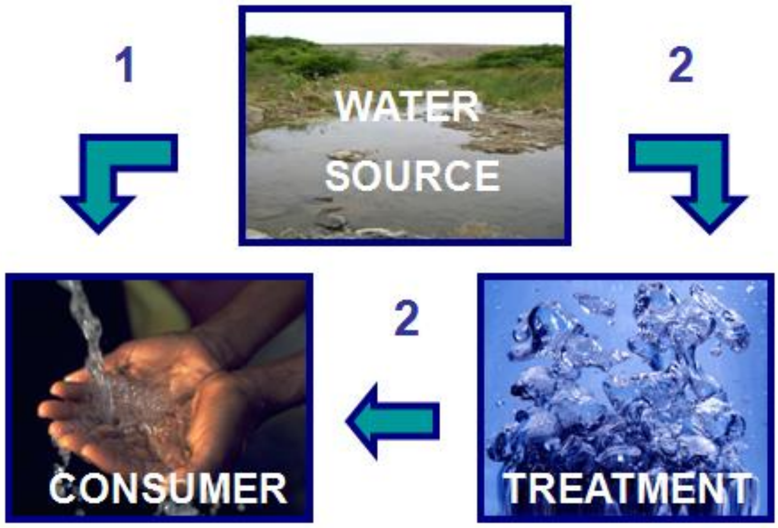


Figure 2: **Drinking Water Pathways**

In countries where the formal water treatment system cannot be relied upon, concerned visitors and a few locals that can afford it overcome water quality issues by purchasing and drinking bottled water. However Luce (2003) wrote an article for the *Financial Times* on the 6th August 2003, reporting the water quality analysis of 17 local and multi-national bottled water companies in India (including Coca-Cola's Kinley brand and PepsiCo's Aquafina). The research carried out by India's Centre for Science and Environment (CSE) whose tests followed the US Environmental Protection Agency's protocols, confirmed 16/17 to be contaminated with a '*cocktail of pesticide residues'* at dangerously high levels (300-400 times more than the maximum accepted EU standards). These included DDT, HCH (lindane) and neurotoxic organophosphates like malathion and chlorpyfiros (Bouguerra, 2006). The allegations however were strongly denied by the 'offending' companies (Luce, 2003).

2.3.1 Waterborne Diseases

The most important water-related health problems are those associated with waterborne diseases especially diarrhoeal in developing countries. This is primarily the case in poorer countries as they are without proper drainage, safe drinking water and have limited vaccination access. A number of human pathogens find their way into a susceptible host through contaminated water. These pathogens often called waterborne pathogens, have the ability to survive at least for a short period in water therefore the water acts as a route of transmission for them (Percival *et al* (2004). It has also been found that water contaminated by faecal matter of a polio sufferer can cause transmission of the disease (Bouguerra, 2006).

2.3.2 Coliforms and Thermotolerant Coliforms

Coliforms are bile tolerant, gram-negative, rod-shaped bacteria found throughout the environment in raw water, soil, organic matter and faeces. They also produce gas and acid from lactose at 35°-37° (Abel, 1998). Their presence however does not necessarily indicate that pathogens are present or are of faecal origin and have traditionally been used as 'indicator organisms' for the 'potential presence' of enteric pathogens (Kay and Fricker, 1997). The waterborne bacterial pathogens that grow specifically in water and soil have their routes of transmission through inhalation or direct contact (bathing), resulting in infections of the respiratory tract, skin lesions or in the brain e.g. *Legionella, Burkholderia pseudomallei* and atypical mycobacteria (WHO, 2006). The coliform group also includes several genera of thermotolerant bacteria (also referred to as 'faecal coliforms') including *Escherichia*, *Citrobacter*, *Enterobacter* and *Klebsiella*. These thermotolerant coliforms (TCCs) are of sanitary significance when present in drinking water, as they not only withstand higher temperatures but produce a colour change (red-yellow) in a culture medium at 44°C during water analysis (Oxfam DelAgua Kit, 2004).

The sanitary significance of using coliforms in general as an indicator has been challenged by the discovery of protozoan pathogens in supposedly high quality waters (Kay and Fricker, 1997). However the introduction of a new indicator such as faecal streptococci, H_2S producers or Bacteroides (also with their own limitations) will be more restrictive, with concerns that many existing water systems will then not meet requirements (Kay and Fricker, 1997). Coliforms are inadequate to differentiate between faecal and non-faecal contamination, *Escherichia coli* (E.*coli*) is considered to be more closely associated with faecal contamination from warm-blooded animals (Gleeson and Gray, 1997). They are normally found in large numbers (10^9 per gram of faeces, Clapham, 2004) in the intestinal flora of humans and animals and are not harmful unless infected into other parts of the body which may then cause serious diseases such as meningitis, bacteraemia and urinary tract infections (WHO, 2006). There are 14 distinct serotypes (groups of microorganisms) of E.*coli* that cause gastroenteritis in humans and animals. Those infected with the disease have profuse watery diarrhoea with a little mucous, nausea and dehydration but no fever (Hunter, 1997).

Most countries use a voluntary reporting system to report the extent of waterborne diseases and rely on doctors to diagnose the cause of their illness (Gray, 2008). Therefore the extent of pathogenic bacterial outbreaks cannot be easily obtained but more concerning is the emergence of new strains of pathogens. For example major outbreaks of E.*coli* 0157:H7 in drinking water in the USA (1998-2000) which affected thousands with several fatal cases. Following infection of the disease 2% of the elderly and 7% of children under five developed Haemolytic-uraemic syndrome (Gray, 2008).

2.3.3 Drinking Water Quality Standards

Drinking water may contain as well as compounds, harmful organisms that are detrimental to human health. Pathogenic organisms have a direct adverse effect on health (generally through the digestive tracts) while some micro pollutants may take years of regular consumption to see any effects (De Moel *et al*, 2006). The pathogenic microorganisms can be subdivided into helminths (>100µm, parasitic worms), protozoa (5-100µ m, unicellular creatures), bacteria (0.5-1.0µm) and viruses (0.01-0.1µm, microorganisms) (Gray, 2008). There are 56 potentially disease causing organisms that can be found in drinking-water, it would be unrealistic to analyse for all when testing water quality therefore indicator organisms are used (Clapham, 2002).

The microbiological water quality standards vary in each country depending on the environmental, social, cultural, economic and dietary conditions in the country which all affect the degree of potential exposure to pathogens (WHO, 2006). Therefore to assess the risk, allocations are made of the tolerable daily intake (TDI) of a contaminant in food and drinking water. It is expressed according to WHO (2006), ''*on a body weight basis (mg/kg or mg/kg of body weight), that can be ingested over a lifetime without appreciable health risk*''.

The 2008 *Guidelines for Drinking Water Quality* by the World Health Organisation provides international standards which can be used by individual countries. For example the Indian Standards Institution (ISI, 1989) and Indian Council for Medical Research (ICMR), prescribe the following bacteriological quality of water in a distribution system:

1. Throughout the year, 95% of samples should not contain any coliform organisms in 100 ml.
2. No sample should contain E. Coil in 100 ml.
3. No sample should contain more than 10 coliform organisms per 100 ml.
4. Coliform organisms should not be detectable in 100 ml of any two consecutive samples.

The significance of using the WHO guidelines is that it is an internationally developed and accepted set of standards for water quality which is adopted and integrated at a national and local level for each individual country. However it is important to take appropriate consideration and adaption for any regional environmental, social, economic or cultural situation, making sure each issue is prioritised. With the correct procedures in place the quality of drinking water may be controlled, this may be achieved by protecting water sources, monitoring treatment processes and effective management and education on the distribution and handling of drinking water (WHO, 2008).

It is through these guidelines that the highest possible level of human health may be achieved, as they support the realisation of the 4th Millennium Development Goal (MDG):'' *to reduce childhood mortality through a concerted* *strategic approach''*. It also assists towards the 7th MDG, Target 10: *''access to safe water and sanitation*'', which is assessed through the WHO UNICEF Joint Monitoring Programme, as water is deemed as a '*basic human right'* (Aertgeerts, 2009).

2.4 Basic Water Treatment

Water treatment should '*produce an adequate and continuous supply of water that is chemically, biologically and aesthetically pleasing'* i.e. it should be palatable, safe, clear, colourless and odourless, reasonably soft, non-corrosive and low in organic content (Gray, 2008). Depending on the quality of the raw water at a source, it will then have to go through both physical and chemical treatments before entering a distributed system. The water treatment system for small communities can be organised into four sections (Binnie *et al*, 2002):

1. *Storage and settlement* - A settlement tank or pond is a key part in the initial treatment system and can significantly improve the quality of poor-quality water, depending on storage time and time of year. Reservoirs storing water for several weeks generally reduce coliforms and E.*coli* by 90%, and in the summer a higher level of 99%. Problems may occur with algae and siltation especially in the summer.

2. *Coagulation and Flocculation* - A process developed over the last 20-30 years where coagulation very quickly destabilises and coalesces fine solids (suspended particles, colloids and DS molecules) in the water. Flocculation then occurs (a longer process) creating larger particles from the smaller particles in coagulation which can then be removed in the next process.

3. *Filtration* -The water is then passed through a granular bed of sand or other suitable medium, at a low speed. The result will be a water of turbidity of less than 0.2 NTU. Two other methods of granular filtering are rapid gravity filters and pressure filters.

4. *Disinfection or sterilisation* - The final stage of disinfection of water can be achieved either through a physical method such as boiling and ultraviolet (UV) irradiation, or through chemical methods of adding ozone or chlorine. Chlorination in a treatment system is the most common application and requires the addition of either:

- Chlorine gas (Cl_2) – liquefied under pressure, it is highly toxic in this state and requires careful handling and maintenance. Hence it is an inappropriate option for basic water treatment systems in a rural setting.

- Sodium hypochlorite solution (14% available chlorine) or chlorine bleach (1% available chlorine)

- Solid calcium hypochlorite (bleaching powder or chlorinated lime, containing 30% available chlorine when fresh), (WHO, 1993).

Figure 3 below provided by WHO (1993), shows the efficiency of each treatment system with regards to turbidity and the removal of thermotolerant coliforms. Disinfection provides 99.0 % removal of thermotolerant coliforms. The most efficient method of turbidity improvement is via slow sand filtering. Clapham (2002) notes that this is due to both physical and biological treatment occurring in slow sand filtering. A layer of microflora and microfauna ('schmutzdecke' containing a mixture of algae and bacteria) develops on the top of the bed which feed on the contaminants in the raw water.

Stage and process	Turbidity			Thermotolerant coliform bacteria		
	Removal (%)	Average loading (NTU)	Maximum loading (NTU)	Removal (%)	Average loading (per 100 ml)	Maximum loading (per 100 ml)
Plain sedimentation	50	60	600	50	1000	10000
Gravel prefilters (3-stage)	80	30	300	90	500	5000
Slow sand filter	>90	6	60	95	50	500
Disinfection	NA	<1	<5	>99.9	<3	25
Distributed water	NA	<1	<5	NA	<1	<1

***Figure 3:* Performance of a small-scale water treatment system**

(Figure 3 source: WHO – Drinking Water Quality Guidelines, 1993)

The NFHS of India found that those households that treated their water supplies used the following five methods: straining with an ordinary cloth, using alum (aluminium sulphate) tablets (as a flocculent), using a candle filter, using an electronic filter or by boiling (SADEE, 2004).

2.5 Water Treatment Technology

The use of membrane technology can be a very efficient form of water treatment especially if the small water supply has an excess of dissolved inorganic compounds. It uses a thin film or semi-permeable membrane which removes particles, large molecules and microbiota from water (Clapham, 2002). Reverse osmosis removes essentially all particles and dissolved chemicals, through the process of water being forced (under pressure) through a semi-permeable membrane. This results in dissolved and particulate materials being trapped and drained away, and also the production of a concentrated contaminated wastewater (Gray 2008).

Ultraviolet (UV) disinfection of water is a process by which water is passed through high-intensity UV radiation, which kills or inactivates the bacteria and viruses (affecting their RNA and DNA) that may be present in the water (Binnie *et al*, 2002). The rate of their death however is dependent on the water clarity, depth and intensity of light. It is particularly useful for disinfecting groundwater sources that are not chlorinated before entering a supply (Clapham, 2002).

Other methods of disinfection include boiling water which although effective at sterilising the water, has major environmental impacts and can be costly. Bromine and iodine are also added to water as a disinfectant and potassium permanganate (not very effective). However the above mentioned processes are preferably for emergency use only (Clapham, 2002).

2.6 Indian Water Legislation

The Indian government's Constitution has always given a priority to the provision of clean drinking water since early Independence (1947-1969). Legislation has evolved through the years, with a transition from technology to policy from 1969-1989. Initially importance was given to implementing projects that focussed on physical infrastructure such as hand-pumps. For ensuring sustainability of such systems a sector reform project aimed at shifting the ''government-orientated supply driven approach'' to a ''people-orientated demand responsive approach'' (Khurana and Sen, 2009).

The government has now formally recognised the importance of water quality monitoring and educational interventions with relation to the sustainability of rural water supply programmes. In order to maintain the quality of water resources the community should be involved in not only the maintenance but other aspects such as hygiene, environmental sanitation, correct storage and disposal (WaterAid, 2009). The Government began the National Rural Drinking Water Quality Monitoring Surveillance Programme in 2006 as an aid to coordinate institutes within the country and by creating a monitoring system across all levels of authority. Gram Panchayats and Village Water and Sanitation Committees play the interactive part with the community, in conjunction with positively contaminated water samples being tested at district and state laboratories (Khurana and Sen, 2009).

The Maharashtra State Water Policy was formulated in response to the fragmented and isolated approach to surface and groundwater development and management over the last 50 years in India. There has been a deterioration of both surface and ground water qualities by the untreated effluent of industries and municipal bodies (MSWP, 2003).

"…when the State's budget resources are limited and stretched, both the State and all water users must find ways to become more efficient and productive" (MSWP, 2003). An improvement in community water treatment systems can be

a step to incorporating the above objectives, as a healthier population results in relatively higher in efficiency and productivity.

3. METHODOLOGY

This chapter presents the theoretical background and methods prescribed for the fieldwork in order to fulfil objectives 1-3,

"We feel that even when all possible scientific questions have been answered, the problems of life remain completely untouched" (Wittgenstein, 1922, sourced from Sayer, 2006)

The above quotation (although a strong view point) brings to mind the issue of the effectiveness of research methods, without direct involvement or awareness of the community being studied. Although the EWB-UK/ EngINdia project was a desk-based study, it was personally deemed necessary that an investigative study in-country be carried out, in order to truly reflect the current, personal requirements of the villagers in Pabal.

3.1 Theoretical Aspects of the Methodology

According to Neuman (2006), there are three main purposes for carrying out research: *exploratory, descriptive and explanatory*. The purpose of this study covers all three aspects: as it is a baseline study exploring the basic facts, a descriptive current account of the situation, as well as providing explanatory theories for the findings.

A flexible design research approach was considered allowing for the evolution of the methodology once in country and a focus was drawn on the appropriate approaches to obtain both qualitative and quantitative data to enable an accurate description of the current water quality and treatment methods.

Table 1 provides a summary of the advantages gained by using a combined quantitative and qualitative approach.

Table 1: **Quantitative Versus Qualitative Approaches**

QUANTITATIVE APPROACH	QUALITATIVE APPROACH
Measure objective facts	Construct social reality, cultural meaning
Focus on variables	Focus on interactive processes, events
Reliability Value free	Authenticity is key Values are present & explicit
Theory & data are separate Independent of context	Theory & data are fused Situationally constrained
Many cases, subjects Statistical analysis Researcher is detached	Few cases, subjects Thematic analysis Researcher is involved

(*Source*: Neuman, 2006)

The approach towards the chosen methodology for the collection of both the qualitative and quantitative data also takes into consideration the 'real world approach' by Robson (2002), who states the value of having a 'scientific attitude' towards research. In the sense that the research should be carried out in a *''systematic, sceptical and ethical'* manner. Carrying out field research as opposed to a desk based study allowed a true reflection of the current situation and needs faced in Pabal.

3.2 Collection of Quantitative Data

3.2.1Site inspection, transport and sampling arrangements

In order to accurately assess the drinking water quality of Pabal, the three main water resources available that could potentially be a risk for the villagers (relying on it for drinking water) were:

1. The water at the reservoir to be pumped and piped to the outlets in the village.

2. Boreholes with hand-pumps located around the village and surrounding hamlets, mainly used by farmers and those without access to the piped water system.

3. Dug wells scattered around the village and hamlets, many of which are currently dry or filed with stagnant water.

The selection of the exact points along the water supply system in Pabal were chosen based on an initial site visit carried out during the first few days of June 2009. The stratified sampling used was to enable a comparison of the water quality along the pipeline distribution system and at the other sources. Samples had to be processed within 6 hours of being taken.

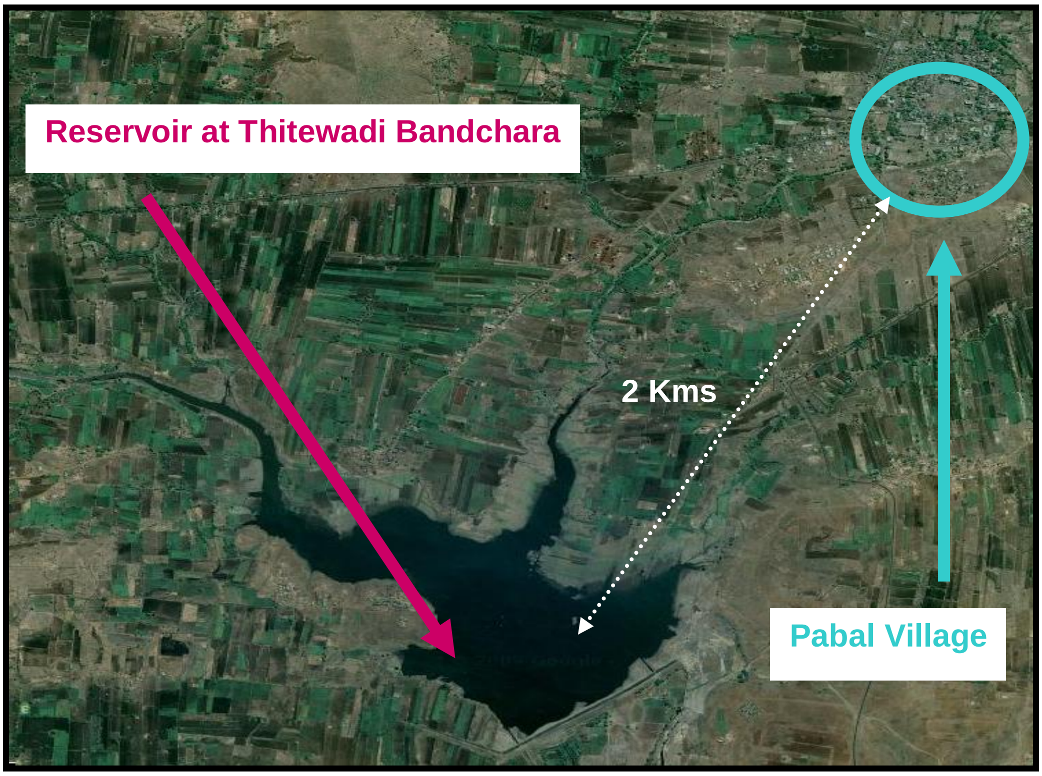


***Figure 4*: Location of the reservoir and the village of Pabal**

Figure 4 illustrates the location and distance of the reservoir that provides the piped-water supply to Pabal village.

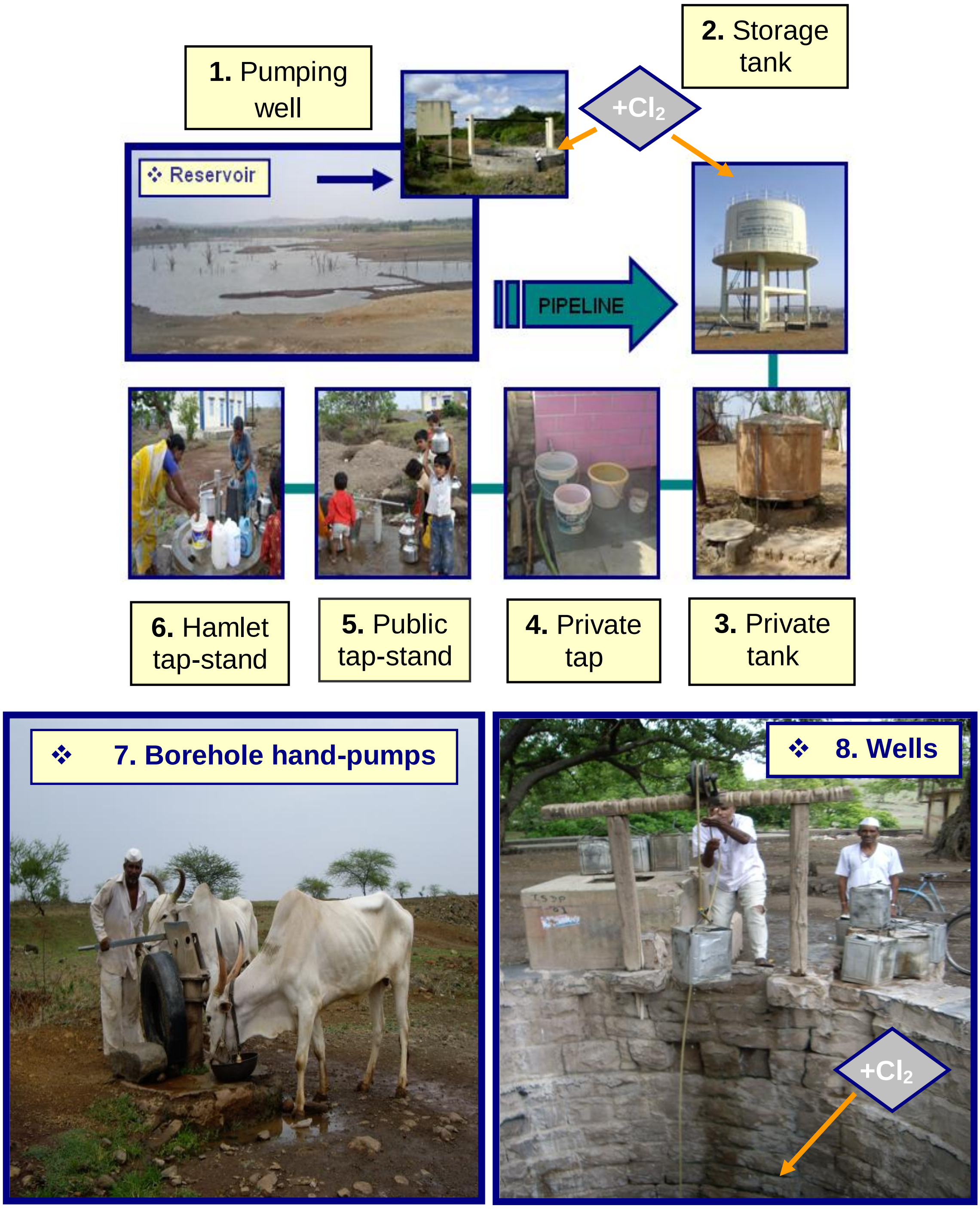


Figure 5: Water supply distribution system for Pabal villagers

KEY:

- The 3 main sources for drinking water: Reservoir (pipeline system), Boreholes and Wells.

No.1-8 are the 8 sampling points in the water distribution system.

Figure 5 is a diagrammatic representation of the three types of water sources, the borehole hand-pump, the well and reservoir supply as well as the numbered sampling points along the system. The eight points chosen were:

1. The pumping well at the reservoir is not directly used by villagers but is the origin of the water supplied to Pabal and its surrounding hamlets.
2. The storage tank on the hill has a 170,000l capacity which inadequately serves Pabal and the hamlet of Rajwara Matung Wasti. However there is currently a new tank nearing completion, on the opposite side of the road.
3. A private storage tank at Vigyan Ashram filled daily from a private connection from the main storage tank on the hill.
4. A private tap outside a house.
5. A public tap-stand in Pabal, next to the main road and used by residents.
6. A public tap-stand in the merging hamlet Rajwara Matung Wasti.
7. A borehole hand-pump frequently used especially by farmers.
8. A well in central Pabal, near the market and commune area.

3.2.2 Preparation and the sampling schedule

Before sampling could commence preparation was required in the form of: charging the battery of the Del Agua Kit, calibration of the internal incubator to a temperature of 44°C, preparation of the Membrane Lauryl Sulphate Broth (growth medium) from a powder to a liquid and sterilisation of all the equipment. These procedures were completed over a few days after encountering problems with the electricity supply, stabilisation of the incubator and access to supplies e.g. distilled water for the broth and a gas stove and methanol for sterilisation.

Plate 1: **Preparation phase** ***Plate 2:*** **Sterilisation phase**

The collection of water samples from the source, storage and consumer points were carried out over a period of 8 days. Due to a limited supply of materials and equipment, the collection of one sample was split over 2 days for all 8 points along the water system.

Table 2 shows a certain order in which samples were taken due to logistical and water allocation reasons. The timings of water supply varied between each point between 6.45 am and 7.30 am, however supply lasted only ½ an hour from start to finish.

***Table 2:* Water sampling schedule**

DAY ONE	***DAY TWO***
6. Hamlet tap-stand	**2.** Storage tank
5. Public tap-stand	**7.** Borehole hand-pump
4. Private tap	**1.** Pumping well
6. Hamlet tap-stand	-
7. Pabal well	-
3. Private tank	-

The water was allowed to flow/ pumped for a minute and the edges of the spouts checked and cleaned to reduce any external contamination prior to sampling. Then two 60ml bottles (the second being a replica sample for accuracy) were filled with water from each tap-stand and the borehole point. In the case of the wells the steel cup provided with the Del Agua Kit was lowered in (using string) to a depth of 30cms below the water's surface before a sample was collected.

3.2.3 Analysis of samples using the Del Agua Kit

The samples were tested for levels of contamination of thermo-tolerant coliforms, using the Del Agua Kit. As the Ashram was within the sampling area, water samples were brought back to the office for analysis

<u>The analysis procedure</u>:

1. 10ml of the water sample filtered through a gridded, cellulose acetate membrane (uniform pore diameter of 0.45 µm) to trap the bacteria.

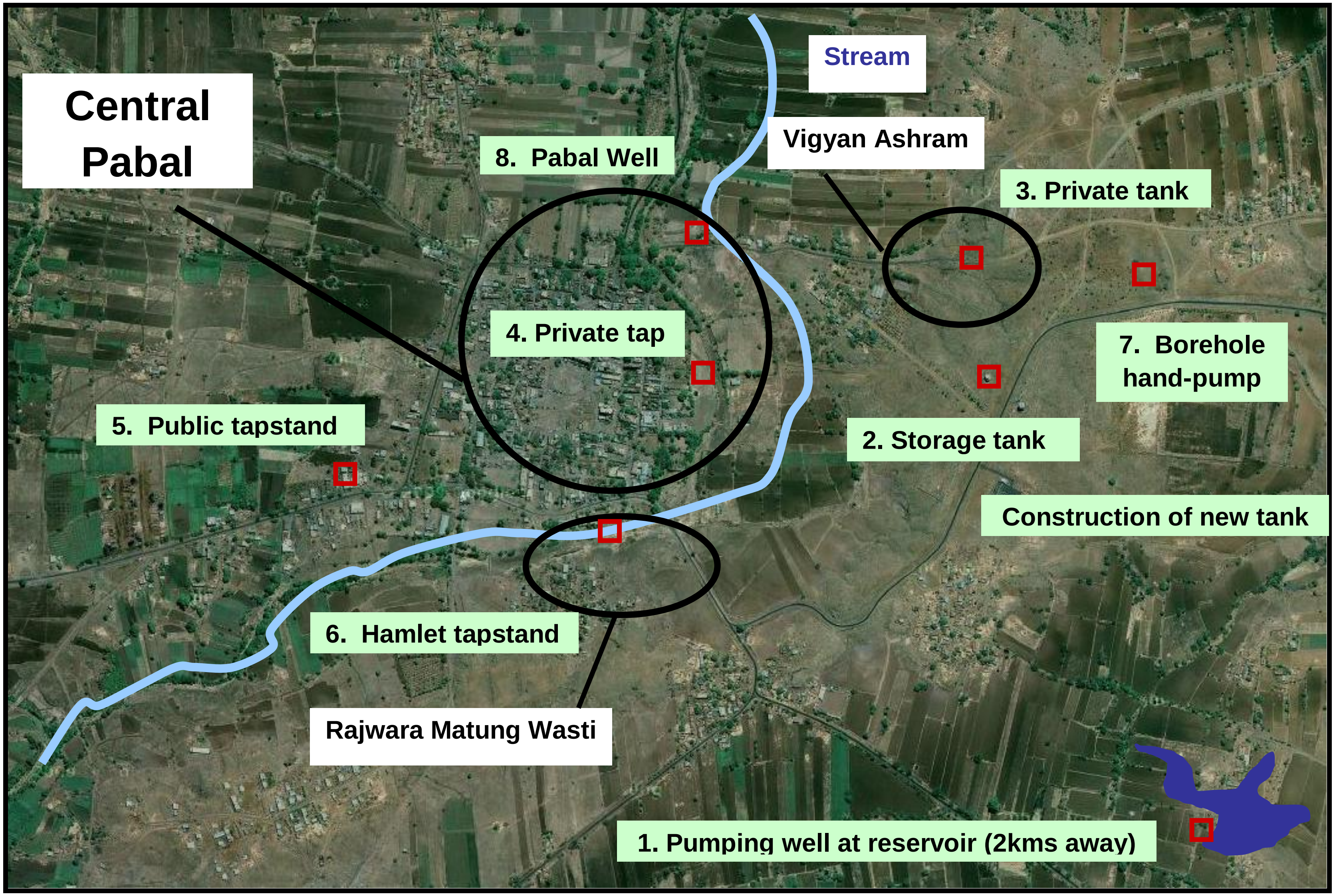
2. The membrane is then placed onto a pad soaked in lauryl sulphate broth (red coloured food for the bacteria), inside a Petri dish. During the incubation period at 44ºC the thermotolerant coliforms ferment lactose and acid, forming visible yellow colonies.

3. As the samples contained chlorinated water they were left to rest for 2 hours to allow the bacteria to recover and then incubated for 16 hours, allowing the growth of the bacterial colonies. Each colony-forming unit (cfu) is counted and the standard expressed is per 100 ml. However samples were filtered at 10ml so results were then multiplied by a factor of 10 to achieve the standard units. The average faecal coliform counts were also calculated as for each sampling point there was a sample bottle and a replica bottle.

Once analysis was completed each day, the bottles were sterilised by boiling for 10 minutes, ready for use the next day. The Petri dishes were opened and boiled with the contents (pads and filtered papers) for ½ an hour to kill off any bacteria before disposal. The pads and papers were later burnt and the Petri dishes re-sterilised by wiping with a cloth corner soaked in methanol.

Additional quantitative data gathered were the temperatures and rainfall during the month of June 2009 from the records kept at Vigyan Ashram.

Figure 6: **Map showing sample points throughout the water system**



3.3 Collection of Qualitative Data

The interviewing opportunity provides an insightful reflection of a situation or issue either through simple observation, casual conversation or heated discussion. The project is then transformed from a mere 'desk-based' problem to a 'real-life' situation, where sound solutions and ideas may actually be impractical.

3.3.1 Questionnaires

A combined questionnaire with a fellow EWB – UK researcher was formulated in order to gather information on sanitation, water quality, usage and treatment. This combined approach was advantageous in that interviews were swiftly carried out together, with one researcher questioning in Hindi (and translating in English), while the other transcribed the answers. A disadvantage to this was the limited space on the questionnaire to go into detailed questioning and not enough time to cover everything. Another limitation to the questionnaire interviews was not having available another local translator to aid with the households that only spoke the local Marathi language. Although the majority in Pabal speak and understand the national language Hindi, those living in the more rural hamlets only spoke Marathi (may have biased the sampling method and results).

3.3.2 Informal & target interviews

Everyday brought new opportunities to meet and converse with the locals, who were generally very friendly, helpful and informative. This random method of informal interviewing resulted in some useful information being obtained and willingly shared. The more semi-structured approach was in the form of 3 target interviews with the Sarpanch (head of the village committee), a school teacher and a local doctor. The aim was to hear the viewpoint of each authoritative/formal body on water quality in Pabal and water treatment, as each potentially holds an influencing position.

4. RESULTS

This chapter presents a summary of both the quantitative and qualitative data collected in Pabal over one month of research:

- *Figure 7* shows a plotted graph for the weather conditions in Pabal during the month of June 2009.
- *Table 3* is the thermotolerant coliform (TTC) counts for the eight water sampling points along the water supply system. The results have been expressed as counts per 100ml.
- *Figure 8 & Figure 9 are bar charts illustrating the TTC counts at each drinking water source i.e. tapstands, well and borehole.*
- *Table 4 is a summary of some of the main social issues gathered from the questionnaires.*
- *Table 5 is a summary of the treatment practices in Pabal gathered from the questionnaire.*
- *Figure 10, 11 & 12 are pie charts illustrating the percentage of interviewees who treat their water supply, with which method of treatment and from which water source.*

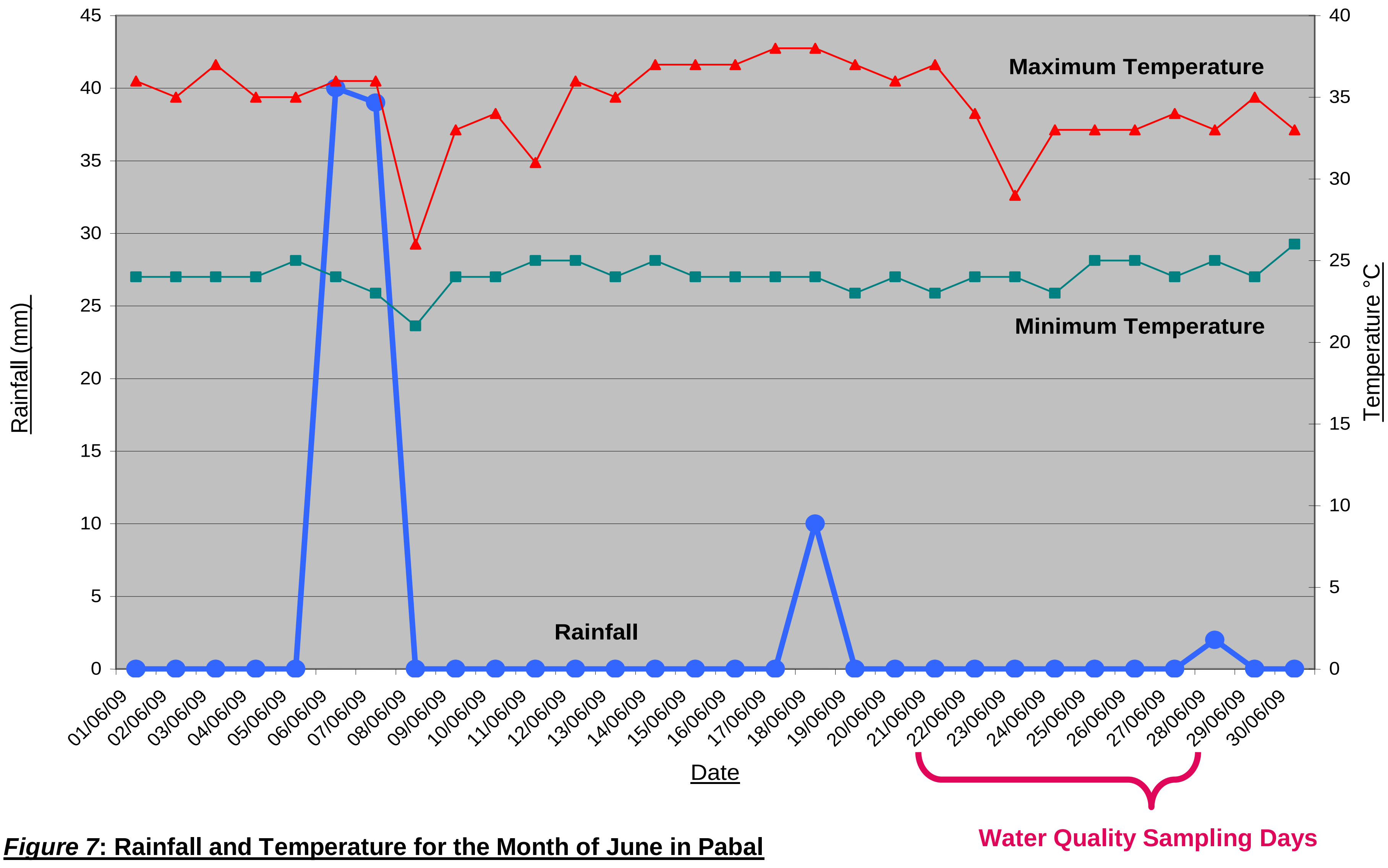


***Figure 7*: Rainfall and Temperature for the Month of June in Pabal**

Table 3: Thermotolerant Coliform Counts (TTC) / 100 ml for 8 Water Sampling Points in Pabal

Water Source		Sample 1 (per 100ml)			Sample 2 (per 100ml)			Sample 3 (per 100ml)			Sample 4 (per 100ml)		
		B1	B2	**Av.**	B1	B2	**Av.**	B1	B2	**Av.**	B1	B2	**Av.**
		Sample taken 22/06/2009			Sample taken 24/06/2009			Sample taken 26/06/2009			Sample taken 28/06/2009		
Hamlet Tap-stand	***(1)***	140	70	**105**	**Equipment Failure**			0	0	**0**	90	30	**60**
	(2)	0	20	**10**				0	0	**0**	**No water supply**		
Tap-stand: public		0	0	**0**				70	50	**60**	20	0	**10**
Private Tap		10	0	**5**				0	0	**0**	**No water supply**		
Pabal well		0	0	**0**				0	0	**0**	0	0	**0**
Private tank		0	0	**0**				0	0	**0**	0	*10	***5**
		Sample taken 23/06/2009			Sample taken 25/06/2009			Sample taken 27/06/2009			Sample taken 29/06/2009		
Chlorination Tank		0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
Borehole Hand-pump		1310	1370	**1340**	0	0	**0**	0	10	**5**	460	420	**440**
Reservoir Pumping well		0	0	**0**	480	910	**695**	1150	1090	**1120**	0	0	**0**

- ***Possible contamination of results from unsuccessful sterilisation of equipment in the sample analysis procedure (by the tweezers used to lift the filter paper).
- **B1** = bottle 1 and **B2** = bottle 2 (a replica sample used as an accuracy measure).
- **Av.** = an average was calculated for the two bottles for each sample.

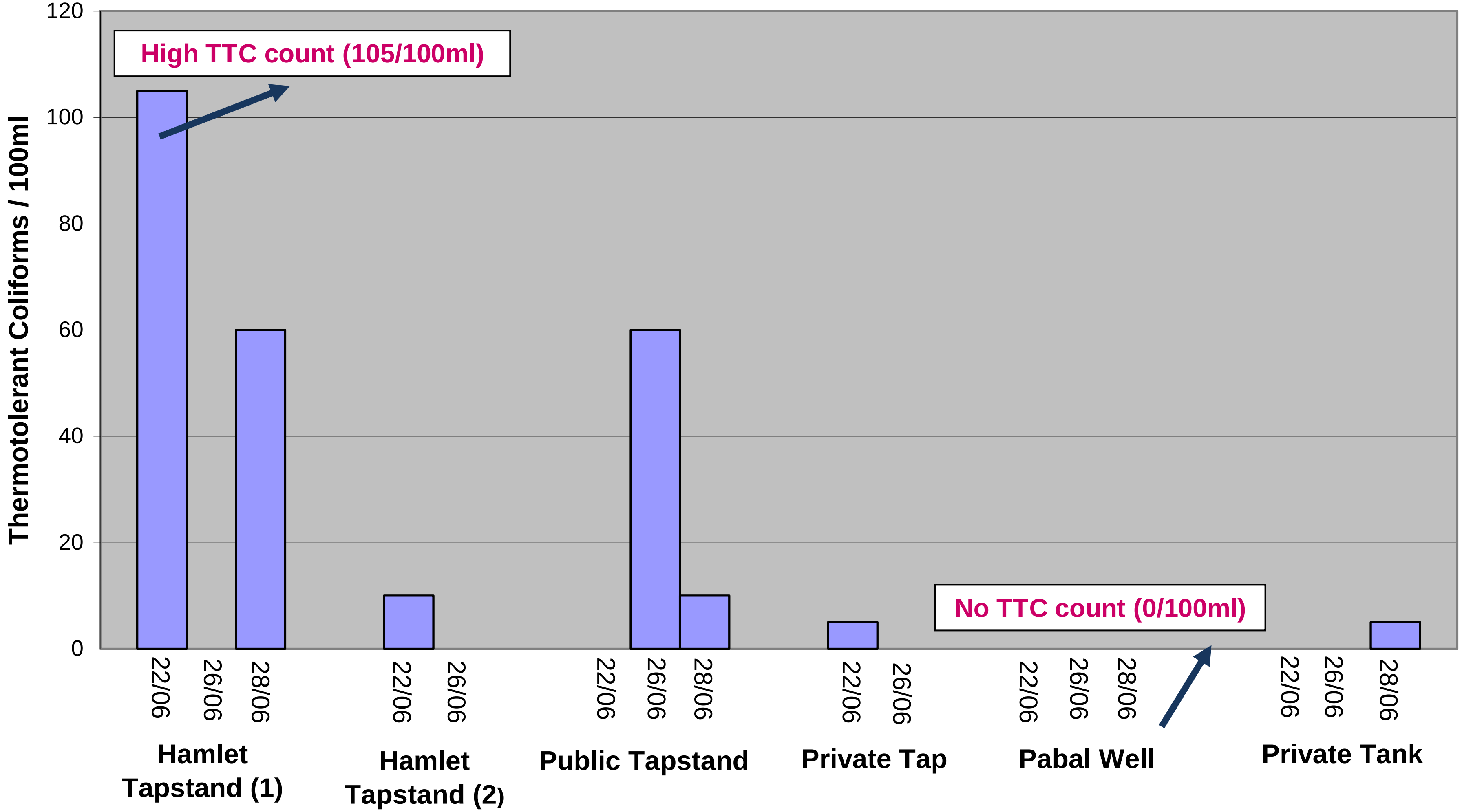


***Figure 8*: Thermotolerant Coliform (TTC) Count at 6 Sampling Points along the Pabal Water Supply System**

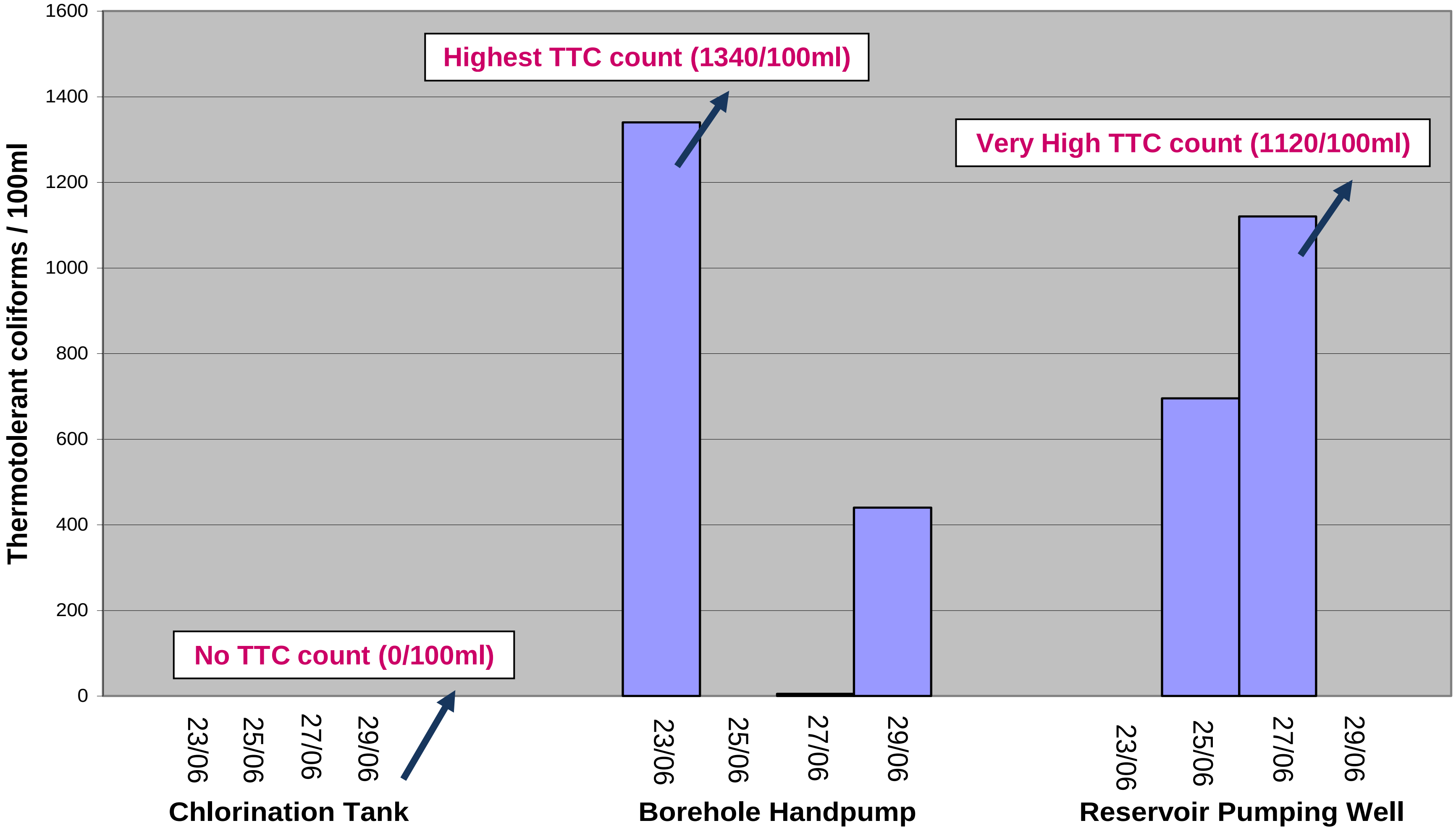


Figure 9**: Thermotolerant Coliform Count (TTC) at 3 Sampling Points in the Pabal Water Supply System**

***Table 4*: Social Issues in Pabal**

Interviewee	Improvements/Changes							Water Supply					Supporting Organisations						Overall
	Education	Infrastructure	Jain Temple	Internet	Lost traditions	Polluted	Population increase	Improved	Limited	Treatment	Late rains	Sickness during rains	Doctors	Vigyan Ashram	Local village committee	Women's Banking Group	School committee	Police Station	
Teacher 1	×		×				×		×	×			×	×					7
Teacher 2							×		×				×	×		×			5
Shop keeper 1	×	×						×				×		×	×	×			7
Shop keeper 2 & Housewife		×						×				×		×	×				5
Shopkeeper 3	×			×									×	×			×		5
Student 1		×						×						×	×				4
Student 2													×						1
Student 3	×	×						×	×				×	×	×				7
Student 4	×													×					2
Student 5	×	×					×							×					4
Farmer/Librarian 1	×							×	×			×	×	×	×				7
Farmer 2	×	×							×		×		×			×			6
Farmer 3				×				×					×	×					4
Farmer 4		×		×				×					×	×					5
Farmer 5					×								×						2
Farmer 6	×	×						×					×						3
Housewife 1	×	×	×									×		×		×		×	7
Housewife 2													×						1
Housewife 3								×					×	×		×		×	5
Housewife 4	×							×	×				×						4
Tailor						×			×				×	×		×			5
Worker	×	×						×				×		×	×	×		×	8
N = 22	12	10	2	3	1	1	3	11	7	1	1	5	15	16	6	7	1	3	

Table 5: Water Treatment Practices in Pabal

Interviewee	Water Source	Individual Water Treatment	Treatment Method
Teacher 1	Private tap supplied from Chlorination tank	Yes	Copper pots (10hr storage)
Teacher 2	Private Borehole	No	-
Shop keeper 1x	Private tap supplied from Chlorination tank	Yes	Filter & storage in copper pots
Shop keeper 2 & Housewife	Private tap supplied from Chlorination tank	Yes	Medichlor (chlorine drops)
Shop keeper 3	Private tap supplied from Chlorination tank	Yes	Storage in copper pots
Student 1	Private tap supplied from Chlorination tank	Yes	Medichlor (chlorine drops)
Student 2	Tapstand supplied from Chlorination tank	Yes	Medichlor (chlorine drops)
Student 3	Private well & water tankers in the summer	Yes	Medichlor (chlorine drops)
Student 4	Tapstand supplied from Chlorination tank	Yes	Medichlor (chlorine drops)
Student 5	Private tap supplied from Chlorination tank	Yes	Medichlor (chlorine drops)
Farmer/Librarian 1	Private well	Yes	Medichlor (chlorine drops)
Farmer 2	Handpump for drinking water & Tapstand supplied from Chlorination tank	No	-
Farmer 3	Pumped from the local well	Yes	Medichlor (chlorine drops)
Farmer 4	Private well	Yes	Medichlor (chlorine drops)
Farmer 5	Private well	Yes (change of seasons)	Medichlor (chlorine drops)
Farmer 6	Tapstand supplied from Chlorination tank	Yes	Medichlor (chlorine drops)
Housewife 1	Private tap supplied from Chlorination tank	Yes	Medichlor (chlorine drops)
Housewife 2	Tapstand supplied from Chlorination tank	Yes	Medichlor (chlorine drops)
Housewife 3	Neighbour's tap supplied from Chlorination tank	No	-
Housewife 4	Handpump	No	-
Tailor	Tapstand supplied from Chlorination tank	Yes	Medichlor (chlorine drops)
Worker	Tapstand supplied from Chlorination tank	No	-

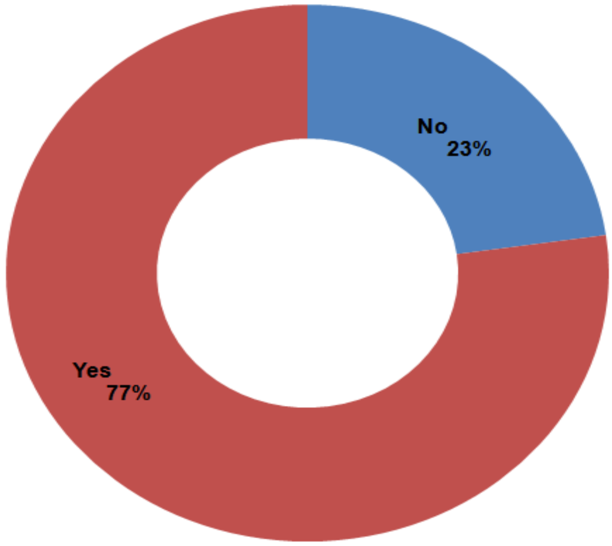


***Figure 10*: Percentage of Interviewees Who Treat Their Water**

- A large percentage of the interviewees treated their water supplies (77%). Those that chose not to either relied on the chlorination by the Gram Panchayat into the piped system or could not afford to do so.

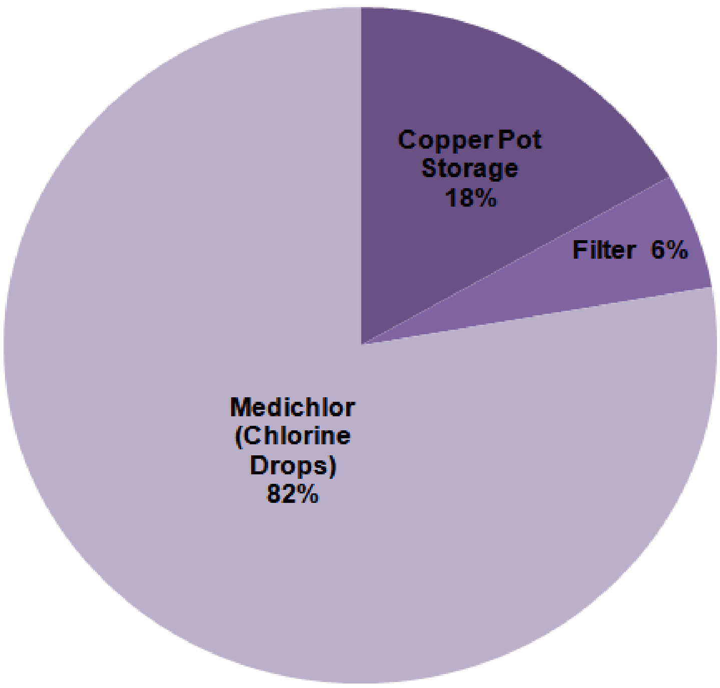


***Figure 11*: Treatment Methods Used by Interviewees**

- Majority of interviewees who treat their drinking water buy and use Medichlor (chlorine drops), as shown on *Figure 11*.

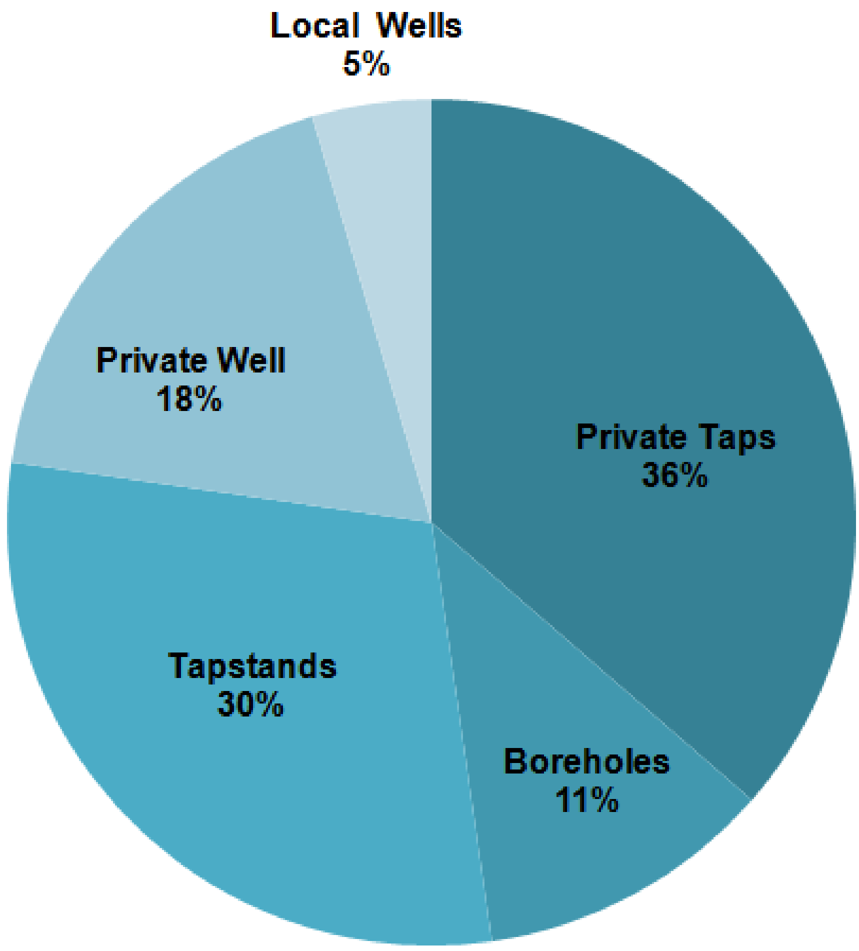


***Figure 12*: Water Sources Used By Interviewees**

- Over half (54%) of the people interviewed had access to a private water source, either a well or a private pipeline and tap supplying water directly to their house.
- 30 % of the interviewees were provided and reliant on the water supplied by the piped water system, and used their closest tap-stand for water collection.

5. DISCUSSION

5.1 Limitations of the research study

Having analysed the results it is necessary to not only mention but acknowledge that although there were many unforeseen limitations to the methodology, research environment and execution of data collection and water sample analysis while in Pabal, such as limited resources, water and power cuts as well as falling ill. The utmost care however was given to accommodate and regulate procedures. The sample size, locations and time period if extended would have provided a much more accurate and detailed analysis of the situation in Pabal. However the results obtained from the research can be seen rather as a 'snap-shot' of the conditions with many interesting issues to be studied further. It has brought to light some social issues as well as some insightful suggestions from the local community themselves.

If not for the time constraints further research was intended to be carried out on a comparison of the following treatment methods currently used in Pabal, as an aid to the researcher's recommendations:

1. Powdered chlorination in storage tank
2. Hand-pumped filter at the Ashram –Mainly used by visitors staying at the Ashram and those working in the office, where it was located. The water was tested from the filter and there were no thermotolerant coliforms present.
3. Bio-sand filter – the particular one visited at a household was unfortunately dropped and broken by the occupant on the day. The importance, value (and loss) of such an item in the household could be seen on the man's face, as well as being read on the engraved stainless steel tank (well-wishes for the wedding couple).

4. Cloth filtering

5. Chlorine drops in household water supply

6. Storage in a copper pot and a clay mutka (pot).

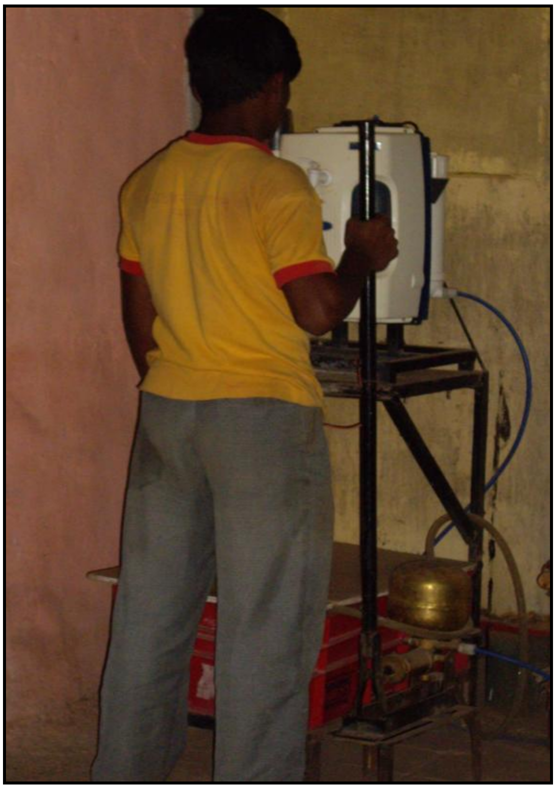


***Plate 3*: Hand-pumped Filter** ***Plate 4*: Broken bio-sand filter**

A further in-depth study into the effectiveness and reliability of the current different treatment methods may be the evidence required by those villagers sceptical of the importance of continual water treatment. Requests were made through an informal discussion with a local, whether tests could be carried out on water samples from alternative water sources. Concerns were raised that some of these sources of water were suspected to be possibly contaminated and the cause of illness e.g. ice and water from 'hotels' (in the loosest of terms) and food houses, fresh sugarcane juice and nimbu pani (lime water) side-street stalls and the public drinking pots. Future water testing should include such secondary water sources as possible contaminant supplies, as it affects those living in the village as well as those visiting.

5.1.1 Research Bias

According to Hartman *et al* (2002) there are two forms of error associated with research that may threaten the validity of a research study. The first being *random* errors such as accuracy in measurements and sample variability, which applies to the quantitative section of this study e.g. the water sample collection timings, analysis of coliforms and cross-contamination of samples. These errors cannot be avoided but have been pre-determined and minimised through careful planning, organisation and attention by the researcher. The second is *systematic* errors or bias which are *'reproducible inaccuracies that produce a consistently false pattern of differences between observed and true values'*. There are many types of biases associated with complex human factors that may arise from the respondent and/or the interviewer. The three main categories of research bias are: selection, measurement and intervention (exposure) biases.

Interviewee (respondent) bias may be due to poor memory, exaggeration or dishonesty, a lack of rapport with the interviewer, or a misunderstanding over the purpose of the interview. With questions relating to health and sanitation responses may be given that the respondent thinks the interviewer would like or expects to hear. This has been addressed in the research design of the questionnaire and structure of the interview questions. The open ended questions allowed each individual to provide answers to the best of their ability and understanding, a clear introduction informed participants of the nature of the research and who was involved and reassured confidentiality of their details and responses. The interviewer for this research was also the translator and avoided any bias by administering questions correctly (non-reactive, with no prompting or pre-empting of answers) and consistently. However although measures were taken to avoid bias during interviewing it is important to be aware that results may not be a complete representation of the population in Pabal, the affect of which may be minimised by allowing for a larger sample size and using another individual as the translator.

5.2 *Quantitative Results*

5.2.1 Water Quality & Treatment

Objective 1 of the thesis was to determine the water quality of Pabal in order to then be able to recommend the appropriate methods of treatment, accordingly to the levels and areas of contamination. As previously mentioned in Chapter 2 rainfall has an impact on the levels and severity of faecal contamination of water supplies. Research was carried out during the monsoon season, which was ideal to be able to show any direct effects of rainfall on the thermotolerant coliform (TTC) counts. However the prominent effects of climate change can be seen in the very late arrival of the rains, usually expected around the beginning of June. The two peaks on the rainfall data shown in *Figure 7* are the only two days that received a continuously heavy downpour for about two hours, where the 6^{th} of June had 40mm and the 7^{th} of June had 39mm.

Table 6: **Weather data collected over the water sampling days**

Date	Minimum Temp. °C	Maximum Temp. °C	Rainfall mm
22/06/2009	24	34	0
23/06/2009	24	29	0
24/06/2009	23	33	0
25/06/2009	25	33	0
26/06/2009	25	33	0
27/06/2009	24	34	0
28/06/2009	25	33	2
29/06/2009	24	35	0

Table 6 is a summary of the weather conditions over the eight days of water sampling and analysis. With an average (maximum) temperature of 33 °C a day there was only 2 mm of rainfall on the 28^{th} of June. Therefore the factor of rainfall with regards to water contamination cannot be included in the possible explanations for contamination of water supplies.

The following *Figure 5* is a diagrammatic representation of the piped water supply system in Pabal, as well as the other two sources of water used (boreholes and hand-dug wells). Numbers 1-8 represent the eight water sampling points starting from the reservoir's pumping well to the consumer points at the taps and tap-stands. A decision was made not to take the water sample directly from the reservoir as water quality was visually poor; the water was muddy and in places polluted with litter and animal faeces near the water's edge. The TTC counts for such water samples would have been very high, requiring a dilution technique of the samples during analysis in order to be able to count each TTC colony with the naked-eye.

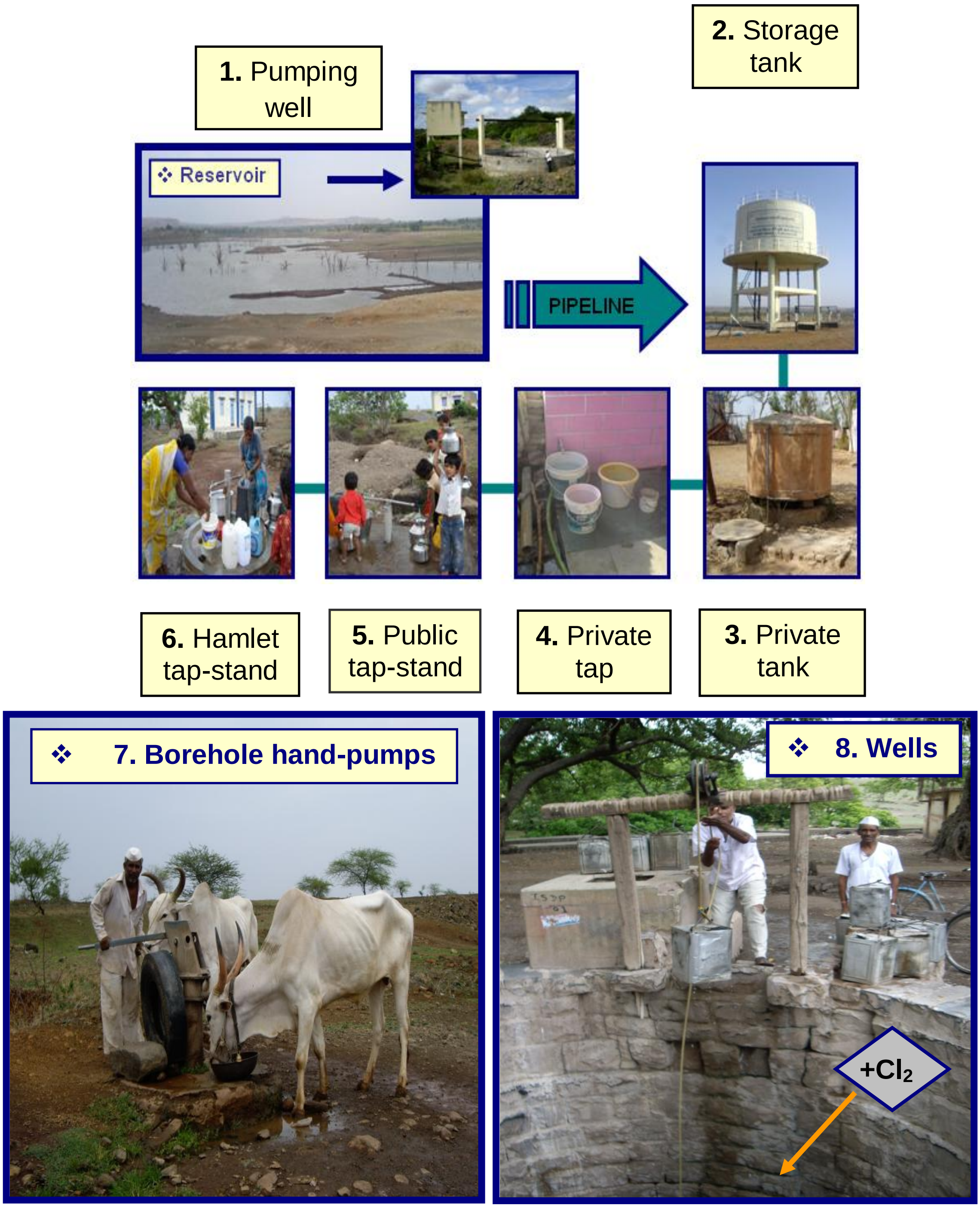


Figure 5: Water supply system for Pabal village

Chlorination by the Gram Panchayat occurs at points 1, 2 and 8. The consumer points 3 -6 are supplied with 'chlorinated water' therefore it is up to the users to carry out further treatment if necessary. The boreholes are left to be used as they are and the water treated accordingly by their users.

The results for the TTC counts at each sampling point (shown in *Table 3*), provides a clear indication of the points along the water supply system that are contaminated with faecal coliforms and possibly E.*coli*. The highest average count (1340/100ml) was at point 7, the hand-pump borehole. Three out of four samples at the hand-pump had TTC counts. This particular hand-pump was used mainly by farmers and a few residents from the hamlet behind the storage tank (who were not served by the piped water system). The picture in *Figure 13* is according to the farmer shown in it, regular and normal practice whereby farmers water their cattle at the base of the pump. The condition of the apron around the hand-pump was one of disrepair, with water pooling on and around the base. The ground and pump's spout were open to faecal contamination from the cattle.

The second highest average TTC count of 1120/100ml was found at the reservoir's pumping well (*Plate 3*), and a second sample had an average count of 695/100ml. Chlorination occurs weekly by the Gram Panchayat and may be the reason for no presence of TTC counts on the 23rd and 29th of June. Another possible reason for no counts may be that on the days of higher concentrations of chlorine in the well's water, a longer incubation period before processing may also be required in order for the TTCs to survive. Also the sample taken on the 29th June was from a considerably lower water level in the well (*Plate 4*), as it was being drained. There were trucks and diggers on site but unfortunately an explanation for the work being carried out was not given. It is assumed the well was being drained for maintenance and cleaning, which if the assumption were to be correct would be good practice by the Gram Panchayat.

Plate 5

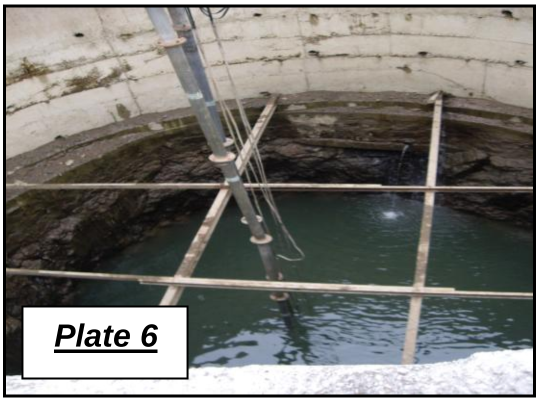


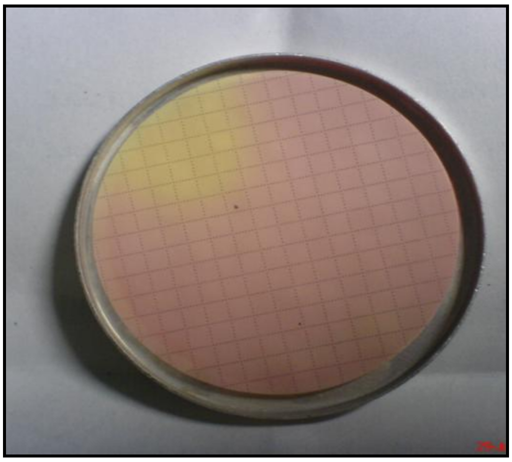
Plate 6

The storage tank positioned on the hill in Pabal also serves as a chlorination tank before water can be distributed into the pipeline system. Again the Gram Panchayat is in charge of chlorination, which is carried out 2-3 times a week depending on the water quality. The water sample analysis showed a positive result for no traces of TTC in all water samples at point 2.

The man working for the Gram Panchayat who was in charge of chlorination was met on one of the sampling days, and when asked about the dosage of chlorination he replied, *"we use accordingly to the water quality, we are given guides of how much to put in but sometimes we add more or less. If there is too much chlorine in the water people complain because of the smell and taste, and they will refuse to use the water. That is when we put less chlorine in"*. Although the exact dosage was not given, it brings forth an important issue with regards to water treatment that the aesthetics of water is also an important issue. It is essential to chlorinate water but if in the wrong amounts people will revert to using their untreated supplies instead, opening them to possible risks of sickness.

The start of the distribution system from the storage tank on the hill had good potable water (no traces of TTCs). However the four consumer points (3-6, in *Figure 13*) were all found to be contaminated. Although not as highly contaminated as the origin of the water supply at the reservoir's chlorination well, they still pose possible risk to human health through the infection of waterborne diseases.

The private tank at Vigyan Ashram is used for drinking water by the students and staff therefore the presence of TTC is concerning however further testing needs to be carried out before making a firm conclusion (as only one sample was contaminated). Two possible sources of the TTCs in the sample dated 28th June are thought to be either from cross-contamination of the filter paper by an unsuccessfully sterilised tweezers (as the gas stove used to flame the tweezers was not operating efficiently), or from the animals on site.



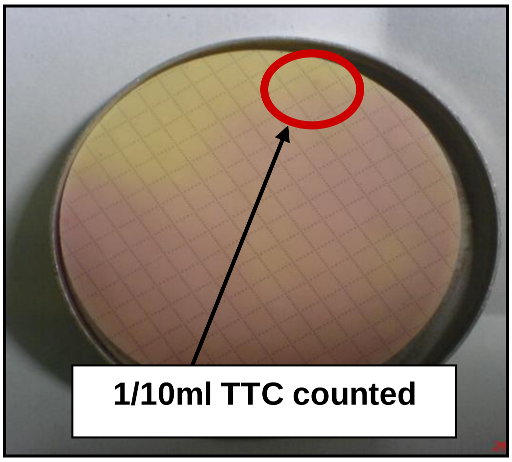


***Plate 7:* Possible cross-contamination**

***Plate 8:* TTC found in sample**

***Plate 9:* Puppy licking water from the tap**

It can be clearly seen on the two filter papers of the water samples taken at the private tank that the edges where the paper was held by the tweezers are yellow, and 1 TTC was counted (*Plate 5* and *Plate 6*). As the samples filtered were 10ml the presence of 1 TTC equates to 10/100ml. *Plate 7* shows the puppy on site taking advantage of the water supply, there are other farm animals which although are kept in pens still provide the opportunity and possibility of faeces to be spread near the taps of the tanks.

The private tap at a household in Pabal had their own piped connection from the pipeline and although the tap was in a sealed compound one sample was found to be contaminated. The tap sampled was outside and would probably not be used for drinking water therefore the health risks for the residents would be low. The sources of contamination could possibly be from the dog that was chained next to the tap, as well the exposed pipes of the tap that were open to any external contamination through cracks or joins in the pipes.

Two out of the three water samples successfully analysed at the public tap-stand were contaminated (ranging from 10-60 counts / 100ml). As one of the samples had no traces of TTCs an interesting point to be discussed is whether the contamination of water occurs through the unrepaired pipes or via contamination of the tap's spout? This will require further sampling and analysis to be able to make a fairer judgement as the sample size was limited to just one tap-stand. It was noted that a large amount of public tap-stands were broken and abandoned, although some were completely unusable others had their tap heads broken off and were blocked up but still leaking water (Plates 8 and 9). It should also be noted that only 3 out of the 4 samples were successfully analysed at the consumer points due to equipment failure, as well as the unforeseen events of there being no water at the time of sampling on the 28th June (private tap and at the hamlet).

The hamlet of Rajwara Matung Wasti (point 6) was the worst area sampled and received a very poor water service. *Plates 10* and *11* show the highly contaminated and dirty water of the stream that separates Pabal and the hamlet, which is also used by some villagers to throw their raw sewage in. The most concerning issue is that the pipeline supplying the hamlet runs over the stream, and during the rains when the stream is flooded becomes submerged in the dirty water (*Plate 12*). *Plate 13* is a picture of the well on the opposite side of the stream, also polluted with solid rubbish and dirty water and is used for potable water when water supplies are low.

***Plate 10*: Leaking Taps, with flooded aprons**

***Plate 11:* Broken and abandoned tap-stands**

Plate 12: **Highly polluted stream running through Pabal**

Plate 13: **Highly polluted stream running through Pabal**

Plate 14: **Partially submerged water pipe supplying the hamlet**

Plate 15: **Well used for drinking water by residents in Pabal**

The water supplied to the hamlet is only for ½ an hour a day, 10 minutes of which are of such a poor quality that residents have to let the taps run as it is unusable. The water is turbid, with chlorine powder residues and it was suggested by a local that a comparison of the two water qualities be tested. The results show the difference in TTCs to be 11 times worse during the first 10 minutes of supply. A local elderly man (Nana Sonane) was able to provide the situational information to the researcher as he is an active member of the community, vocalising the concerns of their poor water supply at the meetings of the Gram Panchayat.

5.3 <u>Qualitative Results</u>

The questionnaires, interviews and general informal daily conversations with locals provided a clear overview of what traditionally Pabal was like and the comparisons to the development it now sees.

The social aspects of the surveyed population show that the community is religiously diverse and living together with no segregation caused through religious reasons. However the hamlet Rajwara Matung Wasti was only occupied by the 'untouchable' caste (the lowest in the Hindu caste system), although integrated into the community and able to work their label remains as the uneducated. The majority of those interviewed considered education and the infrastructure to an important improvement to the Village, allowing the development of their children and providing them with opportunities (both social and economic). The water supply although improved was still noted to be limited as they only received ½ hour - an hour. There are many influencing and supporting bodies present in Pabal, more doctors and hospitals are available which are especially important with the sickness experienced during the rains.

There is an authoritative hierarchy in Pabal which is the determinant of legislation and governance in the village:

1. District Development Officer (the Government district level).
2. Block Development Officer (Government body at the Taluka regional level).
3. Gram Panchayat is the village level authority who has the Sarpanch as their elected representative.
4. The Gram Panchayat council Office is the last level were problems and issues are brought by the local villagers.

This lengthy system is possibly a reason why many people feel their problems are not addressed. It takes time and money for issues to be sorted out and investment into new equipment and systems is very unlikely especially as funds are hard to come by. It is therefore imperative that in order for there to be a sustainable water treatment system in place investment as well as skilled training of the locals should be in place.

5.3.1 Water Quality & Treatment

There are many possible origins of contamination, as there are many stray dogs, pigs, cattle, raw sewage thrown into the stream, rubbish left on open tips and a few cases of open defecation. These will each have to be addressed individually in order to help mitigate the source of the issue of faecal contamination of water. A more preventative approach is required with regards to controlling the source of faeces which inevitably finds its way into drinking water sources. For example open defecation is now illegal in Pabal, people are fined if caught and it is compulsory for each household to have their own latrine if space and finance allow. Additional regulations should be in place e.g. water troughs away from water pumps, as well as improved sewage and drainage systems which will require an investment from the Gram Panchayat.

Observations were made of wells contaminated with rubbish, raw sewage flowing in the stream running through the village which may have leached into groundwater resulting in contaminated well water supplies as well as infiltration into the poorly maintained piped water system. There were still some cases of open defecation, piles of open rubbish tips (those that have not been burnt) some in close proximity to tap-stands, and livestock drinking by the base of hand-pumps as well as women washing their cloths, all possible contributors to contamination.

Water, health and sanitation are all interrelated in terms of playing an integral part in the reduction of water contamination and treatment. By targeting a problem from its cause or source, limits the risk of contamination and spread of disease. The improved health of a community will result in more productive work, and this 'preventative approach' was known and favoured by many villagers. It will help also reduce the health costs and increase the standard of living. Local participation and involvement through schools, the Vigyan Ashram and entrepreneurships will enable an effective and sustainable water treatment system.

5.3.2 Water storage tank and pipeline system from the reservoir

The construction of the water tank on the hill and the installation of the plastic pipeline via the aid of a German NGO and the Gram Panchayat have improved access to water for many villagers by providing ½ an hour running water to tap-stands in Pabal and the surrounding hamlets. The distribution of water is for an equal amount of time regardless of the location of the tap-stand. Although there is an equal and fair distribution, technically this is not the case as the hamlet Rajwara Matung Wasti received a much poorer quality as noted in the results. The feelings and views expressed by one senior occupant was one of frustration at the bureaucracy of no support from the government with regards to their problems, infuriation at having to live with their poor water supply and a passion to change their situation (Nana Sonane).

The key factor to the failures and problems related to the water pipeline system is due to a lack of operation and maintenance. The Sarpanch when interviewed was unable to provide details with regards to the specifics of the water treatment and system, more information may be obtained through other personnel. It is important that there be some form of formal and regular maintenance checks, carried out throughout the system. For example from the reservoir water source (chlorination at the pumping well), to the storage tank with its chlorination dosages and at different tap-stand points along the pipeline. These checks can be carried out sufficiently by locally trained employees, who are able to handle and store chemicals safely as well as keep records on their monitoring and maintenance work.

6. RECOMMENDATIONS & CONCLUSION

6.1 Recommendations

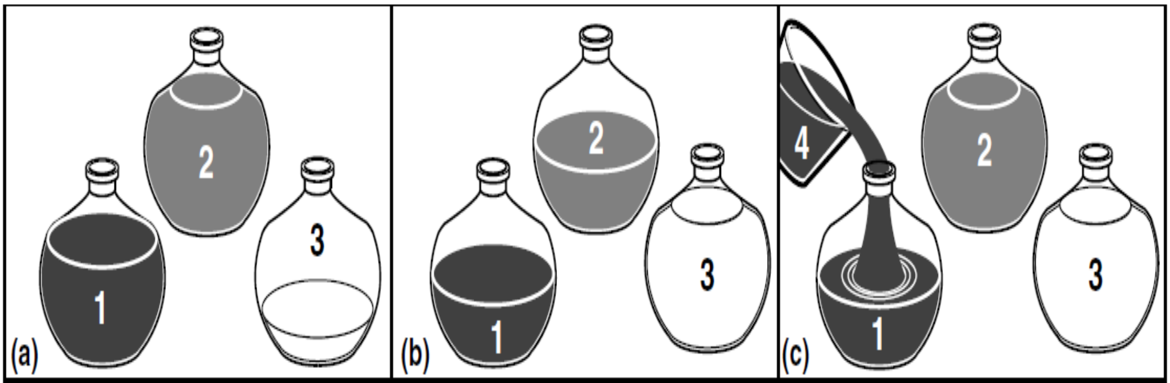
- ***Continual practice of water treatment at a household level***
- ***Water and sanitation, education and health committee***
- ***Storage and settlement, UV filtering and biosand development***

There is a pressing need to address the water treatment problems in Pabal especially in areas such as Rajwara Matung Wasti therefore further research should be given into the development of household level water treatment technologies. Through observations carried out and the results from the questionnaires and interviews it can be deduced that water treatment by the local population is still only being carried out after falling ill to water-borne diseases for a minority of those living in Pabal. The majority of the sampled population (77%) are aware of treatment methods both in central Pabal and out in the hamlets and practice a combination of chlorination (using Medichlor), cloth filtering or the use of traditional copper pots. Those that don't treat their drinking water either rely on the central chlorination pipeline system provided by the Gram Panchayat, are not concerned enough to make the effort or claim they cannot afford the Medichlor treatment.

In order to increase the number of villagers treating their water these issues require addressing and the most effective recommendation would be through education and positive reinforcement. For example setting up a health and water and sanitation (WATSAN) committee, whose aim would be to provide information and a more prominent educational program to help educate and reach out to those in more inaccessible areas i.e. those living in the farming areas. This may be aided by advertisements and the use of radio, posters and wall paintings illustrating the need for good hygiene and sanitation practices such as hand washing as well as explaining the reasons for water treatment. By placing these advertisements at strategic locations such as in medical clinics, in schools, at bus stops or near water collection points will form a method of not only education but a reminder for the need to treat drinking water as well as good health practices. The committee should consist of publically elected members (male and female) who will be trained so that it is a fair and equal organisation to help minimise any personal or governmental agendas. With regards to the issue of cost of water treatment, the Sarpanch mentioned in his interview the availability of assistance for those unable to afford chlorination. Alternatively the WATSAN committee (and those involved with the women's banking group) could also provide advice on financial budgeting as a bottle of Medichlor costs around Rs20 for a 2-3 months' supply. Therefore investing in water treatment would be a cheaper option as compared to having to cover medical costs plus income lost during any periods of sickness due to water related diseases.

Household water treatment involves a combination of the following steps: straining, aeration, storage and settlement, and disinfection. Access to a household water purification system is important, as increasing population pressures also brings in higher risks of contamination to the central formalised supply. The main method of bacterial removal from drinking water can be achieved through various simple techniques such as water filtering, boiling, and chlorination. Boiling is not a cost effective method in Pabal as firewood is scarce and mainly used for cooking purposes. However information gathered from the combined questionnaire with a fellow EWB-UK researcher on biogas development in Pabal, showed the potential and willingness for farmers to have self-sufficient biogas generators which would then allow for water boiling (on a rolling boil for 10 minutes) as a form of treatment for those particular individuals.

Figure 13 is the 'three-pot system' used to improve the quality of raw water by allowing settlement and death of the pathogens from storage, as water stored for one day can kill off more than 50% of most bacteria (Skinner & Shaw,1999). The traditional copper pots as mentioned in the discussion are even more effective vessels for storage of drinking water.



Drinking-water: Always take from pot 3. This water has been stored for at least two days, and the quality has improved. Periodically this pot will be washed out and may be sterilized by scalding with boiling water.

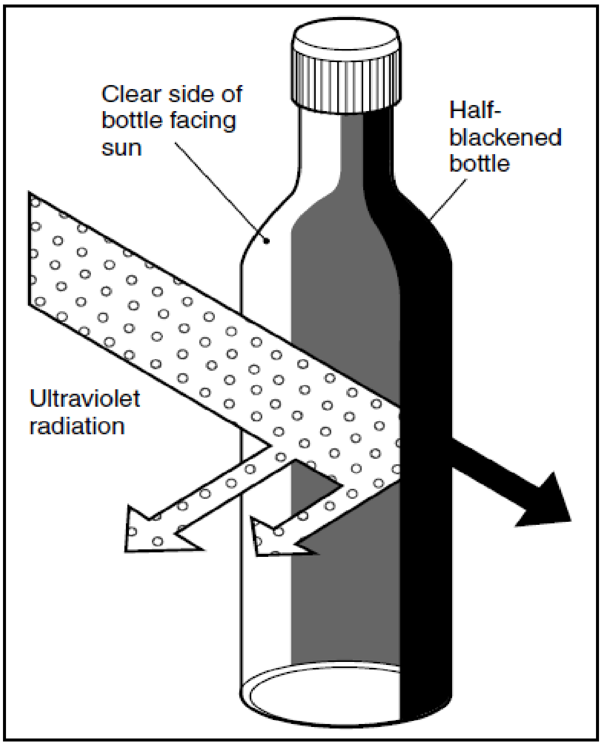
Each day when new water is brought to the house:

(a) Slowly pour water stored in Pot 2 into Pot 3, wash out Pot 2.
(b) Slowly pour water stored in Pot 1 into Pot 2, wash out Pot 1.
(c) Pour water collected from the source (Bucket 4) into Pot 1. You may wish to strain it through a clean cloth.

Using a flexible pipe to siphon water from one pot to another disturbs the sediment less than pouring.

(Source: Skinner & Shaw, 1999)

Figure 13: Three-Pot Treatment System

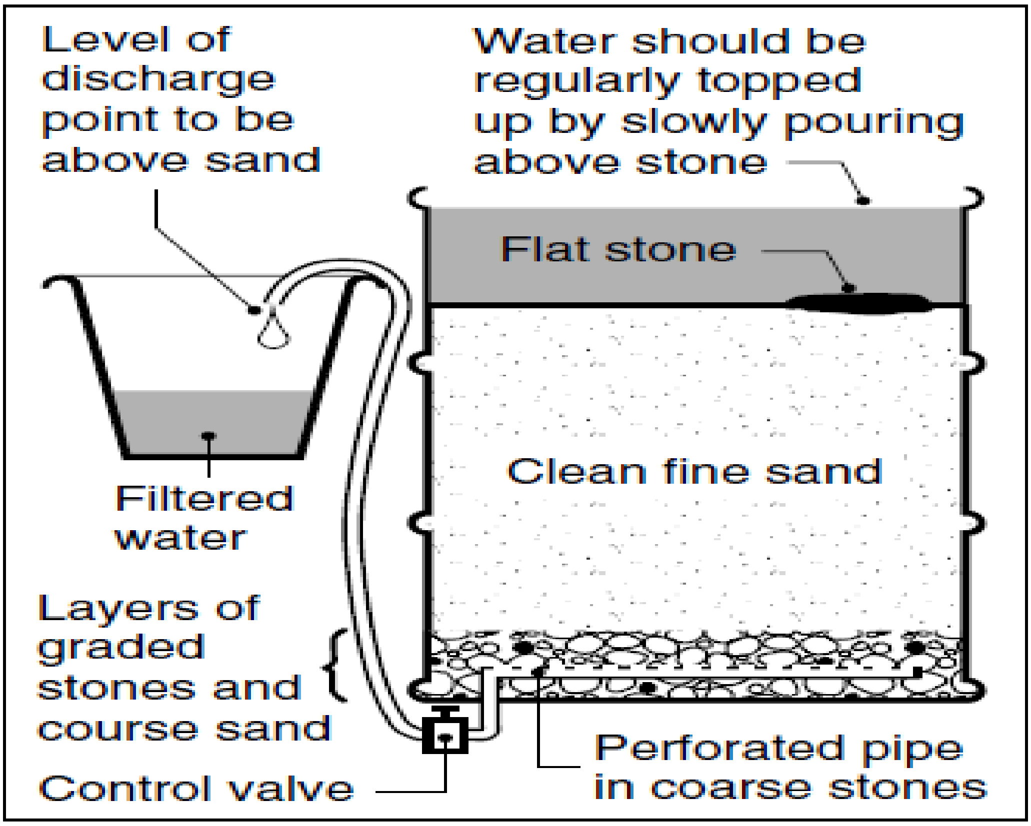


(Source: Skinner & Shaw, 1999)

Figure 14: SODIS Treatment System

The average maximum temperature in Pabal in June 2009 was 35°C and as the area receives high temperatures throughout the year solar disinfection will be an ideal, cheap and effective method for drinking water treatment. *Figure 14* illustrates the SODIS system whereby UV radiation kills off pathogens, with a safe exposure period of 5 hours when temperatures are at the highest (midday). Half the bottle is painted black to increase heat absorption, which may be aided by placing black-side down on a corrugated-iron roof sheet. Before exposure (as well as during) bottles ¾ full should be shaken to increase the oxygen content and the effectiveness of the solar disinfection (Skinner & Shaw 1999, Reed, 1997).

Figure 15 is a diagram of a basic biosand filter which has several advantages over other methods of water disinfection: it is a low energy consuming process, great adaptability in components and low maintenance, and can be built and installed locally with relatively low investment and running costs.



(Source: Skinner & Shaw, 1999)

<u>Figure 15: Basic Biosand Filter</u>

Slow sand filtration passes raw water slowly (velocity of 0.1-0.2 m/h) through layers of differently graded sand and stones, trapping larger suspended particles first. The smaller organic particles are left in the sand creating a slime layer called the 'schmutzdecke', bacteria and protozoa's are either eaten by micro-organisms or are attached to the sand particles until they die. However the grain size in the sand filter should be around 0.1mm in diameter to effectively remove all faecal coliforms and almost all viruses, resulting in potable water (Black & Veatch, Dayton & knight and RBD Consulting Engineers, 1991).

However these particular household water treatment methods should first be tested in Pabal using raw water from the different sources and their effectiveness confirmed before any mass promotion is carried out. Alternative water sources may also be a worthwhile investigation such as rainwater harvesting which will be most efficient during the monsoon period.

*6.2 **Conclusion***

The journey to Pabal provides a good indication of the potential growth of the village, as you bypass the City of Pune you are greeted by large industrial and manufacturing units. The road leads to a small and rural village in Pabal with a large telecommunication mast, a pipeline delivering water to the village as well as little shops. Having spoken to some of the locals the improvements made over the last decade has seen generally a big improvement to the standard of living in Pabal, with the development of schools and medical centres being of most importance. However although there may be an increase in availability to technology and development has been felt by the villagers, the prevailing incidences of poor health especially amongst the less affluent is a clear indication that there are still issues to be addressed in conjunction with water treatment such as improving the infrastructure and drainage system in the village. These additional areas of concern impact on the quality of the drinking water as runoff water eventually enters into the village water sources, so an improvement to these areas would also aid to improve water quality and health.

The villager's health may be safe guarded by utilising traditional methods such as cloth filtering, copper pot storage (that have anti-bacterial properties) in conjunction with chlorination. Further education and future possibly large-scale water treatment designs based on bio-sand and UV filtering can be produced locally via the community involving the Vigyan Ashram educational centre. The Ashram provides a resource of skills based education which has already proved to be a success with former students taking up opportunities in local manufacture and enterprise in the village. Community involvement will also provide a sense of community ownership and working with the Gram Panchayat duties such as maintenance of systems may be shared amongst the villagers.

In conclusion although local efforts are made and systems are in place to treat the water supply in Pabal through a central chlorination tank, villagers should not rely on this as their sole water treatment for drinking water due to the reasons mentioned in the discussion such as disrepair of the pipeline and contamination. Therefore it is essential for drinking water to be treated at a household level, to ensure the safety of those particularly at risk i.e. the young, elderly or sick which will result in the overall improvement to the community's health. This will not only save money in the long- term by reducing their medical costs and enabling them to spend it elsewhere e.g. on further education, but will also offer a general well being for the community by empowering people to utilise and engage in the development of Pabal.

REFERENCES

Abel, P. D. (1998). *Water Pollution Biology*. Second Edition. Published by Taylor & Francis. UK. p177-178.

Aertgeerts, R. (2009). *Progress and Challenges in Water and Sanitation*. Desalination: Volume 248, Issue 1-3 November 2009. p249-255.

Bailey, R. (1996). *Water & Environmental Management in Developing Countries*. The Chartered Institution of Water and Environmental Management. Sponsored by the Overseas Development Administration. p138-144, 161-166.

Binnie, C., Kimber, M. & Smethurst, G. (2002). *Basic Water Treatment*. 3rd Edition. IWA Publishing. The Open University. London. p40, 60-61, 140 & 212.

Biswas, A. K. (1997). *Water Resources – Environmental Planning, Management, and Development*. Published by McGraw-Hill. USA.

Black & Veatch, Dayton & Knight and RBD Engineers (1991). *Slow Sand Filtration*. AWWA Research Foundation. Colorado State University. Available from: http://www.oasisdesign.net/water/treatment/slowsandfilter.htm#top [Accessed: 2nd December 2009].

Bouguerra, L. (2006). *Water Under Threat*. Global Issues. Zed Books, London & New York. p76, 130,139.

Calder, I. R. (1999). *The Blue Revolution – Land Use and Integrated Water Resources Management*. Earthscan. London. p87.

Carson, R. (2002). *Silent Spring*. Edition 001 Series. Mariner Books. Published by Houghton Mifflin Harcourt.

Clarke, R. (1991). *Water – The International Crisis*. Earthscan. London.

Crompton, T. R. (1998). *Toxicants in the Aqueous Ecosystem*. WILEY. Chichester, England. Preface page.

De Moel, P. J., Verberk, J.Q.J.C & Van Dijk, J. C. (2006). *Drinking Water – Principles and Practices*. World Scientific Publishing, p. 213-221.

Desai, V. & Potter, R. B. (2006). *Doing Development Research*. SAGE Publications. London.

Drangert, J. (2004). Norms and Attitudes Toward Ecosan and Other Sanitation Systems. EcosanRes Publication Series, Report 2004-5. Stockholm Environment Institute, Stockholm.

Edwards, M. & Fowler, A. (2002). *Introduction: Changing Challenges for NGDO Management*. The Earthscan Reader on Ngo Management. Earthscan Publications London. p1.

Edwards, M. & Sen, G. (2002). *NGOs, Social Change and the Transformation of Human Relationships: A 21st –century Civic Agenda*. The Earthscan Reader on Ngo Management. Earthscan Publications London. p38-49.

EngINdia, (2005). *Project Proposals: Water Treatment*. Available from: http://home.btconnect.com/engindia/watertreatment.htm [Accessed: 2nd April 2009].

Furminger, E., John, M., Laundon, T., Shah, V., Wagh, P. & Walker, D. (2006). E*ngINdia Final Report – Pabal, Maharashtra India (28th June – 7th August 2005)*.

Gleeson, C. & Gray, N. (1997). *The Coliform Index and Waterborne Disease – Problems of microbial drinking water assessment*. Published by E & FN Spon, an imprint of Chapman & Hall. London.

Gleick, P. H. (1993). *Water in Crisis – A Guide to the World's Fresh Water Resource.* Pacific Institute for Studies in Development, Environment and Security. Stockholm Environment Institute. Oxford University Press.

Gray, N. F. (2008). *Drinking Water Quality – Problems and Solutions*. 2nd Edition. Cambridge University Press. p67, 233-234, 463-464.

Howard, G. (2002). *Water Quality Surveillance – A Practical Guide*. WEDC, Loughborough University, UK.

Hunter, P. R. (1997). *Waterborne Disease – Epidemiology and Ecology*. WILEY. Chichester, England. p143-147.

Indian Standards Institution (ISI, 1989) & Indian Council for Medical Research (ICMR). *Drinking Water Quality Criteria*. Available from: http://www.elaw.org/node/2433 [Accessed: 23rd August, 2009].

Intervention (India) Pvt. Ltd (2003). *Fundraising for NGOs*. Available from: http://www.interventions.org/fraising.html [Accessed: 23rd August, 2009].

Kay, D. & Fricker, C. (1997). *Coliforms and E.coli – Problem or Solution?* The Royal Society of Chemistry, UK. p3.

Khurana, I. & Sen, R. [Water Aid] (2009). *Drinking water quality in rural India: Issues and approaches – Background Paper*. Drinking Water Quality. Water Aid. Available from: http://www.wateraid.org/documents/plugin_documents/drinking_water.pdf [Accessed: 22nd August, 2009].

La Frenierre, J. & Dr. Szyliowicz, J. (2008). *When Appropriate Isn't Enough: The Risk of Ignoring The Social and Cultural Implications of Technology*. INTS 4965: Technology and Sustainable Development. Available from: http://www.lafrenierre.net/uploads/9/7/8/4/978415/when20appropriate20is20not20enough.pdf [Accessed: 28th August 2009].

Luce, E. (2003). *India: Pepsi and Coca-Cola Deny Pesticide Claims.* Financial Times. Available from: http://www.corpwatch.org/article.php?id=7909 [Accessed: 28th August 2009].

Maharashtra Guide (2009) – *Climate and geography*. Available from: http://www.maharashtratourism.net/climate.html [Accessed: 2nd August, 2009]

Mann, H. T. & Williamson, D. (1996). *Water Treatment and Sanitation – Simple Methods for Rural Areas*. Intermediate Technology Publications. Nottingham.

Maps of India, (2006) – *District Map of Maharashtra*. Available from:

http://www.mapsofindia.com/maps/maharashtra/maharashtra.htm [Accessed: 2nd August 2009].

Meier, G. M. & Rauch, J. E. (2000). *Leading Issues in Economic Development.* 7th Edition. Oxford University Press. New York. p521-522.

Neuman, W. L. (2006). *Social Research Methods – Qualitative and Quantitative Approaches.* 6th Edition. Pearson International Edition. USA. p33-35.

Oxfam DelAgua (2004). *Portable Water Testing Kit*. Users Manual with Instructional CD-ROM. Version 4.1

Pearce, J. (2000). *Development, NGOs, and Civil Society*. An Oxfam Publication. UK. p37.

Percival, S. L., Chalmers, R. M., Embrey, M., Hunter, P. R., Sellwood, J. and Wyn-Jones, P. (2004). *Microbiology of Waterborne Diseases*. Elsevier Academic Press, California, USA. p71-82.

Rajiv Gandhi National Drinking Water Mission (RGNDWM), (2009-2012). *National Rural Drinking Water Programme: Movement towards Ensuring People's Drinking Water Security in Rural India*. Department of Drinking Water Supply. Ministry of Rural Development. Government of India. Available from: http://ddws.gov.in/popups/RuralDrinkingWater_2ndApril.pdf

Rathore, H. S. (2009). *Handbook of Pesticides: Methods of Pesticide Residues Analysis*. Publish by CRC Press. p49-51,

Robson, C. (2002). *Real World Research: A Resource for Social Scientists and Practitioner-Researchers*. 2nd Edition. Wiley-Blackwell. Oxford.

Rural Development Education System Report, (2004). *History and philosophy of Vigyan Ashram*. Available from: http://www.picatype.com/etr/rm5u1e.htm#The%20Vigyan%20Ashram%20Project [Accessed 15/08/09].

SANDEE (South Asian Network for Development and Environmental Economics), (September, 2004). *Adoption of Safe Drinking Water Practices: Does Awareness of Health Effects Matter?* Number 4-04. Available from: http://www.sandeeonline.org/publications/policy_brief/policy_brief_som.pdf [Accessed 26/08/09].

Skinner, B. & Shaw, R. (1999). *Household Water Treatment 1 & 2*. Water and Environmental Health at London and Loughborough (WELL). UKs Department for International Development (DFID), London School of Hygiene and Tropical Medicine (LSHTM) and the Water, Engineering and Development Centre (WEDC). Loughborough University.

Smout, I. & Parry-Jones, S. (1999). *Lessons Learned From NGO Experiences in the Water and Sanitation Sector*. WELL – Water and Environmental Health at London and Loughborough. Published by Water, Engineering and Development Centre (WEDC). p5-8.

Stauffer, J. (1998). *The Water Crisis – constructing solutions to freshwater pollution*. Earthscan Publications, London. pxii,

The Times of India, (August 2009). *Pranab heads GoM to monitor drought in India*. Available from: http://timesofindia.indiatimes.com/news/india/Pranab-heads-GoM-to-monitor-drought-in-India/articleshow/4890488.cms [Accessed 15/08/09].

The United Nations World Water Development Report 3, (2009). *Water in a Changing World*. World Water Assessment Programme. UNESCO Publishing. Earthscan.

United Nations. *The Millennium Development Goals Report 2008*. New York.

Water Aid UK (2009). *Diarrhoeal diseases*. Available from: http://www.wateraid.org/uk/what_we_do/the_need/disease/684.asp[Accessed 2nd September 2009].

Water for the World (1). *Methods of Water Treatment – Technical Note No. RWS. 3. M*. Available from: http://www.lifewater.org/resources/rws3/rws3m.pdf[Accessed 25th August 2009].

Water for the World (2). *Methods of Water Treatment – Technical Note No. RWS. 3.P.1*. Available from: http://www.lifewater.org/resources/rws3/rws3p1.pdf[Accessed 25th August 2009].

Water Supply & Sanitation Collaborative Council (WSSCC). *Annual Report 2008*. Available from: http://www.wsscc.org/fileadmin/files/pdf/publication/WSSCC_2008_Annual_Report_final.pdf [Accessed 5th August 2009].

World Health Organisation (WHO), (2009). *Health through safe drinking water and basic sanitation*. Available from: http://www.who.int/water_sanitation_health/mdg1/en/index.html [Accessed 5th June 2009].

World Health Organisation, (2008). *Guidelines for Drinking Water Quality – Incorporating 1st and 2nd Addenda to 3rd Edition.* Volume 1. p22.

World Health Organisation (WHO), (1989). *Disinfection of Rural and Small-community Water Supplies – A Manual for Design and Operation*. Published by the Water Research Centre.

APPENDICIES

1. Target Interviews – water quality and treatment

A) Doctor Golap

B) Sarpanch - Translations

C) 12th Standard Teacher

2. Weather Data for June in Pabal

3. 22 Questionnaires

Hindi translations

(Questionnaires do not include the biogas data collected for the fellow EWB-UK researcher).

1. A) Doctor's interview – water quality & treatment

Name: Dr Golap Date: 02/07/09 Time: 13.50

1. What sorts of water related illnesses are there?

Acute bacillary dysentery which can be very serious with patients developing high grade fever, loose motions and even producing blood and mucus. The other major illnesses are cholera, shigella, e.*coli*, typhoid and salmonella.

2. What medication do you prescribe?

Obviously there are different medications for each disease but I believe 'prevention is better than cure' and so I use a preventative approach. For example the use of Medichlor M which settles the dust in untreated water, it works as an alum and makes the water potable. It is purchased in a small bottle (here let me show you), it has dilution instructions on the back (a few drops in a bucket of water). Filtering is also an effective method of treatment. In the rural areas people use micro pore cloths to filter or traditional mutkas.

3. Does the hospital have any medical educational programs i.e. working in the village or with a school?

The Primary Health Care has an 'epidemic (monsoon) cholera' issue warning system with preventative measures. The Spundun Heartbeat Medical Association has 100 doctors from the Shirur Taluka who all work together.

4. Who are the most vulnerable?

The people who eat and drink at the hotels/food houses, as hygiene practices are not good at all. Water is kept in barrels, bare hands are used to do everything (possibly unwashed) also food and water is open to the heat, flies and insects.

5. Do people spend a lot of money on medical bills?

People spend a lot of money and it is unnecessarily spent!

6. What advice do you give your patients to stay healthy in relation to water related diseases?

Although I use a preventative approach this doesn't happen here in Pabal. The people will only treat their water after they have fallen ill. I encourage them to treat their water and practice good hygiene to stay healthy, especially during the rainy season.

7. Do some of your patients drink untreated water?

Yes, one of the main reasons would be illiteracy amongst the nomadic populations, they are mainly sheppards. 50% are unaware about the importance of washing hands but they all know about and most have mobile phones! They are unwilling to treat water for many reasons such as cost and the taste of treated water. It is very difficult to change certain people's behaviour or ways of thinking.

8. What effective water treatment methods are available/recommended?

Apart from what I mentioned earlier they can buy Bisleri bottled water but this of course is not an affordable option for many. The traditional system of leaving water in a copper pot for 24hr is an effective treatment even for bacteria, also boiling the water. Here at the hospital we use a filtering system called the Aqua Plus Guard however with electricity problems devices requiring power are not very reliable.

9. Do you have more patients at a certain time of year?

During the summer as it is our monsoon season, rains are heavy and with it bring many of the illnesses we are talking about. At the moment our monsoons are late as it was last year. The land is already arid and now many water sources are drying up .The river water levels are low and so the boreholes being used for drinking water contain high concentrations of salts. This is one of the main reasons for another problem faced by the people in Pabal which is kidney stones. The acceptable standards of potable water salts are 50ppm. Tests were carried out by staff at the hospital and they found that 16 samples had levels of 800ppm. The water tested was used for other things and not drinking but at times like this villagers are forced to use such sources.

10. Further comments?

The Nirmal Gram a few years ago advised that villagers in Pabal should each have a toilet and as a direct effect a law was brought out that everyone should have a toilet and septic tank.

B) Sarpanch's (head of Gram Panchayat) interview – water quality & treatment

Date: 02/07/09 ***Time: 15.*****00**

1. What is the population of Pabal?
There are about 15'000 people all together including all the hamlets.

2. Traditionally before the Gram Panchayat (G.P) was formed what was the water supply situation?
The G.P was formed in 1939 but before that people would have to get their water from dug-wells. They would walk and fetch water up to 2-3kms away.

3. What is the current water supply system/coverage?
1 ½ years ago we had a pipeline system installed which serves 5000 people just in the village. The rest of Pabal has another scheme which is going on and it will serve another 5000 people. This is the new tank being built by the storage tank on the hill. A final scheme will help the last 5000 people.

4. What are the G.P responsibilities and duties in the system?
Distribution of water in various ways and maintenance of the scheme. Paying of the bills such as electricity, purification of water and collecting debts/ taxes from people for each connection.

5. Do people have to pay a contribution for the piped water supply?
Yes, the tap stands are cheaper and for a private connection it is more.

6. Who set up the pipe network? (scheme costs/timescale)
The scheme was 90% financed by a German NGO and the 10% was from local contributions. It was funded with German Economic Funds. The higher authority of the G.P was responsible for all the engineering works. We had a few German officials from the NGO that came to look as well.

7. How much water capacity is in the storage tank?
The storage tank is 1 lakh 70'000 litres (= 170, 000L), all the tanks will be split into population sizes.

8. Who is in charge of maintenance and checks of the pipeline and tank?
The Gram Panchayat, we have a specialised contractor for the pipeline and the maintenance of the tank.

9. Is there any water treatment processes carried out?
We use TCl powder in the wells and at the storage tank.

10. If chlorination: how much, how often and was there any training involved?

The government authorities provide us with the ratios, I do not know them.

11. Does the G.P. carry out any regular water testing throughout the water supply system i.e. tank, tap-stands and pipe outlets?
We often take water testing.

12. Are there any plans for a drainage system?
It is happening now; you must have seen the digging outside? Our wastewater at the moment goes straight into the stream.

13. What problems do the villagers bring to your attention regarding water quality and treatment?
Sometimes the water is salty, it is not fresh.

14. Does Pabal have a separate water committee or does the G.P deal with all issues?
There is a separate water committee; we have different people for different sectors.

15. Have there been any illnesses related to poor water quality?
Yes, there are illnesses when the rainy season is here.

16. Does the G.P offer any incentives or help for those households that can't afford to treat their water or don't know how to?
Yes we provide help for those who can't afford it.

17. Are there any governmental water laws or regulations that the G.P has to follow?
Yes, the Indian government sets them.

18. Does the government or the G.P provide any training or education on water quality, treatment and health for the villagers?
No.

19. Are there currently any NGOs working in Pabal or planning to work here?
There are no NGOs here. We are open to suggestions from anyone.

C) School Teacher's Interview – water quality & treatment

Name: ***Mr Jadhav, B. N.*** **Date:** ***02/07/09*** **Time:** ***16.20***

1. Which school do you teach at and at what level?
I teach at Sri Bharnath Vidyan Mandir Junior College in Pabal. It goes up to 12th Standard in Commerce, which I teach.

2. How many children are there in the school?

There are about 1800 students.

3. What is the age range?
It is a High School/ Secondary school.

4. Do you have students from outside of Pabal?
Yes, we have students coming from 10-15 surrounding villages.

5. What water source does the school use for the children (drinking and other)?
We have a well which we use to pump water to our tank which is used for drinking and the garden.

6. Is the drinking water treated?
No the water is not treated. We don't think there is any need to and also the students bring their own water to drink at school.

7. Does the school curriculum cover health & sanitation in any way e.g. hand washing?
We don't have anything specifically like hand washing but in our different subject areas like Biology, it will cover hygiene and physiology. The school provides the girls in 8th-12th Standard with iron tablets and we also have a vaccination program. This is free for all students as the government pays for it.

8. What are you views on the importance of teaching children about health & safety?

9. Does the school curriculum cover anything on water, quality & treatment?
I am a commerce teacher; I do my best with my children. I teach them to stand on their own feet and to do their best for their own future. I think education is very important and it is a disadvantage to those that don't treat their water. We cover the basics in each subject area.

10. Do the children ever fall sick due to water related illnesses?
Yes, but not only the children everyone is open to sickness like Cholera. Again and again we see the problem of gastrointestinal diseases, this is the case when the rains are heavy and we have a change in season. When there is a problem people use bleaching powder to treat their water, otherwise they don't do anything as the water is good enough.

11. Do you have any comments with regards to the water quality and facilities in Pabal?
Rajgurunagar has no treated water at all. The big cities like Pune have water and treatment systems but in the rural areas like Pabal water is not treated properly. The system is insincere as water is a right to every human being, a basic need!

2. Weather Data for June 2009 in Pabal

Date	Min Temp. °C	Max Temp. °C	Rainfall mm
01-Jun	24	36	0
02-Jun	24	35	0
03-Jun	24	37	0
04-Jun	24	35	0
05-Jun	25	35	0
06-Jun	24	36	40
07-Jun	23	36	39
08-Jun	21	26	0
09-Jun	24	33	0
10-Jun	24	34	0
11-Jun	25	31	0
12-Jun	25	36	0
13-Jun	24	35	0
14-Jun	25	37	0
15-Jun	24	37	0
16-Jun	24	37	0
17-Jun	24	38	0
18-Jun	24	38	10
19-Jun	23	37	0
20-Jun	24	36	0
21-Jun	23	37	0
22-Jun	24	34	0
23-Jun	24	29	0
24-Jun	23	33	0
25-Jun	25	33	0
26-Jun	25	33	0
27-Jun	24	34	0
28-Jun	25	33	2
29-Jun	24	35	0
30-Jun	26	33	0

(Source: Vigyan Ashram, 2009)

DECLARATION

This is to certify that the questionnaire survey in Pabal was conducted in conjunction with Thomas Wilson, a fellow EWB – UK researcher. However the questions from the Water Quality & Treatment section and Sanitation are questions that have been used and analysed independently for this thesis.

Aisha Mukadam (September 2009)