Drinking Water in Pahuatlán, Mexico

A social study, a water quality investigation and a technical solution

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DRINKING WATER IN PAHUATLÁN, MEXICO
- A SOCIAL STUDY, A WATER QUALITY INVESTIGATION AND A TECHNICAL SOLUTION

A Minor Field Study

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The MFS Scholarship Programme offers Swedish university students an opportunity to undertake two months of field work in a country in Africa, Asia or Latin America. The results of the work are presented in a report at the Master’s degree level, usually the student’s final degree project. Minor Field Studies are primarily conducted within subject areas that are important from a development perspective and in countries supported by Swedish international development assistance.

The main purpose of the MFS Programme is to enhance Swedish university students’ knowledge and understanding of these countries and their problems and opportunities. MFS should provide the student with initial experience of conditions in such a country. A further purpose is to widen the Swedish human resources cadre for engagement in international development cooperation.

The International Office at the Royal Institute of Technology, KTH, Stockholm, administers the MFS Programme for the faculties of engineering and natural sciences in Sweden.

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This project was carried out in the indigenous community Pahuatlán, located in the state Hidalgo in central Mexico. It is a cooperation between the Division of Sanitary Engineering at Luleå University of Technology, the Division of Environmental Chemistry at Universidad Regiomontana in Monterrey, Mexico and local institutions in Hidalgo. The financial funding was provided by the Swedish International Development Cooperation Agency (SIDA).

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Luleå, February 2004

Jennie Eriksson

Lisa Rabén
This project was conducted in Pahuatlán, one of many small, indigenous communities in the state Hidalgo, located in central Mexico. In Pahuatlán there is need for an improved health situation. People are frequently getting ill and problems such as diarrhoea, eye infections and skin irritation, all of which can be water related, are common, especially among the children. Cases of cholera have also been reported.

The foremost objective with this project was to evaluate the water quality of the drinking water in Pahuatlán and, if necessary, find solutions to provide a safe supply of drinking water.

The approach was to give a multidisciplinary description of the situation, which implies that many factors are taken into consideration, including for example natural prerequisites and socio-cultural aspects. Priorities, habits, possibility to participate, motivation and knowledge are examples of what was included in the socio-cultural investigation. The quality of the water was investigated through bacteriological and physical-chemical analyses.

Based on our own and earlier investigations of the water quality and the health situation in Pahuatlán the drinking water quality needs to be improved. It is probable that most microbiological contamination is caused by the local population and animals and the contamination routes are poorly understood by the inhabitants.

The inhabitants were interested in the project and they were participating in all phases. It was easy to communicate with the people and we were accepted and respected in the community. A drinking water treatment system was implemented in one of the wells in the community. The system consists of a pump; disinfection with chlorine and a carbon filter which reduces the taste and odour of the water. The system was appreciated and accepted by the inhabitants, they contributed financially and they learned how to use the equipment. According to a pilot study the equipment functions satisfactorily. The system is easy and secure to operate and can be applied to other wells in the community.
Este proyecto fue conducido en Pahuatlán, una de muchas comunidades pequeñas, indígenas en Hidalgo, un estado situado en México central. En Pahuatlán hay necesidad de una situación mejorada de la salud. La gente está consiguiendo con frecuencia enfermedad y los problemas tales como diarrea, infecciones del ojo e irritación de piel, que pueden ser agua relacionada, son comunes, especialmente entre los niños. Los casos del cólera también se han divulgado.

El primer objetivo con este proyecto era evaluar la calidad del agua del agua potable en Pahuatlán y, en caso de necesidad, encontrar soluciones para proporcionar una fuente segura de agua potable. El acercamiento era dar una descripción multidisciplinaria de la situación, que implica que muchos factores están tomados en la consideración, incluyendo por ejemplo requisitos previos naturales y aspectos socio-culturales. Las prioridades, los hábitos, la posibilidad a participar, la motivación y el conocimiento son ejemplos de qué fue incluida en la investigación socio-cultural. La calidad del agua potable fue investigada por el muestreo y el análisis.

De acuerdo con nuestros propios e investigaciones anteriores de la calidad del agua y de la situación de la salud en Pahuatlán la calidad bacteriológica del agua potable necesita ser mejorada. La mayoría de la contaminación microbiológica es causada probablemente por la población local y los animales y las rutas de la contaminación son entendidos mal por los habitantes.

Los habitantes estaban interesados en el proyecto y participaban en todas las fases. Era fácil comunicarse con la gente y nos aceptaron y fuimos respetados en la comunidad. Una solución del tratamiento del agua potable fue puesta en uno de los pozos en la comunidad. El sistema consiste en una bomba, la desinfección con cloro y un filtro del carbón. El sistema fue deseado y aceptado por los habitantes, contribuyeron financieramente y aprendieron utilizar el equipo. Según un estudio experimental hecho del sistema, trabaja satisfactorio.
Detta projekt är utfört i Pahuatlán, en av många små indianbyar i staten Hidalgo i centrala Mexiko. I Pahuatlán finns det behov av en förbättrad hälsosituation. Invånarna och speciellt barnen blir regelbundet sjuka av magåkommor såsom diarré och har även problem med ögoninfektioner och hudirritationer. Alls dessa symptom kan vara vattenrelaterade. Även fall av kolera har rapporterats.

Det främsta målet med det här projektet var att utvärdera dricksvattensituationen i Pahuatlán och, om nödvändigt finna läsningar för att rena dricksvattnet.

Ansatsen var att ge en multidisciplinär beskrivning av området, vilket innebär att många faktorer måste tas hänsyn till, inklusive till exempel naturliga förutsättningar och sociokulturella aspekter. Prioriteringar, vanor, möjlighet att delta, motivation och kunskap är exempel på vad som inkluderades i den sociokulturella undersökningen. Dricksvattenkvalitén undersöktes med hjälp av provtagning och analys.

Baserat på egna och tidigare utförda undersökningar av vattnet och hälsosituationen i Pahuatlán behöver dricksvattnet rena. Den mesta mikrobiologiska föroreningen är troligtvis orsakad av lokalbefolkningen själva och av djur. Befolkningen har dålig förståelse och kunskap om hur sjukdomar och bakterier sprids.

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1. INTRODUCTION

On the wall of a shop selling Indian handicraft in the small, Mexican town Real de Catorce, it can be read:

“We do not inherit the earth from our ancestors, we borrow it from our children.”

A sentence with significance almost identical to the World Commission for Environment and Development’s (the Bruntland - commission) definition of sustainable development:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Development is a word frequently used in the world today. But what do we really mean when we talk about development? The development of the industrialized countries can not serve as guiding principle for the developing countries, since it is not environmentally sustainable. Then what is being developed? What is development? What determines whether a country is a developing country or not? Many attempts have been done to define these concepts. However, it can not be ignored that despite the existing definitions, these are concepts that are influenced by personal values, knowledge and experience.

In order to be long-term sustainable, development has to be accomplished in harmony with the environment, and it begins with people. Development should be based on the knowledge and preferences of the people concerned. This project is people-centred, since no real development can take place without the contribution of the people. Sustainable development aims to improve the quality of life for all, without increasing the use of natural resources beyond the capacity of the environment. It is not a new idea. Many cultures have recognized the need for harmony between the environment, society and economy. Many things can be learned from these cultures.

When talking about sustainable development it has to be understood that this involves environmental, economical, social, cultural and political aspects which themselves are interrelated. The concept is also considered different in different parts of the world. In southern countries it is often said that basic human needs such as for example food and shelter are things that have to be taken care of before environmental sustainability can be considered. Many governments in developing countries also mean that economical development needs to be prioritised first.

Mexico is generally not considered a developing country. Even so, it is a country which is highly marginalized. Marginalization is a condition that in it self typify a developing country. It involves big differences between rich and poor within a society. We consider this project to be a development project since our personal values are that access to safe drinking water for all should be a minimum requirement for a country or a community to be called developed.

The world faces a crisis in the water situation. Contamination of available fresh water resources are one of the most important problems in the world today. Contaminated water affects both vulnerable ecosystems and human health. Water related diseases are among the most common causes of illness and death around the world. This is a problem that has given
rise to concern also in Mexico. In Mexico, the cost of diarrhoeal diseases caused by water and soil pollution, as well as the lack of sanitation and by food poisoning has been estimated to around US$ 3,600 million a year (SEMNARAP, 2003).

Mexico is a federal republic composed of 31 states and a federal district, which includes Mexico City. The population is over 97 million and growing at 1.9 per cent per year. The country has a surface area of nearly 2 million km$^2$ and an annual rainfall equivalent to approximately 1.5*10$^9$ m$^3$ of water. This volume should be sufficient for all the needs of the population. However, in many of its regions Mexico currently faces an imbalance between water demand and availability due to the poor geographical and temporal distribution of the water resources. There is also an uneven water quality distribution. Rapid urban and industrial growth, among economic and social factors, has made this worse, 70 per cent of the population live in urban areas. Water needs have grown, water users are fiercely competing with each other and conflicts are emerging as a result. Furthermore, Mexico is slowly overcoming a severe economic and financial crisis which has limited hydraulic infrastructure development and impoverished large population sectors (Rodíguez, 2003).

According to the National Water Commission, 84 percent of the Mexican population have access to drinking water and only 67 percent have access to sewerage services. In other words, fifteen million Mexicans do not have access to water services and thirty million to sewerage services. Furthermore, these national figures do not highlight the differences in the quality of service nor the inequalities between rural and urban areas. In rural areas, only 52 percent of the population has access to drinking water and 21 percent to sewerage services. This implies poor access to services on the part of the 30 percent of the Mexican population living in dispersed communities with less than 2,500 inhabitants (SEMNARAP, 2003).

Many water users, at all levels and sectors, are reluctant to pay for water. Potable water supply has reached acceptable levels of coverage in urban areas but not in rural areas (Rodríguez, 2003). Generally it is held that water supply should be provided at a very low cost or at no cost. This is especially true in situations in which the relative shortage is high. This approach has resulted in very high levels of overexploitation in some regions, and a social reluctance to accept price increases. Water administrative and pricing policies in Mexico have not been very effective in facing increasing water demand under circumstances of relative water scarcity and budget limitations. This affects many of the indigenous communities in Mexico which do not enjoy the same standard and privileges as the rest of the country (SEMNARAP, 2003).

1.1 DESCRIPTION OF THE AREA

This project was conducted in Pahuatlán, one of many small, indigenous communities in the state Hidalgo, located in central Mexico. Hidalgo has a total area of approximately 20 905 km$^2$, which represents 1.1 % of Mexico’s total surface area. The state has a population of about 2.2 million, which represents 2.3 % of Mexico’s total population (Hidalgo, 2003).

Archaeological investigations have dated the presence of humans in Hidalgo to seven or eight thousand years before present. Today, Hidalgo represents an important mix of ethnic groups, indigenous communities and human settlement that makes the state rich in handicraft, archaeological sites and many other cultural treasures. The first humans to establish in this area were the Olmecas tribes. After that the Teotihuacäns and later the Otomíes arrived, followed by the Huasteca, after which the area in the north of the state is named. Huejutla is a
municipality located in this part. The municipality has an abundance of indigenous population of náhuatl origin. Their culture, language and handicraft leave its imprint on the region. Many events have taken place here since the first settlers in the year 671 to the arrival of the Spanish in the year 1541. Huejutla is considered the most important municipality in the Huasteca region, with a population of approximately 108,000 inhabitants. Its total surface area is 377.80 km² (2% of Hidalgo). The geographical location is 21°08’34’’N latitude and 98°25’11’’W longitude. The main occupation in the area is agriculture, which count for 62 percent of the economical activities. The municipality’s many rural communities are in great need of an improved water situation in order to improve the health of the indigenous people. Five of the communities were visited prior to choosing a location, one of which was Pahuatlán (Hidalgo, 2003).

Figure 1. The surroundings of Pahuatlán.  
Figure 2. The community Pahuatlán.

Pahuatlán is one of many communities located along a 30 kilometre long river on an altitude of 172 metre above sea level. The climate is tropical; hot and humid. The typical vegetation surrounding Pahuatlán can be seen in figure 1. The average temperature is 23 °C and the average annual precipitation is 2,500 mm. The temperature in the hot months varies between 35 and 50 °C and in the colder months; December, January and February, the temperature sometimes goes down to 13 °C. The river has a depth varying between 0.5 and 3 metre, depending on the time of the year, but it is never dried out (Navarrete, 2003). Figure 3 and 4 below show the differences in water volume between the seasons.

Figure 3. River during dry season.  
Figure 4. River during rain season.
There is usually no lack of water in the area, according to the people living there, but in the
drier months sometimes a scarcity of drinking water forces the habitants to drink the untreated
water extracted from waterholes. Pahuatlán has subsoil suitable for farming. The land
stretches over 25 hectares, of which 5% is used for farming. The vegetation is rich, there are
plantations of fine woods such as cedar, various fruit trees including oranges, mandarins,
lemon, bananas, mangos and peaches. An abundance of flowers, vegetables and herbs as well
as coffee, corn and beans are grown in the area (Navarrete, 2003).

When visiting the health centre in Pahuatlán it is made clear that there is need for an
improved health situation. According to local health workers people are frequently getting ill.
Problems such as diarrhoea, problems with the eyes and the skin are common, especially
among the children, and every year at least one case of cholera is reported to the clinic. In the
summer Pahuatlán also has a climate favourable for respiratory diseases.

The ambition with this project is that it will be one step on the way of improving the situation
for the indigenous population in Pahuatlán and Mexico. We can not stop or hinder
development towards a more modern society, but we can contribute to point the development
in the right direction, by finding solutions that are developed in harmony with the
environment and with the people. Our personal views on sustainable development and how it
should be achieved as well as some definitions on concepts used in the contemporary
development discourse are given in chapter 1.2 below.

### 1.2 DEVELOPMENT CONCEPTS

In order for a development project to be successful, it is not enough to provide the technical
equipment. Many factors affect whether or not a solution will be accepted, which in turn
determines the sustainability, i.e. the continuous use and function of the solution. Following is
an attempt to explain some of the concepts that were considered in the project. The methods
used in this project are based on the theories described in this chapter.

#### 1.2.1 SOCIO-CULTURAL FACTORS

A number of studies and considerable field experiences have shown that the introduction of
water treatment technology without consideration of the socio-cultural aspects of the
community is unlikely to be successful or sustainable. Therefore, initiatives in water, hygiene
and sanitation must consider these aspects (Sobsey, 2003).

A socio-cultural analysis aims to understand the social and cultural context in which people
operate. To improve health, for example, it is not enough to provide potable water, sanitation
or primary health care. Unless the services are wanted, asked for, by the people, and are
valued, comprehended and properly utilized, they are not useful and in circumstances they can
even make the situation worse. This requires an understanding of the social and cultural
context in which the services are to be provided (Renshaw, 2001).

*Social analysis* aims to identify and characterize the people affected by a project and also
consider relations between different social groups. *Cultural analysis* refers to understanding
the relevant cultural costumes- the values, knowledge, beliefs and practices of the people. The
analysis includes the study of the interdependence between the social, cultural, economic and
ecological aspects that affect the life of the people. In case of many indigenous people, there
is often a complex interrelation between a group’s identity, ecology, social organization and
religious beliefs. This needs to be understood and should be seen as a foundation rather than obstacle to development. One area particularly important is to understand and respect the people’s system of communication and decision-making, in order to facilitate their participation in the project (Renshaw, 2001).

It is important to gain knowledge of the area in which the project will take form. For instance the history of the community can tell a lot of the reasons behind the situation today. Behaviour and knowledge are also crucial factors in health improving actions (Naryan, 1996). If the people do not trust in modern techniques for cleaning water, for example disinfection or filtration, a solution involving these techniques might not be accepted. On the other hand, much can be learned from traditional methods used in the area. It is valuable to use the existing local knowledge as a foundation for development. To make use of the local knowledge of the area and the water sources can save a lot of time in the field work (Chambers, 2002).

1.2.2 SOCIO-ECONOMICAL FACTORS

The affordability, costs and willingness to pay for water treatment technologies are important considerations for their implementation, use and sustainability. The economic situation is often decisive for what can be achieved and how. Income, household structures, affordability and priorities are important socio-economic factors to understand (Forss, 2000).

Failure to sufficiently cover the costs of improved water services in developing countries is a major constraint to achieving the goal of safe water for all on a sustainable basis. In recent years it has been strongly promoted by for example the World Bank that the users themselves pay for services (Evans, 1992). It has been found that too generous funding makes the users unmotivated to care for the solution. The cost for operation and maintenance has to be considered already in the beginning of a project (Naryan, 1996).

Community payment means that communities can not be viewed as beneficiaries but must be seen as partners in the development process. Water programmes need to consider community needs and demands, and provide services which people really want and can make good use of. Evidence from case studies have shown that the water supply systems which provided the most reliable service were those where communities not only contributed to operation and maintenance costs, but paid for it in whole (Evans, 1992).

The relation between the sexes could play an important role in the decision-making. If the women’s role often is to take care of children and the household, the men are often the ones who have an income and take decisions on how the money should be used. Within a community, decisions have to be taken as to who pays for what. If community members are not involved in deciding how operation and maintenance facilities are going to be financed, the burden of payment may fall on the wrong shoulders. If women are the collectors of water they may be asked to pay for operation and maintenance without having access to income. Analysing household income and expenses and deciding together who is going to pay for what may prevent mistakes (Bolt, 2003).

Economic aspects also include resources such as work able persons and existing investments. Both income and priorities affect how much people are willing to spend on a water treatment system. The household structure and the occupation determine whether or not the inhabitants have time and possibility to participate in the project (Bolt, 2003).
1.2.3 PARTICIPATION

There are a lot of definitions of participation. The main aim with a participatory approach though, is to help the community without manipulate or make the people passive (Selener et al., 1997). Participation aims to avoid permanent dependence of external support and instead encourage individuals and communities to help themselves by building their own capacity (Naryan, 1996).

In order to achieve a sustainable solution it is necessary to use a participatory approach (Naryan, 1996). Various studies have shown that to motivate people for a project, they must feel that they are a part of the process. Involvement of users and sharing of responsibilities and management tasks is a prerequisite for proper choice of technological approaches. The most effective water policies and institutions involve the users of water as participants in water management, planning and decision-making. Experience has repeatedly shown that major decisions made without involving local communities and those affected by decisions are considerably more likely to fail (Gleick and Lundquist, 1997; Forss, 2000).

There is no fixed manual to follow in the implementation of a participative approach, since participation implicates that we always have to adapt to the situation (Selener et al., 1997).

1.2.4 GENDER

*Gender* means the relations between men and women and their different roles and interactions in the society. As opposed to sex, which refers to biological differences, gender is a result of a socialisation process which assigns certain attitudes, roles and responsibilities leading to certain forms of behaviour. Gender is the social and therefore changeable differences between a woman and a man in a particular social situation (Bolt, 2003).

A gender sensitive approach implies that attention is given to the relations between the sexes within the studied subjects and that it is integrated in the study (Forss, 2000). The gender approach requires an open mindedness and aims at the fullest possible participation of both women and men (Bolt, 2003).

All men and all women can not be considered as two homogenous groups, class differences may exist within the groups that need to be taken into consideration. It must be recognised that both sexes do not necessarily have the same access to resources and that work, benefits and impacts may be different within both groups (Bolt, 2003).

In many developing countries water, sanitation and household work is the responsibility of women and girls. An intervention that improves the situation within this area mainly contributes to facilitate the situation for women and girls. Acknowledging the role of women in acquiring and managing water is important and the involvement of women at community and other levels appears to be particularly effective and valuable (Gleick and Lundquist, 1997). However, gender approach and women’s involvement are two different concepts. Programmes for women’s involvement often want to change women’s conditions and position, overlooking what men and the relationship between men and women have to do with it. Activities geared toward increasing women’s involvement may then turn out to be ineffective or even have a negative impact, e.g. because they increase women’s workload (Bolt, 2003). For any solution to be accepted the whole population in the community must be considered, hence both men and women should be involved in the project. Men also need to
be sensitised on gender issues, their own roles, and those of women in water supply and sanitation (Bolt, 2003).

Women are generally more sensitive to understand and address adequate attention to health benefits achieved by an improved water situation. Often the women also have good knowledge of the different local water sources. A common hindrance is that men are not used to organize themselves on a voluntary basis to develop household-near facilities that are being used mainly by women (Naryan, 1996).

The list below is adapted from the handbook Together for Water and Sanitation: Tools to Apply a Gender Approach prepared by Evelyne Bolt for IRC, the International Water and Sanitation Centre and provides a checklist for collecting gender-specific data.

Useful information to collect might be for example:

- Data on the roles, responsibilities and practices of men, women and children in the water and sanitation activities in the area.
- Responses from both women and men separately.
- Data on the community’s perceived roles of women and men in water and sanitation-related activities and practices.
- Data on the needs of women and men in relation to improvement of the water and sanitation situation.
- Data on the extent to which women and men are willing to and can participate in the project.
- Both qualitative and quantitative information on the status of women and gender issues for project planning.
- A view on data gaps or differences in the gender issues which will require further study and analysis.

1.2.5 NATURAL PREREQUISITES

Considering natural prerequisites involves taking into account the various environmental factors that influence the quality, quantity and availability of water sources.

To be sustainable, development actions must be carried out in harmony with nature and therefore take local natural prerequisites into consideration (Forss, 2000). It is essential to know which sources of water exist in the area and how much is available, this is determined by various environmental factors. It might be enough to use only one source of water for drinking water, for example groundwater from a well, or it might be necessary to complement with other sources, for example rain water. Vegetation, geology and hydrology influence the flows of streams, rivers and groundwater. Investigating these conditions can give an idea of how contaminations travel and spread to and with the water.

It is important to consider the condition of the environment and to try to predict the impact the project will have on the environment. Experience has shown that, for example, deforestation and over-extraction of groundwater (e.g. for irrigation purposes) have a negative impact on the amount of drinking water available. Water pollution can also be caused by land use or over-extraction of groundwater. Having a closer look at the use of the environment may give information needed to plan and implement a project in such a way that negative impact on the
environment can be prevented or minimized. It may also help to get a good view at the availability of water resources for domestic purposes (Bolt, 2003).

1.2.6 INSTITUTIONS

Institutions might be hospitals, schools, universities and NGOs (Non Governmental Organisations) that operate in the area. The institutions might be necessary for education, motivation and organisation of the community. They could also help to operate, maintain and evaluate the project (Naryan, 1996).

The institutions can contribute with information of the health situation, data over climate factors, maps of the area etc. It is also useful to know if there are any ongoing projects in the area. If the study can be linked to other projects or initiatives to improve the situation in the area it could help assure the sustainability of a water treatment system.

1.3 HEALTH AND WATER

Many studies have shown that access to clean drinking water contributes to better health and increasing equality within the society. Combined with increasing knowledge and improved hygiene habits, an increasing access to clean water can help reduce health problems such as diarrhoea, illnesses that usually affects children the hardest (SIDA, 2002).

Every year, diarrhoea kills between 2 and 3 million people in developing countries - most of them children. Millions more suffer from intestinal parasitic infections and schistosomiasis. In addition, many women spend hours each day for water collection, and they and their families suffer the indignity of inadequate sanitation. Research has also emphasized the critical role of hygiene behaviour, such as hand washing before handling food, in the success or failure of environmental interventions (WELL, 2003).

It is essential to know which health problems exist among the inhabitants, to find out the need for an improved water situation and to learn which contamination routes are the most important to investigate. Health is usually the base of motivation for this kind of project (Naryan, 1996). Thus, if it is stated that the various health problems in the area are related to contaminated water, and if this could be explained to the people in a way that makes them realize the need for improvements, it could help motivate the inhabitants to participate in the project. Control of water related diseases always requires the interruption of transmission cycles. This can be achieved if the community members are educated on avoidance practices, or hygiene, after identifying transmission routes and physical ailments of water related diseases. This step may be the most important part of a project (Cairncross and Feachem, 1993).

Lack of knowledge of bacteriological contamination and transmission of diseases is emphasized by most health education programs in developing countries. Often, the programs are not based on how people themselves perceive that water sources become contaminated, but introduce “foreign” concepts like bacteria and E. coli. Local people may have more useful concepts of water pollution and traditional methods of water use control, which are seldom used in such programs (van Wijk, 1985).
1.3.1 TRANSMISSION ROUTES

Understanding how infections are transmitted will provide insight to how to protect people from water related diseases. There are four main transmission routes of water related diseases: water-borne, water-washed, water-based and water-related insect vector. Table 1 below provides information on four common water related diseases and the routes of transmission (Cairncross and Feachem, 1993).

Table 1. Water related diseases: Transmission and control.

<table>
<thead>
<tr>
<th>Transmission Route</th>
<th>Diseases</th>
<th>Causes</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water borne (or washed)</td>
<td>-Cholera</td>
<td>-Drinking faecal material</td>
<td>-Improve water quality</td>
</tr>
<tr>
<td></td>
<td>-Typhoid</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Dysenteries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water washed</td>
<td>-Skin and eye infections</td>
<td>-Lack of water for proper hygiene</td>
<td>-Increase water, accessibility and reliability</td>
</tr>
<tr>
<td></td>
<td>-Louse borne typhus</td>
<td></td>
<td>-Improve hygiene practices</td>
</tr>
<tr>
<td>Water based</td>
<td>-Schistosomiasis (Penetrating skin)</td>
<td>-Pathogen requires aquatic environment for part of life cycle</td>
<td>-Control snail populations</td>
</tr>
<tr>
<td></td>
<td>-Guinea worm (ingested)</td>
<td>-Eating insufficiently boiled aquatic species</td>
<td>-Reduce surface water contamination</td>
</tr>
<tr>
<td>Water related insect vector</td>
<td>-Sleeping sickness</td>
<td>-Insect that bite or breed near water</td>
<td>-Destroy breeding sites</td>
</tr>
<tr>
<td></td>
<td>-Filaria</td>
<td></td>
<td>-Use mosquito netting</td>
</tr>
<tr>
<td></td>
<td>-Malaria</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In appendix I is given a description of the most common water related diseases.

1.3.2 WATER STANDARDS

Guidelines for the quality of drinking water are set by the World Health Organization, WHO. Safe drinking water, as defined by the WHO guidelines is such that it does not represent any significant risk to health over a lifetime of consumption. It is suitable for all usual domestic purposes, including personal hygiene (WHO, 2002).

The WHO standards have been criticized, because if they were to be followed most water sources in developing countries could not be used. In developing national drinking water standards, it is necessary to take into account a variety of geographical, socio-economic, dietary and other conditions affecting potential exposure. This may lead to national standards that differ from the guideline values. There are generally insufficient resources available to deal with all the contaminants that may occur in drinking water in a country, and it is necessary to establish priorities. Standards should be set for those contaminants that occur frequently and at significant concentration in drinking water and that have the greatest health impact. Microbiological contaminants belong to this category. The establishment of standards should also take into account the possibilities for implementation in view of the socio-economic constraints facing a country (WHO, 2002). The WHO and the Mexican standards are given in table 2 below.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mexican standard¹</th>
<th>WHO standard²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total coliform bacteria</td>
<td>2 MPN/100 ml if the most probable number technique is used or 2 CFU/100 ml when filtration through a membrane is done.</td>
<td>No coliform bacteria in 100-ml sample in 95% of one year’s sample, no sample with ≥3 coliform bacteria in two consecutive samples.</td>
</tr>
<tr>
<td>Faecal coliform bacteria</td>
<td>Must not be detectable.</td>
<td>Must not be detectable in any 100-ml sample.</td>
</tr>
<tr>
<td>Chlorine residual</td>
<td>0.2-1.5 mg/l</td>
<td>For effective disinfection, there should be a residual concentration of free chlorine of ≥0.5 mg/l after at least 30 min contact at pH &lt; 8.0. No more than 5 mg/l of chlorine residual.</td>
</tr>
</tbody>
</table>

¹) The official Mexican standard for drinking water; NOM-127-SSA1-1994, last revision 22 of November 2000
²) WHO, 2002

### 1.3.3 INDICATOR VALUES

Total coliforms, faecal coliforms and *E. coli* are widely used as indicators of the general sanitary quality of treated drinking water. The presence of these in drinking water indicates potential faecal pollution or shortcomings in treatment and disinfection procedures. Total coliform bacteria include a wide range of bacteria, many of which are of faecal origin. Members of this group which are able to ferment lactose are known as faecal (thermotolerant) coliforms, and give a much closer indication of faecal pollution. Included in the faecal coliform group are *Escherichia coli* or *E. coli*. *E. coli* are commonly used as specific indicator of faecal pollution. Although *E. coli* is the most precise indicator, the count of thermotolerant coliform bacteria is an acceptable alternative (WHO, 2002).

The introduction of coliform bacteria as indicators of faecal pollution has revolutionized water quality assessment. These indicators are likely to play a fundamental role in water quality control for a long time to come. However, despite many benefits, coliforms do have shortcomings. Among these are that under circumstances they fail to indicate the presence of resistant pathogens such as viruses and protozoan parasites in treated drinking water supplies (Havelaar et al., 2003).

### 1.3.4 WATER, WASTE AND SANITATION

Water, waste and sanitation are three areas which are closely related to health. These three areas are interrelated and it is ineffective to handle them separately when developing methods for obtaining an improved health situation.

Water sources can be broadly divided into groundwater and surface water sources. Small sources include springs, ponds, shallow aquifers, and small streams. Large sources include regional aquifers, rivers, large lakes and large artesian springs. Large surface and groundwater sources are fed by many smaller sources. A problem with the water sources occurs when a source is no longer adequate or reliable. An adequate source is one that ensures supply of drinking water in sufficient quantity and quality. Once a water source has become inadequate or unreliable, it may still remain the best available source. For instance, polluted water may...
continue to be used if there is insufficient awareness concerning health risks among the users. This is especially the case when the nature of pollution does not affect the taste or colour, or when there is no alternative water source (Lee and Bastemeijer, 2003).

Users of both small and large water supply systems are affected by poor water quality and insufficient source yield. For small community water supply systems the nature of the problems may be such that solutions could be found locally. Environmental factors like the use of on-site sanitation systems, the disposal of organic waste, deforestation and overgrazing are often specifically affecting small sources. Possible solutions to such specific source problems could include physical protection of wells, improved sanitation, improving agricultural practices, and regulating water use. Also here, community motivation and awareness is important, since many water pollution problems are caused directly and indirectly by the water users (Lee and Bastemeijer, 2003).

A common contamination route is when humans or animals come in contact with human or household waste which contain bacteria and spread the bacteria to food and water. Thus it is important to identify when and where this contact might take place (Cairncross and Feachem, 1993).

Diseases could also be spread by insects breeding in stagnant water or by aquatic animals. People could be exposed to infections from flies and other insects that have been in contact with faecal or household waste. Thus a thorough investigation of the places where people collect water and dispose waste is necessary (Cairncross and Feachem, 1993).

Many diarrhoeal infections are water-borne and they spread through intake of contaminated water or by other faecal-oral routes (see chapter 1.3.1 above). Contaminated water could spread for example from latrines which lack proper drainage or from waste deposit sites. The contaminated water could spread by surface water run-off or by leaking into the wells through the ground, since bacteria are able to travel up to two metres in unsaturated soil (Cairncross and Feachem, 1993).
2. OBJECTIVES

2.1 GENERAL

The foremost objective with this project is to evaluate the water quality of the drinking water in Pahuatlán and, if necessary, find solutions to provide a safe supply of drinking water.

2.2 SPECIFIC

- Perform a social-cultural study of the community.
- Evaluate the local situation regarding water, waste and sanitation.
- Implement a system for drinking water treatment in the community.
- Participation
  - Involve the inhabitants in all parts of the project; planning, community survey, decision-making, implementation and evaluation.
- Gender
  - Use a gender sensitive approach.
- Sustainability
  - Develop the suggestions for improvements and the water treatment system so that they comply with the requirements for sustainable development.
  - The system should contain technical equipment that is simple and easy to use, in order to assure the continuous use and function of the solution.
  - For the same reason design the system and interventions in a way that suit the ways and needs of the villagers.
- Environment
  - The treatment system should leave the least possible impact on the local environment.
- Economy
  - The system should be cheap and financed at least partly by the inhabitants themselves.

2.3 SCOPE

After the water sources in the project area were investigated and possible problems and transmission routes of bacteria had been identified, the delimitations were decided. It was decided to not make any further investigation of:

- The river water
- The waterholes
- The sanitary situation
- The waste
It was also decided not to devote any time for education or other preventative actions regarding contamination of water, but to concentrate the project on treating drinking water in one of the wells in the community by implementing a treatment system.

2.4 PREREQUISITES

This project was not commissioned but planned and performed according to the preferences of the authors. The initiative was accepted and welcomed by institutions, local politicians and the people concerned by the project. It is the first project of this kind performed in the specific area.

Universidad Regiomontana in Monterrey, Mexico provided a supervisor as well as laboratory equipment necessary to accomplish the analyses of the water.

The equipment used in the treatment system; the pump, the activated carbon filter and the chlorine, was donated by Grupo Iqua, a company specialising in drinking water treatment equipment in Monterrey, Mexico.
3. MATERIAL AND METHODS

The approach was to give a multidisciplinary description of the situation, which implies that many factors are taken into consideration, including for example natural prerequisites and socio-cultural aspects. Priorities, habits, possibility to participate, motivation and knowledge are examples of what were included in the socio-cultural investigation. The quality of the drinking water was investigated by sampling and analysis.

3.1 STRATEGY

The project was performed according to the following strategy:

1. Initially a literary review and research was carried out at Universidad Regiomontana in Monterrey, Mexico in co-operation with the Division of Environmental Chemistry. Reports from earlier studies within the area and studies of other literature within the subject of development, water and sanitation were reviewed.

2. The research was followed by an on-site field study in the rural area of the municipality Huejutla. Three months were spent in the town Huejutla de Reyes, about 10 kilometres from the studied community Pahuatlán. Many visits to Pahuatlán were made to perform a social-cultural study in order to find out the various aspects of the society that affect if a water treatment project can be performed and how. On-site fact gathering was accomplished through sampling of the water, observations and interviews together with local politicians, health and environmental workers and the indigenous people themselves. An inventory and analysis of the existing institutions associated with health and water was also made.

3. After the initial field study, sampling and analysis of the water from all the water sources in the community were performed.

4. Suggestions for a drinking water treatment solution were developed based on the facts gathered in the field study, the results of the water analysis and through discussion with the supervisor in Monterrey and the company Iqua in Monterrey who specializes in drinking water treatment solutions.

5. The drinking water treatment system was implemented in Pahuatlán. Thereafter the system was left in the care of the inhabitants for six weeks before a revisit was made for evaluation and sampling of the water.

6. The treatment system was evaluated. The drinking water from the treatment system was analysed and suggestions for improving the treatment system were developed.

7. The treatment system in Pahuatlán was altered according to the results of point 6. Samples of the water from the system were collected.

8. The water samples were analysed. Due to the questionable results it was decided to perform a pilot study at the laboratory resembling the conditions in Pahuatlán.
Figure 5 below is adopted from the *Cycle of learning in real life* by Lammerink and Bolt 2002, and illustrates the idea behind the method used in the project.

3.2 FIELD STUDIES

In order to find a suitable location for the project some preceding field studies were performed. The personnel working at Servicios de Salud de Hidalgo (Health Services of Hidalgo), SSH, and Comision Nacional del Agua (National Water Commission) contributed with a lot of information, such as maps and statistics but also with professional knowledge and personal experience. To accompany them on their field work to several communities in the municipality gave a good understanding of the area, of the indigenous population and of which problems that existed in the region.

The preceding field studies were followed by a village survey in Pahuatlán. Here the main part of the data was collected by participating observation. We got to know the area and the people by simply being there and getting acquainted with the inhabitants. Some informal interviews were performed, however we found it easy to communicate with and obtain information from the personnel at the institutions and the inhabitants of Pahuatlán. For this reason we found it unnecessary to perform any more organized interviews and consequently the information was achieved sporadically during conversations and observations.
3.3 GENDER AND PARTICIPATION CONSIDERATIONS

In the study, we wanted the inhabitants to take part in all stages of the project; the village survey, the decision-making, the implementation and the evaluation. Our belief was that if the people are engaged in the project they will feel more responsible for the system, which will help secure the function of the solution after the project has been finished. For the same reason, we also wanted the inhabitants to contribute financially, again so as not to feel as passive receivers.

To obtain sustainable results, men’s and women’s opinions, needs, priorities and constraints were taken into consideration. Since women collect the water, they will be affected by a technical solution, and they are most probably the ones who will use it. For these reasons, special attention was given to the women in the study. It is important to stress though, that the objective with this project was not to change societal norms or to try to affect the relations between the sexes, but to respect the local situation and take these aspects into consideration in suggesting improvements in the water and sanitation sector. The approach was to start with the local experience and knowledge in developing appropriate interventions.

3.4 COMMUNITY WALK

A community walk was arranged with three local women and a woman that works in the health centre in Pahuatlán to take a look at the various locations associated with water; where the people collect drinking water, do their laundry, take baths etc.

Since women walk around the area daily because they are in charge of water fetching, firewood and fodder collection, they were able to provide detailed and up-to-date information. The purpose with the community walk was to observe the different places associated with water, waste and sanitation and to collect information on the inhabitants’ behaviour concerning these matters. The idea with the community walk was developed from Evelyn Bolt’s Together for Water and Sanitation 2003, and was to:

- Gather a small group of community members, in particular women, to join the walk.
- Walk around the area. Observe, ask and make notes.
- Find data about the local situation regarding:
  - How, where and when people collect their drinking water.
  - Where people do their laundry and personal hygiene.
  - Factors influencing water quality, for example pollution by fertilizers or pesticides, wastewater, detergents, waste deposit sites etc.
  - Water quality in streams and factors influencing it.
  - Differences between dry and wet season.
  - The conditions around the collection-points such as presence of animals, waste etc.
- Discuss the findings with the group and with the village leaders, and try to draw conclusions important for further planning of the project.
3.5 INTERVIEWS

The informal interviews were performed before, during and after the community walk and after collecting the water samples. Conversation with the inhabitants was retained throughout the project. The observations during the community walk were an important complement to the interviews since sometimes practices differed from those told. In addition, the observations gave good ideas about what questions were urgent to put forward in the interviews and discussions. No fixed plan for performing the interviews was made, but was developed at place. The interviews were flexible in order to allow improvisation.

The main questions to which we attempted to find answers were as follows (Naryan, 1996):

- How is water supplied?
- What routines are surrounding water collection and sanitation?
- What are the present problems and possibilities regarding these practices?
- In what situation are the men/women taking part, being responsible etc?
- Where can there be a risk of contamination and health affecting activities?
- Is water wasted, reused etc?
- What is water used for?

The information was achieved through the staff at SSH, Comision Nacional del Agua, the staff at the health centre in Pahuatlán, local politicians, the delegates of Pahuatlán and their secretaries and the inhabitants of Pahuatlán.

Both men and women were included in the interviews. We did not find that opinions differed much among the people. However, the limited time did not allow any special attention to the individual.

3.6 THE DRINKING WATER TREATMENT SYSTEM

The idea was to implement a small-scale system for cleaning drinking water, a system that could work as an example for the other communities and similar projects. The purposes of the system were to investigate if it improved the quality of the water satisfactorily and to see if it was accepted and used by the inhabitants.

The implementation of the treatment system was based on local participation. The system was developed together with the inhabitants, the company in Monterrey and the supervisor and aimed to be:

- Economical
- Easy to use
- Secure to operate
- Sustainable
- Environmental sound

The water treatment system should produce water that fulfils the following requirements:

- Health: no disease producing bacteria or hazardous chemicals.
- Flavour: no unpleasant taste or smell.
- Clarity: no gathered organic substances or turbidity.
• Colour: aesthetic to drink.
• Non corrosive: should not act corrosive on pipes or installations.
• Low organic content: to reduce unwanted biologic growth in pipes and reservoir.
• Safe: the system should be safe and easy to use and maintain.

The economy was determining in designing the system, since the belief was that the prospect of a system to be applied to other wells in the community, or in other communities in the area, is greater if it is cheap.

It was decided to use chlorine as a disinfectant. Disinfection with chlorine is very popular in water and wastewater treatment because of its low cost, ability to form a residual and its effectiveness at small doses. Chlorine is highly soluble in water, making it easy to add to water supplies in controlled amounts.

Analysis of the cost effectiveness of water interventions made by UNESCO 2003 suggests that disinfection of water with chlorine tablets, combined with limited hygiene education, gives the biggest health benefit at the lowest incremental cost.

Chlorine and its derivative water treatment products, sodium hypochlorite and chlorine dioxide, are disinfection agents which, when added to water, destroy bacteria and other microorganisms by damaging the cell structure of bacterial pollutants and thereby destroying them (Parr et al., 2003).

Adding chlorine to disinfect the water has been tried in several communities in the project area, though with some difficulties due to the beliefs and preferences of the habitants. The greatest concern of the inhabitants seemed to be the smell and the taste the chlorine adds to the water. This problem could be eliminated with the use of an activated carbon filter. It was our belief that if the smell and the taste of the water could be eliminated, the use of chlorine would be easier accepted.

The treatment process was designed as follows:

1. Water is extracted from the well by means of a small, submergible electrical pump.

2. The water is pumped up to a plastic tank placed beside the well, with a volume of 2.5 m$^3$. Here chlorine is added to disinfect the water.

3. The water then passes through an activated carbon filter to remove the taste and smell of chlorine from the water.

4. The water is distributed by taps placed directly after the storage tank about one metre above the ground to allow space for vessels.

5. The well was covered to avoid people from collecting water directly from the well.

3.6.1 EQUIPMENT

The well
The well is a hand-dug shallow well with a depth of about 4 metres and a diameter of about 1.5 metres. The water depth is around 80 centimetres. The flow of water into the well is rapid
so the water volume in the well is kept almost constant. According to the inhabitants this well contains water all year round, which is not the case for some of the other wells in the community.

The pump
Water extraction from the well was performed by a small submersible pump of the trademark Anauger M-650. The pump can run on electrical power of 115 or 220 V. The pump has a capacity of 300 Watts, and a maximum water column elevation ability of 65 metres, corresponding to a flow of 400 litres/hour. The Anauger pumps operate by electromagnetic force generated by an alternating current. The fact that it does not have a rotating electrical motor provides the product durability and high capacity with low energy consumption. It is made with materials of high quality and durability including the parts that are in direct contact with the water, which are made of aluminium, natural rubber and stainless steel. Technical data about the pump is given in appendix IV (Anauger, 2003).

Storage
A tank of the type Rotoplas was used for storage of the water, see figure 6. The tank has plastic walls of a type that allows the application of bio-oxidant (disinfection agent, e.g. chlorine) without altering the composition of the plastic material. The capacity of the tank was decided to 2.5 m$^3$, according to the water consumption. The walls of the tank have an antibacterial covering, this is supposed to avoid the bacteria contained in the water to reproduce, according to the manufacturers. We are uncertain to which extent this is contributing to improve the quality of the water. However, the antibacterial covering is not toxic and it is approved by the USA Food and Drug Administration. The Rotoplas tank will have to be cleaned at least once a year. The tank should always remain covered (Anauger, 2003; Rotoplas, 2003).

![Figure 6. The water tank with the level indicator.](image)

Level indicator
The filling of the tank is performed automatically by means of a level indicator floater which starts the pump when the water surface drops. The level indicator was installed during the alteration of the system.

The base for the water tank
The base was constructed by some of the men in the community before the installation of the water treatment system. After the alteration of the system the tank was moved to the roof above the well in order to improve the water pressure.
Disinfection
The disinfection of the water took place in the storage tank by the use of chlorine tablets. The chlorine was distributed by the means of a plastic container floating on the water surface. The container is filled with tablets which will slowly dissolve in the water, the outlet of chlorine can be altered by altering the valve at the bottom of the container.

The amount of chlorine needed to disinfect water is called chlorine demand of the water. The chlorine demand varies with the amount of impurities in the water. The aim of chlorination is to satisfy the chlorine demand of the water source. Once the demand has been satisfied, any excess chlorine above the level needed to satisfy the demand remains as a residual of chlorine in the supply. If the supply is to be adequately disinfected, there should be a chlorine residual in the supply, so that there is a capacity to cope with any subsequent bacterial contamination. The chlorine residual should generally be in the range of 0.3 to 0.5 mg of chlorine per litre of treated water, any more than this and the water may taste bad and people may refuse to use it, any less, and there is no guarantee that the supply is adequately protected (Parr et al., 2003).

Chlorine needs at least half an hour of contact time with water to disinfect it. The best is to apply it before storage and use. The chlorine dose required to disinfect a supply will increase if the water is very turbid. In such circumstances, it is best to treat the water to reduce turbidity before chlorination (Parr et al., 2003).

The chlorine used in this water treatment system is in the form of tablets and are of the same kind used for disinfecting swimming pools. The name of the product is TRICLORO BIOLIM and the active ingredient is trichloro-S-triazinetriona. For this product, the recommended pH of the water should be between 7.2 and 7.6 (Bruñen International, 2003).

In recent years, there have been concerns about chlorine. Although chlorine disinfects drinking water, it also reacts with traces of other material or particles (e.g. organic matter such as decaying trees and leaves as well as urban farm run-off) in the water and forms trace amounts of substances known as disinfection by-products. The most common of these are known as trihalomethanes or THMs. THMs (like chloroform) have been linked to increasing cancer risks and birth defects (Swichtenberg, 2003).

Direct contact with chlorine is harmful to health, therefore skin contact should be avoided and the fumes should not be inhaled. Chlorine should be stored in cool, dark and sealed containers, and out of reach of children. The tolerably daily intake of chlorine is according to the WHO guidelines 150 µg/ kg of body weight. The guideline value is conservative, as no specific adverse treatment-related effects have been observed in humans or animals while exposed to chlorine in drinking water (WHO, 2000).

Filtration
When treated, the water of the tank passes through an activated carbon filter with granulate 5 microns. The filter is called C1 from the C Series of Plymouth Products. This filter is constructed of carbon impregnated cellulose media and these dual-purpose cartridges filter out fine sediment particles. The filter has the capacity to retain molecules of colour, scent and flavour of the water, besides to remove the chlorine through various chemical reactions. A polyester reinforcement backing and external netting provide additional strength and dirt-removing capacity.
The disadvantages with these kind of filters are that they have a limited duration and may provide bacterial growth in the filter material (Thompson, 2003). The filter needs to be changed at least every three months to avoid a microbial proliferation (Anauger, 2003). Further information of the filter is given in appendix IV.

**Pipes and Distribution**
The water was distributed from the well to the tank by means of a flexible pipe which was dimensioned according to the outlet of the pump. The material and the dimensions of the pipes used to distribute the water from the tank were altered once. At first the pipes consisted of copper and were then changed to PVC pipes of a bigger dimension.
The water was distributed by the means of six taps installed close to the well. This was changed later, see chapter 3.8.6 below. The taps were installed about one metre above the ground.

Figure 8 shows the equipment used in the water treatment system, from left; the chlorine tablets, the plastic container used for dosage of chlorine, the filter container, the activated carbon filter, the level indicator and the pump. For complete list of material used, as well as costs, see appendix IV.

![Figure 7. Meeting by the well.](image)

![Figure 8. Water treatment equipment.](image)

### 3.6.2 DECISION-MAKING

Before the implementation of the treatment system the idea was discussed with the personnel at SSH to find out their opinions. The personnel have knowledge of the people and the area and are known and trusted by the inhabitants. The idea was also that involving more people in the project might help insure the function of the solution after the project was performed. Their opinions on the system were that they believed it would work and become accepted by the people in Pahuatlán.

The suggestion was then to be introduced to the people of Pahuatlán. A meeting was arranged with the delegates and their secretaries in which the suggestion was presented, see figure 7 above.

To assure the sustainability of the system, it was of great concern that the inhabitants would feel responsibility for the system and use and maintain the equipment. Therefore, the idea was that the system should be at least partly financed by the inhabitants themselves. By making the inhabitants pay for the water tank, which would be the most outstanding part of the equipment (the thing that the people would notice most), the whole system might appear more as their own property and not as a gift, and consequently might make the people more willing
to preserve the system. The suggestion that the inhabitants would contribute with a water tank as well as the construction of a base for the water tank to stand on was accepted by the delegates.

The delegates held a meeting in the community to inform both men and women of the suggested system. Money was then collected from the people who would use the system for the construction of the base and to buy a water tank. A date was set two weeks from then for the construction of the base to be completed and the tank to be acquired.

3.6.3 INSTALLATION AND IMPLEMENTATION

After the two weeks had passed the installation of the system was started in Pahuatlán. Two plumbers from Huejutla were hired to do the work, including the electrical installation. On arrival to Pahuatlán, the men had bought a water tank and finished the construction of the base for the tank, and the women had cleaned the well. The major part of the installation was made by the plumbers. However, the delegates and the secretaries as well as some other men from the village were present and also helping to some extent, see figure 9.

![Figure 9. Putting the tank in position.](image1)

![Figure 10. The drinking water treatment system, after alteration.](image2)

During the installation some problems came up which lead to some modifications of the original idea:

- The activated carbon filter was to be placed after the water tank, but the filter proved to provide high resistance for the water, which resulted in low water flow in the taps. It was decided that the carbon filter would be placed before the tank.

- Since the main function of the filter was to eliminate the chlorine in the water, the chlorine would now have to be added directly to the water in the well instead of, as originally suggested, in the tank. Adding the chlorine to the well, however, had its advantages; the water level in the well was more stable, which made the dosage easier. In addition, the people were already used to add chlorine to the wells and they were told to continue with the chlorination as before.
• During the installation it was revealed by the delegates that the women wanted six taps to be installed.

The well was covered by a heavy wood cover, with only a narrow lid enough to replace a bottle with chlorine tablets but not big enough to put through buckets to collect water.

It was discussed with the men whether or not the filling of the tank should be automatic or manual. It was decided that the pump would be started and stopped manual by the women to have more control of the water usage and to make sure that the pump would not run if the water level in the well would drop.

A water metre was also installed after the tank to measure the water usage.

Unfortunately, since the preference was that both men and women would participate in the implementation, on the day of the implementation most of the women were not present. They had gone to Huejutla to collect the allowance which the municipality subsides to help the families with their children. Consequently the whole implementation was performed only with the men of the village present. The men were asked to explain to the women how to use the pump to fill the tank and other things to consider, for example that they were now not supposed to use their buckets in the well to collect water. It was also suggested that they continue to boil and chlorinate the water before drinking, since it was not yet certain that the water would be safe to drink. Instructions for the use of the pump and things to consider were given to one of the secretaries. A revisit was made a couple of days after the installation to check the system. The instructions were then explained to some women present at the well and they were also given written instructions. The secretary was given written instructions of the use of the pump and was asked to note the daily usage of water during one month. Thereafter the system was left in the hands of the inhabitants for six weeks before a revisit was made for evaluation.

3.6.4 EVALUATION

The evaluation and collection of water samples was performed in Pahuatlán six weeks after the initial implementation of the water treatment system. Fortunately, on arrival all the women in the village were gathered on a meeting held by one of the secretaries. Personnel from the health centre in Pahuatlán and SSH were also present. Thus the opportunity was given to speak to them all to hear their different comments on the system.

It was told that the system was still in use and, according to the delegates, had been so during the six weeks. No major trouble in the use of the equipment had occurred, however some problems were revealed;

• The chlorine content of the water in the well was measured to be low, less than 0.3 mg per litre.

• The activated carbon filter was dirty and green, which indicates organic growth.

• It was a main concern of the women that the water pressure in the taps was too low, so that the filling of the water buckets was now taking a bit longer than before the implementation of the solution.
It could be stated that the water level in the well was kept almost constant. Consequently, the risk that the pump will operate dry is very low. This was discussed with the delegates and it was decided that we would install the level indicator for the pump to fill the tank automatically.

It was decided to take samples of the water and return to Monterrey to analyze the quality of the water and to discuss what could be made about the dilemma.

The water was analyzed and showed to contain even more bacteria than before the implementation, see chapter 4.7 for the results. The problems were discussed with the company who had provided the equipment and with the supervisor at Universidad Regiomontana. In table 3 below are the results of the evaluation.
Table 3. Evaluation of the water treatment system.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible cause</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The water has high content of bacteria.</td>
<td>The chlorine content is not sufficient, either the people do not chlorinate the water as supposed or the water in the well might have a high organic content which results in high chlorine consumption.</td>
<td>Use of a floater in the well in which will be placed ten to fifteen tablets of chlorine which will slowly dissolve in the water. In the floater will be added one or two tablets each day and the staff at the health centre in Pahuatlán will be asked to check the chlorine content at least once a week.</td>
</tr>
<tr>
<td></td>
<td>The top of the tank is not closed, resulting in organic material in the water.</td>
<td>It will be attempted to ensure that the tank is always properly sealed.</td>
</tr>
<tr>
<td>2. The filter is very dirty.</td>
<td>The chlorine content is not sufficient.</td>
<td>Same as for problem 1.</td>
</tr>
<tr>
<td></td>
<td>The filter container is transparent and is in the sun, which favours organic growth in the filter.</td>
<td>The filter container will be painted black or the filter will be placed in a black plastic container.</td>
</tr>
<tr>
<td>3. Low water pressure in the taps.</td>
<td>Difference in height between the tank and the taps is insufficient.</td>
<td>The tank will be placed higher so that the filter and the taps will be in a lower position than the tank.</td>
</tr>
<tr>
<td></td>
<td>The dimension of the tubes is wrong.</td>
<td>The dimension of the tubes will be altered.</td>
</tr>
<tr>
<td></td>
<td>The water meter and the sediment filter present resistance for the water flow.</td>
<td>The sediment filter and the water meter will be removed.</td>
</tr>
<tr>
<td></td>
<td>The tank is not full when the people start taking out water.</td>
<td>A floater will be installed in the tank which will automatically fill the tank to make sure that it is always full.</td>
</tr>
</tbody>
</table>

**Water consumption**

The water consumption had with the help of one of the secretaries and the water metre been measured during thirty days and showed that the average water withdrawal was 5 cubic metres per day. According to personnel at the health centre a household use about 60 litres of water per day for drinking, cooking and cleaning. An average household consists of between
six and eight members. This gives an average daily water consumption of between 7.5 and 10 litres per person and suggests that the well was used by a little more than 80 households.

3.6.5 ALTERATION

Alternatives to the first system were discussed – see chapter 5 below – the system chosen was selected for economical reasons. The reason was not that there was not enough money to implement the other solutions, but since the ambition was that this pilot solution would work as an example which, if it functioned satisfactorily, could be applied to other wells in the village and also in other communities, it had to be a solution which could be afford by the inhabitants. The more expensive the solution is, the more unlikely that the system would be applied on other wells.

A second revisit to Pahuatlán was made together with one of the employees from Grupo Iqua, who helped with the alterations. The system was modified according to the evaluation, see table 3 above. Figure 10 above shows the final design of the system. The alterations were as follows:

- This time only three taps were installed.
- The copper pipes were replaced with PVC pipes of larger diameter.
- After the pipes had been replaced, the water flow in the taps was still very low. Therefore, the water tank was moved from the base up to the concrete roof of the well. This roof had, by the delegates, earlier been estimated to be too weak, but on further inspection by the representative from Grupo Iqua it was estimated to be stable enough. This resulted in an increase in water pressure corresponding to about two metre.
- The filter was placed after the tank and the filter container was covered with adhesive tape to keep the filter away from direct sunshine.
- A flotation devise was placed in the tank to dose chlorine. On recommendation from Grupo Iqua, as many as 30 tablets were placed in the container to assure adequate disinfection.
- The level indicator was installed in the tank, which automatically starts the pump when the water level drops. This will affect the water pressure in the taps, since if the tank is full, the pressure is higher. It will also facilitate the chlorine dosage since the water volume is held more or less stable.

On return to Pahuatlán two days after the alterations, the women complained that the water tasted too much chlorine. The chlorine content of the water from the taps and the tank was measured and both showed a concentration of >5 mg per litre. Thus the capacity of the filter was not sufficient to reduce the high chlorine content. The filter was then replaced with a new filter and the chlorine content was reduced to 15 tablets. On return the following day, the chlorine concentration was measured to >5 mg per litre in the tank and the water from the taps showed no trace of chlorine at all.
It is important that the tank is filled continuously, something which is secured by the level indicator, that is, as long as the power supply is in function. Fortunately, according to the delegates power cuts are not very frequent. The water pressure in the taps was now improved to some extent, and the chlorination seemed to work satisfactorily. It was suggested to the delegates that they construct a roof above the water tank so that the water will not get too hot during the day. Five extra activated carbon filters were left with one of the delegates with the instructions to replace the filter every second month or more often if the water started to taste too much chlorine. The company in Monterrey will continue to provide filters to the system.

3.7 WATER QUALITY INVESTIGATION

3.7.1 SAMPLING OF THE WATER

After discussing the methods of taking samples of the water with the supervisor at Universidad Regiomontana it was decided that the initial collection of samples would be taken at eight locations including the wells, the waterholes and the river. The choice of locations was based on the observations during a community walk and investigation of the area.

During the first sampling, four different types of samples were taken; one sample for physical-chemical analyses, and three types of samples for bacteriological analysis. The bacteriological analysis included quantitative investigation of coliform bacteria using the multiple tube fermentation technique, quantitative investigation of heterotrophic bacteria using the plate count method, and qualitative investigation of Salmonella sp. and V. cholerae. The analyses are explained in appendix II and III.

The physical and chemical properties of the water are important to know in implementing a water treatment process. These factors affect the microorganism content and the water treatment solution has to be designed with the physical and chemical quality in consideration.

The water in Pahuatlán was analysed for the following factors:

- pH
- Alkalinity
- Hardness
- Total solids
- Chloride
- Sulphates
- Detergents

The physical-chemical samples were collected by first washing the sampling bottles in the water being sampled. In the river and the waterholes the bottles were then kept approximately 20 cm under the surface while filling and in the wells they were filled with water from a bucket. The samples for the bacteriological analysis were collected in the same manner as for the physical-chemical. The sampling for the investigation of Salmonella sp. and V. cholerae was performed by using the so called Moore swabs that were placed two-and-two in each location for 24 hours, attached to stones in the water by steel wire. On collection, the wire was cut and the swabs were placed in the bottles containing culture mediums.
The samples for investigating *Salmonella sp.* and *V. cholerae*, could only be collected in the river and the waterholes, since the swabs had to be hidden from the people in order to be left in place for 24 hours. The samples were placed in a refrigerator no longer than 6 hours after they were collected. They were then placed in an ice-box during 14 hours for the transport to Monterrey. The analyses of the samples begun on the same day as arrival.

When location for the water treatment system was selected, the equipment was installed and the second sampling and analysis were performed. The solution was modified once after which the third sampling and analysis were made.

### 3.7.2 PILOT STUDY

After the analysis of the samples collected after the implementation and after the modification of the water treatment system, a pilot system was installed at the laboratory, motivated by the results obtained which showed a high content of bacteria. The aim of this experiment was to see whether the results were due to failure in the water treatment system or caused by other factors. The pilot study was build up in front of the laboratory at the university area (Universidad Regiomontana). This location eliminated the influence of the transport factor.

The pilot study was dimensioned to be half the size of the water treatment system in Pahuatlán. Two containers, with the size of 1100 litres, of the same material as the tank in Pahuatlán, resembled the tank and the well. One tank was placed about 3 metres above the “well”, on a constructed platform. The pump and the carbon filter were also identical to the ones used in Pahuatlán. The pump was placed in the well and the filter was installed between the tank and the tap. The water in the well was contaminated with 8 litres of waste water from the university sewage. The idea was to over dimension the microbiological contamination to better find out if the equipment and the solution were safe to use.

First of all a sampling of the contaminated water in the well was done to see if it was sufficiently contaminated. An aerobic heterotrophic plate count was performed which showed a result close to zero. 12 more litres of waste water were added and stirring and aeration was done by pumping the water to the tank and then back to the well by gravitation. A new sample was taken and analyzed and this time the plate count method showed that the water was contaminated enough to be used in the pilot study. In addition, in order to better recreate the conditions in Pahuatlán, the cultivated bacteria from Pahuatlán were added to the well. The chlorination container was filled with chlorine and placed in the tank. After taking a sample from the well as a reference sample, the pump started to fill the tank with the contaminated water. An hour after the tank had been filled, the pH and the residual chlorine were measured in the tank. The result of the chlorine residual showed 0 mg/l, therefore a new measuring was done which showed a result of >5 mg/l in the tank and 0 mg/l at the tap. These results were satisfying and samples were taken from the tank and from the tap and analyzed.
4. RESULTS

4.1 INSTITUTIONS AND LEGAL FRAMEWORK

Since the 1940s, Mexico, like many other developing countries, experienced an important population growth. As a result, significant federal government funds were diverted to the construction of large water infrastructure projects. During the early 1980s, the water system was deeply affected by the financial crisis that stuck the country. In 1992, the National Water Law (Ley de Aguas Nacionales) was enacted, replacing the Federal Water Law of 1972. This change was driven by the need to adapt the legal framework to the changing conditions in the water sector. The new law provided a framework for water management that promote a greater involvement of the private sector in the water industry. It is combined with other laws at the federal level that deal with water management, ecological balance and health-related issues. The National Water Law regulates and encourages private investment in water infrastructure, including construction and operation of water treatment plants and works for water supply. Mexican authorities are certain that the efforts toward effective decentralization will make it possible to identify local needs and to ascertain the most appropriate response to meet them (SEMNARAP, 2003).

Comision Nacional del Agua –The National Water Commission

The National Water Commission (CNA) was the governments’ response to start the solution to the water problems in the country and was created in 1989, as an independent organization under the Ministry of Agriculture and Water Resources. The commission is the main authority at the federal level dealing with water management. The main role of the CNA is to administer the nation’s water resources and to coordinate investment programs. The main objectives are: to integrate water planning and management; to guarantee adequate institutional coordination among the three levels of government; to strengthen the role of government as a regulator and in the decentralization of responsibilities; to design and build water infrastructure; to define and implement financial mechanisms to support the development of water resources and to promote greater participation of users and society as a whole (SEMNARAP, 2003).

Servicios de Salud Hidalgo - Health Services of Hidalgo

The SSH in Huejutla is responsible for taking samples of the water in a number of indigenous communities in the area, among them Pahuatlán. Samples are collected and analyzed on a weekly basis to search for different diseases. The SSH also run a number of health centres in the communities, including the one in Pahuatlán. The SSH also keeps statistics of the different diseases among the population.

The health centre in Pahuatlán

In 1996 the inhabitants of Pahuatlán made a petition to the president of the municipality for the founding of a clinic. As a result, the establishment of a health centre was initiated and was completed in the year 2000. The health centre in Pahuatlán is governed by the SSH and is a free service for the indigenous population. However a small fee of three peso is collected by the personnel at the health centre for each visit, in order to pay for food and room for a student at the clinic and also to prevent people from consulting the doctor if not necessary.
4.2 PRECEDING FIELD STUDIES

Several indigenous communities were visited prior to starting the project in Pahuatlán. One of the communities that were visited was Zohuala, a rural, indigenous community with between 2000 and 3000 inhabitants. In Zohuala three different systems for supplying drinking water were observed. The first one consisted of a well with an external pump to pump the water up to two concrete reservoirs above the well. The water was then distributed to taps in the houses. The pump was not in use at the moment because there was only a small amount of water in the well. It was told that it was difficult to control the amount of water people use when they take the water directly from the taps in their house, sometimes resulting in a shortage of water.

At the second location the system consisted of a submerged pump which pumps water to a plastic tank above the well. Neither this pump was in use, in this case because, according to the inhabitants, they preferred the colder water extracted directly from the well. During the day, the water in the tank gets heated by the sun. On the other hand, it was also said that the people usually boil the water before they use it.

At the third location the system appeared cleaner and more organized than the previous. The well was surrounded by a fence with a padlocked gate to protect from animals and unauthorized users. The well was covered in order to prevent people from collecting water directly from the well. The well had a submerged pump which was in use, pumping water to a concrete reservoir above the well. The water was then distributed to taps at the houses. This well supported around thirty households, each household consisting of about six to eight people. This system worked well and according to SSH and one of the local women in charge of the supply it was because the system was constructed on the initiative of the people living in this part of the community.

In addition to the visit to Zohuala, a number of other communities, comparable to Zohuala and Pahuatlán, were visited. Different water treatment solutions were observed, where they existed, and the inhabitants were interviewed about the water situation. This gave an idea of which problems that existed in the area, see below. The indigenous population has demanded help from the municipality and various efforts have been made to improve the situation. The most widespread method is to disinfect the water by chlorination as well as trying to educate the people on personal hygiene, waste treatment, how to prepare the food etc.

Common problems:

- It is common with diarrhoeal deceases among the indigenous population. Cases of salmonella, cholera, hepatitis A among others are reported to the SSH. Problems such as skin and eye infections are also common.

- There is often insufficient protection of wells and waterholes.

- Sanitary facilities are often absent and where they exist they lack proper drainage.

- Understanding of disease transmission routes seems to be poor among the indigenous population.
• Drinking water treatment solutions seem to work best where they have been installed on the initiative of the locals.

• Initiatives of the municipality to make the people chlorinate the water often fail due to the smell and the taste the chlorine adds to the water.

• If the water is pumped to a tank, it becomes hot in the day and the people, not wanting the hot water, use other sources of water which might be contaminated.

4.3 SOCIAL, CULTURAL AND ECONOMICAL ASPECTS

After a number of visits to Pahuatlán and also after speaking with people working in the area; in the clinic and with water concerns in Huejutla, it was clear that the biggest problem was of social origin. The most important problems appear to lie in the people’s beliefs, priorities and habits and resistance to change them.

**Occupation and income**
The majority of the inhabitants work with non-income producing activities. Most of the women are housewives. They work at home with taking care of the children, cleaning, cooking, collecting firewood and drinking water and doing the laundry. Among the men the most common occupations are farmer and carpenter. The income is low, most of the men earning less than minimum income. The men also perform all the construction work in the community such as building houses, wells and other facilities. At the time of the implementation the men were constructing a new church in the community, a project that affected both the possibility to participate in the implementation and to contribute financially (Navarrete, 2003).

**Religion**
The majority of the people in Pahuatlán are Catholics, 80% confess to this census, and 20 % are evangelists (Navarrete, 2003).

**Education**
According to the women in the community all the children attend at least the primary school in Pahuatlán and most continue to secondary school in Huejutla. Among the older inhabitants few have reading and writing knowledge. The majority of the people speak both Nahoatl and Spanish, but they feel more confident in speaking Nahoatl.

Various efforts have been made by the municipality to educate the indigenous population on health and better practices, regarding for example personal hygiene and food preparation. The personnel at the health centre in Pahuatlán also make efforts to teach the people better practices in personal hygiene, cleaning, preparing food etc. Information on these subjects and also on common diseases in the community and how they can be avoided are given at the health centre.

**Social system and decision-making**
Pahuatlán use two delegates to deal with conflicts within the community coordinate meetings and organize the inhabitants. They also work as representatives for the community when dealing with for example politicians and the municipality. The delegates are chosen once a year by the inhabitants and the delegates in their turn chose their two secretaries.
Housing
100% of the inhabitants own their houses. The houses are usually constructed of concrete with wood or dirt floor. Almost all of the houses have a kitchen and generally one to three rooms. About 70% of the houses are estimated to have adequate ventilation. 98% of the houses have electricity. As fuel, wood is the most common, a small percentage use gas. Most of the households keep animals such as dogs, cats and poultry. Some have pigs and turkeys. Most households report that they have rats and cockroaches and other insects such as flies. Only 3% of the houses have some kind of latrine on the properties.

Communication
The ways of communication in the community are limited. Only three people have phones installed in their houses, they usually work satisfactorily but sometimes fail to work in the rainy season. The area can be reached by some radio stations and television stations although the reception is sometimes interrupted by climate factors. The community is not serviced by any newspapers.

Diet
The diet generally consist of rice, beans and corn tortillas complemented with some milk, egg, fruit and vegetables and sometimes meat- about half of the inhabitants do not eat meat and the rest one to three times a week or less. Malnutrition is common among the younger children (Navarrete, 2003).

Demography
The age division is as showed in figure 11. The data used in diagram are from year 2002. Total amount of inhabitants year 2003 are 2458 (Navarrete, 2003).

![Age distribution graph]

Curiously, as can be seen in the diagram, there is a decrease of people between 15 and 25 years old. This is probably because nowadays many young people migrate to the big cities to look for employment and a better life.

The mortality was stable between the year 2001 and 2002 on 0.2%. The birth rate increased from 0.1% year 2001 to 2.1% year 2002.
4.4 WATER, WASTE AND SANITATION

4.4.1 OBSERVATION OF THE WATER SOURCES

The water sources used in the community include a river, waterholes and wells. The river is about 30 kilometres and about two kilometres belongs to Pahuatlán. The river is used by many communities both upstream and downstream Pahuatlán for bathing, fishing and washing of clothes, see figure 12. The river also connects to numerous smaller streams in the area. In the dry season the depth in most places was between 30 and 80 centimetres. In the rainy season the water rose to about three metres. According to the local women the river water does not enter any of the wells or waterholes.

The inhabitants usually collect drinking water from the waterholes, figures 13 and 14, or from one or more of the nine wells in the community, figure 15. The wells are shallow, with an average depth of four to five metres. They are hand dug by the men in the community and constructed of stones and concrete, they are all covered with a concrete roof. The bottom of the wells consists of stones. The wells are located at a lower altitude than the houses in the community but at a higher altitude than the river, they are probably mainly fed by groundwater. They are regularly cleaned by the inhabitants by emptying the well of water several times, washing the walls and removing things like plastic bottles and other litter that have fallen into the well.
The water holes are small aquifers fed by ground water and water from small streams from the mountain. The walls are reinforced by stones and concrete. A low wall separates the place where the people collect drinking water from the rest of the aquifer where the women and children stand in the water while collecting drinking water and wash their pots and buckets. The depth is between 40 and 50 centimetres. There is nothing to prevent animals from having access to the water.

There are animals such as dogs, chickens, birds, pigs, cows, horses and turkeys present nearby the wells and the waterholes. None of the wells has anything to prevent animals from having access to the water. Turkeys are often observed near and even on the wells, eating corn that the women bring to the wells to clean.

According to the inhabitants, there is never much scarcity of drinking water, both the river and the small streams which lead water to the waterholes contains water all year round. However, on the time of observation some of the wells in the community were dry. This sometimes forces the inhabitants to collect water from waterholes and streams.

The people working in the health centre in Pahuatlán are trying to make the people chlorinate their drinking water. They also attempt to chlorinate the water directly in the wells by putting tablets of chlorine in a plastic bottle perforated with holes, the bottle is then put in the wells, attached to a string. The problem is that the women take it away, believing that it dries out the wells, that it makes them ill and also because it makes the water smell and taste bad. The personnel of the clinic are trying to convince the people to chlorinate the water but the people are very reluctant to changing their habits. In the end of the community walk we are confronted by a woman who wants to know if they have put any more chlorine in the wells. The woman says that they do not want the chlorine because she believes it dries out the wells. The woman is also complaining that the chlorine makes the coffee taste bad. The nurse from the health centre says that this is a common, this is also confirmed by other people working in the area.

In table 4 below observations from the various water sources in the community are presented, see also figure 16 for a map of Pahuatlán.
Table 4. Observation of the water sources.

<table>
<thead>
<tr>
<th>Indicated on map with #</th>
<th>Type</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>River</td>
<td>Upstream Pahuatlán. Women and children are standing in the river, about half a metre deep, doing the laundry and personal hygiene. This water is not used for drinking water. The water is streaming but the current is not strong. There are cows and horses close by that have direct access to the river. One boy is fishing. The water is clear.</td>
</tr>
<tr>
<td>2</td>
<td>River</td>
<td>The current is weaker. Close by is the place where people dispose their garbage. The garbage lies directly on the ground and there is nothing to prevent animals from going through the waste. This water is used for laundry and personal hygiene. The water is clear.</td>
</tr>
<tr>
<td>3</td>
<td>Small stream</td>
<td>The local women say that they do not take water from this location which is downstream one of the bigger waterholes. It is uncertain whether this stream connects to any of the used water sources. Pigs lie in the water and there are also children playing here while their mothers are collecting water from the close by waterhole. Cows and other animals also drink from this water. The water is clear.</td>
</tr>
<tr>
<td>4</td>
<td>Waterhole</td>
<td>This waterhole is not one of the most used. The area is secluded and there are no animals around while collecting the samples, though there is nothing to prevent their access to the water. This water is used for drinking water and it is clear.</td>
</tr>
<tr>
<td>5</td>
<td>Waterhole</td>
<td>The same as place # 4, a few metres apart.</td>
</tr>
<tr>
<td>6</td>
<td>River</td>
<td>Downstream, at the end of Pahuatlán. The water is shallow, about 20 to 30 centimetres deep. No people in sight. A mare and her foal are drinking from the water. The current is not strong. The water is pretty clear. The riverbed is muddy and rocky.</td>
</tr>
<tr>
<td>7</td>
<td>Waterhole</td>
<td>This waterhole is used by the men from the village while they are working. There are plantations of bananas close by. Cows are trying to steal our shoes while we are collecting samples. The water is clear.</td>
</tr>
<tr>
<td>8</td>
<td>Well</td>
<td>The water is clear. The bottle for adding chlorine is removed. The water is used for drinking.</td>
</tr>
<tr>
<td>9</td>
<td>Well</td>
<td>The water is clear and used for drinking. The women who are collecting water at the time are using a bucket which is attached to a string attached above the well and are filling their pots with water from this bucket.</td>
</tr>
<tr>
<td>10</td>
<td>Well</td>
<td>A girl is drinking the water directly from the bucket she is using in the well. On the walls are written &quot;Clora el agua evita enfermarte&quot; (Chlorinate the water prevents you from getting ill) and &quot;Cuida tu salud&quot; (Take care of your health). The chlorine bottle is removed. Women are using their own buckets in the well. The water is clear and is used for drinking.</td>
</tr>
<tr>
<td>11</td>
<td>Waterhole</td>
<td>The women are standing in the water while they are collecting drinking water from a waterhole separated from the rest of the water by a low, concrete wall. The women use their own buckets for collecting the water. Some children stand in the water and are drinking the water from the place where they are standing. In this waterhole the bottle containing chlorine tablets remains in place, there are also chlorine tablets at the bottom of the waterhole, placed there by the people working in the clinic so that the people won't take away all the chlorine. There is small fish in the water. There is nothing to prevent animals from access to the water. The water is clear.</td>
</tr>
<tr>
<td>12</td>
<td>Well</td>
<td>The water is clear and used for drinking water. The chlorine bottle is gone.</td>
</tr>
</tbody>
</table>
4.4.2 WATER SUPPLY

Figure 17 shows the disposition of water sources in the community. About 50% of the inhabitants take their water from one or more of the nine wells in the village (Navarrete, 2002). According to the local women the people of Pahuatlán are allowed to collect water from any well or waterhole that they wish within the community.

![Pie chart showing water sources](image)

- Pipes in ground, 2.9%
- Pipes above ground, 22.5%
- Well, 51.5%
- Waterhole, 4.1%
- River, 18.9%

*Figure 17. Used water sources in Pahuatlán.*

4.4.3 ROUTINES SURROUNDING WATER COLLECTION AND SANITATION

While we are walking around in the community, there are only women, children and animals in sight around the water sources. The women normally collect drinking water three times a day. The water is collected in bottles, buckets and pots of various sizes. Every one uses their own vessels in the wells and waterholes. The bigger containers are usually carried on the head. The women also send their daughters to collect water in smaller bottles and buckets.

Any closer investigation of the existing sanitary solutions was not performed. About 50% of the inhabitants use latrines and the rest goes directly on the ground, in the bushes or in the river. There is no proper drainage system. Children were observed going to the toilet directly on the ground outside their house.

Women are, as mentioned, responsible for all activities regarding water in the community, which is drinking water collection, cleaning, laundry and food preparation. The men collect water for irrigation purposes from their own collection points, which are some smaller waterholes close to the plantations, here they also collect their own drinking water during the day.

4.4.4 RISKS OF CONTAMINATION

The ways of contamination could be many. The fact that the women use their own buckets to collect water might be a way of faecal contamination of the drinking water. Bacteria can be spread from the household to the water source or the other way around. It could be spread with the buckets, on hands, with children and animals and from waste deposit sites and latrines. Since all the locations for collecting drinking water are located at a lower altitude than the households and since there is no proper drainage solution, contaminated water can
spread through surface water and by leaking through the ground. Bacteria could also easily spread to the water from animal dropping.

The present problems in the community are as follows:

- Most people do not have a latrine but use the river or the forest, and the ones who do have a latrine lack proper drainage.

- Children and animals have free access to all water sources.

- The women bring their own buckets to use in the wells and in the waterholes.

- There is no fence to prevent animals from having access to the wells or waterholes.

- Animals also have free access to the waste deposit sites and since it is uncommon with latrines they can easily come in contact with faeces.

- The inhabitants use the river for laundry, washing and personal hygiene, resulting in detergents in the water. Animals have free access to the water. Waste deposits sites are located close to the river. The river is also used as toilet.

- The inhabitants do not trust in what the people in the clinic are saying, and they are reluctant to changing their habits.

- According to staff at the health centre in Pahuatlán about half of the people boil and/or put chlorine in the water prior to drinking but the other half do not.

- Disease transmission mechanisms are poorly understood by the inhabitants. They lack knowledge about bacteriological contamination, which makes it difficult to create interest for the protection of water sources.

**4.5 GENDER AND PARTICIPATION**

Special attention was given to the women in the community, since they are the ones who are responsible for most activities concerning water in the daily life of Pahuatlán. They are also the ones who will use the water treatment system and will be most affected by it.

Although in this case collecting water is definitely a women task in Pahuatlán, the men showed great interest in the project and their presence and help with the implementation did not have to be asked for.

The women participated to a greater extent in the interviews and the men to a greater extent in the implementation. This was something that happened spontaneously. Since the women collect the water, it was natural that the community walk was made with them, and since the men handle all construction work in the community it was natural that they participated more in the installation.

The main contribution of the women was, as mentioned, given by the interviews. Their beliefs, concerns and priorities were prioritized when the suggestion for a water treatment system was prepared. The women were asked their opinions also after the implementation and
the system was altered according to their priorities. The attempt was made to talk directly to
the women, but the communication also took place through the delegates. That is, the
delegates sometimes acted as intermediaries of the women’s opinions and our questions,
requests and instructions. Occasionally we were confronted by the women but most of the
time we were the ones who initiated the conversations.

The delegates are responsible for all decisions taken in the community, for collecting money
from the inhabitants for investments and for asking financial support from the municipality.
Therefore, the suggestion for the pilot solution was first discussed with them. As a result, they
were the ones who were participating most in the project.

4.6 WATER QUALITY INVESTIGATION

4.6.1 PHYSICAL-CHEMICAL ANALYSES

The results from the analyses of water samples collected before and after the implementation
of the water treatment system and from the pilot study are presented in the tables 5-14 below.

In table 5 the sites in which the different samples were collected before the implementation of
the water treatment system (the initial sampling) are presented.

<table>
<thead>
<tr>
<th>Site number</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Well</td>
</tr>
<tr>
<td>2</td>
<td>Well</td>
</tr>
<tr>
<td>3</td>
<td>Well</td>
</tr>
<tr>
<td>4</td>
<td>Waterhole</td>
</tr>
<tr>
<td>5</td>
<td>Well</td>
</tr>
<tr>
<td>6</td>
<td>River</td>
</tr>
<tr>
<td>7</td>
<td>Waterhole</td>
</tr>
<tr>
<td>8</td>
<td>Waterhole</td>
</tr>
</tbody>
</table>

In table 6 the results from the physical-chemical analyses of the initial sampling are
presented.

<table>
<thead>
<tr>
<th>Site</th>
<th>pH</th>
<th>Alkalinity (mg/l CaCO₃)</th>
<th>Total hardness (mg/l CaCO₃)</th>
<th>Calcium hardness (mg/l CaCO₃)</th>
<th>Total solids (mg/l)</th>
<th>Chloride (mg/l)</th>
<th>Sulphates (mg/l)</th>
<th>Detergents (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well</td>
<td>7.6</td>
<td>52</td>
<td>268</td>
<td>224</td>
<td>326</td>
<td>36</td>
<td>&lt;1</td>
<td>-</td>
</tr>
<tr>
<td>Well</td>
<td>7.8</td>
<td>56</td>
<td>244</td>
<td>224</td>
<td>364</td>
<td>36</td>
<td>&lt;1</td>
<td>-</td>
</tr>
<tr>
<td>Well</td>
<td>7.4</td>
<td>52</td>
<td>244</td>
<td>220</td>
<td>650</td>
<td>18</td>
<td>&lt;1</td>
<td>-</td>
</tr>
<tr>
<td>Waterhole</td>
<td>7.4</td>
<td>48</td>
<td>240</td>
<td>204</td>
<td>562</td>
<td>18</td>
<td>&lt;1</td>
<td>-</td>
</tr>
<tr>
<td>Waterhole</td>
<td>7.5</td>
<td>40</td>
<td>252</td>
<td>244</td>
<td>450</td>
<td>36</td>
<td>&lt;1</td>
<td>-</td>
</tr>
<tr>
<td>River</td>
<td>8.6</td>
<td>56</td>
<td>216</td>
<td>184</td>
<td>316</td>
<td>18</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Waterhole</td>
<td>7.5</td>
<td>44</td>
<td>232</td>
<td>204</td>
<td>434</td>
<td>54</td>
<td>&lt;1</td>
<td>-</td>
</tr>
<tr>
<td>Waterhole</td>
<td>7.3</td>
<td>48</td>
<td>264</td>
<td>232</td>
<td>-</td>
<td>36</td>
<td>&lt;1</td>
<td>-</td>
</tr>
</tbody>
</table>

There was a great similarity between the samples, but the total solids content in the samples
from sampling points 3 and 4 were much higher than in the other samples.
All the samples showed a pH between 7.3 and 7.8 except the sample from the river which presented a pH higher than 8.0. The reason could be that the river was contaminated by soap, since the people wash their clothes in the river. For the same reason only the sample from the river was analyzed for presence of detergents. However the result of the test showed less than 1 mg/l of anionic detergents, which are common components in cleaning articles such as soap.

The measurement of total solids in sample number 8 failed and consequently there is no result presented.

4.6.2 BACTERIOLOGICAL ANALYSES

In table 7 the results from the bacteriological analyses of the initial sampling are shown. Total and faecal coliform bacteria were detected in all the samples, which indicate that the water in all the wells and waterholes and also in the river was contaminated and that the contamination was of faecal origin.

<table>
<thead>
<tr>
<th>Site</th>
<th>Heterotrophic bacteria (CFU/ml)</th>
<th>Total coliform bacteria (MPN/100ml)</th>
<th>Faecal coliform bacteria (MPN/100ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well</td>
<td>265,000</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>Well</td>
<td>140,000</td>
<td>50</td>
<td>21</td>
</tr>
<tr>
<td>Well</td>
<td>11,000</td>
<td>20</td>
<td>8.8</td>
</tr>
<tr>
<td>Waterhole</td>
<td>14,000</td>
<td>≥240</td>
<td>≥240</td>
</tr>
<tr>
<td>Well</td>
<td>18,000</td>
<td>7.6</td>
<td>5</td>
</tr>
<tr>
<td>River</td>
<td>93,000</td>
<td>≥240</td>
<td>96</td>
</tr>
<tr>
<td>Waterhole</td>
<td>4,000</td>
<td>≥240</td>
<td>5</td>
</tr>
<tr>
<td>Waterhole</td>
<td>70</td>
<td>≥240</td>
<td>2.2</td>
</tr>
</tbody>
</table>

In the results from the bacteriological analyses of samples from the initial collection it could be observed that none of the samples contained *Salmonella sp.* or *V. cholerae*.

The water treatment system was implemented at site 3 which is a well. Four new different collecting points were selected; the well, the tank, the tap, and at a nearby well as a reference. Samplings were done after the implementation (the second sampling) and after the modification of the treatment system (the third sampling). In table 8 the results from the bacteriological analyses of the samples taken after the implementation are presented.

<table>
<thead>
<tr>
<th>Sampling point</th>
<th>Heterotrophic bacteria (CFU/ml)</th>
<th>Total coliform bacteria (MPN/100ml)</th>
<th>Faecal coliform bacteria (MPN/100ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The well</td>
<td>63,000</td>
<td>7.6</td>
<td>7.6</td>
</tr>
<tr>
<td>The tank</td>
<td>6,100</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>The tap</td>
<td>6,000</td>
<td>≥240</td>
<td>12</td>
</tr>
<tr>
<td>The nearest well</td>
<td>1,400</td>
<td>21</td>
<td>12</td>
</tr>
</tbody>
</table>

None of the samples contained *Salmonella sp.* or *V. cholerae*.

In table 9 the chlorine residual in the water at the second sampling is shown. Measurements were done in the well and in the tank.
Table 9. The chlorine residuals in the water at the second sampling.

<table>
<thead>
<tr>
<th>Sampling point</th>
<th>Chlorine residual (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The well</td>
<td>&gt;0.3</td>
</tr>
<tr>
<td>The tank</td>
<td>0</td>
</tr>
</tbody>
</table>

In table 10 the results from the bacteriological analysis of the samples taken after the modification of the water treatment system are presented.

Table 10. Bacteriological analyses of the four water samples from the third sampling.

<table>
<thead>
<tr>
<th>Sampling point</th>
<th>Heterotrophic bacteria (CFU/ml)</th>
<th>Total coliform bacteria (MPN/100ml)</th>
<th>Faecal coliform bacteria (MPN/100ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The well</td>
<td>610</td>
<td>≥240</td>
<td>7.6</td>
</tr>
<tr>
<td>The tank</td>
<td>91,000</td>
<td>≥240</td>
<td>≥240</td>
</tr>
<tr>
<td>The tap</td>
<td>73,000</td>
<td>≥240</td>
<td>240</td>
</tr>
<tr>
<td>The nearest well</td>
<td>2,500</td>
<td>≥240</td>
<td>4.4</td>
</tr>
</tbody>
</table>

None of the samples contained *Salmonella sp.* or *V. cholerae*.

In table 11 the chlorine residual in the water at the third sampling is shown. Samples were taken in the tank and from the tap.

Table 11. The chlorine residuals in the water at the third sampling.

<table>
<thead>
<tr>
<th>Point of collection</th>
<th>Chlorine residual (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tank</td>
<td>&gt;5</td>
</tr>
<tr>
<td>The tap</td>
<td>0</td>
</tr>
</tbody>
</table>
In table 12 a compilation of the results from the bacteriological analyses is presented.

**Table 12. A compilation of the results of the bacteriological analyses.**

<table>
<thead>
<tr>
<th>Sampling points</th>
<th>Units</th>
<th>Sampling 1</th>
<th>Sampling 2</th>
<th>Sampling 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>The well</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterotrophic bacteria (CFU/ml)</td>
<td>11,000</td>
<td>63,000</td>
<td>610</td>
<td></td>
</tr>
<tr>
<td>Total coliform bacteria (MPN/100ml)</td>
<td>20</td>
<td>7,6</td>
<td>≥204</td>
<td></td>
</tr>
<tr>
<td>Faecal coliform bacteria (MPN/100ml)</td>
<td>8.8</td>
<td>7.6</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Salmonella sp. Not detected</td>
<td>Not detected</td>
<td>Not detected</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V. cholerae Not detected</td>
<td>Not detected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>The tank</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterotrophic bacteria (CFU/ml)</td>
<td>6,000</td>
<td>91,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total coliform bacteria (MPN/100ml)</td>
<td>12</td>
<td>≥240</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faecal coliform bacteria (MPN/100ml)</td>
<td>5</td>
<td>≥240</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salmonella sp. Not detected</td>
<td>Not detected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V. cholerae Not detected</td>
<td>Not detected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>The tap</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterotrophic bacteria (CFU/ml)</td>
<td>6,000</td>
<td>73,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total coliform bacteria (MPN/100ml)</td>
<td>≥240</td>
<td>≥240</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faecal coliform bacteria (MPN/100ml)</td>
<td>12</td>
<td>240</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>The closest well</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterotrophic bacteria (CFU/ml)</td>
<td>1,400</td>
<td>2,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total coliform bacteria (MPN/100ml)</td>
<td>21</td>
<td>≥240</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faecal coliform bacteria (MPN/100ml)</td>
<td>12</td>
<td>4.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Abbreviations: CFU = Colony forming units, MPN = Most Probable Number*

4.6.3 THE PILOT STUDY

The results of the analyses from the pilot study are presented in table 13 and 14.

Table 13 shows the chlorine residual in the water in the pilot study, before and after the carbon filter. The first sample, which was taken one hour after the start of the chlorination, showed a chlorine residual of 0 mg/l. This could indicate that the chlorine was consumed immediately due to high organic content. Therefore a second sample was taken after 18 hours. This sample showed a chlorine residual of more than 5.0 mg/l. Table 13 also show the pH at the moment when the chlorine residual was measured.

**Table 13. pH and the chlorine residual before and after the carbon filter in the pilot study.**

<table>
<thead>
<tr>
<th>Time of sampling</th>
<th>pH</th>
<th>Chlorine residual (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before the filter</td>
<td>After the filter</td>
</tr>
<tr>
<td>1 hour¹</td>
<td>7,7</td>
<td>7,7</td>
</tr>
<tr>
<td>18 hours²</td>
<td>7,8</td>
<td>7,6</td>
</tr>
</tbody>
</table>

1) Samples taken 1 hour after start of chlorination.  
2) Samples taken 18 hours after start of chlorination.
In table 14 the results from the bacteriological analyses of the inoculated and treated water are shown. The water samples were taken 18 hours after the start of chlorination from the tank, which resembled the well, from the tank which included the chlorination and from the tap.

Table 14. Results from the bacteriological analysis of the experimental inoculated water in the pilot study.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Heterotrophic bacteria (CFU/ml)</th>
<th>Coliform bacterial group (MPN/100ml)</th>
<th>Total coliform bacteria</th>
<th>Faecal coliform bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>The well</td>
<td>108 000</td>
<td>≥240</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td>The tank</td>
<td>Not detectable</td>
<td>Not detectable</td>
<td>Not detectable</td>
<td>Not detectable</td>
</tr>
<tr>
<td>The tap</td>
<td>Not detectable</td>
<td>Not detectable</td>
<td>Not detectable</td>
<td>Not detectable</td>
</tr>
</tbody>
</table>

In table 14 it can be observed that the contamination in the well was high. The chlorine dose added had an effect on the bacteria in the tank, since no bacteria were detected. The results in table 13 show that the carbon filter totally removed the chlorine residual, since there was no trace at all of chlorine in the water from the tap.
5. DISCUSSION AND CONCLUSIONS

5.1 CRITICAL REVIEW AND EVALUATION OF RESULTS

The idea was to keep the cost for the equipment and maintenance of the solution as low as possible, and in our opinion this was achieved, considering the determined budget. The reason we wanted to keep the costs low is our vision that the system, if it works satisfactorily, will be applied to the other wells in the community on the initiative of the inhabitants. Our belief is that since it is a community with very low income the probability for this would be lower if we had used an expensive solution. Also we believe that if the maintenance costs are too high the pilot solution might not be used in the future.

The idea to make the inhabitants finance part of the solution worked out as wished. One obstacle that occurred though was that at the time of implementation of the pilot solution the men were constructing a new church in the community, a project in which the inhabitants all had contributed with money. This affected the willingness to pay for a drinking water treatment solution, even though the solution was something that aimed to improve the health of the people and especially the children.

One conclusion to draw from this would be that religion is prioritised before safe drinking water. However, the answer is not that simple. Poor understanding of the connection between clean water and health clearly affects this kind of prioritising. It must be assumed that the preferences of the people are affected by lack of knowledge or confidence in modern water treatment techniques. Also we draw the conclusion that this lack of understanding lies behind the problem with people prioritising the taste of the water, since it is hard to believe that the taste of the coffee could be prioritised before the health of a child. The belief that chlorine dries out the wells is another example of how beliefs can affect if a specific solution is accepted or not.

The operation and maintenance of the pilot solution consist of running the pump, chlorinate the water, replace the filter and clean the water tank at least once a year. During the six weeks the system was in use before we returned for the first evaluation there had been no problem with the operation. During this time the pump was started manually, it was later changed to operate automatically. From this we draw the conclusion that the people understood to operate and control the system.

It has to be mentioned that in a strictly environmental point of view, the preference was to not use any chemicals in our system. Also, the optimal system should be one which does not depend on resources from outside the community. However, in this case we consider the advantages to be bigger than the disadvantages, which is why we choose this method.

Also the preferred system would be one that does not depend on non-renewable resources. However, the energy consumption of the pump used in the system is low.

The idea was also to use local available material. This is to avoid unnecessary transport and also to make sure that it is easy to find spare parts in case it would be needed. All the material used was found in Pahuatlán or Huejutla except for the pump and the activated carbon filter,
which were obtained in Monterrey. The construction was performed by local available workforce as well as by the inhabitants themselves.

On presenting the suggestion for the delegates, the blunder was that they were only presented with one suggestion and asked their opinions on it. A better method would probably have been to present alternatives, to give them some options. It would also have been preferred to include the women in this part of the decision-making, instead of only asking their opinions before and after the implementation. If the water pressure in the taps had been prioritized initially the alterations that were made later could have been avoided.

Most microbiological contamination is probably caused by the local population and animals. Insufficient protection of wells and boreholes facilitates contamination of the water sources. This is particularly true for the shallow ground water sources. Another problem with these sources is improper drainage from waste and latrines, which might allow the waste water and polluted surface run-off to infiltrate into the aquifers. Human waste is often disposed of near surface water because people defecate near or even in the water for convenience.

There are also many possible ways of contamination between the well and consumption. Carrying water from the collection point to the house might contaminate the drinking water. It can also be contaminated in the household. Washing of hands, buckets and dishes and storage are important habits to explain to the inhabitants.

In the summarized table of the bacteriological analysis results it can be seen that the results are in many ways illogical. The results from the samples taken in the well after the implementation showed a decrease of bacteria from the coliform group and an increase of heterotrophic bacteria. A reason for the decrease of coliform bacteria could be that the well was covered, hindering animals and birds from having access to the well. At some occasions, before the well was covered, birds were observed standing on the walls of the well, resulting in bird droppings in the drinking water. The high content of heterotrophic bacteria might have been caused by inadequate chlorination. The fact that the well was covered involves a change of routines in adding chlorine for the inhabitants, since the bottle with chlorine was placed below the cover.

Water samples taken from a well close to the well used in the treatment system showed great increase of the total coliform bacteria between the second and the third sampling occasion. A possible explanation could be that it was rain season, resulting in a higher infiltration of contaminated water from latrines etc into the well. This could also explain the high increase of coliform bacteria in the well of the treatment system. Then again, it seems unreasonable that the amount of heterotrophic bacteria in the well decreased about 100 times.

The results of heterotrophic bacteria from the second sampling showed a 10 times higher value in the well where the chlorination was taking place than in the tank. The reason could be that the filter, which at that time was placed between the well and the tank, not only removed the chlorine but also bacteria. Conversely, that would also mean that the filter does not affect the total coliform bacteria since the amount of those increased. At the time of sampling the filter was totally green, probably because of growth of algae. If this affected the growth of bacteria in the tank was not investigated.

The fact that there was no chlorine in the tank at the time for the second sampling could have resulted in a growth of bacteria in the tank. However, the short retention time in the tank (it
was emptied twice a day) disagree with that reasoning, since bacterial growth mainly occurs in stagnant water and the time between chlorination and consumption was short. Therefore a growth in the pipes between the tank and the taps is also unlikely. A more reasonable explanation to why the amount of the total and faecal coliform bacteria was higher in the tap than in the tank at the second sampling is incorrect sampling. For example, the taps might not have been sterilized enough before filling the sampling bottles.

Arriving at the area for a third sampling, there had been an electric cut during the night and the morning, and the tank was just about to be filled. The results from the third sampling showed a very high bacterial content in the tank. An explanation could be that the stirring in the tank was insufficient, and consequently the bottle was filled with water that had not yet reacted with the chlorine. Regardless, it is barely credible that the bacterial content in the tank could have been higher than in the well.

In the pilot study, it could be seen that the equipment and the solution functioned perfectly. Therefore it can be excluded that the strange results from the previous sampling occasions were caused by the equipment. The most probable explanations to the results are that they were caused by incorrectly collected samples, mistakes during analysis, or bacterial growth in the samples during transport to the laboratory. Another important conclusion that can be drawn from the pilot study is that it is as important to measure the chlorine contact time with the water as the chlorine dosage. This was not thoroughly investigated in the study.

5.2 CONCLUSIONS IN SHORT

- **Drinking water quality**
  Based on our own and earlier investigations of the water quality and the health situation in Pahuatlán the bacteriological drinking water quality needs to be improved.

- **Contamination routes**
  Based on the inventory of Pahuatlán, most microbiological contamination is probably caused by the local population and animals. Contamination routes are poorly understood by the inhabitants.

- **Participation**
  The inhabitants were interested in the project and they were participating in all phases. It was easy to communicate with the people and we were accepted and respected in the community.

- **The drinking water treatment system**
  According to the pilot study, the equipment functions satisfactorily. The system was appreciated and accepted by the inhabitants and they contributed financially. Based on the evaluation the inhabitants know how to use the equipment.
5.3 POSSIBILITIES TO FURTHER DEVELOPMENT

Our opinion is that if the inhabitants are satisfied with the solution, it could be applied to the rest of the wells in the community. This is provided that the system is properly maintained. If the system is not used properly there is a chance that the system provides a greater risk of disease transmission than before the system was implemented. For example if the water is not chlorinated there might be a risk for bacterial growth in the water tank and/or in the filter. It might have been better not to have implemented any technical solution but instead to have put all the time and effort on educating the people in order to change their attitudes about chlorinating the water. As we left it, the people still had the same beliefs and attitudes against chlorination and subsequently there is a risk that they stop the chlorination. To prevent this, contacts were established with SSH and the health centre in Pahuatlán and personnel from both the institutions ensured us that they would help to look after the treatment system. Personnel at the health centre will make sure the chlorination is maintained and the SSH will continue to regularly analyse the drinking water quality.

If the well and the tank are always properly sealed, it might be possible to stop the chlorination provided that the quality of the water is analyzed regularly. To make the solution more environmentally sound a wind mill or solar cells could be installed to provide the electricity. Alternatives to chlorination include for example disinfection by UV-light. Other examples of solutions to be implemented include improvements in sanitation, physical protection of wells and intakes, soil and water conservation, treatment of waste water and recycling of waste water. The risk of drinking water becoming contaminated during and after transport from the water source could be decreased if pipes were to be installed to distribute the water directly to the households. This would also save time and work for the women. On the other hand this system might also have some disadvantages. There might be a risk for bacterial growth in the distribution system. Also, as was revealed during the preceding field studies, such a system could result in an over-outtake of water.

Different alternatives for increasing the water pressure might be considered. For example, the water tank could be placed at the health centre in Pahuatlán, which is situated at a higher
altitude than the well. Water would be pumped from the well to the tank and pipes would then be drawn to the site of the well, so that the women can continue collect water at the same location. The advantages would be that the water pressure would be good, and also that the staff at the centre could help with the chlorination of the water. However, it was hard to estimate how much the water pressure would increase due to difficulties in measuring the altitude. It is also possible that this solution would result in a higher consumption of electricity due to the work of the pump. Also the pipes would provide an extra cost and more work. Another considerable solution might be to construct a base for the tank with a height of 20-30 metre. The base could be constructed in the shape of a pyramid. There are examples of these kinds of constructions, however also this solution would result in extra costs, work and time. Another alternative that was discussed with the company in Monterrey was the installation of a devise to increase the pressure. This kind of equipment is sold by the company in Monterrey. The water would be pumped first to the existing water tank, then, with another pump, to a tank of 160 litres where the pressure is increased and then distributed to the taps. The pressure would be high and it would not provide much increase in power consumption. This solution would not provide much extra work or time but the price of the tank is between 4 000 and 7 000 peso (≈ 400-700 USD).

The water treatment system must be followed by continuing education to teach the inhabitants better habits in hygiene, waste treatment and excrement disposal. A greater understanding of bacteria and the way of spreading of diseases might also help in convincing the people to change their habits. We consider it important that the people learn better practices regarding hygiene and water related activities. We do not believe it is enough to simply provide the inhabitants with information about better practices. This has been tried in several of the communities in the area with poor results. In order for the inhabitants to use these practices, we believe it is necessary to start by finding out how the people themselves believe that they are getting ill. This was something we did not fully learn in this study, however it was clear that the people did not see the connection between contaminated water, hygiene and disease. Thereafter it is necessary to find a way to explain the transmission routes to make clear where there are risks for contamination of food and water and consequently spreading of disease. After this has been understood the inhabitants might be more open for changing their habits concerning water and hygiene.

5.4 FUTURE

This is the first investigation of this kind that has been conducted in this area. Many people, in addition to the inhabitants of Pahuatlán, showed interest for the project; among others local politicians, teachers and health workers in Huejutla and students and personnel at the university Regiomontana in Monterrey. The question was emerged among these people why they themselves could not perform similar projects. We hope that this project will initiate further research and efforts to improve the situation regarding water and sanitation for the well being of the indigenous people of Mexico, who are in great need. Our aspiration is also that the final report will be of use for people wanting to work with similar projects in Mexico and in other parts of the world.
6. REFERENCES


APPENDIX I. COMMON WATER RELATED DISEASES

1. E. coli

*Escherichia coli*, or *E. coli*, is the species most commonly isolated from human faecal samples and is part of the normal intestinal flora of healthy people. Generally, *E. coli* bacteria are not associated with adverse health effects. However, under certain circumstances *E. coli* may cause serious disease such as urinary tract infections and diarrhoea. Animals such as cattle are the main reservoir for pathogenic *E. coli*, but they also occur in other animal species such as chickens, goats and pigs. Food- and waterborne transmission is the main route of infection. It can be transmitted to humans via animal contact, contaminated food and water or between infected individuals. Person-person transmission occurs in communities where there is close contact between individuals (WHO, 2002).

2. CHOLERA

Cholera is an acute intestinal infection caused by the bacterium *Vibrio cholerae*. It has a short incubation period, from less than one day to five days, and produces an enterotoxin that causes copious, painless, watery diarrhoea that can quickly lead to severe dehydration and death if treatment is not promptly given. Vomiting also occurs in most patients. Most persons infected with *V. cholerae* do not become ill, although the bacterium is present in their faeces for 7-14 days. When illness does occur, more than 90% of episodes are of mild or moderate severity and are difficult to distinguish clinically from other types of acute diarrhoea. Less than 10% of ill persons develop typical cholera with signs of moderate or severe dehydration. The vibrio responsible for the seventh pandemic, now in progress, is known as *V. cholerae* O1, biotype El Tor. In 1991 cholera struck Latin America, where it had also been absent for more than a century. Within the year it spread to 11 countries, and subsequently throughout the continent (WHO, 2002).

Cholera is spread by contaminated water and food. Sudden large outbreaks are usually caused by a contaminated water supply. Only rarely is cholera transmitted by direct person-to-person contact. In highly endemic areas, it is mainly a disease of young children, although breastfeeding infants are rarely affected.

*V. cholerae* is often found in the aquatic environment and is part of the normal flora of brackish water and estuaries. It is often associated with algal blooms (plankton), which are influenced by the temperature of the water. Human beings are also one of the reservoirs of the pathogenic form of *V. cholerae* (WHO, 2002).

*V. cholerae* is extremely sensitive to disinfection processes and outbreaks of *V. cholerae* can be prevented by boiling practices and chlorine disinfection of drinking water (WHO, 2002).

3. SALMONELLA

The genus *Salmonella* is a member of the bacteria family Enterobacteriaceae. Three types of the Salmonella infection may be distinguished. Firstly, gastroenteritis (diarrhoea, nausea and vomiting), secondly, bacteraemia or septicaemia (fever with possible blood cultures) and thirdly, enteric fever (mild fever and diarrhoea). Most waterborne outbreaks have been associated with *S. typhi*, which causes Typhoid fever. At present, there are 107 different
strains of the bacteria. Typhoid fever is characterized by the sudden onset of sustained fever, severe headache, nausea, severe loss of appetite, constipation or sometimes diarrhoea. Severe forms have been described with mental dullness and meningitis. Case-fatality rates of 10% can be reduced to less than 1% with appropriate antibiotic therapy.

Paratyphoid fever can be caused by any of three variations or bioserotypes of *S. enteritidis Paratyphi* A, B and C. It is similar in its symptoms to typhoid fever, but tends to be milder, with a much lower case fatality rate.

Typhoid fever is transmitted by food and water contaminated by the faeces and urine of patients and carriers. Polluted water is the most common source of typhoid. In addition, shellfish taken from sewage contaminated beds, vegetables fertilized by nightsoil and eaten raw, contaminated milk and milk products have been shown as a source of infection (WHO, 2002).

4. **DYSENTERY**

Dysentery may be simply defined as diarrhoea containing blood. Although several organisms can cause dysentery, *Shigella* are the most important. *Shigella dysenteriae* type 1 (Sd1), also known as the Shiga bacillus, is the most virulent of the four serogroups of *Shigella*. Sd1 is the only cause of epidemic dysentery. In addition to bloody diarrhoea, the illness caused by Sd1 often includes abdominal cramps, fever and rectal pain. Less frequent complications of infection with Sd1 include sepsis, seizures, renal failure and the haemolytic uraemic syndrome. Approximately 5-15% of Sd1 cases are fatal.

Few studies have been done to determine how dysentery is spread. The most likely modes of transmission are person-to-person contact, and contaminated water and food. Epidemics of Sd1 usually occur in impoverished areas. They affect people of all ages, with the highest age specific incidence occurring among adults and the highest case fatality rates occurring among children (WHO, 2002).
APPENDIX II. PHYSICAL-CHEMICAL ANALYSES

In implementing a water treatment process it is important to know the physical and chemical properties of the water. These factors affect the microorganisms, and a water treatment system has to be designed with the physical and chemical quality in consideration.

The water in Pahuatlán was analysed for the factors shown in table II-1:

Table II-1. The analyzed physical and chemical factors and their Mexican analyse method norms.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Mexican analyse method norms used in the analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>NMX-AA-8-1980 “AGUAS – DETERMINACIÓN DEL Ph”</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>NMX-AA-36-1980 “AGUA – DETERMINACIÓN DE ACIDEZ Y ALCALINIDAD TOTAL”</td>
</tr>
<tr>
<td>Total solids</td>
<td>NMX-AA-20-1980 ”AGUAS – DETERMINACIÓN DE SÓLIDOS DISUELTO TOTALES”</td>
</tr>
</tbody>
</table>

The permitted physical and chemical limits, due to the official Mexican standard for drinking water; NOM-127-SSA1-1994 last revision 22 of November 2000, are presented in table II-2.

Table II-2. The permitted physical and chemical limits due to the official Mexican standard for drinking water.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Mexican standard for drinking water</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.5 – 8.5</td>
</tr>
<tr>
<td>Hardness</td>
<td>500 mg/l</td>
</tr>
<tr>
<td>Total solids</td>
<td>1000 mg/l</td>
</tr>
<tr>
<td>Chloride</td>
<td>250 mg/l</td>
</tr>
<tr>
<td>Sulphates</td>
<td>400 mg/l</td>
</tr>
<tr>
<td>Detergents</td>
<td>0.50 mg/l</td>
</tr>
</tbody>
</table>

**pH**
Measurement of pH is one of the most important tests in water chemistry. Practically every phase of water treatment is pH-dependent, such as acid-base neutralization, water softening, precipitation, coagulation, disinfection, and corrosion control (APHA-AWWA-WPCF, 1989).

**Alkalinity**
Alkalinity is a measure of the capacity of water to neutralize acid, the sum of all the titratable bases. It is significant in use and treatment of natural water and wastewater. Alkalinity helps to regulate the pH and the metal content of a water body. Bicarbonate and carbonate ions in water have the ability to remove toxic metal ions (such as lead, arsenic and cadmium) by precipitating the metal salts out of solution (APHA-AWWA-WPCF, 1989).
**Hardness**

Total hardness is defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per litre. Reported here are both total hardness (mg Ca, Mg/l) and calcium hardness (mg Ca/l).

The hardness of the water has importance in the daily life since hard water has influence on laundering, dishwashing and personal hygiene. The amount of hardness minerals in water affects the amount of soap and detergent necessary for cleaning. Bathing with soap in hard water leaves a sticky film on the skin. The film may hinder removal of dirt and bacteria. The soap layer prevents the skin from returning to its normal, slightly acid condition, and may lead to skin irritation. Heated hard water forms a layer of calcium and magnesium salts which may lead to inefficient operation or failure of water-using appliances. This layer can also clog pipes, resulting in reduced water flow and ultimately in pipe replacement (Oram, 2003).

**Total solids**

“Total solids” is the term applied to the material residue left in the vessel after evaporation of a sample and its subsequent drying in an oven at a defined temperature.

Total solids refer to matter suspended or dissolved in water or wastewater. The analysis is important in the control of biological and physical water treatment processes. The level of total solids may affect the water quality adversely in many ways. For example, too much dissolved solids in water can affect humans by inducing a higher concentration of bacteria giving a laxative effect. A high content of total solids reduces water clarity, may rise water temperature and reduce oxygen levels as a result of reduced photosynthesis. The solids can also bind toxic compounds such as pesticides and heavy metals in the water (Murphy, 2003).

**Chloride**

The chloride (Cl\(^-\)) ion is one of the major inorganic anions in water and is generally combined with calcium, magnesium, or sodium. Almost all chloride salts are highly soluble in water and the chloride content varies a lot. High chloride content is not harmful to health but can give a salty taste to water and may harm metallic pipes and structures, as well as growing plants (Budget water USA, 2003).

**Sulphates**

Sulphates (SO\(_4^{2-}\)) occur in almost all natural waters, and are one of the major dissolved constituents in rainwater. Discharges of sulphur compounds are measured and calculated as sulphate (SO\(_4^{2-}\)) because most of the sulphur compounds ending up in water bodies are explicitly sulphates. High concentrations of sulphate in drinking water causes a laxative effect when combined with calcium and magnesium, the two most common components of hardness (Budget water USA, 2003).

**Detergents**

Detergents consist of a number of components, which is referred to as surface-active agents. Using special active agents that give detergents their specific properties, detergents can be classified as cationic, non-ionic, amphoteric and anionic. Sources of detergents in the specific area are household cleaners, laundry and personal hygiene products.

The method selected, for measuring the amount of detergents, covers the determination of compounds that react with methylene blue to form a blue colored complex that is extracted.
into an immiscible organic solvent. The compounds are referred to as methylene blue active substances, and are calculated and reported in terms of the reference material, linear alkyl benzene sulfonate (Water Quality Program, 2003).
APPENDIX III. BACTERIOLOGICAL ANALYSES

1. INVESTIGATION OF COLIFORM BACTERIA
2. HETEROTROPHIC PLATE COUNT
3. INVESTIGATION OF Salmonella sp.
4. INVESTIGATION OF Vibrio cholerae
5. CULTURE MEDIA AND BIOCHEMICAL TESTS

1. INVESTIGATION OF COLIFORM BACTERIA

The coliform group includes all aerobic and facultative anaerobic, gram-negative, non spore-forming, rod-shape bacteria that ferment lactose and produces gas and acid within 48 hours at 35 ± 2°C (APHA-AWWA-WPCF, 1989). The standard test for the coliform group was performed using the multiple-tube fermentation technique, which consists of the presumptive phase and the confirmed phase, as shown in figure III-1. The results from the examination of replicate tubes and dilutions were reported in terms of the Most Probable Number (MPN) of organisms present. The MPN, verified in a specific table which is based on certain probability formulas, table III-1 below, is an estimate of the mean density of coliforms in the sample.

![Presumptive phase](image)

**Presumptive phase**

In the presumptive phase a sterilized lactose broth was used as culture medium. 10 ml of the sample was put in each of five tubes containing 20 ml lactose broth, 1 ml of the sample was transferred to a tube containing 10 ml lactose broth and 0.1 ml of the sample was put to a tube containing 10 ml lactose broth. This was repeated for all the samples. All tubes included an inverted vial (Durham tube), see figure III-2. The tubes were incubated in 35 ± 2°C for 24-48 hours. Production of gas in the tubes within the incubation time resulted in a positive presumptive test.
Confirmed phase for total coliform organisms
All the tubes from the presumptive phase that showed any gas were submitted to the confirmed phase, see the left part of figure III-1. 0.1 ml of culture medium from each positive tube were transferred to corresponding tubes containing 10 ml of brilliant green lactose bile broth and an inverted vial. After 24-48 hours incubation at 35 ± 2°C, the tubes with any gas formation in the inverted vial were regarded as positive in the confirmed phase. A Most Probable Number (MPN) was then calculated using a specific table, see table III-1.

Confirmed phase for faecal coliform organisms
Elevated temperature tests are used to separate the organisms of the coliform group which are of faecal origin (intestines of the human and warm blooded animals) from those derived from non-faecal sources (APHA-AWWA-WPCF, 1989).

All the presumptive fermentation tubes showing any amount of gas within the incubation time were submitted to the confirmed test for faecal coliform organisms, see the right part of figure III-1. 0.1 ml from a tube was collected and transferred to a tube containing 10 ml of Escherichia coli broth (EC broth) and an inverted vial, this was repeated for all the tubes. The inoculated EC broth tubes were incubated in a water bath at 44.5 ± 0.2°C for 24 hours. A gas production was considered as a positive faecal coliform reaction. Using a specific table, the MPN was calculated from the number of positive tubes see table III-1.
Table III-1. MPN index and 95% confidential interval for a variety of combinations of positives and negatives results when using: 5 tubes with 10 ml of sample, 1 tube with 1.0 ml of sample and 1 tube with 0.1 ml of sample.

<table>
<thead>
<tr>
<th>Number of tubes with positive reaction</th>
<th>MPN index per 100 ml</th>
<th>95% confidential interval</th>
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<tbody>
<tr>
<td>5 tubes with 10 ml of sample</td>
<td>1 tube with 1.0 ml of sample</td>
<td>1 tube with 0.1 ml of sample</td>
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<td>0</td>
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2. HETEROTROPHIC PLATE COUNT

The heterotrophic plate count, formerly known as the standard plate count, is a procedure for estimating the number of living aerobic heterotrophic bacteria in water. Colonies may arise from pairs, chains, clusters, or single cells, all of which are included in the term “colony-forming-units” (CFU). The pour plate method was used in this analysis. It is a simple method to perform and can accommodate volumes of sample or diluted sample of a wide range. The colonies produced are relatively small and compact, showing less tendency to encroach on each other than those produced by surface growth in for example the spread plate method (Collins et. al., 1991). The samples in different concentrations were poured into sterilized plates. The sample concentrations used were 1.0 ml, 0.1 ml, 0.01 ml and 0.001 ml. Thereafter a nutrient agar solution was poured into the plates and the plates were rotated first in one direction and then in the opposite direction. After the medium had solidified, the plates were inverted and placed in an incubator for 14 hours at 35°C.

The counting was done manually using a Quebec colony counter and the number was reported as CFU per millilitre. Described below is the counting method (APHA-AWWA-WPCF, 1989).

If there are less than 10 colonies/cm² the colonies are counted in 13 squares of the colony counter; seven squares horizontally across the plate and six squares vertically, having representative colony distribution. The sum of the number of colonies is multiplied by 5 to cover the 65 cm² of the plate area and then multiplied by the concentration of sample in the plate to compute estimated colony per plate.
When there are more than 10 colonies/cm\(^2\) but less than 100 colonies/cm\(^2\), five representative squares are counted. The average count per square centimetre is multiplied by 65 and then by the concentration of sample in the plate. When bacterial count on crowded plates is more than 100 colonies/cm\(^2\) the result is reported as greater than 6500 times the reciprocal concentration of sample in the plate.

The reported value for each sample is calculated by dividing the maximum value by the minimum of the different concentrations. If the outcome is greater than 2, the result reported is the mean value of the counting of colonies of the two greatest contiguous concentrations. If the outcome is less than 2, the result reported is the value of the counting of the plate with less dilution.

3. INVESTIGATION OF *Salmonella sp.*

Collection of samples
The collection of samples was performed using “Moore swabs”. The swabs were prepared from cheesecloth folded to a size of approximately 10 times 5 cm and wrapped with a 5 metre long steel wire. After being sterilized the swabs were placed at the collection points and secured with a wire. They were placed 20 cm below the water surface during 24 hours before collection.

Inoculation in pre-enrichment medium and incubation
On collection, the swabs were placed in sterilized bottles containing 250 ml of lactose broth as a pre-enrichment medium. The samples were then transported in an icebox during approximately 15 hours to the laboratory. Arriving at laboratory the bottles were incubated at 35 ± 2°C for 24 hours.

Inoculation in enrichment medium and incubation
After the incubation, 1 ml of each sample was transferred to a corresponding tube containing 9 ml of tetrathionate broth (enrichment medium). The tubes were then incubated at 35 ± 2°C for 24 hours.

Inoculation in selective mediums and incubation
After incubation in the enrichment medium, samples from the tubes were streaked on Petri plates containing the following selective culture media:

- Xylose lysine desoxycholate agar (XLD), which is a selective medium containing sodium desoxycholate which inhibit growth of non-pathogenic bacteria.
- Brilliant green agar (BGA), which is a selective medium containing brilliant green dye.
- *Salmonella Shigella* agar (SS agar), which is a selective medium for *Salmonella*.

All the plates were incubated for 24 hours at 35 ± 2°C.

Identification of colonies by biochemical reactions
A further verification of the colonies from the selective culture media was performed using an oxidase test and other biochemical reactions. Suspected colonies from the plates containing...
the selective media were transferred to tubes containing the following culture media: Triple Sugar Iron agar (TSI), Lysine Iron Agar (LIA), MIO agar (testing for motility, indole production and ornithine metabolism), Tryptone broth, Methyl Red and Voges-Proskauer agar (MR-VP) and Simmons citrate agar. The use of different culture media and the performed biochemical tests are further explained below.

The tubes were incubated for 24 hours at 35 ± 2°C. The results from the biochemical reactions were compared with specific tables (ASM, 1981; Cowan & Steel, 1974). Colonies with *Salmonella* characteristics were inoculated in blood base agar and incubated for 24 hours and then verified with the Gram stain technique and by microscopic observations.

A further identification of the most suspected colonies was done in an API system (bioMérieux). The API system is an identification system, for *Enterobacteriaceae* and other non-fastidious Gram negative rods, in which standardized and miniaturized biochemical tests and a database are used. The API strips consist of micro tubes containing dehydrated media and substrates, which are inoculated with a bacterial suspension which reconstitutes the media. During incubation, metabolism produces colour changes that are either spontaneous or revealed by addition of reagents. Two types of API tests were used, the API 20 NE (for colonies which resulted as positive in the oxidase test) and the API 20 E (for colonies which resulted as negative in the oxidase test). The reactions are later on read according to the Reading Table and the identification is obtained by referring to the Analytical Profile Index which comes with the API test (bioMérieux sa, 1999).

4. INVESTIGATION OF *Vibrio cholerae*

**Collection of samples**
The collection of samples for the investigation of *V. cholerae* was done in the same manner as the sampling for the investigation of *Salmonella* sp. using the Moore swab technique.

In addition, the water remaining from the samples collected primary for physical-chemical analyses and the water remaining from the samples collected to search heterotrophic bacteria and coliform organisms were analysed for *V. cholerae*. These water samples were filtrated, in laboratory, through sterilized 0.45-µm pore size Millipore membranes.

**Inoculation in enrichment medium and incubation**
On collection the swabs were placed in sterilized flasks containing 250 ml of alkaline peptone water (APW) as enrichment medium. The samples were then transported in an icebox during approximately 15 hours to the laboratory. Arriving at the laboratory the bottles were incubated at 35 ± 2°C between 6 and 24 hours.

The Millipore membranes were transferred to tubes containing 20 ml of alkaline peptone water and thereafter the analysis was performed in the same manner as for the Moore swabs.

**Inoculation in selective medium and incubation**
The transfer of samples from the enrichment medium to the selective medium was performed after the incubation time using sterilized cotton swabs. Samples were taken from the surface of the enrichment medium and then streaked out on Petri plates containing thiosulfate-citrate-bile salt-sucrose agar (TCBS) as a selective medium. The plates were then incubated at 35 ± 2°C for 24 hours.
Identification of colonies by biochemical reactions

The various colonies which had appeared on the Petri plates containing the selective medium after the incubation time were inoculated in tubes containing nutrient agar and incubated at 35 ± 2°C for 24 hours. Later on, the colonies were confirmed by the Gram stain technique, observation in microscope, the oxidase test and through other biochemical reactions. The following cultivate mediums, which are explained further below, were used in the biochemical reactions; Triple Sugar Iron agar (TSI), Lysine Iron Agar (LIA), MIO agar (testing for motility, indole production and ornithine metabolism), Tryptone broth, Methyl Red and Voges-Proskauer agar (MR-VP) and Simmons citrate agar. The results from the biochemical reactions were compared with specific tables (ASM, 1981; Cowan & Steel, 1974).

After the confirmation, the colonies that had shown a positive result in the oxidase test were verified in an API test (bioMérieux) and finally the reactions were read according to the reading table and the identification was made by referring to the Analytical Profile Index which comes with the API test, see 3: Investigation of Salmonella sp.

5. CULTURE MEDIA AND BIOCHEMICAL TESTS

In the verification of colonies an oxidase test and biochemical reactions were used. The use of different culture media and the performed biochemical tests are further explained below (Cowan et. al., 1974).

Oxidase test

This procedure tests the presence or absence of the enzyme cytochrome oxidase, as a method for distinguish between groups of bacteria. Coliform bacteria are oxidase negative, Pseudomonas spp. and Vibrio spp. are oxidase positive.

Some of the colonies were removed from tubes containing the solid medium Blood base agar with a NiCr thread, and smeared on the oxidase test strip. A dark purple colour that develops within 10 seconds was considered as a positive oxidase test.

Lysine decarboxylase

Lysine iron agar (LIA) is used to test the ability of bacteria to decarboxylate the amino acid lysine.

The tubes with containing inclined agar were inoculated and incubated. A colour change from yellow to violet or reddish-violet constituted a positive reaction and was noted.

Indol production

The tryptophane broth is used to analyze the production of indol, which is a product of the metabolism of tryptophane.

After inoculation in sterilized broth and incubation, a few drops of Kovac’s reagent, which is an amyl alcohol, was added and the tubes were shaken. A dark red colour which appears on the amyl alcohol surface layer after 10 minutes indicated a positive indole test. The original colour of the reagent constituted a negative test. An orange colour probably indicated the presence of skatole, a breakdown product of indole.
Methyl red and Voges-Proskauer tests
The MR-VP medium (peptone-glucose medium) is used for the methyl red test and the Voges-Proskauer test. These two are related and are useful in differentiating members of the coliform group.

Methyl red test
The methyl red test measures terminal pH; i.e., it tests for acid production from glucose by bacteria.

The culture was inoculated and incubated and thereafter 5 drops of the methyl red indicator solution was added. A distinct red colour was recorded as a positive reaction while a distinct yellow colour was recorded as a negative reaction.

Voges-Proskauer test
This test looks for acetoin, which is produced metabolically by certain coliform bacteria in peptone glucose medium.

The culture was inoculated and incubated, and thereafter a few drops of naphthol solution were added together with a few drops of 40 % KOH solution. Development of a pink colour within 5 minutes constituted a positive test.

Citrate utilization
The Simmons citrate agar is used to test the ability of bacteria to utilize citrate as the sole source of carbon.

Inoculation was done on the surface of the medium. Growth on the medium with a blue colour was a positive reaction, absence of change of colour was a negative reaction.

Ornithine decarboxylase, motility and indol production test
The MIO medium is used to test motility, production of indole and ornithine decarboxylase.

Motility
The nutrient agar was inoculated and incubated. A diffuse growth through the medium from the point of inoculation was considered as positive.

Indole production
After inoculation of the MIO medium and incubation, a few drops of Kovac’s reagent was added. If a dark red colour in the amyl alcohol surface layer appeared after 10 minutes, the indole test was positive. The original colour of the reagent constituted a negative test.

Ornithine
The MIO medium also tests the ability of bacteria to metabolize the amino acid ornithine. A change of colour to violet in the centre part of the medium, after sterilization, inoculation and incubation, indicates a positive reaction. No change of colour indicates a negative ornithine reaction.

Triple sugar iron reactions
The TSI agar contains the three sugars lactose, sucrose and glucose. It also contains an iron salt. It is used to test the ability of bacteria to metabolize the three sugars and to check the production of gas and H₂S as a result of the metabolism.
Colonies were inoculated in the sterilized, inclined agar and then incubated.

**Sugar fermentation**
- A yellow acid bottom of the tubes and a red alkaline slant indicated that glucose had been fermented but not sucrose or lactose.
- A yellow acid bottom and a yellow acid slant indicated that lactose and/or sucrose had been fermented.
- A red alkaline bottom and a red alkaline slant indicated that neither glucose, lactose nor sucrose had been fermented.

**Gas production**
Gas production was indicated by bubbles in the bottom of the tube.

**Hydrogen sulphide production**
Hydrogen sulphide production was indicated by a change of colour to black in the bottom of the tubes, due to a reaction between hydrogen sulphide and the iron salt to form black iron sulphide.
APPENDIX IV. THE TECHNICAL EQUIPMENT

1. THE PUMP
2. THE CHLORINE
3. THE ACTIVE CARBON FILTER
4. MATERIAL AND COST

1. THE PUMP

The technical data regarding the electrical installations of the pump are given in table IV-1.

Table IV-1. Technical data for the pump M-650. Ref: Anauger.

<table>
<thead>
<tr>
<th>Tension (Volts)</th>
<th>Current (Ampere)</th>
<th>Power (Watt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>115 V</td>
<td>8.5 A</td>
<td>300 W</td>
</tr>
<tr>
<td>220 V</td>
<td>5.5 A</td>
<td>300 W</td>
</tr>
</tbody>
</table>

To determine the capacity of the pump, it is necessary to obtain the total elevation of the installation:

1. Determine the height, H, in metre, from the water level to the reservoir
2. Determine the total length of the pipes, L, in metre, from the pump to the reservoir
3. Use table IV-2 below; find the total elevation, in metre water column.

Ex: H = 30m and L = 200m the elevation will be 40 metre water column.

When the total elevation is determined, use the performance graph and find the corresponding flow for the pump.
Ex: An elevation of 40 metres water column corresponds to a water flow of 400 litre per hour.

L = overall length of the pipe (in metres) from the pump to the reservoir.
H = Resulting elevation in metre water
h = length, in metres, from the dynamic level to the reservoir

Table IV-2. Water flow.

| L     | 10  | 20  | 40  | 60  | 80  | 100 | 125 | 150 | 175 | 200 | 225 | 250 | 300 | 350 | 400 | 450 | 500 | 600 | 700 | 800 |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| H     | 5   | 6   | 6   | 7   | 8   | 9   | 10  | 11  | 13  | 14  | 15  | 16  | 18  | 20  | 23  | 25  | 28  | 30  | 35  | 40  | 45  |
| 10    | 11  | 11  | 12  | 13  | 14  | 15  | 16  | 18  | 20  | 21  | 23  | 25  | 28  | 30  | 33  | 35  | 40  | 45  | 50  | 55  |
| 15    | 16  | 17  | 18  | 19  | 20  | 21  | 23  | 24  | 25  | 26  | 28  | 30  | 33  | 35  | 38  | 40  | 45  | 50  | 55  | 60  |
| 20    | 21  | 22  | 23  | 24  | 25  | 26  | 28  | 30  | 31  | 33  | 35  | 38  | 40  | 43  | 45  | 50  | 55  | 60  | 65  | 70  |
| 25    | 27  | 28  | 29  | 30  | 31  | 33  | 34  | 35  | 36  | 38  | 40  | 43  | 45  | 48  | 50  | 53  | 55  | 58  | 60  | 65  |
| 30    | 32  | 33  | 34  | 35  | 36  | 38  | 39  | 40  | 41  | 43  | 45  | 48  | 50  | 53  | 55  | 58  | 60  | 63  | 65  | 70  |
| 35    | 37  | 38  | 39  | 40  | 41  | 43  | 44  | 45  | 46  | 48  | 50  | 53  | 55  | 58  | 60  | 65  | 68  | 70  | 75  | 80  |
| 40    | 42  | 43  | 44  | 45  | 46  | 48  | 49  | 50  | 51  | 53  | 55  | 58  | 60  | 63  | 65  | 70  | 75  | 80  | 85  | 90  |
| 50    | 53  | 54  | 55  | 56  | 58  | 59  | 60  | 61  | 63  | 65  | 68  | 70  | 73  | 75  | 78  | 80  | 83  | 85  | 88  | 90  |
| 60    | 63  | 64  | 65  | 66  | 68  | 70  | 72  | 74  | 76  | 78  | 80  | 83  | 85  | 88  | 90  | 93  | 95  | 98  | 100 | 103 | 106 |

Appendix IV
Precautions
- The pump should not be in contact with the electrical cable, cord or wire.
- Installation and maintenance should always be performed with the electricity disconnected.
- The voltage of the electrical network should be in agreement to that of the pump (indicated on the pump).
- The water flow should not be interrupted or stopped with the pump connected.
- The pump should work totally submerged in water. It should not be in contact with any surfaces, including the ground.
- The pump should only be used for clean water.

2. THE CHLORINE

Information about the chlorine:
Name: Tricloro Biolim
Producer: Empacado en México por: Bruñen International S.A. de C.V.
Bernardo Reies 5505 NTE. MTY. N.L.
Active ingredient: Tricloro-S-triazinetriona
Inert ingredients: 1 %
Available chlorine: 99%

3. THE CARBON FILTER

Information about the carbon filter:
Product name: C1
Producer: USFilters Plymouth products
Active ingredient: Carbon impregnated cellulose media, 5 microns
Size: 2.5” x 10”
Other material: Polyester reinforcement backing and external netting
4. MATERIAL AND COST
In table IV-3 is shown the material used in the implementation of the water treatment system and its costs.

Table IV-3. Material used in the implementation of the water treatment system, and its costs.

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>COST (peso)</th>
<th>TOTAL (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equipment:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon filter</td>
<td>100</td>
<td>9</td>
</tr>
<tr>
<td>Pump</td>
<td>3000</td>
<td>262</td>
</tr>
<tr>
<td>Water tank Rotoplas 2500 litre</td>
<td>2870</td>
<td>247</td>
</tr>
<tr>
<td><strong>The base:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 packages of cement</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>1 roll reinforcement bar</td>
<td>370</td>
<td></td>
</tr>
<tr>
<td>10 kilo steel wire</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Rent of wood to construct</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Manpower</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1365</td>
<td>118</td>
</tr>
<tr>
<td><strong>Hydraulic:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maguera Reforzada (Rubber hose)½” 0.12</td>
<td>22.26</td>
<td></td>
</tr>
<tr>
<td>11 conector r/interior cobre 13mm. ½” (connectors,</td>
<td>52.47</td>
<td></td>
</tr>
<tr>
<td>internal, copper)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 conector r/exterior cobre 13mm ½” (connectors,</td>
<td>12.36</td>
<td></td>
</tr>
<tr>
<td>external, copper)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 codo 90º cobre 13mm ½”</td>
<td>8.28</td>
<td></td>
</tr>
<tr>
<td>4 codo 45º cobre 13mm ½”</td>
<td>14.08</td>
<td></td>
</tr>
<tr>
<td>6 tee cobre 13mm ½”</td>
<td>14.64</td>
<td></td>
</tr>
<tr>
<td>6 llave de jardín conex/mang. (taps, copper)</td>
<td>89.46</td>
<td></td>
</tr>
<tr>
<td>Soplete en blister s/tanque 1 boquilla</td>
<td>98.58</td>
<td></td>
</tr>
<tr>
<td>Tanque de gas desechable</td>
<td>20.16</td>
<td></td>
</tr>
<tr>
<td>Tubo de cobre rigido (copper tube) 6.1mt ½”m”</td>
<td>70.10</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>402.39</td>
<td>34</td>
</tr>
<tr>
<td><strong>Electric:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alambre (steel wire)</td>
<td>74.30</td>
<td></td>
</tr>
<tr>
<td>Interruptor (switch)</td>
<td>51.58</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>125.88</td>
<td>11</td>
</tr>
<tr>
<td><strong>Cover:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 boards 30x3m</td>
<td>165</td>
<td></td>
</tr>
<tr>
<td>1 board 5x3m</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Hinges</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Nail</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>184</td>
<td>15</td>
</tr>
<tr>
<td><strong>Manpower:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manpower</td>
<td>800</td>
<td>69</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>765</td>
</tr>
</tbody>
</table>

1. URL: http://www.forex.se 2004-02-16