

Evaluation and monitoring of water project in Twabidi, Ghana

Preface

In February and March 2005, a water system was built for the community of Twabidi no. 1, a small village in Ghana. In July 2005, we, Annemiek Hilberink and Joep Niermeijer, two mechanical engineering students of Delft University of Technology went to Twabidi to evaluate and monitor the system. We inspected the technical, social and institutional aspects of the project and the results of our evaluation are presented in this report. Unfortunately, the report does not contain any pictures, since these were stolen during our travelling.

We hope this report will be useful for our successors, especially concerning the future extension or water supply for the maternity clinic of Madam Augustina.

Joep Niermeijer and Annemiek Hilberink

Table of Contents

1	Technical monitoring	4
1.1	System check.....	4
1.1.1	Current water system	4
1.1.2	System extension to maternity clinic.....	5
1.2	Maintenance	6
1.2.1	Polytank	6
1.2.2	Water reservoir and pump.....	7
1.2.3	Water quality	7
2	System performance evaluation	8
2.1	Tap points	8
2.2	Pump.....	8
2.3	System efficiency	8
3	Institutional implementation	10
4	Social impacts analysis	11
4.1	Observation of system use	11
4.2	Interviews.....	12
4.2.1	Key persons	12
4.2.2	Community members.....	13
5	Appendices.....	15
5.1	Appendix 1 Expenses.....	15
5.2	Appendix 2 Inventaris Equipment at Maternity clinic.....	16
5.3	Appendix 3 Required pump capacity for source behind clinic.....	17

1 Technical Monitoring

1.1 System Check

1.1.1 Current water system

After arriving in Twabidi we have investigated the situation of the condition of the system. Our findings during the inspection are listed below for each part of the system.

Solar panels and controller:

- The solar panels were clean.
- The vegetation around the solar panels was kept low enough, so the surrounding plants don't cause any shade on the panels.
- The metal construction with which the solar panels were mounted on the pole was very rusty.
- It was hard to open the controller box, since its mounting frame caused it to bend. This was solved by introducing two small wooden pieces between the controller and the pole.
- All cables between the controller and the pump were still covered with sand and completely dug in.

Pump and water reservoir:

- All water couplings after the pump, at the non-return valve were completely dry.
- The pump sometimes causes a lot of vibrations and thus noise. In the next chapter the pump behaviour and performance will be discussed in more detail.
- All pipes between the reservoir and the polytank are still completely dug in.

Polytank:

- The two couplings or plugs in the bottom of the polytank both leak a little.
- The covering lid is not closed.
- About two metres of pipe between the polytank and the tap point were uncovered due to heavy rainfall. Atta covered it the same day.

Tap points:

- The tap points were working fine and all of them were used.

Furthermore, the head between the tank and pump have been calculated based on some measurements:

- Static pressure

$$p_{static} = 1.4 - 1.5bar = 1.45 \cdot 10^5 Pa$$

- Dynamic pressure

$$p_{dynamic} = 1.8 - 2.0bar = 1.8 \cdot 10^5 Pa$$

Calculation head based on static pressure:

$$p_1 + \rho gh_1 + \frac{1}{2} \rho v_1^2 = p_2 + \rho gh_2 + \frac{1}{2} \rho v_2^2$$

$$v_1 = v_2 = 0$$

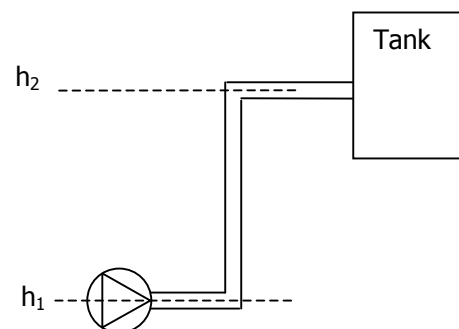
$$\rightarrow \Delta p = \rho gh$$

$$\Delta h = \frac{\Delta p}{\rho g} = \frac{1.45 \cdot 10^5}{1000 \cdot 9.81} = 14.8m$$

The head could also be calculated based on the dynamic pressure, according to:

$$P_{dynamic} = P_{caused\ by\ pipe\ resistances} + P_{static,\ due\ to\ height\ difference}$$

depending on $v[m^3/s]$



The relation for the pressure difference due to the pipe resistance which is depending on v could be estimated. When v would be known the flow follows from $\varphi = v \cdot A$. But it is hard to calculate, because of uncertain losses.

1.1.2 System extension to maternity clinic

After observing the system and performing maintenance, we have had a discussion with Samuel, the plumber, and Madam Augustina, the charge-nurse of the maternity clinic, about the extension of the water system to the maternity clinic.

From this discussion it was found that Madam Augustina did not trust the water quality from the system. She would rather fill up here polytank with the water from the well behind the maternity clinic, since it delivers more constantly and the water is much cleaner to her opinion. In the dry season, when the polytank is not filled with rain water, the well provides about 15 gallons a day, which might not always be sufficient for the clinic. Therefore, they suggested to drill the well further to solve this problem. They said this would cost about 5,000,000.- cedis, but we have heard amounts about ten times higher than this.

They would like to have a pump driven by a generator, since it is more reliable than a solar system and because Samuel is electrician. You can turn on the generator whenever necessary, which is not the case with a solar cell. According to Samuel the system including drilling, an electrical pump and a generator system would cost 15,000,000.- cedis.

A handpump is less suitable, since Madam Augustina cannot do that much with her hands, although she does not fetch water now because her girls do that. Also one should think of a system that brings up the water from the well into the polytank.

Madam Augustina herself came up with the "kralenpomp" or rope pump from "Stichting Pompen doet Leven". If she would get this for free and water could be brought up into the polytank, she would be satisfied as well. One can get more information on these pumping systems from WOT of the University of Twente in The Netherlands.

It was decided not to connect the maternity clinic to the water system in the village because of the following reasons:

- If rain water is insufficient to fill up the polytank of the maternity clinic, they say that the community source will be insufficient. On the other hand, Atta said that during the dry season the tank has been overflowing as well. This means that the available amount of water is fluctuating significantly during the year as well as the amount of solar energy available for the pump.
- The water in the clinic is clean at the moment, but Augustina is afraid of the water from the community source, since it contains surface water. This might not be clean enough for use in the clinic.
- The well behind the clinic serves the clinic with water in dry seasons. This is done by lowering a bucket at a rope into the water in the well and pulling it out again. This is very heavy. And afterwards, the girls have to carry the water onto the stairs to drop it in the polytank. Discussed solutions are:
 - o Hand pump such as cantilever, rope pump, mill pump
 - o Electrical pump either on solar or generator.

For a better overview of the amount of water delivered by the different sources, the table below contains an overview.

Season	Whether	Source behind maternity clinic	Community water system
November to March; Dry season	In November it sometimes rains during the nights. From December to March it does only rain once a	December to March about 15 Gallons a day, after that it is dry	The system runs from 21 st of April 2005. The people in Twabidi say there was sufficient water and sometimes the tank even

	month.		overflows.
April	Somewhat less dry.	Sufficient	Sufficient
June to August; Raining season	It rains all the time and there won't be any sun	Sufficient	The people in Twabidi say that there is sufficient water in the reservoir, but that the pump does not have enough energy due to insufficient sun. However, we have seen, that the pump empties the reservoir and that it therefore did not pump. Madam Augustina and Samuel said that there would be insufficient water.
September to October	It rains about once a week	Sufficient	Sufficient

Furthermore, we were told by the people in Twabidi that the stream never dries and always supplies water.

1.2 Maintenance

1.2.1 Polytank

On Sunday 17th July 2005, Samuel came over to Twabidi and around noon we cleaned the polytank. After disconnecting the couplings at both sides of the polytank and letting the water out, the polytank was laid on its side. It was found that quite a lot of sediment contaminated in the polytank. Samuel's son has entered the tank and with a bucket he has taken the last water and sediment out. After that he swabbed the tank from the inside. According to the amount of sediment, we estimate that cleaning the polytank is required about three or four times a year in this situation, when no adjustments are made to the system.

The couplings at the bottom of the tank appeared to be leaking. For one of the couplings we brought a new one to replace it, but it wasn't the correct one since no fast-coupling was present. One of the rubber rings was used for the coupling on the other side to stop it from leaking. This helped for one week, but at the day we were leaving, it started leaking again. If you want to replace the coupling at the side of the taps next time, contact Samuel. He knows what coupling is needed and he can buy it for you.

After putting the polytank in its place again and connecting the couplings, Samuel put some alum and chlorine into the water for purification. According to us, this is only an instant solution that gives you a lot of chlorine containing water during the first tank volume. But it will all be disappeared after.

According to the amount of sediment, we concluded that no filtration was included in the system. Samuel affirmed that the water reservoir was partly filled with grind, but that the wholes in the pump pipe reached higher than the grind and thus were above the grind. The pump pipe is wrapped in gauze. But since the resistance above the grind will be lower than at the height of the grind, the pump will suck water directly from the surface and not the water coming through the grind.

System improvements can be made, by either inserting a slow sand filtration in the reservoir or including a filter in the polytank.

The slow sand filtration system could be realised according to the drawings below.

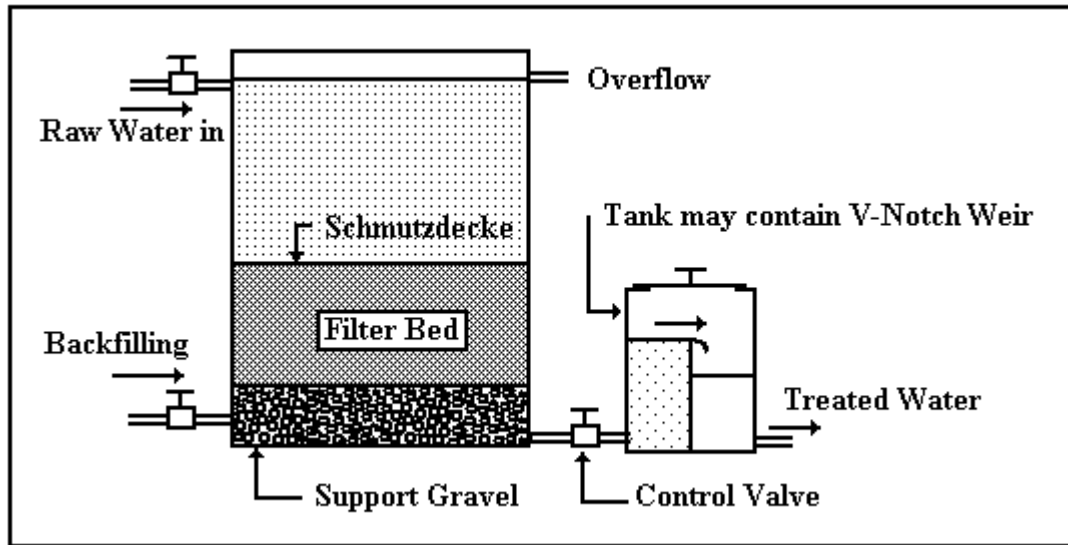


Figure 1 Slow sand filtration system

Samuel suggested to include a filter in the pipe just before the polytank, but according to our opinion you don't want any resistances or obstructions in this pipe. The pump should be able to pump the water into a free reservoir. However, he told us that "Royal Ventures Max" in Kumasi sells charcoal filters, which cost about € 50.- each. They are wrapped in a piece of cotton that can be washed and replaced by the people in the village.

1.2.2 Water reservoir and pump

After cleaning and maintaining the polytank, we would have liked to clean the reservoir and pump. However, due to our maintenance, there hadn't been any water for the people during the morning. Therefore it was decided that it was not possible to clean the reservoir and pump this same day. Unfortunately, Samuel needed to go to Kumasi the rest of the week. But he promised us to clean the pump after his return.

The two concrete lids on the reservoir could not be removed since they were fixed with cement. These seals would only be removed when actual maintenance would take place and cement was available. Samuel told us that because of the floater connected to the pump, an extra pump would be required to get all the water out of the reservoir. But when this needs to be done, one can also deactivate the floater function with the controller. Probably not much sediment will be present in the reservoir, since it is pumped away into the polytank and further to the tap point.

Samuel will contact us with his findings after he has checked the pump.

1.2.3 Water quality

Since the quality of the water is not known and the people of Twabidi are concerned about it, we went to Biaso to check the water quality. We are still waiting for the result. The only characteristics we know now are:

Parameter	Measured value	Recommended value
Acidity [pH units]	pH=6.9	6.5<pH<9.2
Apperent colour [Hazen units]	HU=30	HU~25

If the water quality results to be insufficient, the problem of adding chemicals is the discontinuity of the system in Twabidi. To add chemicals in the right amount, computer steered dosing systems are required to add the proper amount of chemicals. These systems are far to expensive. Therefore, we hope that the water is clean enough or that a filter is sufficient and adding chemicals is not necessary.

2 System Performance Evaluation

2.1 Tap Points

To check the system performance concerning the water pressure, we closed each tap with the manometer and measured the delivered pressure by opening the tap.

The resulting tap pressures for respectively the lowest until the highest tap are as follows:

1. 1.1 bar
2. 1.0 bar
3. 0.95 bar

2.2 Pump

During observation of the system we observed some remarkable things at the pump.

At Saturday the 16th of July, the weather was alternately cloudy and sunny. The pump emptied the water reservoir until the floaterpoint. After about fifteen minutes it started again for two minutes, and then it was empty again.

On Thursday the 21st of July, the controller indicated that the pump should be running, but it does not function properly, it alternately stops and starts for really short time periods. It seems like the static friction of the pump is too high, which avoids it from running during cloudy weather. In the next section the power delivered by the solar panels with cloudy weather will be measured.

2.3 System Efficiency

To get an idea of the amount of water taken from the system, at the 15th of July 2005 at 6 pm the flow meter indicated $1,136.663 \text{ m}^3 = 1,136,663 \text{ litres}$.

The system efficiency can be calculated based on some simple measurements. First of all we have measured the flow by disconnecting the pipe between the pump and the tank from the tank and:

1. Filling a 34 bucket with the water coming out and measuring the required time with a stopwatch.
2. Putting the flowmeter in and measure the flow over a certain period of time, measured with the stopwatch.

Then, we measured the voltage and current delivered by the solar panels with a multimeter, immediately after measuring the flow.

Now to different capacities can be calculated:

1. The mechanical capacity, according to $P = p \cdot \varphi$
2. The electrical capacity, according to $P_{mpp} = V_{mpp} \cdot I_{mpp}$,
in which mpp stands for maximum power point.

Based on these two calculated capacities, the overall system efficiency can be calculated according to:

$$\mu = \frac{P_{mechanical}}{P_{electrical}}$$

We did three measurements at the 22nd of July. The first and third measurement include both the electrical and mechanical system and the second only the electrical part. Therefore, the system efficiency can only be calculated for the first and third measurement.

The first measurement was around 13.45 under sunny conditions and gave the following results:

- Flow:
 - o 34 cm bucket (contains about 14 litres) was filled in 28 s, with 1.7 bar.
This corresponds with a flow of: $\varphi = 14 \cdot 10^{-3} / 28 = 5 \cdot 10^{-4} \text{ m}^3 / \text{s}$

- Flowmeter measured a flow 0.001 m^3 in 22 s, with 1.7 bar

This corresponds with a flow of: $\varphi = 1 \cdot 10^{-3} / 22 = 4.5 \cdot 10^{-5} \text{ m}^3 / \text{s}$

- Electrical:
 - $V_{mpp} = 91V$
 - $I_{mpp} = 2.9A$

This results in:

- A mechanical capacity of: $P_{bucket} = p \cdot \varphi = 1.7 \cdot 10^5 \cdot 5 \cdot 10^{-4} = 85W$
 $P_{flowmeter} = p \cdot \varphi = 1.7 \cdot 10^5 \cdot 4.5 \cdot 10^{-5} = 7.65W$
- An electrical capacity of: $P_{mpp} = V_{mpp} \cdot I_{mpp} = 91 \cdot 2.9 = 263.9W$
- System efficiency for sunny conditions: $\mu = \frac{P_{mechanical}}{P_{electrical}} = \frac{85}{263.9} = 0.32 = 32\%$

The second measurement only included the electrics for lightly clouded weather:

- Electrical:
 - $V_{mpp} = 87V$
 - $I_{mpp} = 2.2A$

This results in:

- An electrical capacity of: $P_{mpp} = V_{mpp} \cdot I_{mpp} = 87 \cdot 2.2 = 191.4W$

The third measurement was just after 14.00 during somewhat cloudy conditions:

- Flow:
 - 34 cm bucket (contains about 14 litres) was filled in 56 s, with 1.6 bar
 This corresponds with a flow of: $\varphi = 14 \cdot 10^{-3} / 56 = 2.5 \cdot 10^{-4} \text{ m}^3 / \text{s}$
- Electrical:
 - $V_{mpp} = 85V$
 - $I_{mpp} = 1.8A$

This results in:

- A mechanical capacity of: $P_{bucket} = p \cdot \varphi = 1.7 \cdot 10^5 \cdot 2.5 \cdot 10^{-4} = 42.5W$
- An electrical capacity of: $P_{mpp} = V_{mpp} \cdot I_{mpp} = 85 \cdot 1.8 = 153W$
- System efficiency for sunny conditions: $\mu = \frac{P_{mechanical}}{P_{electrical}} = \frac{42.5}{153} = 0.28 = 28\%$

3 Institutional Implementation

According to the community and the chief, the Water board functions well. Also the people from the Water board are satisfied with the functioning of the Water board. If people in the community have any problems with the water system they will tell it to one of the Water board members. The Water board Management has meetings once a month, during which they discuss the appearing problems and the collecting of the money.

The water board and community decided that each family should pay a monthly contribution of 5,000.- cedis, until the saved amount of money would be high enough to pay any necessary maintenance and replacements for the water system. If a sufficiently high amount of money will be saved, the contribution fee can be lowered in the future.

The water contribution for May was collected. Each family, independent of the number of family members, had paid the amount of 5,000.- cedis. During the week we were in Twabidi, all the money for June was collected. This we could see from the bookkeeping of Atta. In August the Water board planned to open a bank account on which they could save the collected amount of money.

The Water Board Management, Chief Nana and Madam Augustina emphatically pointed out that the Water Board was functioning very well and that the people in The Netherlands should only take into consideration those reports about the system that were send by the Water Board and no information send by other people. This to avoid situation such as happened with Daan Verboon who came to Twabidi for nothing, because he heard the system was not functioning.

4 Social Impacts Analysis

4.1 Observation of System Use

The concrete platform with the taps is kept clean. Everybody takes off its sandals before entering the platform. Furthermore, the women of Twabidi have been split into groups of ten to fifteen and each week, every Tuesday, one of the groups cleans the concrete with chlorine water and brushes.

Each day, Atta switches on the pump at 6am00 and switches it off at 6pm00.

Most people fetch water two or three times a day, between 5am and 7am, around noon and another time between 3pm and 5pm. Some people, especially the grown up, queue for the lower tap. But the teenagers use the higher taps as well. Sometimes the queue for the lower tap became about three to five people long, but the taps obviously function as a social meeting point for the women. And for the children it is a meeting point as well. When there is no supervision, they start playing with the water and each other. But mostly, the tap is closed immediately after the buckets are filled, and little water is spoilt.

Each time a woman or girl is alone with a full bucket, the shopkeeper helps to lift the bucket on her head. When it gets busier around the tap point, Atta passes by to coordinate and supervise a little.

Per day we observed the following:

Friday 15th July 2005

We arrived at noon. Continuously there was a row of about three to four people fetching water. Most people were queuing for the low tap, which has a higher capacity than the two higher taps. The higher ones were sometimes used, but not frequently. Once and a while Atta passed by for supervision. Around 17.00 nobody was fetching water anymore, no water was available. Atta shut off the pump at 6 pm.

Saturday 16th July 2005

Around 6 pm it was quite busy at the taps. After most people left for the farm, some people were still fetching water, but only one at a time. Some people do use the higher taps, but they are always the same people. The water looked a little bit red, the colour of the sediment. After 4pm30 the taps get busier again, most of the time there are about two or three people getting water. After 5pm almost no water comes out anymore and at 5pm30 nobody is collecting water anymore. It looks like all water has been pumped out of the reservoir.

Sunday 17th July 2005

This morning it is cloudy and nobody is fetching water. I went to the pump and it is not running. Probably there is insufficient sunlight. We cleaned the tank between 12pm30 and 1pm30, a lot of sediment came out.

Monday 18th July 2005

We didn't do any observations during the day, since we left for Hwidiem. Around 5pm, when we returned, people were fetching water.

Tuesday 19th July 2005

This morning, some people were fetching water, continuously about one at a time. At around 7am, a group of ten women started to clean the concrete around the taps with water and chlorine powder. Atta passed by for some supervision.

Wednesday 20th July 2005

From 6am people fetch water. Around 8am it gets busier and all taps are occupied. After 9am most people are on the farms. Around 3pm it gets more crowded again.

Thursday 21th July 2005

From 6am until 8am it is crowded, continuously about five people at the tap point. All taps were used. Atta put some chlorine powder in the water reservoir early in the morning and switched on the pump at 8am. Since it was clouded this morning he thinks the pump won't run anyway.

4.2 Interviews

4.2.1 Key persons

We started with a meeting with several key persons at the chief's palace and after that, we interviewed a couple of key persons within the community of Twabidi individually. Below you will find their ideas about the water system.

Discussion with community members present at the palace

The most important things that resulted from the discussion were the concern about the availability of sufficient water. If the sun shines and the pump is able to pump, they would like to fill two instead of only one polytank, so they have a larger buffer for times when the sun does not shine. Therefore, they ask for another polytank.

Furthermore, they are concerned about the quality of the water. After heavy rainfall, the water has the brown-red colour of the earth. We promised them to go to Biaso to test the water quality.

They told us that the Water Board was functioning well and that they are the only once giving valid information to The Netherlands. Only this information should be relied on and trusted in The Netherlands.

Nana, Chief of Twabidi no. 1

Nana told us that there had been some problems with payments, mostly because these people were still using the old sources. Now they are paying, because Nana told them to pay. Furthermore, Nana sees it as a problem that people talk too much at the tap point. It is too much of a social meeting point. Still the new system leaves the women more time to do other things. They are encouraged to more work such as weeding and sweeping. Nana's opinion is, that people from other villages should be allowed to fetch their water in Twabidi without being charged, so that they will decide to move to Twabidi which will enrich the village.

Nana suggests that the improvement with highest priority is an extension or at least a water connection for the clinic.

Madam Augustina, Charge-nurse of the maternity clinic in Twabidi

Madam Augustina tells that everybody within the community of Twabidi no. 1 is profiting from the system. All families pay the amount of 5000 cedis a month, although some of them had complained. They do pay anyway, because she told them to pay. She explained them that now the amount of 5000 cedis is necessary to build up a buffer from which maintenance expenses can be paid. Later on, when the amount is enough, the contribution of the families will be lowered. Since they started the contribution collection, they bought bleach from the collected money to clean the concrete of the tap point.

Normally the people don't use the old sources anymore. But during the raining season, the sun was not shining for three days, so there was insufficient energy for the pump to run. Then the people wanted to fetch water from the well behind the maternity clinic, but Madam Augustina refused to allow them, because she does not fetch their water either. Then the people had to go to the old sources.

Since the installation of the new system, men do also fetch water now. So besides the reduction of time spend on fetching water, some women don't have to fetch water that often anymore. They can spend more time on washing cooking and their children. Furthermore, they have less pain in their back and shoulders.

The most common diseases in the community are diarrhoea, which has decreased since the introduction of the new water system, and malaria, which is not directly related to water. Another problem is the Buruli Ulcer, a sickness related to water. A bacterium comes underneath the skin and causes sores. When those sores are not treated early, the sores will result in the destruction of massive areas of skin and bone. Therefore, Augustina is concerned about the water quality.

Furthermore, she told us that the reservoir was cleaned two months ago and that nearby villages were jealous because of the water system.

Atta, Foreman during the project and system operator

Atta told us that indeed everybody is paying and he showed us the bookkeeping. Some families are complaining though. The organisation functions well and there are no controversies. He also told us that the community would like to have another tap point more up in the village, so that people don't have to walk that far. Furthermore, he asked for help since the community wanted to start a pineapple farm.

J.E. Badu, Chairman of the Water Board

He tells us that he likes it to be a chairman. But after that he did not give any answer himself, all other people around him answered the questions. They tell us that he, as a chairman, advises the people of the Water Board Management. For example he tells them to pay the taxes, to wash and clean the tap points and to weed around the solar panels, which happens every week (we did not see it).

Furthermore Atta tells that the chairman also wants an extra polytank, because when the sun shines the water flow is sufficient to fill another polytank with water.

Teachers of primary and secondary school

The teachers agree that due to the new water system, work at school has become easier. The children can now fetch water before they go to school, while it used to be that they were busy fetching water half morning and they came late at school.

Furthermore, the children are less tired than they used to be. This resulted in a better concentration level and higher marks. Since the introduction of the new water system, no child has been disturbed by water bound diseases this far. The water safety has improved. The intake of new students has increased as well.

Another advantage is, that the teachers don't need to go to the city anymore to show the children how a pipe born water system works and what a solar system is. They can now show it in their own village.

After this a couple of questions and remarks follow:

- It would be better if some more taps were added, for example in the classes.
- They would like to have some solar panels for light in the classes, especially for night classes.
- Some of the teachers don't have accommodation. Therefore, it would be really useful if we could arrange some staff accommodation, which saves a lot of travel time.
- They asked if it could do any harm when parts of the pipes are exposed to the air, which they saw. We told that it would not directly cause any harm, as long as the pipe would not be damaged, but that Atta actually should recover the pipes quickly after heavy rainfall.

4.2.2 Community members

We interviewed several women in the community, in houses that are spread within the village. In general they gave the same answers, which we summarised in the next paragraph. Besides, some women gave different answers, which will be handled separately after.

All women like the new water system better than the old one. They agree that the water quality has improved. The only problem they have is that when there is no sun, the pump does not pump any water. This seems to happen on a regular base during the raining seasons, from June until July or

August. Then sometimes they are forced to use the old sources again. When they can use the new system, they are less tired and have fewer problems with their backs and shoulders. Many of them mention that they like to go to the tap point because they meet other people and talk. Most families fetch significantly more water from the new system than they used to fetch from the old sources, as can be seen from the table below. When we interviewed them, nobody complained about the price of the water. And they all agreed with the structure and organisation.

Name of interviewed person	Family size in persons	Buckets per day from new source	Buckets per day from old source (34 bucket contains 14 litres)
Nana	4	6	4
Cecilia	6	12	12
Wredowaa	4	8	3-4
Haw a Bewie	4	4	4
Zaria Tu	8	12	8
Kwadwo Owusu	2 (only wife and man)	4	4
Yaa Abrafi	8	13	6
Akwasi	13	6	4
Ernest	25	10	5
Naomi	5	12	12

Haw a Bewie a mother of one son and one daughter told us that they went to the old source every day, to fill one bottle. Just because she believed that she couldn't leave the old source, which would bring misfortune.

Zaria Tu living near the polytank mentioned that it is still a far walk to the tap point and she asks for an extra tap closer to her house.

Kwadwo Owusu mentioned also living up the hill near the polytank mentioned that although it is less far now, his wife still has pains. Furthermore, he mentions that they are less sick than they used to be.

Akwasi mentioned that she likes the taps much more than the sources.

Ernest mentioned explicitly that his family suffered less from diarrhoea.

Naomi mentioned that she did not like the water, because it still did not work as a medicine for her hips. Furthermore, she wants another polytank. Without this second tank, she thinks 5000 cedis is too much.

5 Appendices

5.1 Appendix 1 Expenses

Exchange	Ex 1	14-07'05				€ 200.00	10500	2,100,000.00
Category	Receipt	Date	Type of expenditure	Supplier	Valuta	Amount	Rate	Euros
Components	C1	14-07-'05	PE pipe 25 mmx2.3x100 m 3 PE compression couplings 25 mm 2 PE comp red coupling 40 x 25 mm	Interplast, Accra	Cedis	686,090.00	10500	€ 6534
Labour		17-07-'05	Samuel work 1 day		Cedis	13,000.00	10500	€ 1.24
Labour		22-07-'05	Samuel pump check, 1 day		Cedis	200,000.00	10500	€ 19.05
Labour		19-07-'05	Employee water institute Biaso for testing the water		Cedis	200,000.00	10500	€ 19.05
Tools		14-07-'05	Telephone card	Spacefone	Cedis	75,000.00	10500	€ 7.14
Tools		18-07-'05	TV and DVD-player		Cedis	150,000.00	10500	€ 14.29
Tools		18-07-'05	Fuel generator		Cedis	40,000.00	10500	€ 3.81
Tools		20-07-'05	Multimeter	Yowk Electircals, Goaso	Cedis	50,000.00	10500	€ 4.76
Transport		14-07-'05	Transportation costs pipe	STC	Cedis	18,000.00	10500	€ 1.71
Transport		15-07-'05	Transportation costs pipe in tro-tro		Cedis	20,000.00	10500	€ 1.90
Transport		18-07-'05	Tro-tro and taxi to Hwidiem		Cedis	18,000.00	10500	€ 1.71
Transport		18-07-'05	Fuel Benz Kennedy to Goaso		Cedis	10,000.00	10500	€ 0.95
Transport		19-07-'05	Fuel Benz Kennedy to Biaso		Cedis	150,000.00	10500	€ 14.29
Transport		22-07-'05	Fuel Benz Kennedy to Hwidiem		Cedis	70,000.00	10500	€ 6.67
						1,700,090.00		€ 161.91

5.2 Appendix 2 Inventaris Equipment at Maternity Clinic

Number	Equipment description	Type, size
1	Flowmeter	¾"
5	Fast coupling	Straight, ¾"
5	Fast coupling	90°, ¾"
1	Fast coupling	90°, 1 ¼"
1	Manometer	¾"
1 and 1 installed	Saddle for manometer with screws	¾"
1	Valve/tap in line	¾"
1	T-junction	1 ¼"
3	Fast coupling	Reducer, 1 ¼" – ¾"
1	Pipe	¾" 100 m
1	Pipe	1 ¼" 20 m
1	Coupling, thread end and fast coupling	90°, ¾"
1	Endpoint for open flow	1 ¼" too short thread for assembly in tank
1	Endpoint for open flow	¾"
1	Gas burner	Small
1	Digital multimeter	DT – 830D
1	Digital multimeter	Digi-38 ampere meter broken
	Small box containing screws bolts, nuts and rings	
1	Ceramic switch	
1	Screw driver	Cross-head
1	Screw driver	Flat-head
1	Wire cutter	
1	Cutter pliers	
1	Riveting pliers	
1	Pointed pliers	
1	Brush	1 ½"
	Picklocks	10 to 17
	Kroonsteentjes	
1	Tiewraps	100 and 250 mm
1	Loctite 222	
1	Lute squirt	
	Frame pieces for solar panel	
1	Moordenaar	
	Bolts and nuts	Large
1	Electrical box	100 x 100 mm
3	Diodes	Big
2	Diodes	Small
4	Connectors for solar panel	
1	Airplane earplugs	
1	Speed drill	22 mm
	Electrical terminals	
	Bolts	M6, square-head
	Varia PVC	
1	Calculator	

5.3 Appendix 3 Required Pump Capacity for Source Behind Clinic

Assume:

- Source depth $= 15[m]$ (actually 10 [m])
- Maximum offtake, 1 tank capacity per day $200l / day$
- Sun hours per day $4 \text{ sun hours} / day$

This results in:

- Pressure $p = \rho g \Delta h = 1000 \cdot 9.81 \cdot 15 \approx 1.5 \text{bar} = 1.5 \cdot 10^5 \text{ Pa}$
- Required flow capacity $50l / hr = 1.4 \text{m}^3 / s$
- Required pumping capacity $P = p \cdot \varphi = 1.5 \cdot 10^5 \cdot 1.4 \cdot 10^{-5} = 1.5 \cdot 1.4 = 4.00W$

Taking losses and a shorter pumping time into consideration, a pump with a capacity of 10 Watt should be sufficient.