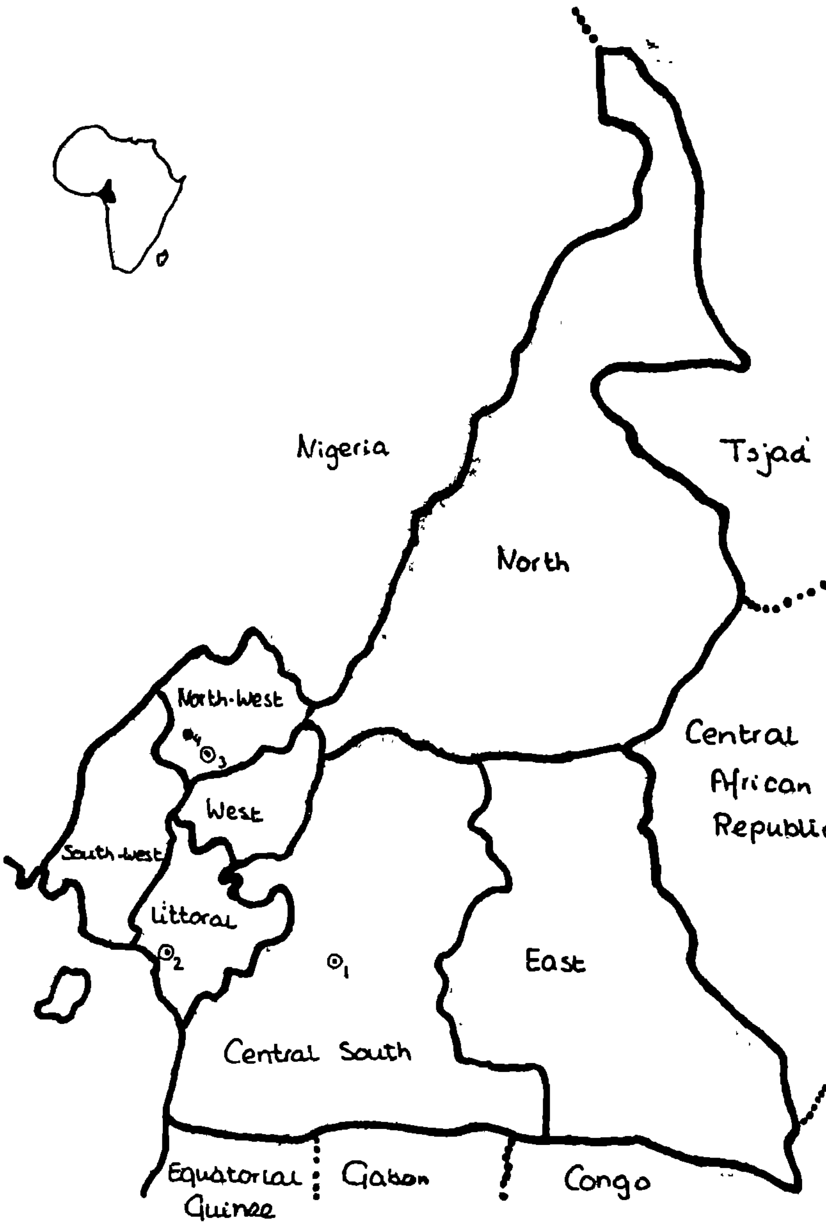
HEALTH, DRINKING-WATERQUALITY AND QUALITY IMPROVEMENT

A critical research on drinking-waterquality in NW Cameroon



by Dedde de Jong

824-4893

PREFACE

This research on waterquality in NW Cameroon was done in 1982 from march to august within the scope of the study Tropische Kultuurtechniek at the University of Agriculture, Wageningen, The Netherlands. The research was done under supervision of Mr. van der Knaap, who is responsible for the course on drinking water supplies in low income countries.
It was Han Heynen, staff member of the International Reference Centre for community water supply and sanitation in Rijswijk, who made it possible to do the research in the field. Thanks to him and later to Jan Teun Visscher the necessary test equipment for the research was provided by the IRC.
I am also very grateful to Mr. Tschopp, Ruedi Fisscher, Thomas Cajacob, Mr. Cabin and Mr. Ngwang Gumne of the Swiss Association for Technical Assistance and Community Development for their cooperation. They realized the programme of visits to a lot af villages for which many things had to be improvised. Thanks also to the caretakers of the water supplies and to other SATA/CD employees who helped me a lot, especially the SATA-driver, Martin Obal, with which I passed a lot of time. Finally I like to thank the people that gave me hospitality in their houses.

Dedde de Jong

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INTRODUCTION

This report is based on a research on the quality of drinking water delivered by rural water supplies in the North West Province of Cameroon. The research was done in 1982 within the scope of the study Tropische Kultuurtechniek at the University of Agriculture, Wageningen, The Netherlands.
In behalf of the research 27 drinking water supplies, partly already functioning for years and others under construction, were visited. The results, written down in chapter IV and Annex I, give a first indication on the quality of the sources which are used. Besides the effect on the quality of treatment and transport to and storage in the houses could be checked on several places.
In the same time the research gave the possibility to get practical experience in the field with the portable test equipment. These experiences are described in Annex II.

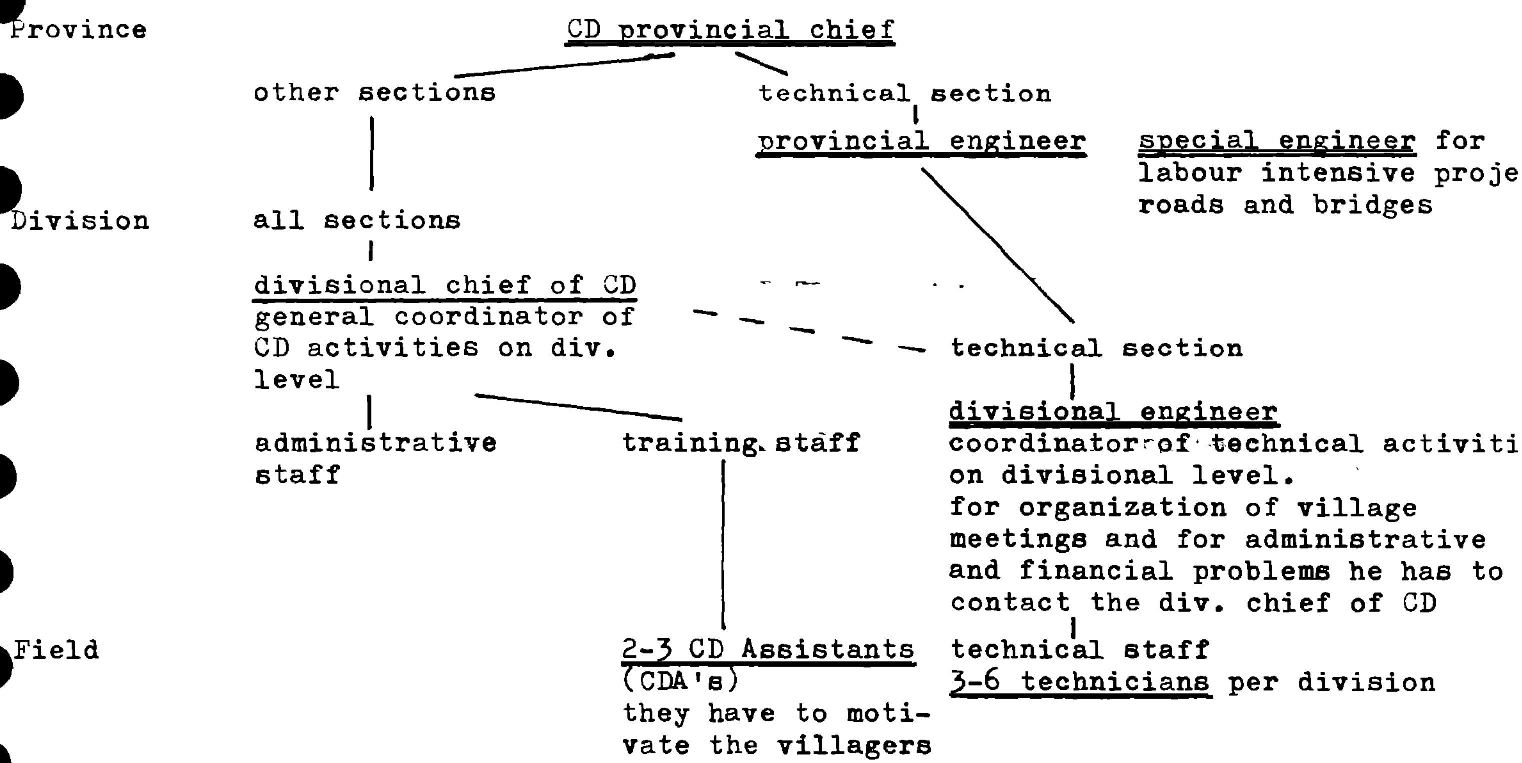
In the first place clean water is supposed to have a positive effect on the health of the people. Although quality refers to a combination of characteristics, in the situation of the tropical rural areas generally it is the amount of disease organisms in the water that makes it useful or useless for drinking water. Does the biological quality not meet certain standards than the water has to be treated or the source has to be condemned for drinking water.
In the North West province you will find treatmentstations (sedimentation, slow and/or rapid sand filters) where a stream is used as source.
The extra cost for a treatmentstation is legitimated by the importance that is attached to water quality improvement in relation to health. And if treatment is impossible the source is condemned. This has leaded to the next question in relation to the water quality research:
What is the relative importance of quality improvement of drinking water for health, in view of possible other measures that will effect the health in a possitive way? Which standards have to be used for the decision if the water has to be treated, condemned or used without treatment? This question is worked out in chapter III and returns several times in the report.

The visits to the drinking water supplies to do the tests made it possible to orientate on other items. With the introduction of a treatment it is often forgotten that also new problems can be introduced. The fact is that neglected maintenance or technical shortcomings are very realistic in low income countries and form a great risk for the good functioning of the treatment or for the water supply as a whole. In the worst case the quality improvement will be totally lost.
This has leaded to a second qeustion in relation to the water quality research: How far form neglected maintenance and technical shortcomings a threat for the drinking water system (and especially for the functioning of the treatment) and in that way for any positive effect on health?
That is why in chapters V and VI the principles and the technical design of the treatmentstations in the North West Province are discussed. Especially the consequences for operation, maintenance and management are discussed.

So water quality is subsequently related to health, quality tests, technical aspects of quality improvement (treatment) and to the necessary operation, maintenance and management to garantee any effect on health of the improved water supply.
In chapter VII, Conclusions and Recommendations, guidelines are given for the priorities in the field of health and water supplies in a situation as the North West Province of Cameroon.

the village. Examples of projects are churches, water supplies, fishponds or healthposts.
The committee is responsible to the traditional council. As a matter of course one committee is stronger than another.
The villages are also familiar with the idea of community work.
On a community-work-day all trade or farming within the village is forbidden. The succes of the community work depends primarily on the authority of the project committee and of the chief. This apply much more in the case of the collection of cash money for the project.
Finally the organisation of community activities is easier in a village where all inhabitants are native to the village than in a village where many immigrants came in. In the NW Province a lot of refugees from Biafra came in during the war and these "Ibo's" are still living in a lot of villages.
As a result of the community activities in many villages is a primary school, a church and sometimes a dispensary. Besides a large net-work of foot-pathes connects the villages to eachother.
Large villages are situated along roads. Especially in Momo division in rainy season the roads are very sleepy and dangerous.
The population produces corn, cocoyams, yams, cocosha, potatoes, casave, groundnuts and different types of vegetables and fruits.
Food production is the task of women. The greater part of the produced food is for direct consumption. A small part is sold on the market, as well as special products as palmoil or palmwine.
The marketsystem is well developed and organized within a tribe.
Some men have their own farm where they grow cashcrops as coffee, cocoa and fruits. On the unfarmed grasslands there is a lot of husband ry.
Generally speaking the unemployment is high, especially under men.
Some of them try to find a job in the larger cities or in Nigeria.
Apart from the expected impact on health it is one of the objects in view of a water supply project to make a village more attractive also for young people. It is hoped that so too much emigration from the villages will be prevented and that new activities will be attrackted or developed.

technical staff for the fieldactivities of CD-SATA. In various courses masons, plumbers, woodworkers, draughtsmen, foremen, building supervisors and caretakers for water supplies are trained. 60% of the overall training is done on job-sites as practical work. Although the entry for BTC is free, the selection is perforce very strict. After Completion of BTC one is almost sure to be employed by CD-SATA. In this way BTC has an important role in the camerooni-zation of the CD activities. SATA also mediates in some cases to send cameroonian technicians abroad for higher training.
The aim of the provincial workshops is to ensure the smooth running of all departmental vehicles including light and heavy equipment as well as other mechanical outfit of the field projects.
Nowadays the SATA forms more or less the Technical Service of CD and mediates between CD and Foreign Aid Agencies. SATA concentrates on water supplies, bridges, village end secondary roads.
Next scheme gives the organigramm of CD-SATA in the NW Province, which can be devided in five divisions: Mezam, Momo, Menchum, Bui and Donga-Mantung.



Sometimes the functions of divisional chief and of divisional engineer are combined. Divisional engineers and technicians are Cameroonians. However in Mezam and Momo the divisional work is done by the provincial engineer, who is a Swiss. There is no money to employ a divisional engineer.

The most impertant task of the previncial engineer is the management of the provincial store from which all materials and tools for construction, maintenance and repairs are distributed.
Technicians and CDA's work on the same village level. They are very important to give relevant information and to explain procedures to the villagers.

2.2 The water supply project: organization

If a village likes to start a water supply project they inform the divisional chief of CD by way of the CDA or by means of a letter. Then assistance is given by the CD Department when the following requirements have been met:

1) A strong project committee has to be formed, which is capable to organize the project.
2) The project committee has already started the collection of some money from each future beneficiary to form a starting fund of for instance CFA 200000 (=$670). This amount is deposited with CD. To CD-SATA this action proves that the project is supported by the whole population and not only by some leaders of the village.
3) A meeting has to be organized by the project committee. The population or their representatives and the CD-SATA technician will be invited to discuss the wishes and possibilities concerning the project.

If these conditions have been met the CD-SATA will support the project. They will make a technical report and a final cost-estimate. Then also the contribution of the village in cash and in kind will be fixed. The CD-SATA will apply for a state grant and for foreign aid. Then the construction can start. Generally it is the responsibility of the community to provide sand and stones and to dug holes and trenches. The project committee, the foreman and the CD-SATA technicians have to coordinate the work.
Also a central person is the caretaker. He is a villager who has been choosen by the village to get the responsibility for the operation and maintenance of the completed water supply in the future. During the construction he is trained on the job-side. Besides he will be trained for some weeks in BTC Kumba.
CD-SATA finish their direct involvement after completion of the

construction. Up till now they don't supervise the caretaker when he has to operate and maintain the supply. If the caretaker takes the initiative and applies for assistance, SATA-CD will give it of course.

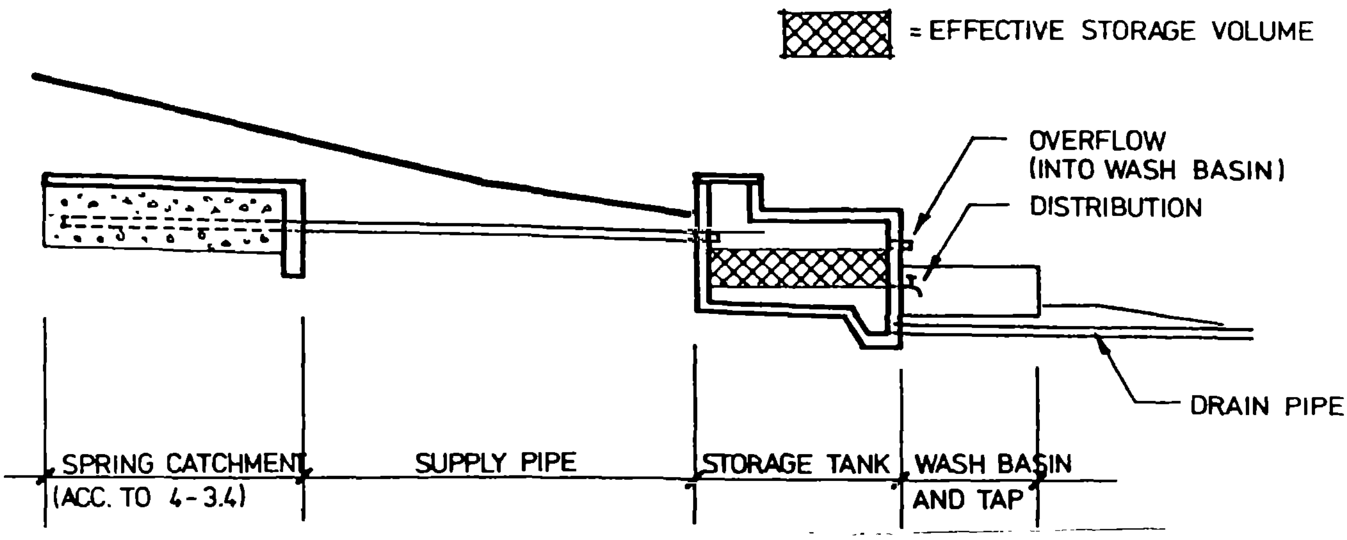
2.3 The water supply project: finance

The finance of a project is rather complicated. In the first place place the community has to contribute in cash and in kind. The rest is contributed by the government and by foreign aid which is applied for by the SATA director in Yaounde (capital of Cameroon). In practice the contribution of the community is 15%, of the government 20% and of the foreign aid 65%.
The service of CD-SATA has not to be paid by the projectbudget.
At this moment the application for foreign aid becomes more and more difficult. According to the principles of the aid agencies Cameroon is too rich in relation to other developing countries. Even SATA in Switzerland reduces the contribution. This means that several functions within the organisation (f.i. divisional engineers) cannot be filled.
Another problem is the salary of the caretaker after completion of the construction. During the construction he is paid from the projectbudget. Afterwards his salary has to be paid by the village for a period of one or two years, before he will be government-employed. However CD-SATA refuses to send the files of the caretaker to the government if an arrangement for his salary for the transition period has not been made by the village.
Another problem is the finance of spareparts. Also spareparts have to be paid by the village. Generally the collection of cash money in a village is much more difficult than the provision of building materials or labour.

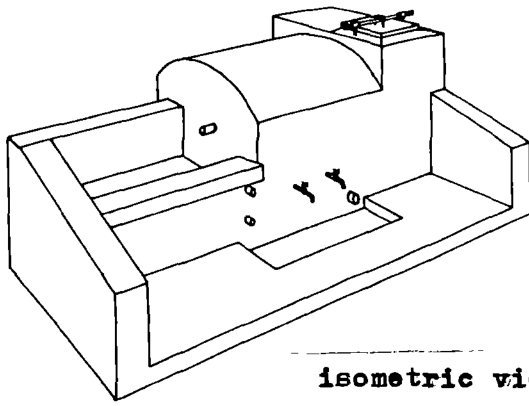
2.4 The water supply project: technical aspects

In the NW Province emphasis is on solid longlasting structures of simple design and on the use of labour intensive methods and local materials, wherever possible. The goal is to achieve systems of trouble-free operation, stable quality of drinking water and minimal, simple operation, maintenance and management requirements. This

waterpoint with drainage problems



waterpoint - lay out



isometric view

policy leads to a preference for water supply by gravity, avoiding pumps. Building material is principally stone masonry. Floors, large slabs and standpipes are made out of reinforced concrete.

For the treatment no chemicals are used. The main treatment in the NW-province is the slow sand filter in the case of a water supply based on a streamcatchment. This treatment is brought about by different processes within a filterbed of fine sand. To avoid soon blockage of the filter, because of a high turbidity of the raw water, the water is pre-treated by sedimentation and sometimes by a rapid sand filter.

Although some houses were connected directly to the pipes, in the NW Province the water was generally supplied by pipes to public taps. From there the water was carried in a vessel to the house where it was stored in a covered or uncovered bucket. Sometimes no distribution system was built.

Depending on the source and the distribution system one can distinguish three types of water supply in the NW Province.

A waterpoint is based on a spring. The spring is catched by a dam in the ground. For the rest the waterpoint consists of a storage-chamber and a wash basin. The storage-chamber functions also as a small sedimentation tank for coarse sand.

There is no distribution system.

A lot of waterpoints were built in the past especially in cases where the use of a spring beneath the village was the only possibility. Besides the waterpoint is the cheapest solution.

The second possibility is a spring catchment with a distribution system. Often one or more springs are catched and afterwards collected in a so called inspection-chamber, The inspection-chamber is necessary to control the water quality and quantity, if the storage-tank is far away. Besides the small basin in this chamber functions also as a small sedimentation tank for coarse sand.

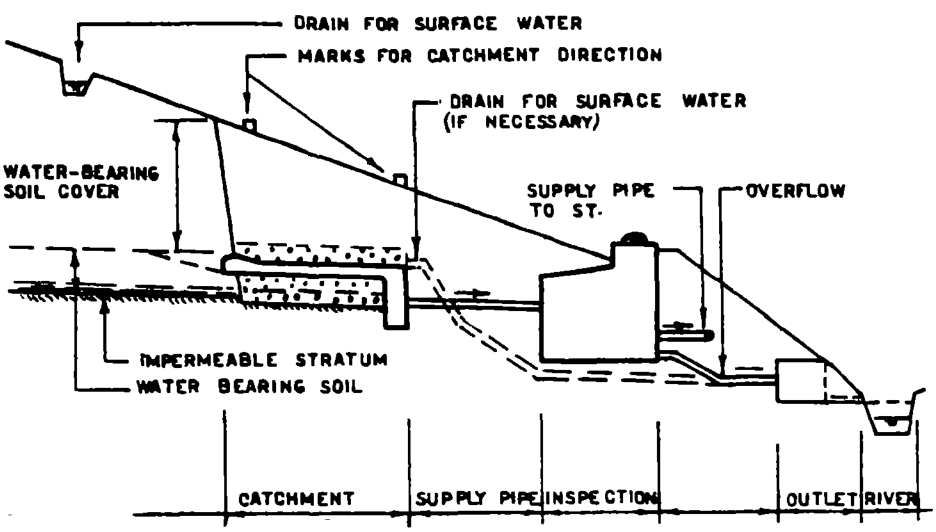
No further treatment is necessary.

The storage-tank is the second structure. From there the water is transported to the public taps, fountains, washbasins and sometimes a showerhouse.

The third possibility is a river catchment. The water is diversed by a small dam. Succesively the water pases a sedimentation-tank (6-8 hours), a rapid sand filter and a slow sand filter before it is stored in a storage-tank. From there it is distributed in the same way as in the case of a spring catchment.

Wastewater from the tap etc. is drained in a soakaway or freely into the field depending on the field situation.

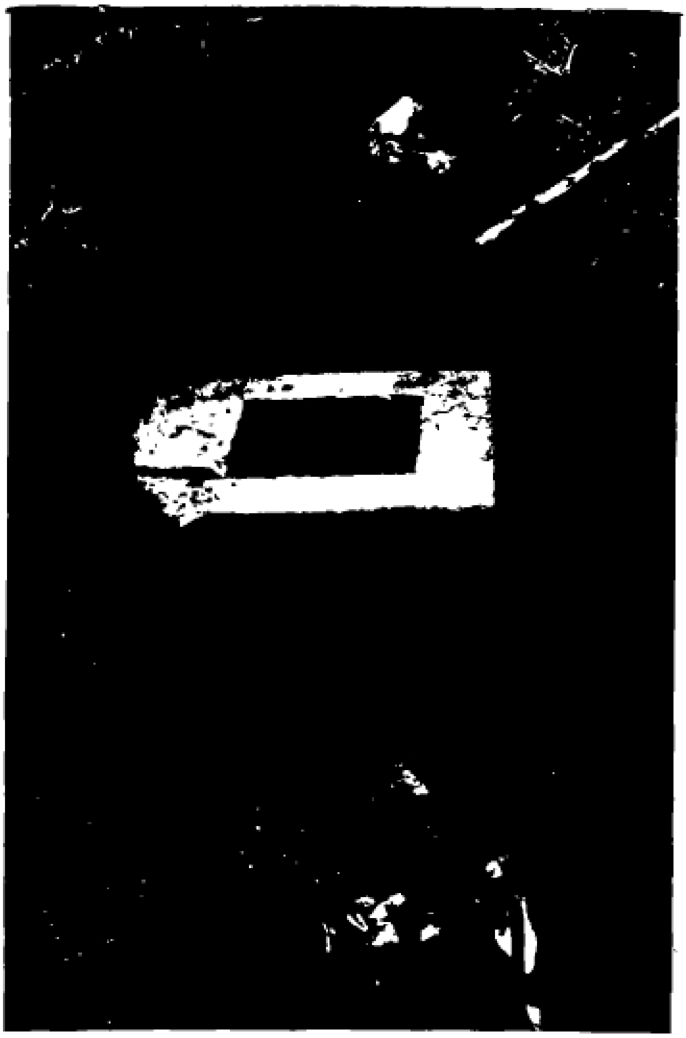
dam under ground (under construction)
inflow



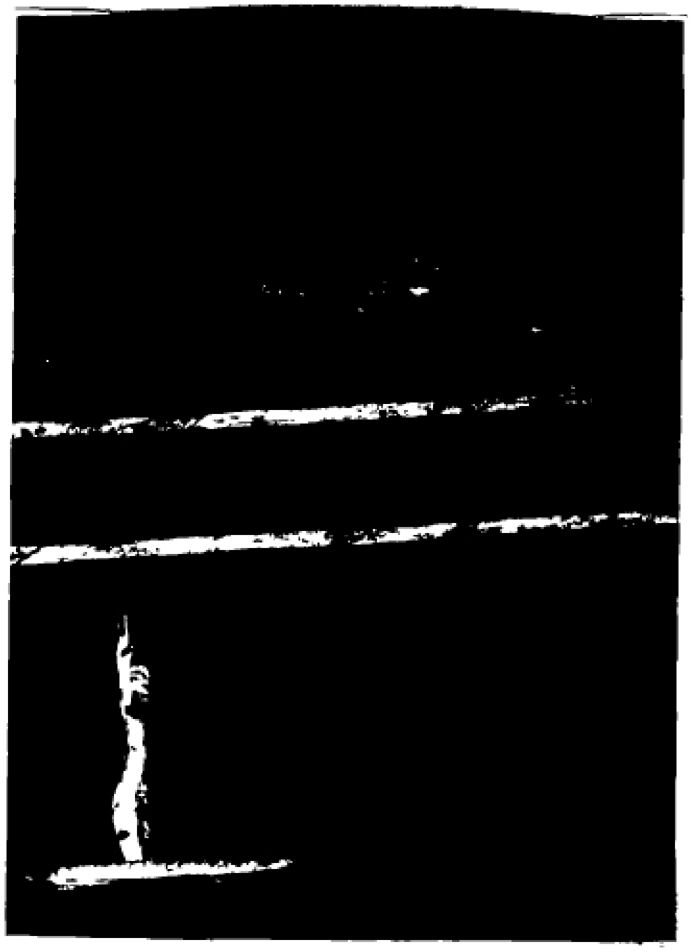
springcatchment - lay out

2

SPRINGCATCHMENT

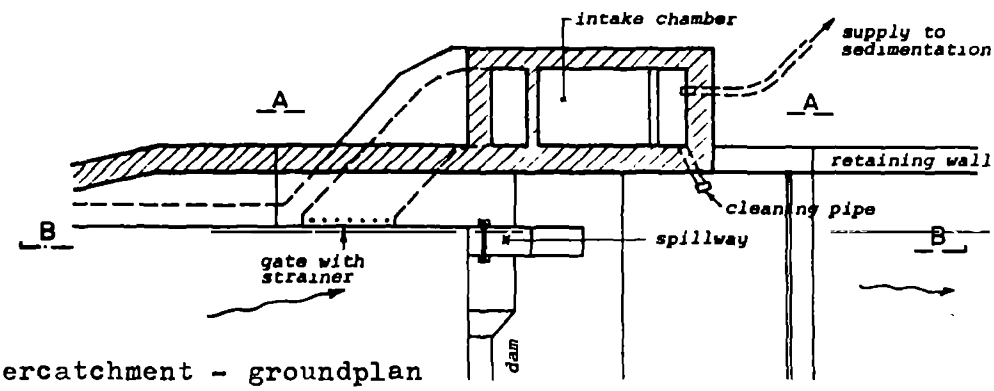


dam under ground
outflow
(under construction)



inspection chamber
(under construction)

dam and intake-chamber



rivercatchment - groundplan

The SATA policy leads to a preference for water supplies by gravity depending on a spring. A good spring gives a constant flow of water of a constant, good quality throughout the year. Apart from a very short sedimentation to remove the coarse sand, no treatment is necessary.

In many cases for one village the water of more springs is used or a combination of springs and streams is made.

CHAPTER III BIOLOGICAL WATER QUALITY AND THE RELATIVE IMPACT ON HEALTH

3.1 Introduction

Water is a rather elementary thing and fill many functions in human life. It is used for drinking, cooking, washing (clothes, dishes etc.) and cleaning the own body. Sometimes it is used for productive purposes like agriculture or industries.
As a means of transport water removes waste out of the village, but on the other side it can also bring in waste from other sources.
Finally the presence of water not only influences the activities of people, but also attracts animals and insects either harmful or not.

3.2 Water related diseases and quality

In the case of many tropical diseases the transmission mechanism has something to do with water, either the quality, accessibility, use or presence of water in general.
One can divide these waterrelated diseases in four groups (Feachem, 1977; Cairncross, 1980):
1. Waterborne diseases A truly waterborne disease is one which is transmitted when the pathogen (bacterium, virus, larva etc.) is in the water which is drunk by a person or animal, which then become infected. The faeces of this person or animal will be infective again.
Potentially waterborne diseases include the classical infections, notably cholera and thyphoid, but also a wide range of other diseases, such as infectious hepatitis and bacillary disentry, These diseases depend on waterquality.
However all these so called faecal-oral diseases can also be transmitted by any other route than water which permits infective faeces of one person to reach the mouth of another such as by contaminated food or inadequate cleanliness (see also waterwashed diseases). This is the reason that, while many waterborne feacal-oral diseases cannot be controlled without watersupplies of good quality, the provision of such supplies alone will not control them because the faecal-oral disease can also be primarily non-waterborne.
2. Waterwashed diseases These infections may be reduced following improvements in domestic and personal cleanliness. These often hinge upon increased availability of water and the use for hygienic purposes of increased volumes of water. So quality is relatively unimportant for these purposes like washing body and washing clothes.

Three main types of waterwashed diseases can be distinguished. First again the faecal-oral diseases that are previously mentioned under waterborne diseases. Recent investigations have shown that many diarrhoeal diseases decrease with the availability of water and with the volume of water used but not appear to be strongly associated with the microbiological quality of the water. In other words in many situations faecal-oral diseases seem to be primarily waterwashed and secondly d pending on water quality.
The second type of waterwashed infections includes infeotions of the body-surface, of the skin and the eyes.
The third type of waterwashed infections comprises infections carried by insect parasitic on the body-surface, especially lice, which may be reduced by improving personal hygiene and therefore reducing the probability of the infestation of body and clothes.
3. Waterbased diseases A waterbased mechanism is one in which the pathogen spends a part of its life in an intermediate aquatic host (or hosts). All these diseases are due to infection by parasitic worms which depends on aquatic intermediate hosts to complete their life cycle. Eggs enter the water through faeces but larvae can only develop by means of a host. In one case the larvae enter the human body again through the skin (schistosomiasis). In other cases the organisms enter the body through the mouth (f.i. guinea worm).
4. Waterrelated Insect Vector Mechanisms These waterrelated diseases like malaria, yellow fever and river blindness are spread by insects which either breed in water or bite near water. Here concentration on environmental characteristics is important like standpipes surroundings and pipe joints which may create puddles and marshy ground which are likely to favour mosquito breeding. Second, arrangements for water storage in houses need inspection to see that thanks and small earthenware and other containers are proofed against and free from insect breeding.

Subjoined Table gives a summary of the mentioned mechanisms and shows in which direction preventive strategies have to be looked for.

Table I The four mechanisms of waterrelated disease transmission and the preventive strategies appropriate to each mechanism

Transmission mechanism		Preventive strategy
1. Waterborne:	water contaminated with human or animal faeces	-improve water quality -prevent casual use of other unimproved sources
2. Waterwashed:	lack of hygiene because of shortage of water	-improve water quantity -improve water accessibility -improve hygiene
3. Waterbased:	parasites are living in the water where they need an intermediate aquatic host	-decrease need for water contact -control snail populations (schistosomiasis) -improve quality
4. Waterrelated: insect vectors	water is breeding place for harmful insects	-improve surface water management -destroy breeding sites of insects -decrease need to visit breeding sites -remove need for water storage in the home or improve design of storage vessels

As the table is showing an improved water supply can influence these mechanisms directly by easy accessibility or improved availibility and good water quality. Better accessible water at shorter distance of the house will increase the quantity of the water that is used. This can create a more hygienic situation in and around the house, the quarter, the market etc..

On the other side these effects will not work if the supply is not used, because it was not designed in agreement with the wishes of the population or if the supply is not functioning very well because it was not well constructed, operated or maintained. Sometimes watersupplies create large puddles in the village, because of lack of drainage.

Besides recent surveys show that improved village water supplies often have favourable effects on health only if at the same time programmes on health education are implemented which are geared towards improved personal and domestic and village hygiene. Also the problem of waste disposal, pitlatrines, domestic washplaces and husbandry has to be encountered.

Summarizing the technical requirements from the point of health for a water supply system can be discribed in terms of quality of the water, quantity of the water, environmental characteristics and the reliability of the water supply system.
Quality refers to the choice of the source, protection of the source and catchment area from human and animal activities, treatment, storage and use in the houses and operation and maintenance.
Quantity refers to the choice of the source, design of the system and operation and maintenance.
Environmental characteristics refer to good drainage, but also to measures to create a better hygienic situation. These measures can include the building of domestic pitlatrines, washplaces, public pitlatrines (for instance on marketplaces).
Reliability refers to design, construction and operation and maintenance.
In the same time health education is very important.

In practice of course it is impossible to meet all these requirements at the same time. Priorities have to be made.
Just for this reason it is astonishing that generally the improvement of the water quality has this priority in many projects. Rather easily a treatmentstation is planned although it is costly, it needs always intricate operation and maintenance (in spite of appropriate technology) and quality is as has been seen only a small factor in relation to water-related diseases. Besides a treatmentstation is very vulnerable. If it is not well maintained, it will loose its treatmentfunction very soon. And maintenance is often a problem in Third World countries.
The designer needs some data on which the decision can be made if treatment at that moment is necessary or not. At what limit of the quality it becomes unwarrantable to supply the water untreated.
For this you can use several standards which will be explained now.

3.3 Quality testing: indicator organisms

From the health point of view the most important characteristic of good water is the absence of pathogenic organisms. Both the principle of the test on pathogenic organisms as the use of the standards need more explanation.
The most meant organisms as bacteries, virusses, protozoën and worms originate from faeces of infected people or animals. If this faeces enters the water, the water will be contaminated and can function as a vector in the cyclus of these pathogenic organisms. If this water enters through the mouth of a human being, some disease of the waterborne or waterbased groups may be the result. Especially children who did not built up some immunity, form a vulnerable group. (Again has to be emphasized that for the mayority of these diseases water is not the only possible vector. Any other route which permits feacal material of one person to reach the mouth of another can transmit these diseas, see also chapter 3.3).
It is not practical to test water for all the pathogenic organisms. Instead water is tested for bacteries which are excreted in large amounts by animals and humans and whose presence is indicative of faecal pollution. These organisms, which are not pathogenic themselves, are indicator bacteries whose presence in the water can easily be investigated.
Three important indicator bacteries are distinguished:

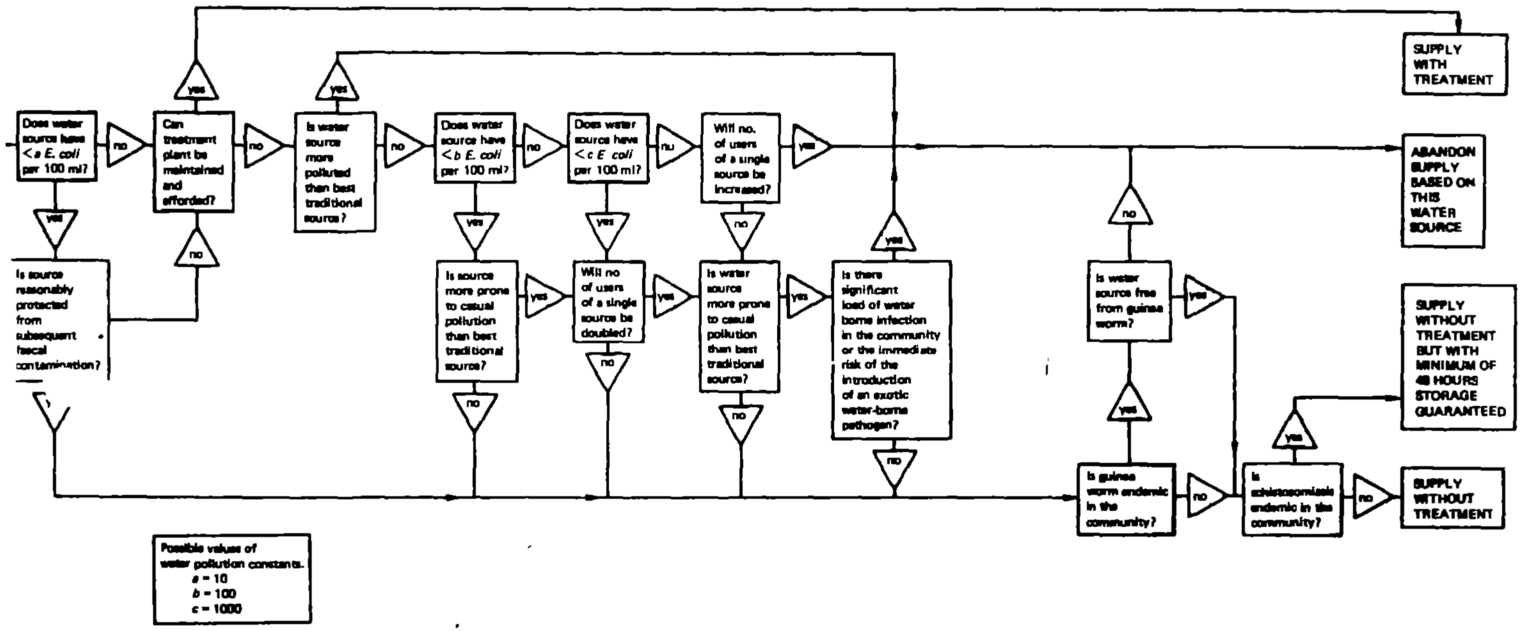
- total coliform
- faecal coliform
- faecal strptococci

The faecal coliform test must be taken as the most sensitive and specific indicator of faecal pollution at present available. Faecal coliliform and faecal streptococci are of specific faecal origin, while total coliform also include some bacteries which are living free in nature.

3.4 Quality appreciation: standards to judge a source

The WHO guideline is based on more than one sample per year:

- arithmatic mean less than 10 total coliform/100 ml
- never more than 20 total coliform/100 ml in two consecutive samples or in more than 10% of the samples



An algorithm of the decision to treat, not to treat, or to abandon a particular water source

algorithm of Feachem

As stated before the WHO standard is too high for the NW-Province, because this standard should lead to the condemnation of nearly all the water supplies or to the introduction of costly water treatmentstations with neglect of the positive effects for the health because of the improved quantity of the water that is supplied to the village.
A better approach is given by Feachem (Feachem, 1977). He argues that in the situation of developing countries usually it will not be possible to contemplate the perfect water supply, but only an improved one.
Improvements in water quantity and availibility will effect that component of the faecal-oral diseases load which is not waterborne and will also reduce the prevalence of infections in the water-washed category.
Improvements in water quality will affect the truly waterborne component of the faecal-oral load and also guinea worm and schistosomiasis, where these are found. To improve the water quality to high standards generally one or more (extra) treatments are required.
To facilitate the decision which improvement has to be made Feachem designed an algorithm (fig. I) which guides the planner or designer to on of four eventual decisions: to supply with treatment, to supply without treatment, to supply without treatment but with 48 hours storage timein the system, or to abandon a supply based upon the specified water source.
He gives the following scheme:

less than 10 E-coli/100 ml*	supply untreated unless guinea worm or schistosomiasis is endemic, then 48 hours storage is required because all infective cacariae* will die within 48 hours
between 10 - 100 E-coli/100 ml	good quality, treat if possible, if not supply untreated
between 100 - 1000 E-coli/100 ml	poor quality, treat if possible, if not supply untreated or abandon depending on various other factors
more than 1000 E-coli/100 ml	grossly polluted, treat if possible, if not abandon or supply untreated depending on various other factors

So Feachem suggests the possibility of providing piped water supplies of known low quality in certain circumstances.

*E-coli=Escherechia-coli=Faecal coli

*cacaria= aquatic host

A mayor objection to the deliberate piping of poor quality water is that one may thereby increase the risk of a waterborne epidemic. However this risk must be related to the existing risk of a waterborne epidemic.
The risk of a waterborne epidemic is only increased if the piped water is of poorer quality than the existing water sources, if the piped water has greater chance of casual faecal pollution than existing sources or if the new supply will serve more (in the range 100 -1000 E-coli/100 ml: two times more) people than any one existing water source.
If no extra risk is created by piping dirty water to the community this piped water may well have an effect on the many infections related to waterquantity and so be beneficial.
So in the algorithm the quality and the proneness to casual pollution of the new source and the number of future beneficiaries have been taken into account in relation to the existing sources.
Finally the algorithm ensures that a community known to have a high load of waterborne diseases is considered differently from one which hase little waterborne diseases .
The algorithm is based on E-coli (faecal coli). According to Faechem the use of a total coliform index would be quite inappropriate as a measure of the health hazard of untreated waters in hot climates.
If it is possible to collect data on the biological quality (E-coli) and besides on the proneness to casual pollution of existing and new sources, as well as on their present and expected number of users and if something can be known about the "load" of waterborne diseases in the village, this algorithm can be very useful to make priorities in a combined water supply - health program. Especially for villages on remote places and with low income a realistic planning can be made, based on several years, with an optimal impact on health. Besides governmental and foreign money can be spread over more projects. But also to judge existing watersupplies the Feachem approach is much more realistic than the WHO standards in these situations.
I think a realistic standard for acceptable piped water in the NW Province based on total coliform is:

untreated water	less than 250 total coli/100 ml
treated water (after slow sand filtration)	less than 25 total coli/100 ml

CHAPTER IV RESEARCH PROGRAMME: WATER QUALITY TESTS

4.1 Quality parameters, measurements, standards

4.1.1. Introduction

The research had three objectives:

1) to test the quality of the water delivered by SATA/CD built water supplies to get an indication of the quality of the delivered water, from wells, springs (waterpoints) and streams.
2) to test the changes in water quality within one system to get f.i. an indication if a treatmentstation is working or not or if pollution enters the system somewhere.
3) to get experience with the test equipment in the field.

For the description of and the experience with the test equipment you are directed to Annex II.
Objectives 1) and 2) are worked out in this chapter

Quality is related not to one, but to several characteristics of the water. One characteristic has been discussed already in chapter III, namely that water can be the carrier for disease organisms. In the same way poisonous organic and anorganic matter (f.i. chemicals for agriculture) can be dissolved in the water. Both can be harmful to health if the water is used for domestic purposes. These poisonous matter was not expected in the NW-Province.
Other characteristics are the aesthetics (turbidity, colour), taste, odour and the aggressivity to materials.
Because of practical reasons the tests within this research programme were restricted to:

1) turbidity
2) pH (aggressivity)
3) iron (colour)
4) total coli (indicator for disease organisms)

Generally speaking the quality of drinking water is good when it is "wholesome and palatable". This term is described as follows by Fair e.a. (Fair, 1966): "To be wholesome, water must be free from disease organisms, poisonous substances and exoessive amounts of miniral and organic matter. To be palatable, it must be significantly free from colour, turbidity, taste and odour and well aerated." Finely it must be harmless to the materials used for the buildings and transport-system of the watersupply.
These terms like "free from", "significantly free from" and "harmless to" have been translated to standards or guidelines for certain parameters which are related to the mentioned characteristics.
If these parameters does not meet these standards or guidelines, the water has to be treated or has to be condemed. But of course there is a lot discussion on these criteria. Conventional engineering wisdom has held that all water supplies, except those using high quality ground-water sources, should be treated to improve their quality and that such treatments will pay substantial dividents in improved health.
It has further been held that treatment should bring water quality standards up to those recommended by the World Health Organization (WHO) appropriate international water quality standards neglecting the consequences for the cost and the operation and maintenance for instance (Feachem, 1977).
A lot of things can be said about these statements. In chapter III f.i. it was already explained that improved water quality alone has only a very limited effect on health. Other important factors that effect health are water quantity and environmental characteristics especially in relation to hygiene. Besides the WHO guidelines (especially for bacteriological quality) are far too stringent for hot climates and would wrongly lead to the condemnation of the vast majority of existing watersupplies in low income countries (Feachem, 1977) or to the intro-duction in an early stage of an costly treatmentstation which introduces new operational and maintenance problems.
Because other parameters are generally of less importance than the bacteriological parameter, it is not necessary to use the standards very strictly in situations where money is very scarce.

Each parameter that has been tested will be discussed no below. Apart from a short description and the standard also the possible variation and the relevant testplaces will be mentioned.

4.1.2 Turbidity

Turbidity is a straightforward measurement for the suspended matter in the water, This turbidity is caused by clay particals, organic matter, algae, etc. that float in the water. Limits to turbidity of drinking-water are established because turbid water is unpleasant and high turbidity can possible cause gastrointestinal irritation. Besides in the case of any treatment filter high turbidity will make often cleaning of these filters necessary.

Variation:
Increase of turbidity is expected for streams in the rainy season. Espcially after heavy rains the turbidity increases considerably, but normally decreases to the former value after some hours, depending on the catchmentarea. This increase will be greater if farming continues in the catchment, because this will cause erosion. In the dry season and in spring catchments the turbidity is expected to be constant.

Tests and standard:
The raw water and the water from the tap were tested. Also the efficiency of the sedimentation, rapid sand filtration and slow sand filtration were tested because these treatments are supposed to diminish the turbidity.
All turbidity tests were done once in the dry season and once in the transition period between dry and rainy season when heavy rains occur, especially in the afternoon. Because the tests were done in the morning the raw water could be considered of rather constant turbidity for a treatment period (6-8 hours) So the turbidity before and after the treatment could be compared.

Turbidity was measured by a nephelometer in Nephelometric Turbidity Units (NTU, see annex II).
The WHO standard for drinking-water is :

highest desireble level	5 NTU
highest permissible level	25 NTU

This standard is realistic for the NW Province.

4.1.3 pH

If the water is too acid it can cause corrosion of building material and in addition a higher turbidity at the lower taps.
pH is the negative logarithm of the concentration of H^+-ions.
Water is concidered acid if the H^+-concentration exceeds the OH^--concentration and alkaline if the OH^--concentration exceeds the H^+-concentration. Contains the water an equal amount of both the water is called neutral.

Variations:
No large variations are expected.

Tests and standards:
Because the pH is expected to be rather constant through the year it was measured only once in the dry season.
The raw water and the water from the taps were tested. Also the efficiency of the rapid sand filter and the slow sand filter were tested because these treatments are supposed to make the water more neutral.

The WHO guideline for drinking water is:

highest desireble level	7,0 - 8,5
highest permissible level	6,5 - 9,2

In the case of soft water there is more danger for corrosion if the pH is low. Therefore it is advisable to use in the case of soft water the highest desireble level as highest permissible level.

4.1.4 Iron

Too much Iron in the water colours the water, causes turbidity and the growth of iron-bacteries and gives the water a bad taste.

Variations:
No large variations are expected.

Tests and standard:
Because the iron content is expected to be rather constant through the year it was measured only once in the dry season.
The raw water and the water from the tap were tested. Also the efficiency of the rapid sand filter and slow sand filter were tested because these treatments are supposed to diminish the iron content.

The WHO guideline for drinking-water is:

highest desireble level	0,3 mg/liter
highest permissible level	1,0 mg/liter

This standard is realistic for the NW Province.

4.1.5 Total coli

As stated in chapter 33 the feacal coliform test is the most sensitive and specific indicator of feacal pollution at present available. Feacal coliform and feacal streptococci are of specific feacal origin, while total coliform is a group of coliforms which also include some bacteries which are living free in nature.
Because of the fact that only equipment for a total coliform test was available this test was done. More details you can find in Annex II.

Variation:
Increase of faecal contamination is expected in the transition period between the dry and rainy season especially in streams. Heavy rains cause surface runoff. Just after the dry season the whole nature is cleaned by the first rains. This surface runoff water is not filtered by the soil before it enters the streams. Later in the rainy season less pollution will occur and in the dry season the water will be rather clean.

Tests and standards:
The raw water and the water from the tap were tested. Also the efficiency of the slow sand filter was tested because this treatment is supposed to improve the biological quality. Besides it was checked if the sedimentation, the rapid sand filtration and the storage had any positive effect on the biological quality. Finally in some houses the stored water was tested.
The tests were done only once in the transition period between dry and rainy season. Although the value of one test is very limited, it gives some very general information about the biological quality of the raw and the supplied water, as well as about the functioning of the treatments.
For the discussion about the standards you are directed to chapter
I think a realistic guideline for acceptable piped water in the NW Province based on Total Coliform is:

untreated water	less than 250 total coli/100 ml
treated water (after slow sand filtration)	less than 25 total coli/100 ml

4.2 Work programme

All projects were visited two times. During the first visit in the dry season (April and May) the turbidity, iron and pH were tested. Because no big variation was expected for iron and pH these tests were not repeated during the second visit in the transition period between the dry and the rainy season. Because the first rains (June) cause an increase in turbidity, this test was repeated. Also in this period the possible feacal contamination reaches it highest point. Because the equipment for the Total Coliform Test had not yet arrived in May, this test was only done during the second visit.

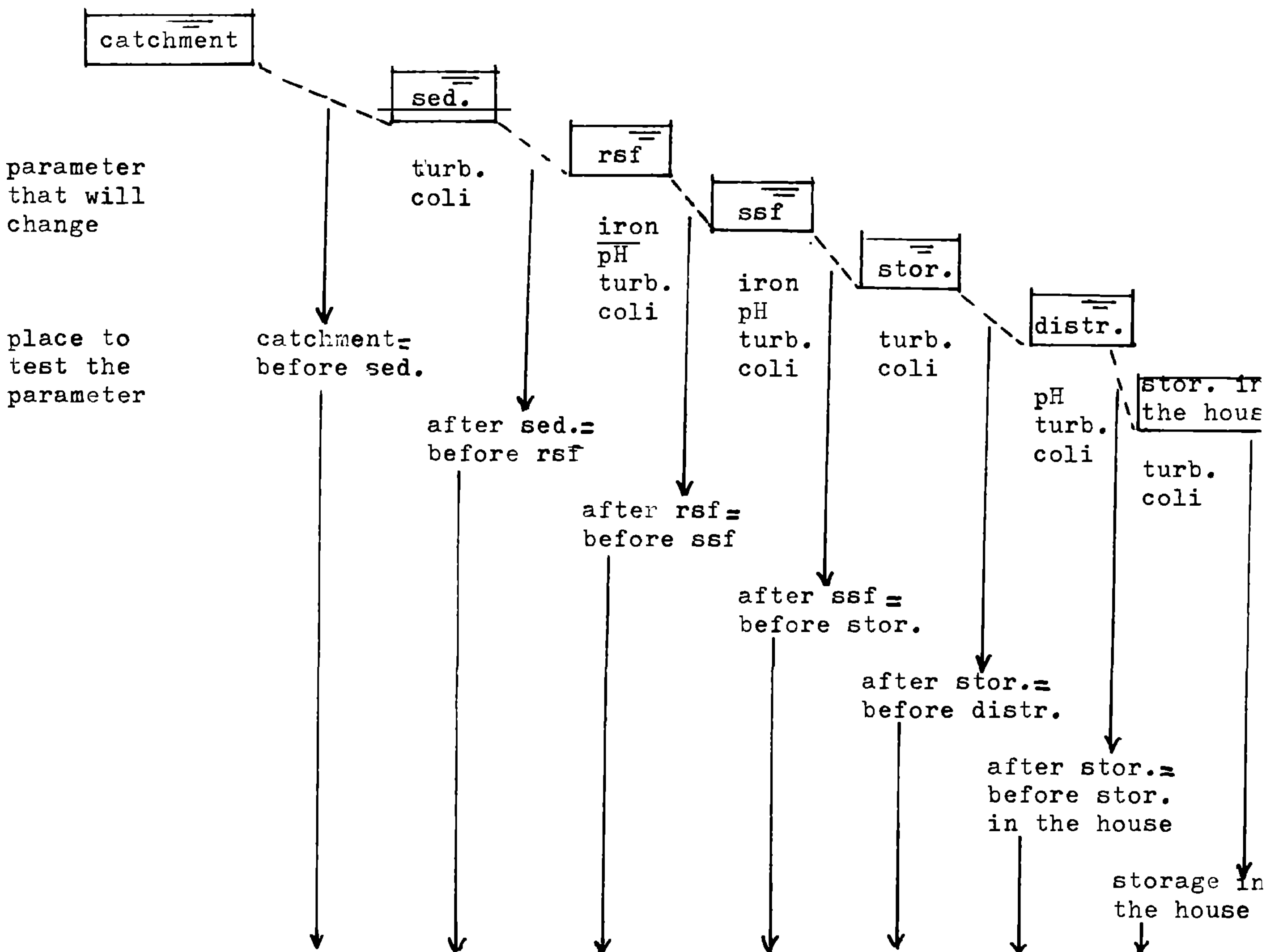
It will be clear that one or two tests at one point is the absolute minimum, and can give only a very provisional indication of the water quality.

To get some insight in the changes within a water supply system at relevant points within the system test were done.

The scheme below gives a summary of the sample points.

Summary of sample points

The summary of the sample points is given in the scheme below:



universal name for each place	catchment	after sed.	after rsf	after ssf	after stor.	last tap	storage in the hou
parameters to be tested in the dry season	iron pH turb.	turb.	iron pH turb.	iron pH turb.	(turb.)	pH turb.	turb.
parameters to be tested in the rainy season	turb. coli	turb. coli	turb. coli	turb. coli	(turb.) coli	turb. coli	turb. coli

4.3 Results

4.3.1 Introduction

The results of the water quality tests have been summarized in the tables below. The following categories are used:

-streams: these streams supply or will supply the raw water for piped water supply

-springs: these springs supply or will supply the raw water for piped water supply

-waterpoints: piped water is supplied only on the place where it is catched from a spring, the tested water is considered as coming directly from the spring

-well: self evident

-traditional stream: these streams traditionally supply the water for untreated use. It is also used if the piped water supply has broken down

-supplied water: this is water as it is tapped from the water supply system;in the case of total coliform the sample was taken after storage, in the case of turbidity and pH the sample was taken after treatment

-effect sedimentation: only the sedimentation in the case of a streamcatchment has been taken into consideration

-effect rsf: self evident

-effect ssf: self evident

-effect storage: self evident

-effect distribution: meant is the effect of the storage and the transport through the pipes to the tap; samples were taken before storage and at the "last" (=most remote) tap.

-effect transport to and storage in the house: meant is the effect of the transport from the tap to the house and the storage in the house; samples were taken from the tap and from the buckets in some houses depending on that tap.

A general review of the test results for each project is found in Annex I . The tables below give for each quality parameter the minimum value, maximum value and the number of observations. Besides in the cases of turbidity, pH and iron the arithmatic mean

and in the case of total coli the geometric mean[1] has been calculated. The results are also presented in a visible form in figures and . The line gives the range from minimum and maximum value and the cross refers to the arithmatic or geometric mean. For turbidity and total coli logarithmetic scales are used. Finally as a supplementary indication for the effects on the quality parameters by treatment, storage and distribution, it was also appointed if the value "before"-value "after" was positive or negative.

The values on effects are only based on projects where measurements were done "before" and "after". The aim of this presentation is only to give a first impression of the water quality and of the effects of treatment, storage, distribution etc. It is based on one tests for each point (two for turbidity). Because of the limited number of observations statistical processing was avoided. But nevertheless the figures give a first indication.

4.3.2. Turbidity

Table 5 gives the values for turbidity (see next page). Generally the values for turbidity are low. The effect of the rainy season is not proved by these figures. Anyway none of the values above surpasses the highest permissible level of the WHO Standard,but in reality in the rainy season high turbidities (>100) will occur suddenly as shows the table below. Turbidity can fluctuate a lot after heavy rain.

Table 4 Turbidity measurements in Acha Tugi

	day I		day II			day III			day IV
time	11.00	15.15	9.00	12.00	18.00	8.30	11.45	16.00	10.00
turbidity intake	32.5	19.0	12.0	19.0	>100	20	24	78	16.5

But the supplied water shows low turbidity. The maximum of 12 NTU is caused by corrosion in the storage tank because of acid water.

The positive effect of sedimentation is not convincing. The difference in values "before" and "after" seems more the result of fluctuation of the turbidity of the raw water (the water at the

[1] The geometric mean is calculated by taking the mean of the logaritm of the individual concentrations and then taking the antilogaritm of that value

Table 5 Turbidity values of tests in the dry season and in transition period between dry and rainy season (between brackets)

	minimum		arith. mean		maximum		number of observatio	
streams	1.3	(1.6)	3.3	(5.7)	10	(18)	11	(13)
springs	0.13	(0.22)	1.1	(0.66)	13	(2.5)	17	(16)
waterpoints	0.62	(0.43)	1.8	(1.1)	4.2	(2.0)	4	(4)
traditional streams	0.73	(0.80)	1.8	(5.5)	2.9	(14)	3	(4)
supplied water		(0.25)		(1.8)		(12)		(22)
effect sedimentation								
before	1.3	(1.7)	3.7	(5.2)	10	(18)	9	(9)
after	1.3	(1.5)	3.0	(4.2)	12	(20)	9	(9)
before > after							6	(5)
before < after							3	(4)
effect rsf								
before	1.5	(1.8)	1.8	(2.1)	2.0	(2.4)	2	(2)
after	0.70	(0.65)	1.4	(0.77)	2.0	(3.9)	2	(2)
before > after		--					1	(2)
before < after							1	(0)
effect ssf								
before	1.3	(0.9)	5.1	(6.5)	12	(20)	6	(6)
after	0.60	(0.26)	2.1	(2.1)	7.5	(6.4)	6	(6)
before > after							5	(6)
before < after							1	(0)
effect distribution								
before	0.15	(0.22)	2.1	(1.3)	7.5	(6.4)	10	(9)
after	0.30	(0.28)	2.2	(2.7)	6.9	(12)	10	(9)
before > after							7	(2)
before < after							3	(7)
effect transport and storage								
before		(0.25)		(0.27)		(0.30)		(3)
after		(0.50)		(1.3)		(2.2)		(3)
before > after								(0)
before < after								(3)

end of the tank entered six hours before) than of the sedimantation process itself. Probably the time settlement of the particles that cause the turbidity is longer than the detentior time of the sedimentation tank.
The figures don't prove that high turbidities (>50 NTU) are not reduced considerably. It is very possible that in the case of high turbidities after heavy rains the water contains a lot of coarse sand that will settle very quickly.
Anyway it seems good to analyse the matter that causes turbidity. In the case of much coarse material a sedimentation tank is supposed to be very useful. In the case of much fine material a sedimentation tank of six to eight hours is of no use at all.

The positive effect of the slow sand filter is very clear and stronger than the effect of the rapid sand filter. This strenthens the idea that this turbidity is caused by fine material.

The effect of the distribution is only clear in the case of Mbibgo where the turbidity increases from 0.35 NTU in the storage tank to 12 NTU at the "latest" tap, probably because of corrosion of the storage tank. (see Annex I)

Transport to the house and storage in a bucket seem to increase the turbidity, probably because of dust. The highest value, 2.2 NTU, was found in an uncovered bucket. The other buckets were covered.

4.3.3. PH

The following table gives the values of the pH.

Table 6 PH-values

	minimum	arithmethic mean	maximum	number of observations
streams	6.1	6.6	7.1	13
springs	5.8	6.2	6.7	25
waterpoints	6.0	6.2	6.4	4
supplied water	5.8	6.5	7.5	34
effect rsf before	6.4	6.6	6.8	2
after	6.5	6.6	6.8	2
effect ssf before	6.3	6.7	7.1	6
after	6.2	6.7	7.0	6
effect distribution				
before	5.9	6.5	7.0	13
after	6.3	6.8	7.5	13

Generally the pH values are low, especially if the water will prove to be soft (but the test on carbonate hardness has not been done). Fifteen out of twenty-seven have a pH value below 6.5 and twenty-three out of twenty-seven have a pH value below 7.0. Especially springs are acid.

The figures don't prove that the filters bring the pH more to a neutral point.

The positive effect of the distribution seems the highest of all effects.

Nevertheless only once corrosion of cement was established (Mbibgo, pH=5.9) and once corrosion of iron pipes was established (Bifang, pH=6.3). Prevention will be difficult. In many new spring-projects now expensive PVC pipes are used. Cement is protected by painting the walls. The disadvantage of painting is that, if the paint blisters, the water will be contaminated. The best solution is good maintenance.

4.3.4. Iron

The following table gives the iron values.

Table 7 Iron values

	minimum	arithmethic mean	maximum	number of observations
streams	0.35	0.71	1.4	13
springs	0.10	0.36	0.85	25
waterpoints	0.40	0.54	0.87	4
supplied water	0.0	0.41	1.1	35
effect rsf				
before	0.40	0.48	0.56	2
after	0.24	0.27	0.30	2
before > after				2
before < after				0
effect ssf				
before	0.30	0.83	1.4	6
after	0.30	0.49	1.1	6
before > after				5
before < after				1

Generally the iron content of supplied water is between the highest desirable and highest permissible level of the WHO Standard. Only once the iron content of supplied water is more than 1 mg/l. The iron content of streams is higher than of springs. Both filters (rsf and ssf) seem to diminish the iron content considerably.

It can be concluded that high iron contents don't occur in the NW Province.

4.3.5. Total coli

The following table contains the values for total coli.

Table 8 Values for total coli [2]

	minimum	geom. mean	maximum	number of observations
streams	280	1210	5400	10
springs	0	29	700	17
waterpoints	0	48	380	4
well		22		1
traditional streams	440	1845	3400	4
supplied water	0	40	880	22
effect sedimentation				
before	34	732	5400	7
after	24	660	5200	7
before > after				6
before < after				1
effect rsf				
before	2200	3382	5200	2
after	4	16	64	2
before > after				2
before < after				0
effect ssf				
before	64	323	1600	4
after	6	12	70	4
before > after				3
before < after				1
effect storage				
before	4	80	600	10 [3]
after	28	126	880	9 [3]
before > after				3
before < after				6
effect distribution				
after storage	24	43	180	7
last tap	4	17	230	7
after stor. > last tap				6
after stor. < last tap				1
effect transport to and storage in the houses				
tap		24		2
storage house	380	473	590	2
tap > storage house				0
tap < storage house				2

[2] The values are rounded off upwards

[3] Guzang has one storage tank for two catchments

As is explained in Annex II mistakes in counts can easily be introduced if the volume of the filtered sample is too large and too much colonies appear on the filter. If besides the sample volume is much less than 100 ml, the mistake is multiplied, because the result of the test has to be expressed in coli/100 ml. So it is good to keep in mind that a positive or negative mistake of 10% is reasonable for these values. Although it is hoped that bigger mistakes are not made, they can not be eliminated, because only one test was done.

It is very clear that streams are more contaminated than springs or waterpoints. It is very clear too that generally the supplied water is of better quality than stream water. Nevertheless the total coli value surpasses six out of twenty-two times the standard of untreated water as discussed in Chapter (Bafut (school), Kai Tonomba, Kai New Town, Oshum, Tojei, Bafut (waterpoint IV) and Acha Tugi (docter's hill). Also the water in two other places shows some contamination (Tinkom and Abegum).
Probably the contamination is caused by improtected catchments or by the fact that the source is feeded by surface water that enters the ground at short distance from the place where the water is catched from the ground.
For the rest these figures are no reason for panic, although improvements of the situation are always welcome.
The water stored in the houses seemes to be contaminated at the same level, although it was clean when it was collected at the tap.

Sedimentation of six to eight hours seems to diminish the bacteriological content a little bit. But for a considerable effect a storage of several days till weeks is necessary (Wagner and Lanoix, 1959).

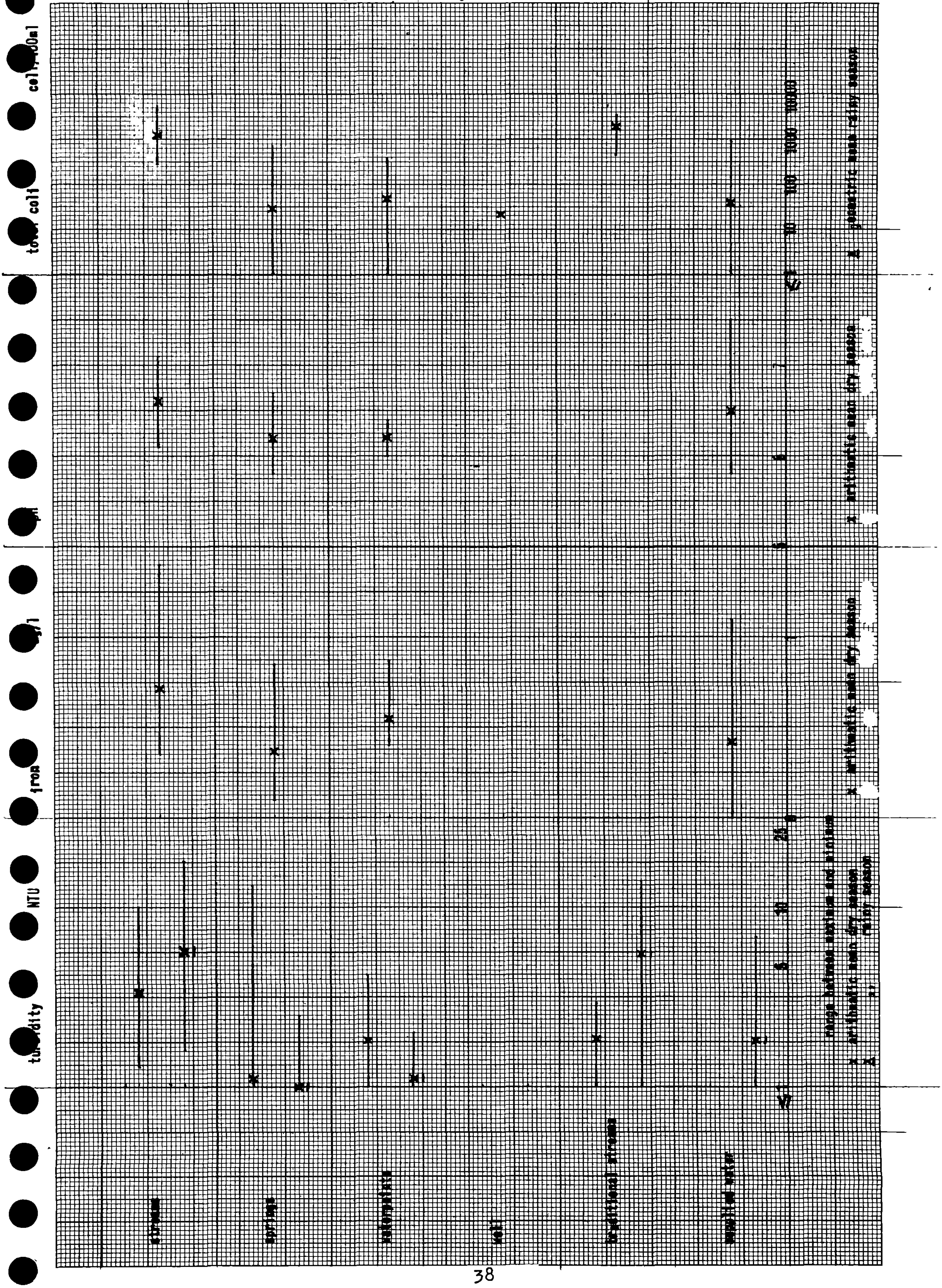
The slow sand filter reduces the bacteriological content as could be expected. Only the ssf of Ndu supplied water with more than 500 coliforms, probably because the filter was too dirty. The filters of Ngondzen, Guzang Awom , Guzang Akwa and Ndop were just cleaned.

Surprising is the enormous reduction of coliforms in the rapid sand filter. Generally the reduction in rapid sand filters is limited, because the filter rate is too fast to develop biological

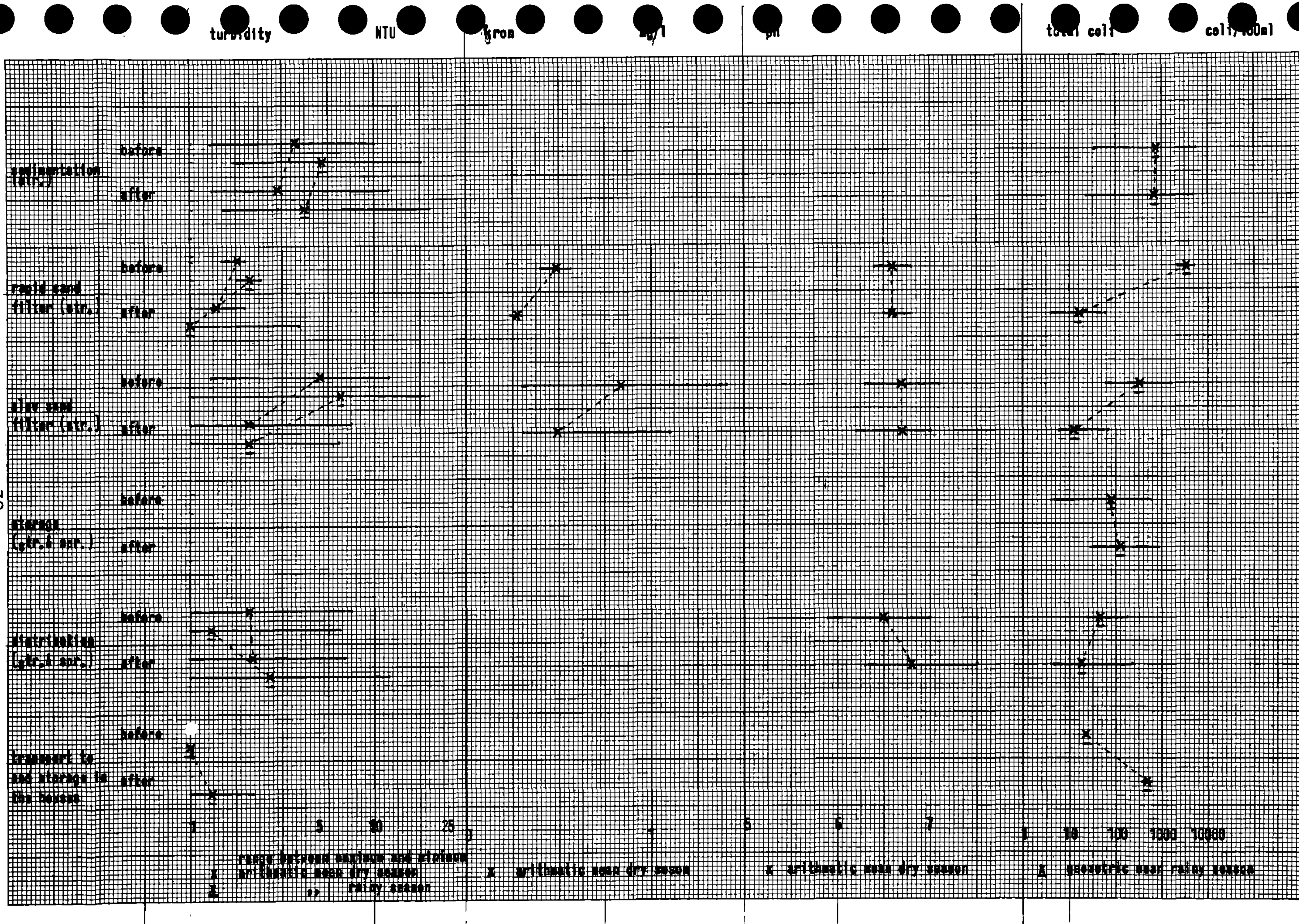
activity in the filter. Nevertheless these two rapid sand filters are functioning as slow sand filters. The rezson is diskussed in the section on technical aspects (6.2).

Storage seems to increase rather than to diminish the bacteriological content.
On the contrary distribution seems to diminish the coliforms.

Schematical summary of quality tests results



Schematical summary of quality tests results



CHAPTER V WATERQUALITY IMPROVEMENT METHODS IN THE NW PROVINCE

5.1 Introduction

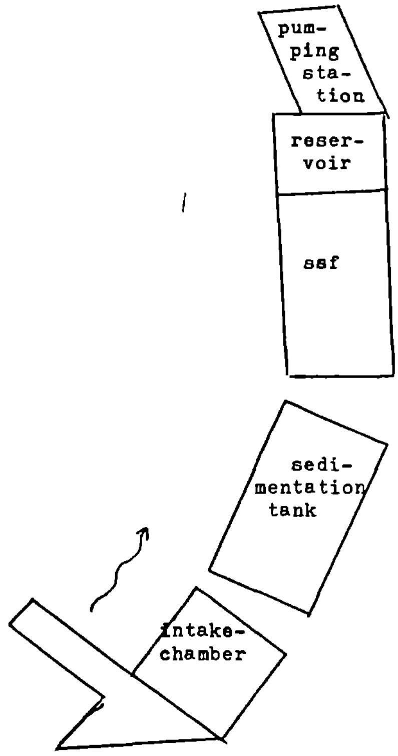
In chapter III it was made clear that the installation of a treatment station has to be a decision related to many other factors than only water qualitie. Knowing this the principles of the treatment methods in the NW Province can be discussed more in detail: How do they improve the quality, what operation, maintenance and management do they need.

Treatments which are practised in the NW Province (generally only in the case of streamcatchments) are sedimentation, rapid sand filter, slow sand filter.

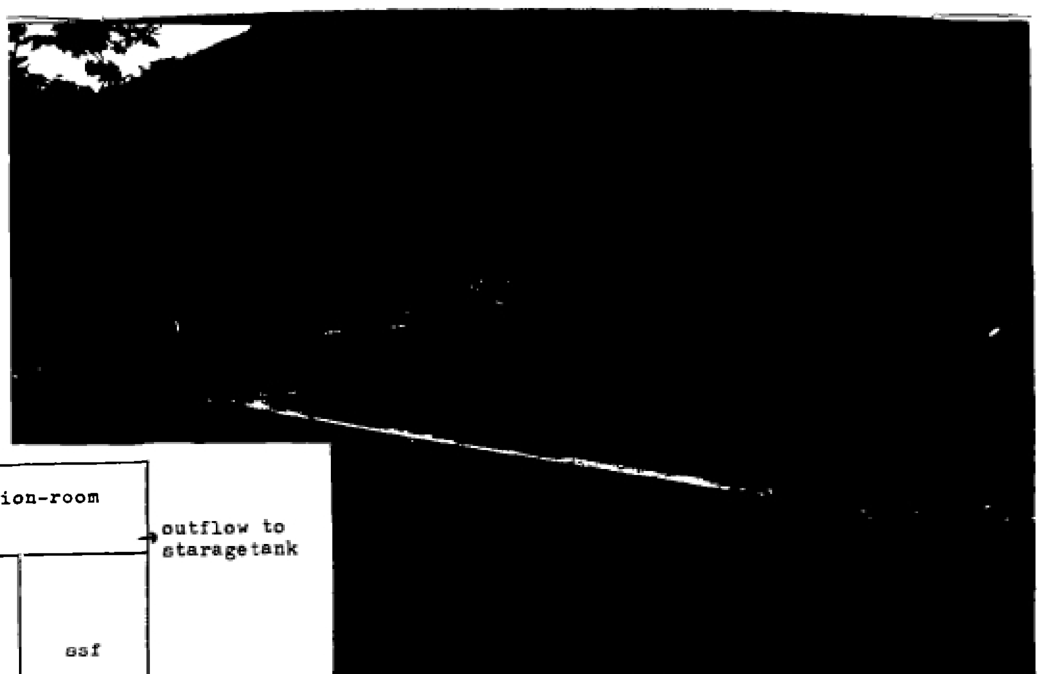
5.2 Sedimentation

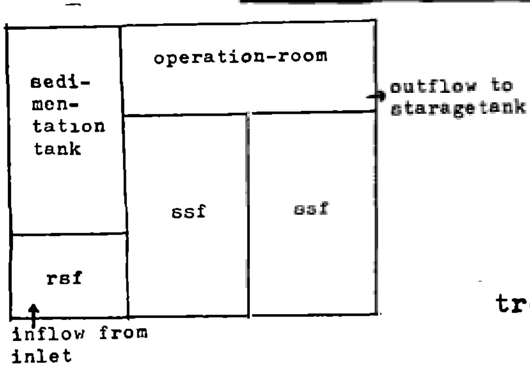
Sedimentation is the settling and removal of suspended particles that takes place when water stands still in or flow slowly through a basin. Due to the low velocity of flow, turbulence will generally be absent and particles having a mass density higher than that of water will be allowed to settle. These particles will ultimately be deposited on the bottom of the tank forming a sludge layer.
To stimulate the sedimentation special sedimentation basins are built.
Apart from the physical cleaning in a basin also the feacal micro-organisms will die. In that case the water has to be stored for 6-30 days. But in the NW Province the detension time is limited to 6-8 hours, so no biological improvement can be expected.
To design a good sedimentation-tank is rather complicated. It is important to achieve uniform flow of the water over the crossection. So the efficiency of the sedimentation process depends largely on the designs of the inlet and outlet. Agitation of settled solids

TREATMENTSTATION



treatmentstation - construction ± 1965





treatmentstation - construction ± 1980

sand-washing place

from the sludge zone has to be prevented. Hence certain relations between length, width and depth are needed. Besides the temperature within the tank has to be as uniform as possible.
The design of a sedimentation-tank is controlled by the following equations:

$$s_0 = \frac{H}{T} \qquad T = \frac{B\ L\ H}{Q} \qquad s_0 = \frac{Q}{B\ L}$$

s_0	= settling velocity	m/hr
T	= detention time	hr
Q	= flow rate	m^3/hr
H	= depth of tank	m
B	= width of tank	m
L	= length of tank	m

If the detension time for SATA built sedimentation-tanks is 6-8 hours and the depth is 2.50 meter, it will be clear that only particles with a settling velocity of more than 0.3 meter/hour (silt) will settle.
The efficiency of the tank depends largely on the content of silt and fine clay in the water. If the water contains a lot of particles that settle more slowly than 0.3 meter/hour, the tank will not be very useful.
The content of the water has to be tested before the design is made.

The main operation and maintenance activities are:
- to control, to drain and to clean the tank every fourteen days
- to keep clean the installations, overflow, ventholes and drains
- to cut the grass around the entrances
- to grease doors, locks valves etc.

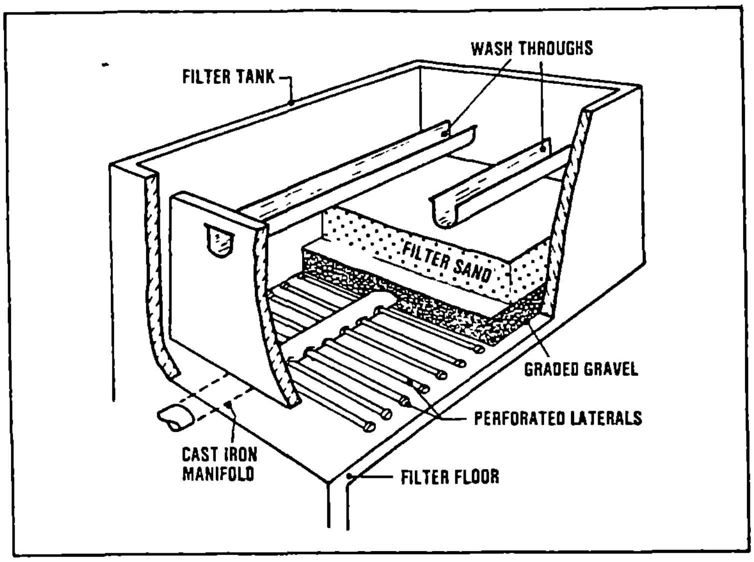
Twice a year a general check up of the building has to be made for damages such as cracks or leakages. Minor repairs have to be done without delay to prevent waste of water and contamination.

5.3 Rapid sand filter (rsf)

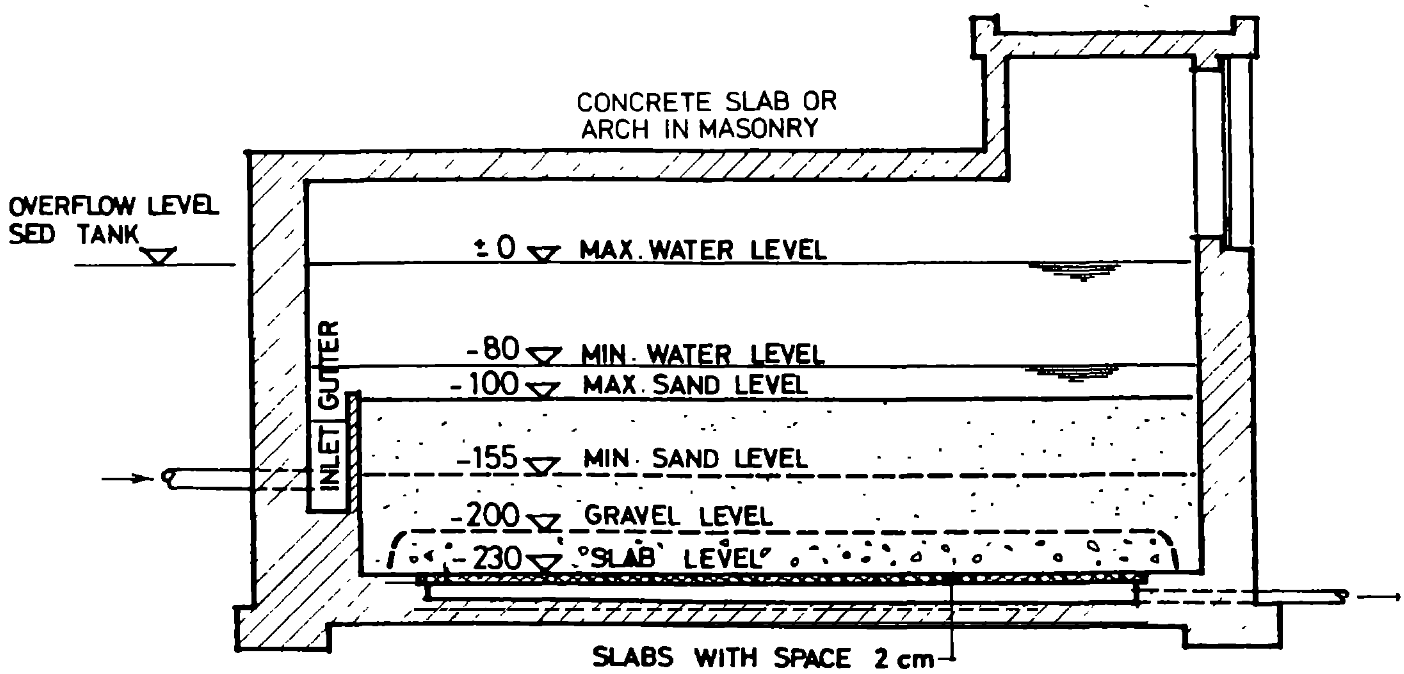
The rapid filtration is effected by a filter medium, commonly sand with an effective grain size in the range of 0.4 - 1.2 mm, that permits a filtration rate between 5 to 15 m^3/m^2/hour (Hofkes, 1981). The relative high filtrationrate of the water causes elektro kinetic charges in the filterbed apart from the natural existing charges.

That is why adsorption of ions and small particles is very important in the case of a rapid sand filter (rsf). So the main function of a rsf is reducing the turbidity and apart from that the removal of iron and magnese (only after aeration). The removal of pathogenic organisms is much less important.
Also because of the high rate and the coarseness of the filter-material, the impurities contained in the raw water will penetrate deep into the filterbed.
For the design of a rapid sand filter three parameters need to be selected: the grain size of the filter-material, the thickness of the filterbed, the pressure difference of the supernatant water. These parameters determine the rate of filtration.
In the NW Province rectangular basins are built. The basin is covered to avoid the entrance of dirt, animals and direct sunlight. The filter consists of one layer of course sand and one layer of gravel. The system of underdrains consists of concrete slabs laid with open joints on concrete ribs.

Because the dirt enters the filter deeply the filter has to be washed totally each time. To remove only the top layer is not sufficient. The cleaning is normally effected by backwashing. This is a high-rate-flow back through the filterbed whereby it expands and is scoured. The backwash water carries the deposited cloggings out of the filter. The cleaning of a rsf with backwashing can be carried out quickly (about half an hour is needed) and can done as frequently as required, if necessary every day. A backwash facility consists of a system of perforated pipes on the   of the filter. The water passes upwards through the filterbed under pressure (5 meter water pressure). If the raw water is rather clean and sufficient head is available, the unfiltered water can be used and a pump can be avoided. But if it is necessary to use the filtered water or in the case of insufficient head a pump and generally also a reservoir have to be installed to meet the necessary pressure and backwash rate. The table below gives some characteristical backwash rates.



rapid sand filter (with backwashing)



slow sand filter - lay out

Table 2 Typical backwash rates at 20°C giving about 20% expansion

average grain size of filter sand in mm	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
backwash rate in m^3/m^2/hour	14	20	26	33	40	48	56	64	73

In the case of a rsf of 4 m^2 and a backwash rate of 20, a volume of at least 4x20x0.5=40 m^3/day is withdrawn from the (filtered) volume of the water, if the rsf is backwashed each day for half an hour. (To compare: the consumption of a village of 2000 inhabitants is more or less 2000x0.05=100 m^3/day)
Perhaps these are reasons that in the NW Province no backwashing was provided. The sand was washed by hand. Besides each time only the top layer of the filter was scraped away however according to the character of a rsf it is necessary to wash the whole sandbed each time.

As a matter of course the absence of a backwash facility hampered the operation and maintenance a lot.
Apart from the washing of the sand, the operation and maintenance requirements are the same as for a sedimentation-tank.

5.4. Slow sand filter (ssf)
The slow filtration is effected by a filterbed of fine sand with an effective grain size in the range of 0.15-0.35 mm, that permits a filtration rate uptill 0.1-0.3 m/hour.
If the filter is well maintained the water quality improves considerably during the passage of the water as can be seen in the the next table (van Dijk, 1978, page 24).

Table 3 Performance of slow sand filters

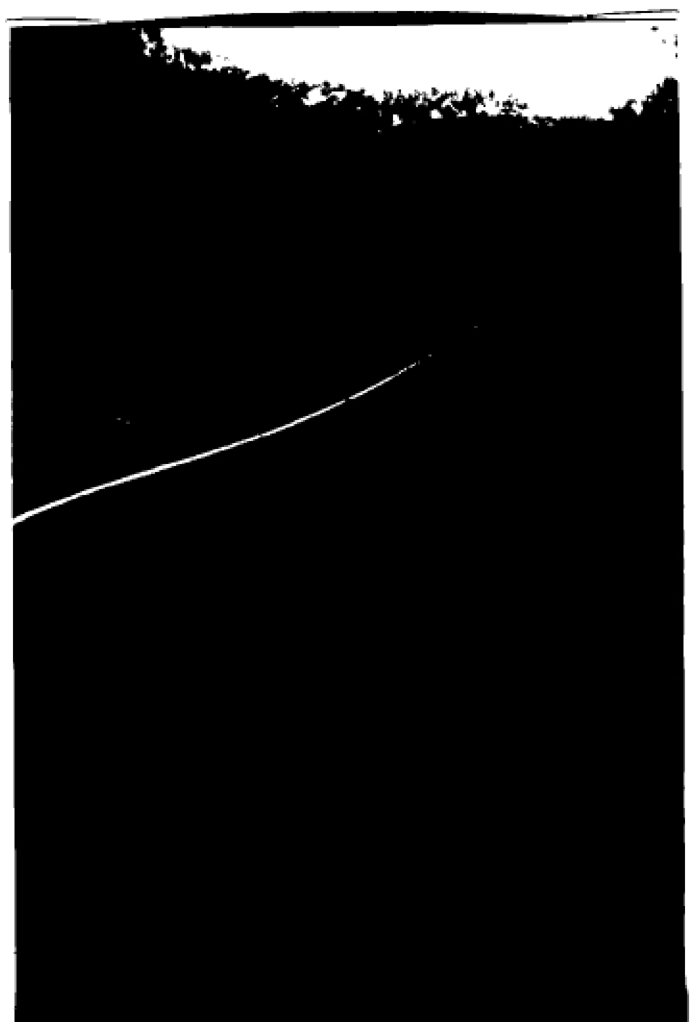
parameter	purification effect
organic matter	slow sand filters produce a clear effluent, virtually free from organic matter
bacteria	between 99% and 99.99% of pathogenic bacteria may be removed; cercariae of schistosoma, cyst and ova are removed to an ever higher degree. E.Coli are reduced by 99-99.9%
viruses	in a mature slow sand filter, viruses are virtually completely removed
turbidity	raw water turbidities of 100-200 NTU can be tolerated for a few days only; a turbidity more than 50 NTU is acceptable for a few weeks; preferable the raw water turbidity should be less than 10 NTU; for a properly designed and operated filter the effluent turbidity will be less than 1 NTU.

The removal of impurities from the raw water is brought about by a combination of different pr cesses such as sedimentation, adsorption, straining and, most important, biochemical and microbial actions.
The purification processes start in the supernatant raw water.
Then straining removes those suspended particals that are too large to pass through the pores of the filterbed. This takes place almost exclusively at the surface of the filter where the impurities are retained in the top layer, this in contrast with the rsf. This will improve the straining effect, but also increases the resistance against the downward waterflow. So periodically the accumulated impurities have to be removed by scraping off the top layer. Several scrapings can be done before the minimum thichness of the filterbed is reached. Then the whole filterbed has to be removed and washed.
To lengthen the period between two scrapings, it is important that the raw water has already a rather low turbidity before it enters the filter.
The most important purification effect of a ssf is the removal of pathogenic micro-organisms. The sedimentated and adsorped organic matter in the upper centimeters of the filter form a good environment for intensive biological activity. This upper layer is called the Schmutz-decke. Here non-pathogenic bacteria and other micro-organisms from the raw water are absorbed. They multiply using the organic matter and the pathogenic feacal organisms as food. Although their activity concentrates itself in the Schmutz-decke, it extends to

0.6 m downwards in the filter. The organic matter is decomposed and at greater depth the products of the biological processes are further removed by fysical processes (adsorption) and chemical action (oxidation).
It should be stressed that the biological activities need time to establish themselves. Hence after each scraping a ripening period of two days and after washing and replacement of the sand a period of one week is required.
It is also better that although the resistance of the filter increases, the filtertration rate remains as constant as possible in favour of the biological activity. This can be effected by controlling the outflow with a valve that can be adjusted periodically. The increasing resistance of the filterbed can be compensated by opening the valve.

In the NW Province rectangular basins are built. The basin is covered by a roof of alumunium (old projects) or by an arch of masonry (new projects) to avoid the entrance of dirt, animals and direct sunlight. Daylight, necessary for the growth of algae can enter through windows. The filter consists of one layer of fine sand and one layer of gravel. The system of underdrains consists of concrete slabs laid with open joints on concrete ribs. The outflow is not controlled by a valve that can be adjusted by hand, but by a ball-valve controlled by for instance the water level in the storage-tank.
Generally two or three filters are built to make it possible to clean one without stopping the supply.
Apart from the washing of the sand of the filter, the operation and maintenance requirements are the same as for a sedimentation tank and a rsf.

storagetank under construction - communitywork



storagetank under construction - foundation

CHAPTER VI REMARKS ON TECHNICAL ASPECTS, OPERATION, MAINTENANCE,AND MANAGEMENT

6.1 Introduction

To satisfy the want to get some insight into the technical design and the practice of operation and maintenance it was decided to visit each (completed) pjoject during at least half a day. or one day. The first visit was brought in April or May during the dry season. During that time the system was visited from catchment till tap together with the caretaker. Turbidity, iron and pH were tested and some questions were asked to the caretaker in an informal way. Besides the system was inspected on breakdowns and technical problems.

Some villages, like Guzang, Widikum and Acha Tugi were visited for some days.

The 'half to one day" visits gave general information on the state of maintenance and gave a superficial impression of the causes of negligent maintenance. The "more days" visits gave the possibility for a profound inspection of the system and a more profound impression of the causes of negligent maintenance. Besides it was possible to give some attention to environmental characteristics as standing water, pitlatrines, waste disposal etc.

Nearly all projects were visited quickly a second time during the transition period between the dry and the rainy season in June or July. Then the bacteriological test was done and the turbidity test was repeated. Besides it was possible to check the observations of the first visit. If a filter should be washed or a pipeline should be dugged out or surroundings of a tap should be cleaned or the payment of a caretaker should be arranged, it was possible to check what was done and what not and also why not.

In Widikum area (Abegum and Tinkom) the investigator participated in the start of a new project on repairs of an old system before an extension was planned. The relevant places were visited with villagers. A report was made for the villagers and for CD-SATA in which the different alternatives for a new project were discussed. Finally a meeting was organized for some sixty representatives of the villagers and a CD-SATA technician. On this meeting a projectcommittee and a caretaker were choosen and the

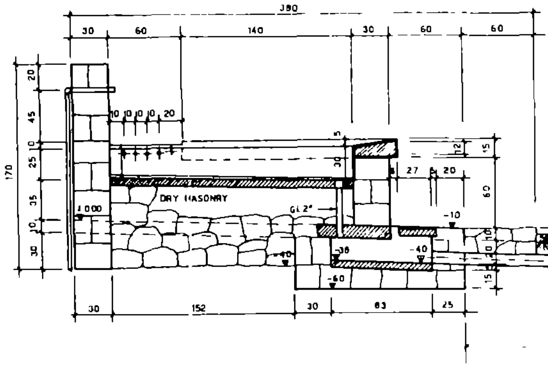
principal decision was made to repair the existing system first, before extensions will be made.
A similar participation in the cleaning of a slow sand filter and in small repairs in Acha Tugi was not realized, because of misunderstandings and time problems.

It seems good at this moment to give definitions of operation, maintenance and management.
Operation refers to all activities and resources that are necessary to make the water supply doing what it is intended to do if every part of the system is in good condition. So operation includes regulating of valves, weirs etc. and provision of labour, energy and raw material (water). In the case of a well designed water supply by gravity where no pumps or difficult treatments are used, the operation problems are very limited. Generally this is the case in the NW Province.
Maintenance is different. Any system, so also a well built water supply system, suffers from dirt and wear and tear. Unless special efforts are made to maintain or to restore the capacity of the system, the ability to do the work will be reduced or parts of the system will break down.
The periodic inspection, replacements or repairs of damaged or worn parts, lubrication, removal of unwanted internal and external waste-build up or vegetation, protective painting etc. are what is meant by maintenance.
Principally two types of maintenance can be distinguished:
1) preventive maintenance: is conducted to prevent or to minimize break downs, or other obstructions that threaten the functioning
2) corrective maintenance: is done after a break down has occured

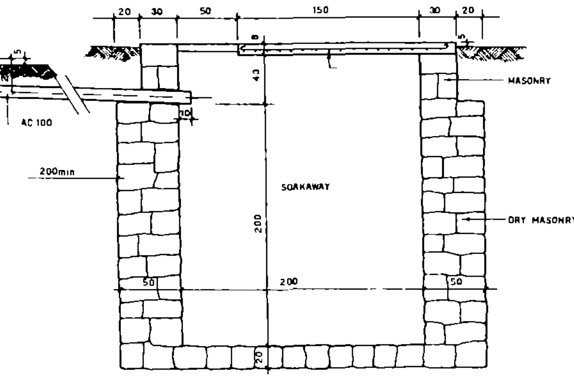
In some types of water program and social setting corrective maintenance will be less costly than preventive maintenance but it will also involve more and lengthier interruptions of service. Finding the right balance between the two types is an important aspect of maintenance strategy and planning. (Cairncross, 1980)
In the NW Province there was no strategy for preventive maintenance. The main maintenance activities are: inspection of the catchment and the catchmentarea, cleaning of the filters, cleaning of the

sedimentationtank, cleaning of the storagetank, cleaning of the surroundings of buildings and taps, inspection of the drainage facilities, lubrication, repairs on taps, pipes and masonry.
In the NW Province the absence of pumps and of dificult treatment processes avoid a lot of operation and maintenance problems. Except from the cleaning of the filters no big technical problems exist.
On the other side from the management point of view there are two big problems. Management refers to the organizational and financial part of the functioning of a water supply.

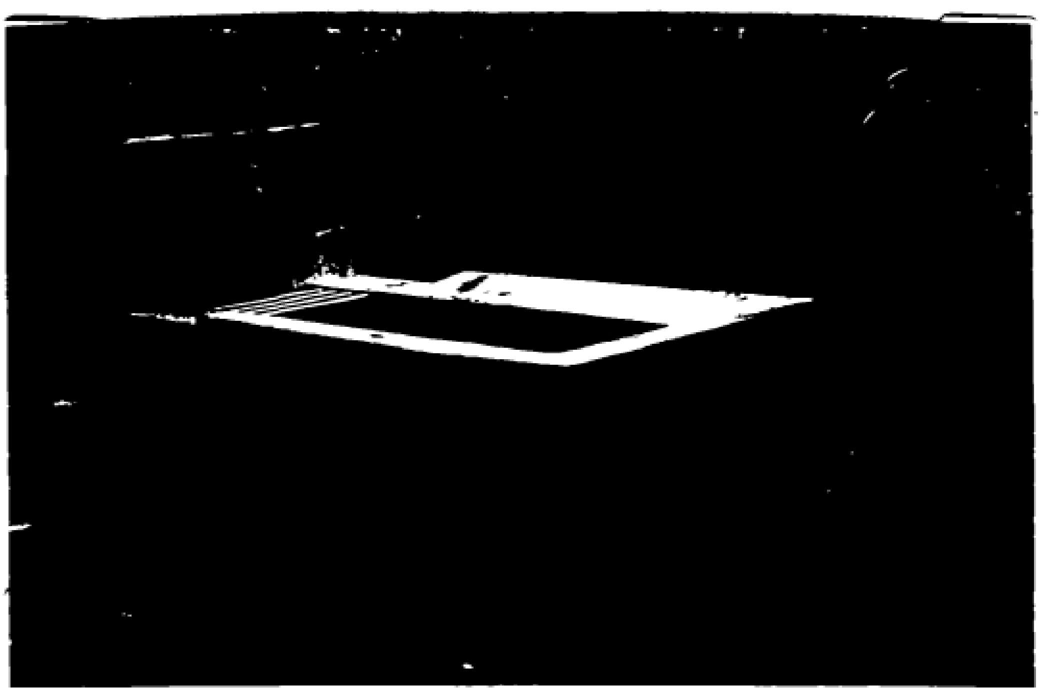
In the first place arrangements on the distribution of the responsibilities for operation and maintenance are not always clear. The first responsible person is the caretaker, a villager who has been trained during the construction works and attended a caretakers-course of several weeks. He is controlled by the village maintenance committee (the former project committee).
For larger problems the caretaker is depending on the technical service of CD-SATA, but he has to apply for it himselve. For some work, like cleaning of the filters, he is depending on the help of the community. The community work has to be organized by the maintenance committee, for the caretaker himselve has no power.
Users of a tap are obliged to keep the tap in a proper condition, otherwise the tap will be blocked by the caretaker.
In the second place finance is a problem. Although it is the task of the community to pay the caretaker and to collect money for spareparts, this is often neglected and this is the main cause of negligent maintenance. The caretaker is dismotivated and spareparts cannot be bought.
For that matter in many new projects the caretaker has except of a toolbox a small store with some spareparts to his disposal. But of course this is not a sollution of the problem in future.
In some projects the caretaker is taken over by the gevernment or the rural council.



washbasin - lay out

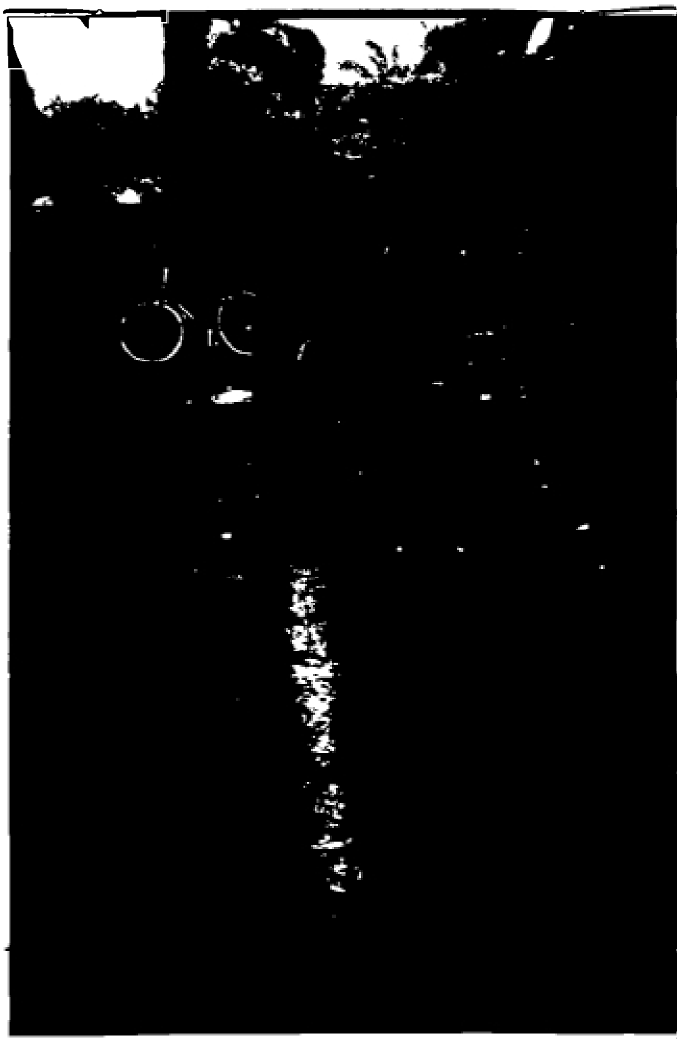


soak away - lay out



washbasin with drainage problems

PUBLIC WASHBASIN



wild drainage - no soak away .....

..... and result - standing water

public tap under construstion

public tap before connection

6.2 Technical aspects

Generally the streams gave a lot of water. Instead spring catchments sometimes dried up at the end of the dry season. Dry springs were found in Tadu and Sehn. In both cases the water supply was depending on more than one spring.

The most important observation concern the treatment facilities, such as sedimentationtank, rapid sand filter (rsf) and slow sand filter (ssf).

The ssf is the main filter and the rsf and sedimentationtank are pre-treatments to diminish the turbidity of the water before it enters the ssf. Because of this pre-treatment a period of ssf-operation between two washings will be longer.

Generally a sedimentationtank and a ssf are constructed in all stream catchment supplies. In the new projects also one or more rsf's are installed. In Kai Benjok the sedimenationtank and rsf were built but the ssf was not yet constructed, although the system was already in use.

According to the qualitytests on the effect of the ssf's it can be concluded that this type of treatment is functioning very well, providing that it was cleaned periodically. Probably this was not the case in Ndu.

Generally the sand was removed and washed by hand by the community. In newer projects a provision was made to wash the removed sand with untreated water under such a pressure that the sand was expanded and the dirt could be washed out.

Instead of the ssf the functioning of the rsf and the sedimentationtank is doubtful.

First the rsf had no backwash facility. The sand had to be removed and washed by hand in the same way as in the case of the ssf: a very time-consuming activity. But the difference is that it is characteristic for a rsf that it is washed more regularly than the ssf and that each time all the sand has to be removed and washed instead of only a small layer. It will be clear that in practice the rsf's are not washed often enough and it was observed that both rsf's that were in function were blocked very soonly after some rain. The filtration rate decreased, resulting in shortage of water because the capacity of a rsf is designed on a high filtration rate. The low rate makes biological activity possible. That is why according to the quality tests both rsf's reduce the numbers of coliforms enormously although primarily it is the function of a ssf. So the rsf functions as a ssf, with a far too small capacity for the situation.

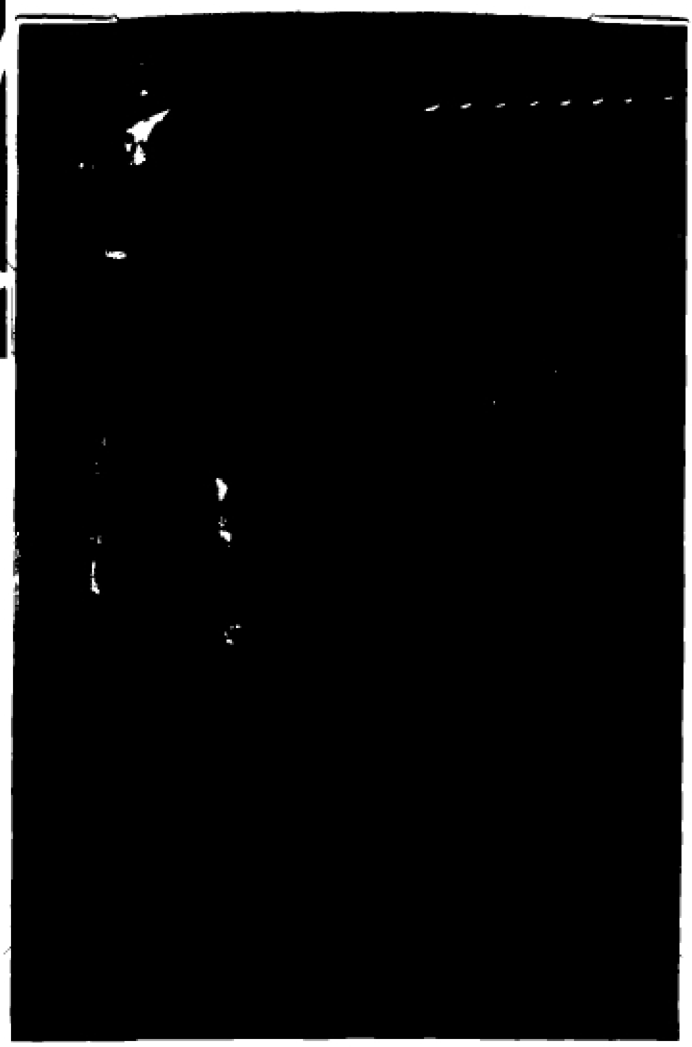
Also according to the quality tests it is doubtful if the size of the sedimentationtank is appropriate to remove the specific load of coarse and fine material that causes the turbidity of the raw water of a stream.
In the case of springs it is known that the small turbidity is caused by coarse sand which can be sedimentated within ten minutes. A sedimentationtank in the case of a stream catchment also has the pretention to sedimentate the finer particles. But it is doubtful if the extension of the detention time to 6-8 hours will meet this aim. Perhaps also here a small sedimentation basin could be sufficient, if it is followed by a rsf with a back-wash facility.

Generally springcatchments were not provided with a drain for surface water. In Nyen such a drain was built afterwards, because it was clear that surface water that entered the soil caused a lot of sand in the catched water direct after rain.
Also a remark about the drainage from taps and washplaces can be made. The water was drained in a soak-away or was drained freely to a lower place.
If coarse materials can enter the soak-away or people use the soak-away to dump their waste the soak-away will block soonly. Sometimes you found clothes and slippers in the soak-pit. If the soak-pit is too deep then (more than 1.50m) it becomes very difficult to clean it again, because it is impossible to enter it.
In the case of free flow to a lower place good trenches has to be provided and maintained. Two times a waterpoint was seen without an adequate drainage (Bafut school, Whem). It was also seen that drained water collected at a lower place.

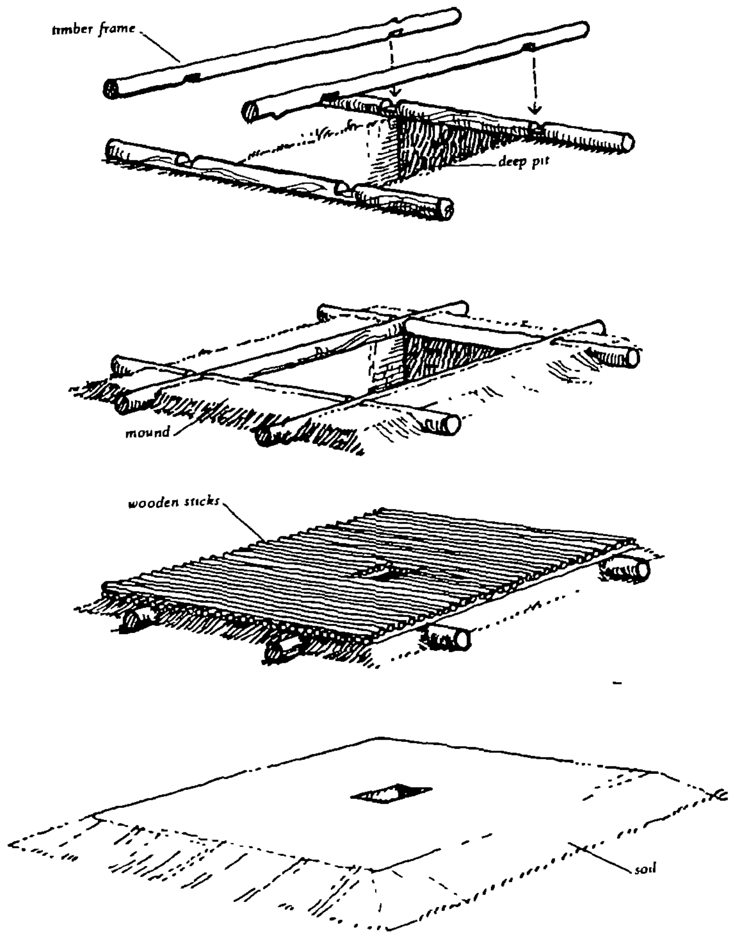
Concerning the taps and washplaces on a marketplace can be said that at least one tap must be planned in the surroundings of future public pit-latrines, so that people can wash their hands after using the pit-latrine and before handling the marketfood again. Perhaps even the construction of adequate public pit-latrines on marketplaces can be a part of the watersupply project, because this provision is expected to have a considerable impact on health.
Showerhouses have to be avoided (Müller, 1978). They are expensive. More than one centralized showerhouse in a village is not possible. So generally only the people living in the surrounding are benefitting from it.

From the health point of view the provision of each compound with a pit-latrine and a small wash-house (where one can wash oneselve by using a bucket of water) is much more important. The same is in force for public pit-latrines on the marketplace.
Showerhouses are only useful for schools, hospitals.

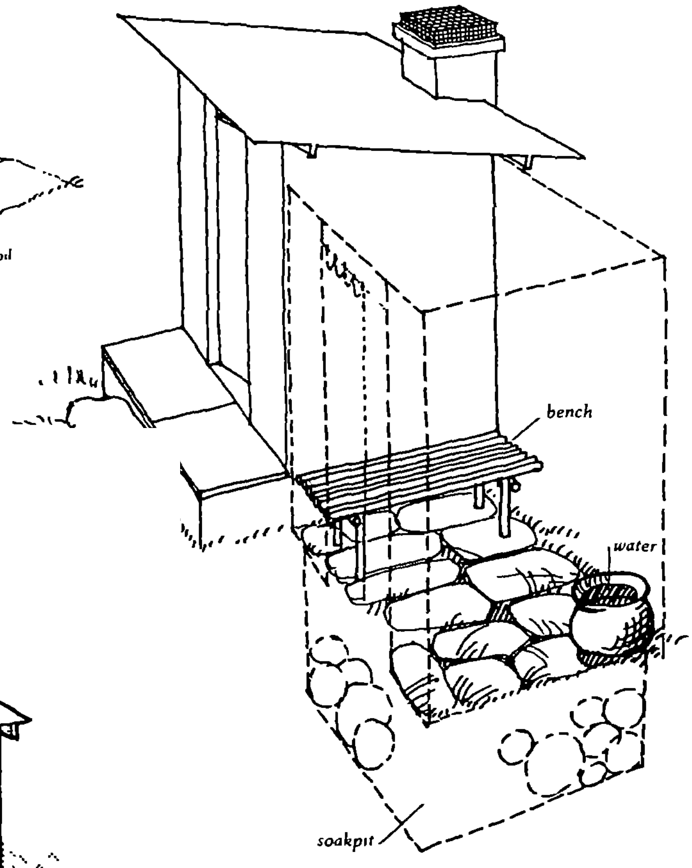
marketplace -
improved water supply



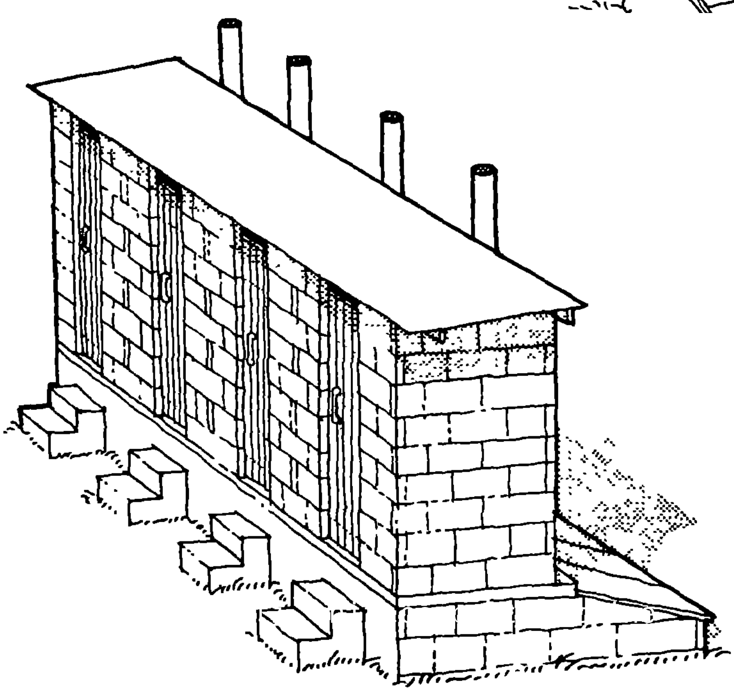
marketplace - not-improved pitlatrines



traditional pitlatrine



pitlatrine and bathroom



possible multi unit compost latrine
for market places

6.3 Operation,maintenance and management

As could be expected in these water supplies "by gravity" no operational problems were found. Only in Acha Tugi shortage of water was caused by wrong operation of valves by a person who replaced the caretaker during his absence. The result was an empty storagetank.
Negligent maintenance was found several times. The main example is Abegum where a normal functioning of the water supply was made impossible by a lot of leaking taps and spoiled masonry. The main cause was that there was no caretaker. Only the referent father feeled some responsibility for the water supply. He locked the system in the night to avoid the wastage of water through the spoiled taps in the village and to build up some storage for the next morning. But the villagers only suspected him of filling his own storagetank by locking the supply to the village.
Also in Guzang the masonry of the old system needed some repairs. Here during the extension no repairs on the old system were done.
Finally often waterpoints were not so well maintained. The drainage was not sufficient and taps were lacking, although this was no problem for the people using leaves or bamboo to stop the water. Sometimes the supply pipe was disconnected.
Generally a lot of small slabs were broken or missing.

Generally the inspection of the drainage in the villages was neglected by the caretaker. several soak-aways were blocked by leaves, plastics, clothes or even slippers. A blocked soak-away is difficult to clean by hand because you cannot enter a pit of two meter filled with water.
Sometimes the lack of good drainage resulted in standing water in the nearness of houses. One time the building of a drainage facility was prosponed (Oshum). Delay of the building of a drainage facility is dangerous and can result in a source of standing water for years.

An important problem form the treatment filters. As was explained in 5.1 the rsf's are not cleaned often enough because a backwash facility is lacking. Besides only a small layer of the filter is removed instead of the whole filterbed. The washing of the sand by hand is very laborious if you have to do it several times a week.

The maintenance of a ssf is also more laborious and requires more knowledge than handbooks tell us. In the first place the caretaker has to decide when the filter has to be cleaned Then he has to drain the filter basin during one day. Next day he can scrape off a layer of some centimeters. Then the filter can be put into function again but the connection with the distribution system may be established only after some days. Especially the last aspect is often not observed by the caretakers.

Also in relation to management can be said something, in the first place about the position of the caretaker.
Generally the caretakers are educated by SATA-CD and very capable for their jobs and they like their work. But often, if the payment of the caretaker was depending on the collection of money within the village he was not paid, which was rather disappointing for him. The villagers knowing that other caretakers were paid by the government prefered that situation of course.
One time the caretaker had no toolbox (Oshum). The SATA-CD refused to deliver the toolbox till the village had arranged something for the salary of the caretaker. But for the caretaker the situation was not very motivating.
The caretaker can block the tap in a quarter if the users refuse to keep the surroundings clean, but for larger community work and for the collection of money for spareparts or his own salary the caretaker is depending on the maintenance committee. Often the cooperation between the caretaker and the maintenance committee was very good (Guzang, Nyen), but sometimes the committee was too week to organize the villagers. For instance in Oshum it seemed to be impossible to organize the villagers to dug out a blocked pipeline. In Acha Tugi Hospital no committee exists, so for the caretaker it is very difficult to organize some people, because he has no power.
Two times finally the caretaker showed his power by blocking the whole system to get his salary. Of course this was impossible without support of important villagers.
One caretaker told that he had more power in the village as a government employed person than if the villagers should pay his salary. The villagers were not willing for instance both to pay the caretaker and to do community work.

To some extend the situation of one caretaker is different from the situation of another. A large scheme as Guzang where water has to be treated needs a full-time, paid caretaker. In the case of Oshum three days of caretaking a week is enough because the springcatchment system is small and don't need treatment. But also in this case the caretaker needs a compensation.
In the case of a waterpoint or well where the supply is concentrated on one place only a volonteer is needed to take the responsibility to keep the surroundings and drains clean.

The provision of spareparts is a second big problem. In new projects a store with some spareparts is provided. Besides new spareparts can be bought in a central store in Bamenda. The problem is how to finance the spareparts. Generally a spoiled tap is paid by the direct users. Money is collected within the quarter, otherwise the caretaker blocks the tap. But larger spareparts (also a bag of cement) have to be paid out of a fund deposited with Community Development. In the case of Guzang there was always sufficient money provided by people who worked outside the village and were exempt from community work. In Kai the "fon" gave money for the fund. But in the case money had to be collected as a form of tax from the villagers it was very difficult, especially if the maintenance committee was week.
It is not clear if cash money is really scarce in the village or that other reasons held people back from paying even small amounts of money. Generally villagers like to know exactly what is done with money they offered. They will not pay if they cannot trust the collectors. Sometimes the collection for a big new project seems to be easier than for the monthly salary of the caretaker or for incidental spareparts. Often the reason can be that no clear arrangements about payments were made with the government after completion of the water supply and that the arrangements differ from village to village. Sometimes people contributed in the past, but still their quarter is not benefitting from the water supply.
The problem of the collection of money has to be investigated more seriously and has to be related to comparable collections for school fees, a village health post, the building of a church etc.
Perhaps sometimes it is better that the government takes over some

costs, but in some way it is contrary to the principle of self-supporting. Asking the government for money means that the government will ask you in future. Then it will be more difficult to control the use of the money.

Finally some general remarks can be made.
Generally repairs were corrective. Perhaps discussions can start with the caretakers how to develop cheaper preventive strategies. In the first place yearly repairs on masonry can prevent total break-downs as in Abegum. Also the periodical replacements of sealings of stopcocks can extend the life of such axpensive parts. In that case it is not necessary to close the tap very strongly and the screwhead is spared.
More insight can be collected about parts that often break down and on the possibilities to prevent it.
This type of discussions can be done during refreshercourses for caretakers. Refreshercourses will be very useful to revive and to extend the knowledge of the caretakers. Besides the caretakers will learn from eachother.
Also supervision of the caretakers by the technicians will be very useful.
In future the first generation of caretakers has to be replaced by a new generation that will never have been trained during the construction, so a new type of education has to be developed to train this second generation of caretakers.
Finally questions for extensions of the existing water supply were heard in many villages. Nevertheless it is better to start with repairs and improvements of the existing system before new extension will be considered. In Abegum a project on repairs of the old system has been started and will be followed by a project for extension: the new source will supply the water to the repaired and improved old distribution system.

Chapter VII Conclusions and recommendations

7.1 Technical Design

The main conclusion in respect to the treatments as sedimentation, rapid sand filter and slow sand filter is that these treatments do not seem to function as they are designed to do.
The sedimentation tank should reduce turbidity before the water enters the slow sand filter. In practice only gross turbidity can be removed by sedimentation with a detention time of 6-8 hours. The reduction of turbidities by sedimentation caused by fine clay or colloidal matter may take several days. If the water contains a lot of fine clay and colloidal matter a sedimentation tank with a detention time of 6-8 hours is of no use. In that case an other treatment has to be introduced, such as a rapid sand filter. The sedimentation tank can probably be reduced to a small tank with a detention time of half to one hour to remove the coarse material or can be left out.
So it is very important to analyse the raw water with respect to the ratio of coarse and fine material, before the choice for sedimentation and/or rapid sand filter is made.

The rapid sand filters in the NW Province are built without a possibility of backwashing. So if the filter has to be washed all the sand has to be removed and is washed by hand. And this has to be done very often. In practice the filter is washed less than necessary and besides only the top layer is removed. Of course the filter blocks soonly. So as the quality tests show, the filter is not well maintained, but also functions as a slow sand filter in improving the biological quality considerably, because of the low velocity of the water. The capacity of the treatment is lowered considerably by this and besides the maintenance of such a treatment is made more difficult.
So in old and perhaps also in new systems where a rapid sand filter is built or required, a backwash system has to be introduced. The main choice that has to be made is if the water has to be treated before it is used for backwashing. If is choosen for treated water it is necessary to install a pump and a reservoir to provide sufficient treated water at sufficient height above the sandlevel of the rapid sand filter.

The slow sand filters were functioning very well by reducing pH, turbidity and improving the biological quality. The main conditions are that the upper layer is removed periodically and that the filter is left unused for several days to re-establish the Schmutz-decke. It is not sure that this is done in all the projects.

All these conclusions are based on only a few observations. A lot will be checked in the PACT-project on maintenance.
It should be very useful if within the scope of this project the whole treatment will be evaluated both technically and in respect to operation, maintenance and management. A proposal for such research will be done in annex III.

7.2 Operation, maintenance and management

Apart from the maintenance problems in relation to treatment stations, which can be solved by technical improvements and better education, some remarks can be made on maintenance of the drainage facilities of taps (or washplaces). It should be realized that with the introduction of piped water in a village without good drainage facilities also the possibility of standing water is introduced. This standing water forms a potential breeding place for insects often in the nearness of houses especially where the water is drained freely into the field and no special provision like a soak-away is made. To avoid standing water several things can be done to maintain the drainage capacity:

1. periodical inspection by a health official or caretaker
2. people living around the tap has to be told not only to keep the surroundings of the tap clean but also to maintain the trenches for the drainwater
3. in some cases it should be better still to built a soak-away
4. it should be avoided that a tap or washplace is built, but that provision of drainage facilities is postponed because of some reason.

Also soak-aways have to be inspected periodically. If the soak pit is blocked by dirt either from washing clothes or because of domestical waste and the water has risen, it is very difficult to restore the capacity by hand again. So a soak pit of more than two meters is not recommendable.

Generally it is doubted if the maintenance of drainage facilities gets suffiɐient emphasis in the caretaker's course. The same can be said with regards to the maintenance of masonry.

Often lack of money is given as the reason why spare-parts cannot be bought or why the caretaker cannot be paid. It is doubted if lack of money for repairs means "there is no money". Of course this can be a problem but perhaps the main problem is that it was not agreed who has to pay for the repairs: the government, the rural council, the village council or the direct beneficiaries. It will be an important issue of the PACT-project to analise these financial problems within the village and to design practical appointment about the responsibilities. Maybe it is good if Community Development stimulates actively the village to save money that is deposit by Community Development to finance new projects and in the case of existing water supplies, the operation and maintenance.
It is important if money is collected in the village, that it is very clear to the villagers for what purpose their money is used. The villagers has to realize that in this way they can control better that their money is used in their own village than when they have to pay tax to the government and ask the government to finance the operation and maintenance and the caretaker.

In many cases the caretaker likes his job and is capable for his job. Only his position is difficult and this is not very motivating. For he needs some compensation for his work. Secondly he needs power to punish beneficiaries who do not get their tap in a proper condition or do not like to pay for repairs or who spoil water. Finally he needs a strong maintenance committee that can provide the necessary funds for operation and maintenance and that can organize community work if necessary.
Sometimes after completion of a project a caretaker will have forgotten a lot of what he learnt. Lack of knowledge can be compensated by an active supervision by CD-SATA technicians and by refresher courses.
Supervision after completion of the project is important. The caretaker keeps contact with the CD-SATA and the technician is aware of the technical and organizational problems in the field. He can assist where necessary, even in explaining CD-procedures for extensions and so on.

Refresher courses for caretakers are especially important, because in these meetings the caretakers can learn a lot of each other. Apart from the typical operation and maintenance issues, more general things related to rural water supplies can be discussed, like health, community development, how th break in someone who can replace the caretaker during his absence, or in future when he is retired. Repairs on pipes, masonry and so on can be exercised. Before the course starts an examination can be done to test the knowledge of the caretakers. The results give an indication which subject have to be dealt with during the course.
An important discussion can be how to extend preventive maintenance. The size and character of a water supply must have consequences for the dutysheet of a caretaker, for the height of his compensation and for the decision whether he will be paid by the government, the council or the village.

Generally repairs and improvements of an existing water supply system in a village has to have priority before a new project or extension is started, but it can be a part of a new project.

7.3 Water quality tests

With the exeption of Ndu, Oshum, Tojei, Acha III, Nyen IV, Abegum and Tinkom*, the results of the quality test are satisfactory. In the case of Tojei, Abegum and Tinkom the solution has to be sought in a better protection of the catchments. The use of Acha III and Nyen IV can be reduced in favour of other sources. In Ndu the cleaning of the filter will probably improve the situation. In Mbibgo the storage-tank has to be lined to prevent the corrosion of the cement.
Nevertheless these tests were only of very limited value. For more reliability the tests have to be repeated.

Not any test has the same priority in the NW-Province.
Generally the test on iron can be stopped, because normally high values don't occur in the NW-Province. Besides high values can easily be seen or tasted.
The measurement of pH can be interested in the case of new sources. Then it is better to test the carbonate hardness and alkalinity also, in order

*See for results per sample point Annex I

to make e good judgement of the corrosiveness of the water. So new sources can be compared with each other and, if it is possible, the source that gives water with the smallest danger to materials will be taken. Or, if only high corrosive water is available it can be decided to install (more expensive) PVC pipes, although prevention of corrosion of cement will be very difficult. Good maintenance will be the best solution. In the rural areas the water will never be condemned for this reason nor will it be treated only to lower the danger of corrosion.

Especially measurement of turbidity and coliforms are interesting in the case of new sources. Also in these cases tests give information which makes it possible to compare different sources, or f.i. to judge if a spring is feeded by groundwater (few fluctuation in quality after rain) or directly by rain- and surface water (clear fluctuations after rain). But, more important, the measurements will give arguments to condemn or to accept the source and will give an indication for the treatment that is required.
In the case of turbidity it is more important to make a better analysis of the content of sand, silt, clay and colloidal parts individually (after heavy rains) than one over-all turbidity value. So a more appropriate combination of better disigned treatments (sedimentation, rsf) can be built.

In agreement with Feachem the total-coli test has to be replaced by a feacal -coli test which is more specific for feacal contamination. Sources can be judged following the algorithm of Feachem which will reduce the necessity of the installation of a ssf in the first stage considerably.

Periodical tests in existing water supplies are only interesting to control the effect of treatment on turbidity and bacteriological quality, which means a control on good maintenance.
The water quality of springs is very constant and will only change if the situation near the spring changes because of the influence of cattle or human activity, which has to be avoided.
Testing of the bacteriological quality of the water that is stored in the houses can lead to beter education on this point by village health-workers. Generally speaking quality-testing and -improvement is useless without special attention for environmental healthfactors. So quality-testing and treatment generally have no priority if nothing is done to avoid standing water in the village, if no health education is given and no improvement of the hygienic situation follows.

7.4 Water supply projects within the scope of health

In many cases in rural areas water quqlity improvement does not have priority in relation to health before other hygienic measures have been made. In view of the relative importance of water quality improvement to health and in view of the extra problems treatment introduces in relation to maintenance, which even can reduce the effect till zero, one should have the biggest reserve to the introduction of any treatment in an early stage in the rural areas. In many cases sources that don't meet the highest standards can be used for a water supply without biological treatment (provided that the water is not worse than the water the people are used to). The better quantity will effect the hygiene in the community in a possitive way.
The money that is saved by reducing the amount of treatmentstations and by using the standards in a very flexible way, can be used to realize a simple water supply in more villages. Treatment can follow in a later stage

The effect of an improved water supply on health will be greater if it is combined with health education. F.i. cleaning of the drainage facilities and save storage of water in the houses are very important within the scope of health.
In view of this common interest it is strange that there is no official contact between CD and the health officials. Besides the approach of the "primary health care" in the NW-Province is almost the same as the approach of SATA/CD in the case of water supplies:
The village health post starts with the forming of a village health committee, the choice of a village health worker who will have the responsibility for the functioning of the post (part time). He or she is trained in and supervised by a hospital and paid by the village.
Not only organizationally a lot of parallels can be found, but besides the effects of a village health post and an improved water supply strengthen each other. The village health worker is directly confronted with the problems of the lack of safe water. Hygiene is one of his first concerns.
A water supply project seems a logical follow up for a village health post project. Besides a cooperation between a village health worker and a caretaker (both villagers) can be very useful for the village.
From this point of view the involvement of CD-SATA in the construction of public pitlatrines (for instance on market places) as a part of a water supply project, is very logical.
Besides the emphasis on the construction of pitlatrines and small washhouses in the nearness of each compound should have the priority above the construction of central public showerhouses.

7.5 Water supply projects within the scope of community development

From the health point of view perhaps it is better to take measures for health improvement first on places where a large population is concentrated, such as cities and villages along traderoutes, shortly "the centres." There the risk on epidemies (of which many are water-related) is larger than in remote areas.
On the other side, from the development point of view, development has to start in remote places with arrears, shortly "the perifery." The development priority for the perifery has to prevent young people to go to the cities where unemployment is waiting for them. Besides this development strategy aims at diminishing the differences in development potential between the centre and the perifery. Projects have to be spread as much as possible over a region. From the last point of view, which is near to the Community Development filosophy, water supply projects have to be done with priority in remote places, far from the main roads. Besides, because the limited budget has to be spread as much as possible, it is better to do many rather cheap projects than only a few expensive projects. Also the possibilities of the CD-SATA technical service is limited. So not all energy has to be given to a few very big longlasting projects, but has to be spread over many small and short projects.

Instead most new CD-SATA projects seem to be large, very expensive and in villages along the main roads. Very few waterpoints have been constructed in the last ten years. Only a few have been repaired:

	before 1978	between 1978-1980	cost (CFA)/ beneficier	total of beneficier
spring and stream	21	28	6,000-12,000	1,000-3,000
waterpoints	98	7	1,500- 2,500	250

If no priorities will be made it is expected that most of the diminishing funds will be consumed by this type of big projects in future and by extension of existing projects at the cost of a lot of small projects in remote bush places.
It is more a credit to the filosophy of Community Development still to make these priorities by using the following stages (Feachem, 1979).

stage I Piped water supply with or without treatment (following the algorithm of Feachem) for as much people as possible. Quality has to be improved in the first place by protection of the source and the catchment area. Health education and construction of pitlatrines and washhouses in every compound are important.

stage II Building of treatment-plants in existing projects to improve the water quality. Extension of the supply.

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ANNEX I TESTRESULTS PER SAMPLE POINT

		turb. dry s.	turb. rainy s.	pH	iron	total coli
		NTU	NTU		mg/l	coli/100 ml
Abegum, Diche I						
river	catchment	5.0	1.7	6.84	0.4	624
	after sed.	1.5	1.7	6.59	0.46	TNTC
	last tap 1	1.2		7.2	0.49	
	last tap 2		1.9	6.9		wasted
river traditional		1.7	2.8	6.75	0.48	2500
river new source Diche I						2450
Acha Tugi Hospital						
river	catchment		17			4600
	after sed.		--	6.4	0.6	
	after ssf					
spring I	catchment	0.13		6.5	0.6	
	last tap	0.13		6.5	0.6	
spring II	catchment	0.55	0.52	6.6	0.4	282
	last tap		0.72			
spring III	catchment	0.31	0.25	6.2	0.4	48
spring IV	catchment	13.0	2.5	6.3	0.3	42
spring V	catchment	0.2	0.75	6.2	0.3	18
	last tap 1	2.1		6.4		
	last tap 2	0.78		6.6		
Ashong						
waterpoint		1.6		6.3	0.45	
Bafut						
waterpoint school	1	0.9	1.4	6.1	0.42	38
river trad. Njinteh		2.9	4.2	6.1	2.6	3380
waterpoint 2		4.2	2.0	6.35	0.87	362
waterpoint 3			0.43			376
Bangolan						
well						12
Bifang						
river	catchment	1.3	2.1	6.35	0.6	wasted
spring	catchment	0.43	1.3	6.3	0.3	wasted
after	after sed.	1.3	1.5	6.35	0.6	wasted
	after ssf	0.6	1.3	6.75	0.3	38
	after s or.					111
	last tap	0.62		7.8	0.0	

Dzeng						
spring	catchment	0.22	0.38	6.2	0.3	7
river	traditional	0.73	0.80	6.1	0.7	432
Fuh						
spring	catchment	0.72	0.45	6.1	0.2	6
	after sed		0.14			
Guzang Akwa						
river	catchment	2.6	3.7	6.66	1.0	1840
	after sed	2.0	1.9			1560
	after rsf					
	after ssf	0.85	0.26	6.7	0.46	6
	after stor.					32
Guzang Awom						
river	catchment	2.9	7.9	6.4	0.56	1340
	after sed	2.0	2.4			2150
	after rsf	2.0	0.9	6.5	0.30	64
	after ssf	2.0	0.26	6.65	0.30	70
	after stor.		0,26			32
	last tap 1	11.0	0.30	7.45	0.8	4
	last tap 2	5.5	0.25	7.05	0.4	24
	stor. house 1		0.50			wasted
	stor. house 2		1.1			584
	stor. house 3		2.2			380
	stor. house 4		0.29			28
Kai Benjok						
river	catchment	3.0	1.7	6.84	0.4	5360
	after sed.	1.5	1.8			5160
	after rsf	0.7	3.9	6.78	0.24	4
	after ssf	not yet constructed				
	after stor.		0.65			28
	last tap					28
Kai Tonomba						
spring	after sed.	1.0	0.4	6.1	0.3	692
Kai New Town						
spring	after sed.	7.0	1.5	6.3	0.4	514
	after stor.					652

Mbibgo						
spring	catchment	0.3	0.22	5.9	0.3	34
	after sed.	0.27	0.35			24
	last tap	3.4	12.0	6.25		4
Mbikop						
spring	catchment	0.24		6.0	0.5	
Meluf						
spring	catchment	0.35		5.8	0.4	
river	catchment	1.8	1.6	6.5	0.7	275
Ndop						
river	after sed.	12.0	13.0	7.13	1.4	112
	after ssf	4	3.7	6.95	0.5	6
Ndu						
river	catchment	10.0	18.0			TNTC
	after sed.	11.5	20.0	6.1	1.4	TNTC
	after ssf	7.5	6.4	6.2	1.1	560
	after stor.					180
	last tap	6.9	5.6	6.4		222
Ngondzen						
river	catchment	2.0	2.9			1032
	after sed.	1.7	1.8	6.6	0.4	880
	after ssf	0.76	0.42	6.8	0.3	8
	after stor.					28
	last tap	0.66	0.52	6.7		8
Nseh						
river	catchment	5.5	7.2			600
	after sed.	3.9	5.6	6.85	1.0	440
Ntumbaw						
spring	catchment					
	after sed.	0.77	0.71	6.2	0.4	8
Nyen						
spring III	after sed.	0.25	0.51	6.3	0.1	
spring IV	catchment	0.5				
	after sed.	0.8	0.55	6.3	0.24	
spring V	catchment	0.55				
	after sed.	0.3	0.55	6.1	0.1	343
	after stor.					72
	last tap	0.32	0.31	6.3	[illegible].0	19

Oshum Kishum						
spring	catchment	0.0	1.3	6.5	0.4	
	after stor					29
Oshum Ngaku						
spring	catchment	1.0	1.3	6.1	0.85	
	after stor.					10
Oshum Tojei						
	catchment	0.2	0.75	6.0	0.3	600
	after stor.					880
Sehn						
spring	catchment	0.28	0.22	6.2	0.3	9
river	traditional		14			3100
Sob						
spring	catchment	0.45	0.35	6.7	0.5	0
Tadu						
spring	catchment	0.13	0.27	6.5	0.4	90
Tatum						
spring	catchment	0.15	0.22			0
	after sed.	0.15	0.22	6.2	0.4	
	last tap	0.3	1.0	6.9		6
Tinkom						
river	catchment	1.3	1.8	7.0	0.4	348
	after sed.	1.5	1.8	6.9	0.35	314
	after stor.					340
	last tap	1.4	1.8	0.3	0.3	wasted
Vekovi						
spring I	catchment	0.32	0.58	6.3	0.2	1
Whem						
waterpoint		0.62	0.52	6.0	0.4	0

ANNEXII Manual for the equipment for water quality tests

I Introduction

The equipment is suitable for the following tests:

- total coliform, faecal streptococci; 0-150,000 indicator bacteries
- turbidity; ranges 0-1 NTU, 0-10 NTU, 0-100 NTU
- pH; range pH 5.5 - pH 8.5
- iron; range 0-5 mg/l

All tests can be done in the field so that any delay in examination of the samples can be avoided.

In the text below the principles of each test will be discussed. Also a description will be given of the used test equipment and test procedures. Here and there some practical experience will be added. For more information about the use of the various instruments one is referred to the manuals of the manufactures

The issue "Standards" will be discussed seperately. At the end a list will be given of the necessary material and the proposed extension of the equipment.

II Bacteriological test

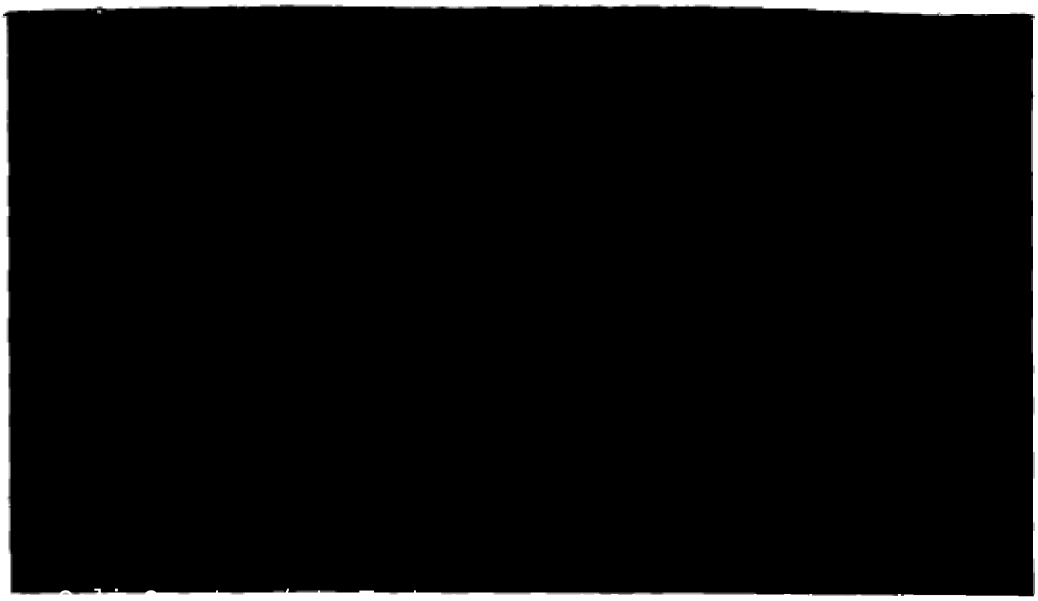
Introduction

A basic requirement for drinking water is that it is free or almost free from pathogenic organisms. The most of meant organisms, as bacteries, virusses, protozoën and worms originate from faeces of infected people or animals. If this faeces enters the water, the water will be contaminated and can function as a vector in the cyclus of these pathogenic organisms. If this water "enters through the mouth" of a human being, some disease may be the result. Especially children form a vulnerable group.

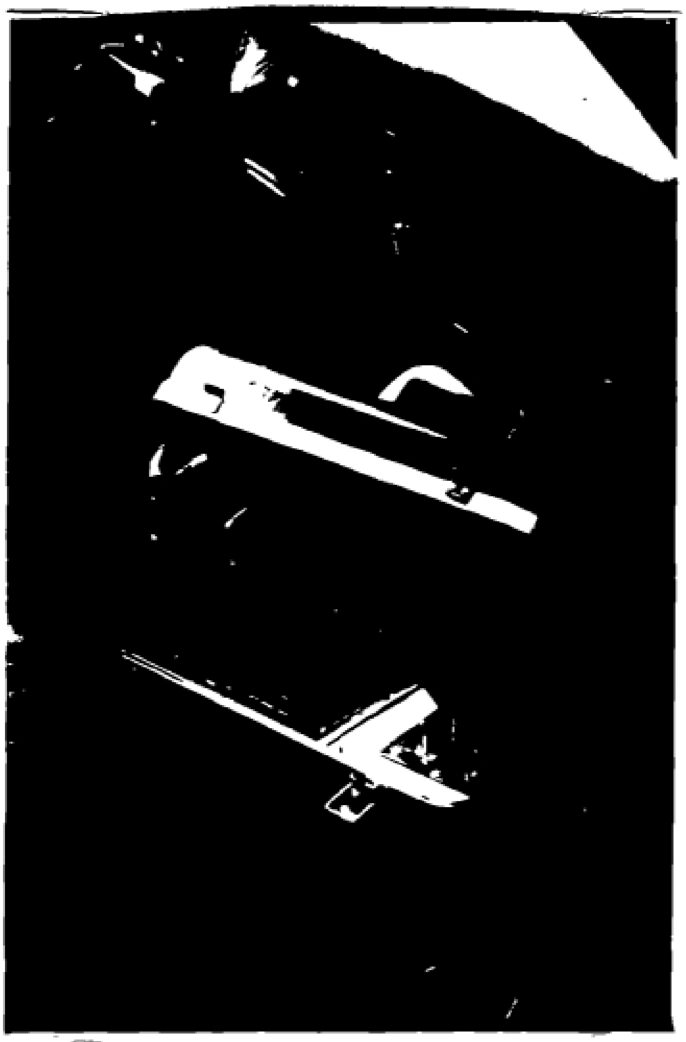
Again feaces of infected people will be infected; also if they will not show the external features of the disease themselves.

The diseases that are transferred in that way, are called "waterborne" and are particularly of the "faecal-oral group" which includes diarrhoea infections as cholera, typhoid, infectious hepatitis and bacillary dysentery.

To avoid misunderstanding: all waterborne diseases can also be transmitted by any other route which permits faecal material of one person to reach the mouth of another, such as contaminated food!



Millipore Coli Count Water Tester   Millipore Field Monitor



Millipore portable incubator

Principles

It is not practical to test water for all the pathogenic organisms. Instead water is tested for bacteries which are excreted in large amount by animals and humans and whose presence is indicative of faecal pollution. These are the indicator bacteries whose presence in the water can easily be investigated.

Three important indicator bacteries are distinguished:

- total coliform. The coliform bacteries form a large family. Many of them are not only native to the gut of warm-blooded animals and humans but are also living free in nature. As a group coliforms are considered harmless and often helpful (to digestion and vitamin synthesis) in the gut. Outside the human or animal body the coliforms outlive and outnumber the pathogenic organisms. So it is not too difficult to prove their presence in the water. Are coliforms proved to live in the water this is considered as a first indication of recent or remote faecal contamination, i.e. of the possible presence of pathogenic organisms.
- faecal coliform. These coliforms are specially faecal. One of this group is the Escherichia coli (E. coli). The presence of faecal coliforms in the water definitely indicates faecal contamination, i.e. a possible presence of pathogenic organisms.
- faecal streptococci. Also these bacteries are specifically faecal. Also the presence of faecal streptococci in the water is considered as a definite indication of fairly recent faecal contamination especially of animal origin, i.e. of possible presence of pathogenic organisms.

To detect these indicator bacteries two types of tests exist.

The eldest, cheapest and rather laborious test is the multible tube fermantation test, which results in the "Most Probable Number" of bacteries in 100 ml. This test is not used in the NW Province and will not be discussed here.

The other possibility is the micro- or membrane filter technique. This technique is very suitable to do the test in the field, which is a benefit especially in the case of bacteriological tests. Delay in analyzing the samples will result in less accurate results because of the die off of the bacteries.

Besides it has been shown to have a high degree of precision (reproducibility of results) and permits the examination of larger

volumes of sample in a shorter time than does the multible tube procedures.

On the other hand the method cannot be used for the examination of larger volumes of water, in the case of high turbidity and embracing growth of algae or other suspended materials that would dog the filters or cover then with a film. A high density of non-coliform organisms in the water under examination may interfere with accurate enumeration of coliform colonies. But these limitations have proved to be no problem in the NW Province. A real problem is that every piece of the equipment has to be ordered from abroad.

The technique is based on the following principles, which are the same for each indicator bacterie.

After taking a sample of the water under examination a certain volume (large for clean water, small for contaminated water) of the sample is filtered through the microfilter. All bacteries remain on the filter.

Next a nutrition medium is added and the filter is incubated for a certain time at a certain temperature (controlled within narrow limits). Nutrition medium, incubation time and -temperature are specific for each type of indicator bacterie.

After incubation each indicator bacterie has formed one visible colony on the filter which can be distinguished from other colonies by typical features (color, sheen).

These typical colonies are count by using a microscope and are reported as number of indicator bacteries in 100 ml of sample.

Table Various tests and their characteristics

Test	Nutrition medea	Incub.temp.	Incub.time	Typical feature
total coliform	MF-ENDO Broth	$35^{\circ}C \pm 0.5^{\circ}C$	20-24 hours	basically pink or red green metallic sheen
faecal coliform	M-FC Broth	$44.5^{\circ}C \pm 0.2^{\circ}C$	24 hours	light blue to dark blue-green
faecal streptococci	K F Agar	$35^{\circ}C \pm 0.5^{\circ}C$	48 hours	pink to red

During the test one has to avoid carefully any contamination of the water to be sampled and of the sample itself by skin, sample bottle or cup, filter, filterholder, the petridisk in which the filter is incubated and all tools one needs.

If necessary these things have to be sterilized in the field.

This microfilter technique is worked out by the Millipore Company in appropiate equipment. Two Millipore systems were used in the NW Province:

1. Millipore Field Monitor (total coli, faecal coli, feacal streptococci)
2. Millipore Coli Count Water Tester (total coli, faecal coli)

Both systems will be discussed for the test on total coli. This is the only test done in the NW Province. To test faecal coli a special incubator is necessary that is able to control the temperature of $44^{0}C \pm 0.2^{0}C$, which was not available. For the faecal streptococci test the feeding medium is not commercial provided. One hasto make it himself, which was impossible for the investigator in charge.

Millipore Field Monitor

This ia a complete filtration capsule, that can be used for one test only. The filterholder, the filter and absorbent pad form one prefabricated sterile whole.
The filterholder has an inlet and an outlet. By means of a handvacuum pump the sample volume, which can be choosen with the degree of contamination of the water, is filtered through the filter. The sample can be taken with a stainless steel cup.
Next the feeding medium is added to the absorbent pad[1)] (ENDO).
This nutrient medium can be bought in ampules of 0.8 and 2.0 ml and in bottles of $^{1}/4$ lb.
Then the whole capsule with filter is incubated for 20-24 hours.
The capsule replaces the petridish.
When the incubation is completed the capsule can be opened and the filter can be removed for analysis.

This system reduces the danger for contamination during the test considerably. Except the stainless steel cup, nothing has to be sterilized in the field.

✱ Sampling:

-If there is no scum or other dirt on the water surface, you can use the stainless steel cup to take a sample.
-The cup has to be free from residues of contamination of former

1) To avoid airbubblesthat causeairlock of the filter and to absorp the nutrition medium

tests and any new contamination by skin, sampling method or something like that has to be avoided.
How to arrange for that in practice in the field one is referred to the schedule below.

former sample place other conditions	characteristics former test place	minimal rinsing before taking a new sample
spring expected to be almost free from contamination	no human or animal activities around the catchment; dam properly built and backfilled	rinse cup three times with water that has to be tested before taking the sample
spring or stream expected to be slightly contaminated; after filtration; waterpoints	dam spring not properly built or backfilled; some animals around the catchment; any stream above the major human activities	rinse the cup with filtered water of the former test (already at the former testplace), this water is free from bacteries; rinse the cup three times with water that has to be tested before taking the sample
stream expected to be heavily contaminated; after each 5 or 10 tests	any source beneath human or animal activities; generally when you filtered a volume $\leq$ 10 ml	rinse the cup with desinfectance inside and outside; because the cup has to be totally free from desinfectance, before you take the new sample, rinse the cup again with very hot water that was boiled for 5 minutes (stored in a flask); then rinse the cup three times with water that has to be tested before taking the new sample

Figure Rinsing schedule

-Take the sample on a representative place avoiding any hand contact with the water to be sampled.
Open taps and valves to waste water for some moments before taking the sample from them.

* The appropriate filtration volume
One has to choose a proper filtration volume corresponding with the expected contamination of the water sampled. You choose your filtration volume in such a way that it will result in 20-80 indicator colonies on the filter after filtration and incubation.

This means:

$$20 < \frac{\text{filtration volume (ml)}}{100} \times \text{expected count/100 ml} < 80$$

-The lower limitation is because of the statistical validity of the test. The variation in the lower counts is greater than in the higher counts. This especially influences the results of tests where low volumes (much less than 100 ml) are filtered.

For instance:

filtered volume	coli count variation	result in coli's/100 ml	difference between minimum and maximum
100 ml	15 ± 2	13 - 17	4
1 ml	15 ± 2	1300 - 1700	400

A result <20 coli's and >10 coli's on the filter is acceptible in the cases that a high volume is filtered.

-The higher limitation is because of the countability of the colonies. If there are more colonies than 80, it is often difficult to distinguish the seperate colonies from each other. The resulting colonies are also smaller. Mistakes are introduced.

If high accuracy is not required in practice a count up to 150 coli's is countable very well.

The possibility to enlarge the range is important in the cases the source is never tested before. So the lack of knowledge about the contamination makes it difficult to estimate the expected colicount. Often it is necessary to take more samples of different volumes to use a large range.

The next table fascilitates the choice of an appropriate volume.

Table Results in coli's/100 ml, by filtering a certain volume of sample, resulting in the growth of respectively 10, 20, 80 and 150 coli-colonies on the filter

filtered	number of coli's			
volume	10 coli's	20 coli's	80 coli's	150 coli's
0,1		20,000	80,000	150,000
1		2,000	8,000	15,000
5		400	1,600	3,000
10		200	800	1,500
20		100	400	750
25	40	80	320	600
30	33	67	268	495
40	25	50	200	375
50	20	40	160	300
100	10	20	80	150
150	7	14	56	105
200	5	10	40	75

* Filtration, adding nutrient medium, labelling

A. Filtration of ≥ 25 ml

Take a sample with the sanitarian cup.

Measure out the filtration volume in the cup, marking the quantity with the calibrations on the inside wall of the cup.

Fix a Field Monitor with the outlet (red) port to the inlet of the hand vacuum pump. Fix a sterile sampling tube to the inlet port of the Field Monitor and pump the filtration volume through the filter following the instructions in the Millipore Manual.

Catch the sterile filtrate in the second sanitarian cup. This water can be used to rinse the sampling cup.

B. Filtration of < 25 ml but ≥ 5 ml

Take a sample with the sanitarious cup.

To measure out the filtration volume and to pump the volume through the filter, now the plastic syringe (sterile[2]) is used.

Follow the instructions in the Manual. Take care that you first remove the syringe plunger before you insert the syringe cylinder into the inlet (blue) port of the monitor.

C. Filtration of < 5 ml

More precision is required now.

Take a sample with the sanitarian cup.

Measure out the filtration volume now with a sterile[2] pipet.

The filtration procedure is the same as under B. Because the filtration volume is too small now to spread equally over the filter, the volume is diluted in the syringe cylinder by an amount of sterile water (for instance water filtered by a microfilter) up till some 10 ml before it is filtered.

For volumes of 0.1 ml and 1 ml you can also use a Millipore Coli Count Water Tester.

Appropriate filtration volumes are 1,5,10,25,50 and 100 ml.

After filtration you remove the pump or the syringe cylinder, but you don't replace the red nor the blue plug before you have added the nutrition media.

Add the nutrient media through the outlet port to the absorption pad.

[2] The syringe, pipets etc. can be sterilized in the laboratory in the same way as the stainless steel cup, see also the section about sampling.

The required volume of 0.8 ml is measured by a small syringe if one has not prefabricated 0.8 ml ampoules to one's disposal. Follow the instructions in the Millipore Manual. Take care that the fluid is spread equally over the absorption pad by rotating the monitor.
Remove the sampling tube and replace the sealing plugs in their respective ports.
Label the monitor with for instance small self-adhesive labels. On the label you write the following information:

1. place of sampling
2. filtration volume
3. date and time of incubation

Remark: Keep the monitors during the transport from the sampling place to the incubator in inverted position (gridside of the filter downwards). Disturbance of the filter can cause bad results.

✱ Incubation

After completion of the filtration procedure, the labelled monitor has to be incubated in inverted position (gridside down). In the case of total coliform the temperature has to be controlled on $35^{O}C \pm 0.5^{O}C$ and the incubation period has to be 20-24 hours (so you can plan the analysis of the filter for the next day).
To make incubation possible in the field Millipore designed portable incubators, that will operate on 6, 12 and 24 Volts DC as well as 115 or 230 Volts DC or AC. Power cord adapters are supplied for connections to battery terminals, automobile cigarette lighter sockets or round prong wall outlets. There is place for 30 monitors.
Operating controls are a temperature adjustment control and an input voltage selector switch. No on/off power switch is incorporated. The incubator will start to heat as soon as it is plugged in, and will switch on and off automatically to stabalize the temperature. A red lamp indicates the incubator is heating. When it switched off automatically you cannot see the incubator is working properly. But you can control the temperature by the rachmounted thermometer inside the cavity.
To fix the temperature on $35^{O}C$ you have to adjust the temperature control knob untill the desired temperature is reached and maintained (stand 4.5 - 5). Often after being switched in the

temperature rises to 38^{0}C or more before it drops to 35^{0}C and is maintained on that temperature.
The stand of the temperature control knob depends on the type of voltage used. So if you like to change the incubator from the car to the laboratory for instance, you have to adjust the temperature again after switching the voltage selector knob in the right position.
Besides it is very save to control the temperature periodically. The tension of a car battery for instance is rather save, but not always constant. The currency in the labaratory is very constant but can suddenly be switched off by lightening or repairs elsewhere in town and your tests will be useless after all.
For the rest a certain fluctuation in temperature, although not allowed by Standard Methods, seems not too harmful for the growth of the colonies along my experience.
According to the manufacturer the incubator controls the temperature from 27^{0}C to 60^{0}C with an accuracy of $\pm$ 1^{0}C untill ambient temperatures as low as -40^{0}C. But what about ambient temperatures above 40^{0}C, not unusual in a car in a tropical climate. In our testperiod the temperature did not reach these amounts, but I am doubting if the incubator will still succeed in controlling the temperature.
For the rest the incubator was functioning very well both connected to currency of 220 Volts DC and to a 12 Volts car battery. Also the presence of some spare parts, provided by the manufacturer, gives a safety feeling.

* Analysing results

After incubation the monitor cultures may be examined in the laboratory or in the field, although wind, rain, clouded sky and the absence of a stable table can disturb you a lot in the field. The monitor is opened with a coin, still in inverted position (remove first the blue plug). The filter is removed from the absorption pad with a forceps. Then the filter is dried for some 20 minutes on toilet paper. Experience will learn to judge if the resulting cultures are valuable to count or not.
For counting a microscoop (bioculair, 10 times) is used. The best is to place the dry filter between two appropriate glass slides for counting (for instance Millipore Petri Slides). False sheens

because of relief of the filter and disturbance of wind in the field are avoided then.
Very important is a good illumination that provides cool diffuse light and is placed as vertical as possible above the filter all to avoid false sheens. Recommended is a daylight fluorescent illuminator. But also normal daylight can be used, although a cloudy sky in the rainy season can disturb your program. Normal (yellowish) lamps are useless.
Only these colonies are count as coliforms, that show the typical features of coliform colonies. The typical coliform colony is basically pink to dark-red and has a green or gold metallic surface sheen. The sheen area may vary in size from a small pinhead to complete coverage of the colony surface.
Non-coliform colonies will have a light or darkred appearance only. If the light source is too strong or not vertical (sunlight!) it may reflect on the surface of the (generally wet) non-coliform colonies and give them a false sheen. This can be corrected either by using a more diffuse light source or by drying the filter longer before examination.
Daylight can be tempered easily by using your hands.
Because of irregularities of the filter or because of dirt sometimes colonies have an irregular form. Sometimes it is difficult to see if there are two confluent colonies or just one.

* Report

The calculated coliform density is reported in terms of total coliforms per 100 ml. The computation is made by using the following equation:

$$\text{total coliform/100 ml} = \frac{\text{coliform colonies counted}}{\text{ml sample filtered}} \times 100$$

When there are excessive colonies on the membrane filter, the report should be "TNC" (Too Numerous To Count). If there is growth without well defined colonies, the report should be "confluent". In either case a new sample should be requested and more appropriate volumes selected for filtration.
If more samples of one source have been taken and if the filter-counts are individually too low, all such counts should be totalized and the values based on the total volume of sample examined.

Millipore Coli-Count-Water-Tester

In the case of the coli-count-water-tester (c-c-water-tester), both the filter and the absorbent pad are constructed to one pocket-sized paddle, which has been put away in a plastic case. This case is used to take the watersample.

For this method no pump is used for filtration. The c-c-water-tester operates by capillary attraction adsorption. When the paddle is immersed in the with sample filled plastic case, water moves actively into the dry core area up to the cores capacity of 1 ml passing the microfilter.

The water then saturates the special dehydrated coliform medium in the core. Excess water is thrown away before the paddle, restored in its case, is incubated for the prescribed time at the prescribed temperature. Only colonies which are blue/blue-green in color should be counted total coli.

The limitation of this method is the volume that can be sampled. This volume is restricted to maximum 1 ml which makes it possible only to prove a minimum of 1.000 - 1.500 coli's per 100 ml. This is a rather high minimum in relation to the standard of the WHO and in practice only suitable for streams. The other possible volume, 0.1 ml, can be achieved by dilution (see Manual).

Unlike the Field Monitor, the c-c-water tester is incubated in the "gridside-up" position.

For the rest labelling, incubation and the report of the results are the same as for the Field Monitor system.

III Turbidity test

Turbidity is a straightforward measurement for the suspended matter in the water. This turbidity is caused by clay-particals, organic matter, algae, germs of bacteries etc. that float in the water. Limits to turbidity of the drinking water are established, because turbid water is unpleasant. Besides high turbidity can possibly cause gastro-intestinal irritation.

Turbidity is measured by a nephelometer. A light beam enters the sample through the bottom of the sample cell. As the light passes through the sample, some light is scattered by suspended matter in the sample. The other light is captured into a light-shield to help to minimize stray light. A portion of that light scattered

at 90^0 is sensed by a photocell and the resulting photocell output is conditioned to drive the instrument meter.
The meter-scale is calibrated in nephelometric turbidity units (NTU) to provide direct turbidity read outs.
The turbidity-meter used is an instrument of the Hach Company. The instrument itself and its assecoirs are built in a relative large, not so handy, kit. Operating power is supplied by a rechargable battery.
The instrument operates in three ranges: 0-1 NTU, 0-10 NTU and 0-100 NTU. In the event sample turbidity exceed 100 NTU the sample can be diluted by filtered sample water or the result is reported as > 100 NTU.
Before each measurement the instrument has to be standardized with the help of the "focussing template" (blocks the light-way to the photocell and has to give the display zero) the turbidity standard of 10 NTU, the zero-control and the Span-control. This has to be done each time you switch from one range to another. (Use "rizer" in range 0-100 NTU).
The kit contains three sample cells of 18 ml. Both sample cells and the standard cell have a dot to orientate the cell in the same position each time.
To test the water a sample cell is filled to the white line with sample. Dry the cellwand properly and place it in the cellholder. Cover the cell with the light-shield and allow the meter to stabilize. Read the turbidity of the sample.

Operational notes:

- The sample-cell has to be very clean. However it is difficult to clean and dry the cells in the field after each test. Instead you rinse the cell three times with the water to be tested before you take the sample and test it. Before placing it in the cellholder, the filled cell is dried throroughly with a clean, dry towel so that no dirt or drops of water on the cellwand will influence the measurement. Take care that there is no sand in the towel which can cause scratches on the cellsurface.

After a day of testing you can clean and dry the cells thoroughly.

- Variations in sample volume can affect the accuracy of the determination.
- When measuring the lower ranges (0-10 and 0-1 NTU) air bubbles will cause false high readings. Before covering the sample cell with the light shield, observe the sample in its cell. If finely divided air bubbles are present, five minutes may be required before the bubbles can rise past the photocell so that a valid reading can be taken. Avoid straight sunlight on the sample cell during this time.
- If a water sample being tested, is supersaturated with oxigen, air bubbles may appear on the side of the sample cell in sufficient numbers to prevent turbidity measurements. This problem can be corrected by placing a drop of brane filtered Triton^{r} X-100 solution in the cell before filling it with the water sample.
- Protect the surface of the turbidity standard cell and the sample cells from nickes and scratches as they cause light to scatter and indicate false turbidity.
- The instrument is very sensitive to bright sunlight. The standardization has to be repeated frequently then. So use the instrument if possible in the shade.
- The instrument is also very sensitive to moist. If moist enters the case, it will be impossible to use the lower ranges (you cannot adjust the meter to zero). You have to demòntate the instrument to dry the case thoroughly and to leave the instrument like that, till the instrument has dried enough to use it again.
This problem will arise especially if you use the instrument during rainy season.
- Maintenance requires some technical skill. For lampalignment, focusing and calibration of the instrument you find extensive directions in the manual, but it seems not so easy as the test itself. For instance the liquid latex turbidity standard in the kit is a second standard for calibration which is not stable indefinitely. But the preparation of the official Formasin Turbidity Standard will be very labourious and need experience. Thos problem arises when you use this instrument in a developing country and it can discourage to use it.
- The whole instrument seems to be rather vulnerable. If you spoil the turbidity standard (and this is very easy in the field) or the battery-recharger (as I did) you cannot use the instrument till

the spareparts arrive from the USA.
- If the instrument works, the test can be done in the field very easily and quickly.

IV PH Test

If the water is too acid it can cause corrosion of building material and in addition of the waterquality (higher turbidity at lower taps for instance).
PH is the negative logarithm of the concentration of H^+-ions. Water is considered to be acid if the H^+ concentration exceeds the OH^- concentration and alkaline if the OH^- concentration exceeds the H^+ concentration.
The principle of the pH test is based on the addition of a reagent to 5 ml of a water sample. The reaction that follows produces a color that is characteristic for a certain pH. This color is compared with a continuing color disk. The disk is rotated untill the color of the sample corresponds with the color of the disk. Then the pH is read directly. The testbox is of the Hach Company.

In addition to the provided small and practical testbox, a rack for the sample tubes and a towel are useful. The stainless steel cup of the bacteriological test can be used to take the sample. Rinse the cup three times with the water to be tested, before you take the sample.
Also sample tubes must be rinsed completely free of any solution that might have been used previously. Therefore rinse the tubes three times with the water that has to be tested.
The presence of chlorine in the water will cause a slight interference in the test. So chlorine has to be removed before.
The reagent has to be checked from time to time by using a reliable standard (see manual).
You compare the colors of the samples and of the disk with a white paper as background and sufficient light.

V Iron Test

Too much iron colors the water, causes turbidity and the growth of iron bacteries and gives the water a bad taste.
The principle of the test is based on the addition of a reagent to

5 ml of water sample. The reaction that follows produces a color that is characteristic for a certain iron concentration. This color is compared with a continuing color disk. The disk is rotated untill the color of the sample corresponds with the color of the disk. Then the iron concentration is read directly.
The testbox is of the Hach Company.
In addition to the provided small and practical testbox, a rack for the sample tubes and a towel are useful. The stainless steel cup of the bacteriological test can also be used for this test to take the sample. Rinse the cup three times with the water to be tested before you take the sample.Also sample tubes must be rinsed completely free of any solution that might have been used previously. Therefore rinse the tubes three times with the water that has to be tested.
You compare the colors of the sample and the disk with a white paper as background and sufficient light. The color will develop regardless of the form in which the iron is present . If the iron is presented as dissolved iron, the color will develop almost instantly. If the iron is in the form of rust, a minute or two is required for complete color-development.
The reagent has a shelf life of 6-12 month. How to check if the reagent is still performing properly is described in the manual.

Standards

I. Total coliform (untreated water, inclusively slow sand filter)

Many standards are based on more than one sample per year.
The WHO has designed the following standard:

- the arithmetic mean has to be less than 10 coli's per 100 ml
- never more than 20 coli's per 100 ml in two consecutive samples or in more than 10% of the samples might be found.

The following values were found in the NW Province (June 1982):

- streams	250 - 5500 coli's per 100 ml
- springs	0 - 700
- waterpoints	0 - 400
- na ssf	10 - 500
- last tap	5 - 225
- strorage in houses	380 - 600

The WHO standards are very high for the NW Province. It should be be pointless to condemn all supplies which contain too much coliforms along these standards especially where alternative sources of water are more grossly polluted. Besides high standards are less urgent in these circumstances, because the people were used to much more polluted water in the past and their immunity for pathogenic organisms is much higher than for instance in Europe. This immunity will not decrease after using clean water for some time.

On the contrary if the waterquality of a supply suddenly get worse because of a break down or a not well functioning slow sand filter, children will suffer first, because they did not build up the immunity yet.

In general it is difficult to say how many coli's are necessary to cause diarrhoea.

Rather bacteriological testing should be used to examine the amount of pollution, the quality of the alternative sources and whether the level of pollution can be reduced. A source expected to be a very clean spring, can be proved to be polluted by bacteriological testing. The reason can be that the stream enters the ground some distance from where it reappears as a spring.

Besides bacteriological testing can be used to control periodically the functioning of the treatment station, especially of the slow sand filter.

The best will be to follow the algorithm of Feachem to judge a source.

The highest quantity of coliforms will be found during the transition period between the dry and the rainy season.

[illegible]

[illegible]

[illegible]

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ANNEX IIA LIST OF REQUIREMENTS

Bacteriological tests:

- sampling, filtration, feeding, labelling, incubation, analysing:
  - 2 stainless steel cups
  - stainless steel syringe (handvacuum pump)
  - sample tubes
  - 5 disposable plastic syringes
  - disposable pipets
  - field monitors (incl. blue plugs)
  - red plugs
  - nutrition media in 0.8 ml ampoules (can be opened by hand)
    if no 0.8 ml ampoules are available:
    - 2.0 ml ampoules or of other amount
    - saw to open these ampoules
    - pipets or syringes (f.i. injection syringes) to measure 0.8 ml nutrient media and to add it to the field monitor
  - small self adhesive labels
  - pen
  - incubator inclusively kabel and connections for automobile cigarette lighter sockets and round prong wall outlets
  - toilet paper
  - forceps
  - (petri slides)
  - microscope (bioculair, 10x)
  - (daylight fluorescent lamb)
- to desinfect:
  - bottle desinfectance
  - flask with hot boiled water
- diverse:
  - waste bag
  - clean towel
  - small plank

Turbidity test

- turbidity meter
- turbidity standard cell 10 NTU
- 3 sample cells
- focussing template
- light shield
- cell riser
- silicone oil
- recharger and round prong wall outlets
- clean towel
- standard for sample cells
- plank
- screw-driver
- spare sample cell

PH and iron tests

complete Hach testbox with:

  - reagent
  - 2 sample tubes
  - spare sample tubes
  - color disk in holder
  - cabs for tubes
  - for iron test: scissors
  - towel
  - standard for sample cells
  - white paper

ANNEX III PROPOSAL FOR RESEARCH TO SEDIMENTATION, RAPID SAND FILTRATION AND SLOW SAND FILTRATION

Normally in the NW Province stream water is treated by sedimentation, rapid sand filtration (not always) and slow sand filtration. Schematically the functions of these treatments are as follows:

treatment structure	function	treatment process
sedimentation tank	removal of gross turbidity	by sedimentation
rapid sand filter	removal of turbidity removal of iron, mangaan	by filtering and absorption
slow sand filter	removal of fine turbidity neutralization of pH reduction of pathogenic organisms	by filtering and biological processes

The turbidity of the raw water that enters the slow sand filter must not exceed certain limits. Otherwise the slow sand filter has to be cleaned too often. That is why pretreatment is applied.

Chemical treatment is avoided, because it needs extra skill, high operational costs and regular supply. These things generally will will give problems in a country like Cameroon.

Sedimentation is useful only if the water contains a lot of coarse and fine sand and silt. This material will sedimentate within a few hours. However the reduction of turbidities caused by fine clay or colloidal matter may take too much time. The construction of a reservoir under such conditions would serve no useful purpose.
So it is important to study the amount and the characteristics of the suspended matter in the raw water both in dry and in rainy season. Also it has to be decided which part of the suspended matter has to be removed by the sedimentation tank and which part has to be removed by other treatments such as rapid sand filter or slow sand filter. This will influence the required capacity of the sedimentation tank.

The most important function of a rapid sand filter is to reduce the turbidity of the water considerably before it enters the slow sand filter. It is very important to clean the sand often in periods of high turbidity. Then the whole bed has to be cleaned, because the impurities enter deeply in the relative coarse matter.
Although a bachwash facility is very necessary to clean the sand,

such a facility was not provided in the NW Province. The sand was washed by hand, which gave a lot of practical problems. The sand was washed not often enough and the filter blocked and started to function as a slow sand filter.
The low filter velocity caused a low capacity of the rapid sand filter. The result was shortage of water.
It will be useful to do research at least to the possibilities of the installation of a bachwash facility. The problem of such facility is probably that for the bachwashing of the sand filtered water has to be pumped back through the rapid sand filter. To install a pump and perhaps a filter 6 meter above the sand level is against the principe that pumps have to be avoided. Perhaps also unfiltered water can be used.

The main function of the slow sand filter is to destroy the pathogenic organisms in the water. Besides turbidity is reduced. But very turbid water will block the filter soonly and makes often cleaning necessary.
The filter medium of the slow sand filter is finer than the sand of the rapid sand filter. The surface is larger. Important is the Schmutz Decke, a thin layer in which the biological activities of the filter are concentrated. Cleaning of the filter means the removal of this layer of 2-3 cm. So after each cleaning this layer has to be restored before the filter treats the water satisfiing again. This takes a week at least.
It is not clear when the filter has to be cleaned and how many times a year to maintain sufficient capacity. Literature gives a variation of several weeks to several years. After several cleanings the thickness of the filterbed is reduced to a minimum level and the whole filter has to be washed and to be backfilled. In the NW Province normally this was done by hand by the community. Sometimes a wash-facility was installed to wash the sand with unfiltered water.
A research to the whole operation and maintenance of a slow sand filter both technically and organizationally should be useful.

Summerizing the research has to be an evaluation of the existing treatment facilities, their expected and realized function and their problems in respect to maintenance.
Proposed technical improvements have to be suitable for both existing and future water supplies.