CICD Series Vol.2: Well-Drilling and Rural Water Supply. DAAD Summer School Embedded in the Trade Fair Geofora.

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CICD Series

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Preface

The DAAD Alumni Summer School Groundwater Well Drilling and Rural Water Supply took place prior to and in the context of the trade fair Geofora in Hof, Bavaria, from 3rd to 15th September 2007. The Summer School was organised and managed by Ingrid Althoff, University of Siegen. 25 Alumni from 18 different nations participated in the DAAD Summer School. The objective of the Summer School in Hof consisted in the knowledge transfer or the experience exchange among the participants and with external experts in the field of well drilling and water supply/management as well as with representatives of the private sector, organisations and public authorities.

At this point, the University of Siegen wants to thank the contributors from the private sector (Mr. Hübner, Wilo Emu GmbH; Mr. Etschel, Etschel Brunnenservice GmbH; and Dr. StandfuSS, Fernwasserversorgung Elbaue-Ostharz GmbH), those from Hofer Energie und Wasserversorgung (HEW-Hof), the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) in Hannover (Dr. Himmelsbach), the Bayrisches Landesumweltamt (Dr. Rothmeier), the Amt für Wirtschaftsförderung (Mr. Friedl) and the city of Hof for the pleasant reception, as well as the Alumni for their contributions and the high-level discussions.
Moreover, we would like to thank the DAAD (Deutscher Akademischer Austauschdienst) for their financial and logistic support with regard to the organisation and realisation of the Summer School.

Preface

Figure 1: Source: Firma WiloEmu

From the 12th of September to the 14th of September 2007, the Geofora - trade show and conference for Drill Rig Technology, Well Drilling and Geothermics - took place in Hof/ Bavaria. This trade show and conference gave the impetus to hold a summer school of the DAAD in 2007. The participation of these experts from numerous countries was a great benefit for the city of Hof, for the exhibitors and for the trade show itself. On the one hand, the fair could gain in internationality. On the other hand, a lot of participants were very interested in meeting the international partners of the summer school.
An intensive professional dialogue took place between the members of the summer school, as well as the participants and exhibitors of this fair. Projects were presented and useful links were established. The activities in the evenings provided a basis for further dialogues.
The members of the summer school enjoyed the city of Hof and her region. Hof itself tried to be a good host for the summer school. The intention consisted in the participants' well-being. They should remember their visit in Hof with joy.
At the same time, the city of Hof wanted to give a good impression as a competent business location in the field of water and environmental technology.

If a project in the water and environmental technology sector commences in the member countries of the summer school, these will remember Hof and the powerful enterprises in this region.
Until then, thank you very much for the visit and perhaps we will see us again in Hof!

City of Hof, Department of economic development

CICD Series Vol.2: Well-Drilling and Rural Water Supply. DAAD Summer School Embedded in the Trade Fair Geofora.

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1.1 Abstract

The population in the Gaza Strip, Palestine, faces potable water scarcity throughout the year in general, and acute drinking water problems in lean periods of the year. To mitigate this problem, various capacities of BWRO desalination plants were installed in various locations of Gaza characterised by high salinity of groundwater. General performance of these plants was undertaken to focus attention on the physiochemical quality of water at various stages of treatment, present status with respect to operation and management (O&M) financial implications and overall management in a current situation.

1.2 Introduction

About 1.5 million people live in the Gaza Strip, a coastal area of about $365km^2$. This strip has a big water problem in terms of water quantity and water quality. Due to over-abstraction of groundwater from the Gaza aquifer and to seawater intrusion, most of the water pumped from water wells is characterised by high salinity and does not meet the WHO standards. The PWA considered various desalination technologies such as membrane processes as well as thermal evaporation and distillation processes for brackish water and seawater treatment as new water resources. Each process was evaluated in view of cost and ability to meet the water quality standards. As a result, the Water Authority considered desalination of brackish water/sea water a vital option to reasonably face the water deficit and to provide people with safe drinking water in Gaza.

1.3 Water Resources

In the Gaza Strip, the main source of groundwater comes from the coastal aquifer (shallow aquifer), which consists mainly of sandstone, sand and gravel. The aquifer is an extension of the coastal plain aquifer in Israel. The aquifer is highly permeable with a transmissivity of about $1.000m^2$/day and an average porosity of 25%. The depth to water ranges between 70 metres in the highly elevated area in the east and 5 metres in the lowland area. The total annual recharge of the aquifer is estimated at 55 MCM. A deficit with an average of 70 MCM/year is observed

in the water balance due to overpumping. Therefore, the aquifer is replenished from brackish water or seawater, which results in a deterioration of quality.
An average of 160 MCM/year is pumped from the groundwater aquifer and distributed over domestic and agricultural water wells.
A water balance model was developed to determine the impact of all the integrated aquifer management programme activities. New water resources account for nearly 25% of the balance. New resources include additional water purchases from Mekorot, small SWRO desalination plants and regional SWRO plants.

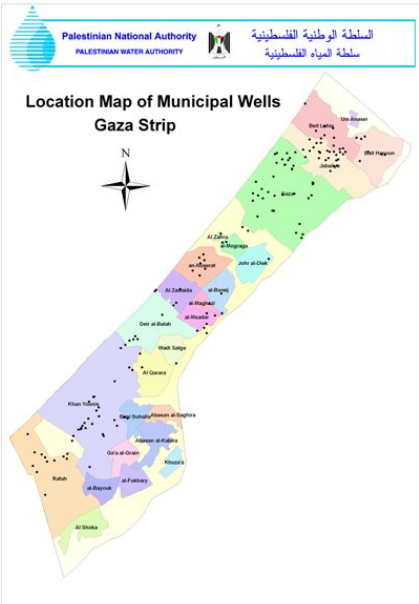

Figure 1.1: Location map of municipal water wells in the Gaza Strip

1.4 Water Quality

The main quality problem is the increase in salinity and nitrate content. The nitrate concentration reaches more than 200 mg/l in the northern part of the Gaza Strip and salinity reaches more than 1.600 mg/l in the middle and southern parts of the Strip. T In addition to seawater intrusion in the case of Gaza, this deterioration in the water quality could be related to the unregulated disposal of various forms of waste, including domestic industrial solid waste as well as liquid and agricultural waste (fertilisers and pesticides). PWA reports mentioned that 70% of the Gaza Strip population obtains water with a high salinity and a chloride average of more than 500 mg/l up to 2.500 mg/l, while a large number of drinking water wells contain an average nitrate level of more than 100 mg/l. Moreover, the average water supply per capita in the Strip reaches 80 litres per day. However, most of this water contains a high salinity concentration.

1.5 Existing Drinking Water Sources

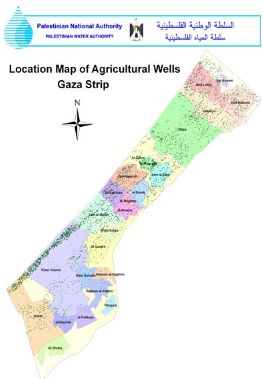

Figure 1.2: Location map of agricultural wells in the Gaza Strip

There are the following five sources of drinking water:

1. 130 domestic water wells produce about $78Mm^3/year$ (see Figure 1.1).
2. More than 4000 agricultural water wells produce $80Mm^3/y$ (see Figure 1.2).
3. Water is purchased from an Israeli company called “Mekorot” ($3Mm^3$/y).
4. Four BWRO plants produce $0.4Mm^3$/y.
5. The Middle Area SWRO plant produces $0.2Mm^3$/y.

1.6 History of BW and SWRO Desalination in Gaza

The first RO plant in the Gaza Strip was built in 1991 in the town of Deir al-Balah by EMS, a subsidiary of the Mekorot company. This plant was constructed to desalinate brackish water and has a capacity of $45m^3$/h with a recovery of 75%.
Between 1997 and 1998, through an Italian development cooperation programme, two RO plants were constructed in Khan Younis to desalinate two brackish water wells. Each RO plant has a capacity of $50m^3$/h to supply a part of the town of Khan Younis with potable water.
In 1998, USAID financed a BWRO plant built by an American company called “Metcalf&Eddy” in the Gaza Industrial Zone. This plant has a capacity of $40m^3$/h and was designed to supply water to the surrounded industrial complexes and adjacent parts of Gaza City.
In 1999, the private sector local companies started investing in the desalination field. They installed small-scale BWRO plants with different capacities to desalinate low brackish water wells in various areas of the Gaza Strip. The capacities of such plants currently range from 10 to $200m^3$/d and recoveries from 40 to 70 percent.

1.7 Seawater RO Desalination

The Palestinian Water Authority began with the first SWRO plant in 1999. This plant was designed to have a capacity of $1.250m^3$/d in the first phase and was built by “Degremont"” through a grant from the government of France. The plant has not yet begun its operation. The second SWRO plant was financed by Austria and built by “GWT” (Austrian Company). This plant has a capacity of 600m^3/d at the first stage and could be expanded to produce 2.400m^3/d at the final stage. It is now in operation just for a few hours due to incapacitation.

1.7.1 North and Middle Area SWRO Plants

The governments of France and Austria financed two seawater RO plants with a capacity of 1.250m^3/d and 600m^3/d, respectively. The French-sponsored plant is located in Northern Gaza (“Northern RO plant”), the Austrian-sponsored plant in the middle area (“Middle RO plant”).

The Northern RO plant is fed by raw seawater from two beach wells. It comprises chlorination and coagulation systems, sand filters, acid and antiscalent dosing, dechlorination and cartridge filters. The post-treatment unit includes the addition of lime and sodium hypochlorite.

The Middle SWRO plant is supplied with feedwater by two beach wells operating alternately. This plant consists of a pre-treatment unit, which includes the dosing of chemicals such as sulpheric acid, sodium hypochlorite, flocculent and antiscalent. The water passes through a multi-media filter and five micron cartridge filters before entering membranes at a high pressure (60 bar). Finally, desalinated water is post- treated by adjusting the pH and disinfected before it is pumped to the consumers.

The Northern RO plant has not yet been completed with respect to installing electromechanical works. The Middle RO plant is now working and produces 600m^3/d. A part of the produced water is directly pumped to the consumers through a network in Deir al-Balah and Al Zawaida, while the remaining part is transferred and sold by tankers in the middle area. Seawater is desalinated through two passes in order to offer a good quality with a TDS of about 100 ppm.

1.7.2 Regional SWRO Desalination Plant

The PWA launched an agreement with USAID to build a regional seawater RO plant with a capacity of about 60.000m^3/d at a first stage in the middle of the

Gaza Strip, expandable to $150.000m^3$/d. This plant will be supplied with feed-water by an open seawater intake located about 800m from the shore.
The SWRO plant consists of a pre-treatment unit including the addition of chemicals, ultra filtration, multi-media filters and cartridge filters. It also includes high pressure pumps and membrane units. A post-treatment system includes pH adjustment and the addition of limestone. The desalinated water will finally be pumped into the North-South National Water Carrier and mingled with well water in the municipal network.

1.8 Private BWRO Desalination

Although public institutions such as the Palestinian Water Authority (PWA) and Gaza Municipalities own some BWRO desalination plants, local investors in the private sector have already begun to establish a desalination business since 1999, constructing various small BWRO plants in Gaza. Such plants have to be licensed by the PWA and the Ministry of Health according to certain conditions, so that they are monitored in terms of compliance of the product water to the Palestinian water guidelines. The private sector has now about 40 private BWRO plants. These could reasonably satisfy some of Gaza's drinking water needs. However, these plants are considered only small units having, operational capacities from $20-150m^3$/d.

1.9 Drinking Water Supply

Around 98% of the Gaza Strip population benefits from piped water supply systems. The remainder depends mainly on cisterns and springs for their water use. The overall loss of water in the Gaza Strip through the system is estimated at 45%, of which 35% is due to physical losses and 10% to unregistered connections (see figure 1.3).
However, there are two main systems to distribute the desalinated water from RO plants.

1. *Domestic water network:*

The municipalities of Khan Younis and Deir al-Balah are responsible for pumping the desalinated water into the network, where the consumers can get their fresh water. This takes several hours since the people are aware of the schedule of pumping such water.

2. *Water tankers*

   The private sector local contractors play an important role in transporting the desalinated water from the sites of the RO plants to the consumers and water shops where they are not connected to the networks of the plants. Customers have to fill their Jeri cans directly from the tankers or the tanks owned by supermarkets. A provision for direct connections shall be allowed for high-rise buildings and hotels. Desalinated water from the regional plant will be distributed in the municipal distribution networks and will be paid as part of the water bill.

Month	Total Production(1)	Total Consumption (2)	System Efficiency %
January	6,078,113	3,451,372	56.8
February	5,550,509	3,300,022	59.5
March	5,985,522	3,434,989	57.4
April	6,380,229	3,503,506	54.9
May	6,800,202	3,628,097	53.4
June	7,259,524	3,867,097	53.3
July	6,950,197	3,683,120	53.0
August	7,772,707	4,036,704	51.9
September	6,921,523	4,123,717	59.6
October	7,116,214	3,839,279	54.0
November	7,145,352	3,807,035	53.3
December	6,815,252	3,639,563	53.4
Total	80,775,344	44,314,501.00	54.9

Figure 1.3: Overall System Efficiency (1,2: Production and Consumption excluding the UN-wells)

1.10 Technical Appraisal

In evaluating the competing RO brackish water desalination processes, many factors need to be taken into consideration. The main points are discussed below.

1.10.1 State of Development

BWRO plants are now in a mature phase of technical development, and it seems unlikely that there will be significant further technological advances in the process, particularly in membrane technology, pre-treatment and detail engineering. The development of chlorine-tolerant membranes or, alternatively, the adoption of biocides that are non-aggressive to membrane materials would be a significant advance. Membrane replacement, however, is still a considerable factor in O&M, if we could estimate the life period of such brackish water membranes of 5-7 years under good operation conditions.

1.10.2 Energy Consumption

It has been seen that BWRO plants have a lower energy consumption than SWRO plants, making this option attractive in high-energy cost conditions. Energy consumption forms about 25 to 50% of the total cost required to produce desalinated water by BWRO plants, taking into consideration the cost of energy which amounts to 0.09US$ /kWh.

1.10.3 Operational State

Most of the BWRO plants have still not reached a full daily operational status (24 h). This is due to many challenges such as:

- low maintenance level for the system.
- lack of chemicals such as antiscalants or acids imported to run the units.
- inefficient distribution in networks to the whole area where the plants are located.

- dependence of operational hours on the limited quantities of desalinated water marketed in some areas of the Gaza Stripe.

1.11 Conclusion

The study indicated that the performance of these RO plants was satisfactory in removing high TDS, though the efficiency deteriorated with time. The average utilisation of these RO plants, from their installation on, was about 50% as compared to the design capacity, mainly due to a non-continuous availability of power in some areas, time lapsed in repairs of pumps, and the non-availability of spares. The average capital cost/m3 and O&M cost/m^3 of product water from these plants amounts to \$0.29 and \$0.10 respectively, on condition that the plants are utilised as per the design capacity. These costs are high and not affordable by the rural population. The RO plants were socially acceptable since the population was satisfied with the treated water quality.

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2 Principle of Cost Recoverage in the German Water Sector - Ingrid Althoff

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Water Resources Management Group

2.1 Abstract

As a consequence of the EU Water Framework Directive (WFD), target values exist for a nationwide protection of water bodies. These target values were implemented under national law. The most important principles, that were laid down in the directive are the "polluter-pays-principle" and the "precautionary principle", as well as the objective to achieve a "good ecological condition" of surface water and a "good quantitative and chemical condition" of groundwater until 2015. Part of the polluter-pays-principle and the precautionary principle is among others the "cost covering principle" (WFD, 2000). By means of cost-covering water pricing, which is requested by EU (Article 9, WFD), water supply utilities are able to establish and maintain a water-supply infrastructure. In Germany, water prices are already formed by this cost coverage principle. Thus, all costs that incurred because of drinking water supply must be covered by the water price. When it comes to sustainability in Germany, cost covering has led to the possibility of public water supply utilities continuously investing in maintenance, modernisation and enhancement of facilities. The same applies to calculation of wastewater charges (Branchenbild der deutschen Wasserwirtschaft, 2005).

The cost coverage principle is legally embedded in the Local Tax Laws (LTL) of the federal states. Which means: the LTL prescribes the obligatory the adherence of the cost coverage principle for the public-law utilities, including the costs for preservation of real-asset values and refinancing of the facilities. The quality standard in Germany is characterised by low water losses, high drinking water quality, a continuous renewal and rehabilitation of the drinking water network and a connection degree of 99% to the public drinking water network. In European comparison the quality standard reaches a very high level. Moreover, the scale and quality of wastewater treatment are very high; the same applies to the connection degree to the sewage network (96%) and the wastewater treatment plants (94%) (purification of wastewater with highest EU standards, that is, biological wastewater treatment with nutrient elimination, hence 3rd purification stage, according to EU-Directive 98/15/EG - "municipal wastewater". Domestic wastewater that is not connected to a central wastewater system (ca. 6%) is treated by decentralised small sewage treatment plants or the like (Statistisches Bundesamt, Fachserie 19/2.1, Heft 2004). The high supply and disposal quality

in Germany has its price that is directly defrayed by the consumers, who have to pay 98% of the costs for drinking water supply and 93% of the costs for wastewater disposal (VEWA- Studie, 2006).

2.2 Introduction

In July 2007, the European Commission has presented its concept for an economical use of water by making the announcement "nswers of the challenge of water shortage and drought in the European Union"; this concept is up for consultation and shall assume a law form until 2010. Furthermore, the objective of this announcement is to begin a discussion about water management in the Member States and European Parliament. In 2008, the Commission will publicise a research report. According to the Commission, the costs of water consumption are prospectively to be calculated alone by the amount of water consumed. The aim of this is a more economical water usage and the preparation of the European Union for the increasing drought in some regions.

Within the scope of the European Union, the concept of the economical water usage is already known. Regulations for economical water usage do already exist, see article 9 of the Water Framework Directive (WFD, 2000), *"Member States shall take account of the principle of recovery costs of water services, including environmental and resource costs, having regard to the economic analysis, [..]Member States shall ensure by 2010"*. According to the polluter-pays-principle, at least the main user groups, which are industry, agriculture and households, should have an adequate share in the costs that accrue to the water supply utilities.
Furthermore, a fee policy, oriented on environmental targets, is to be formed in a way that adequate incentives for the users will be created, so that an efficient and sustainable use of water resources can also be established. In Germany, water supply and wastewater disposal are the responsibility of public services of general interest, within the competence of the municipalities, thus they underlie the municipalities right of self-government (Artikel 28, Abs. 2, Grundgesetz). Hence, the water supply and wastewater disposal are particularly committed to environmentalism and the sustainability concept (Artikel 20a, Grundgesetz). Next to their actual activities and tasks, the water supply and wastewater disposal utilities

take care of other responsibilities, which serve the protection of water bodies and the protection of the water resources as a whole. Particularly in Germany, instruments for internalisation of environmental and resources costs are available due to the wastewater levy, water abstraction levy, as well as compensation levy for nature protection (BMU - Umwelt Bundes Amt, Nov. 2004). The German water sector is subject to a constant modernisation process. It is important to maintain and develop high standards and to keep prices at a stable level. Prices, quality, environmental requirements and water extraction rights are subject to strict control by the state. Voluntary benchmarking is used to a huge extent throughout the water sector. It serves the water supply and wastewater disposal utilities to compare one another and improve onet's performance (Branchenbild der deutschen Wasserwirtschaft, 2005).

2.3 Water Consumption in Germany

In 2005, around 6400 water supply utilities guaranteed public water supply in Germany. For the abstraction of drinking water mostly ground and spring water (73.5%) are used, as well as surface water (bank filtrate, impounding reservoirs, enriched ground water, direct extractions from rivers and lakes) with 26%. The public water supply uses about 5.4 billion m3 per year that is equal to 2.9% of the available resources in Germany; the total renewable water reserve amounts to 188 billion m3 per year (Figure 2.1). The main water consumers, who are supplied from the public water supply, consist of around 80% of households and small business enterprises; the rest is divided into e.g. larger industrial enterprises, schools, authorities and hospitals etc (BDEW Wasserstatistik, 2005; BMU - Umwelt Bundes Amt, Jan. 2006).

The EU-Commissiont's announcement in July 2007, "answers of the challenge of water shortage and drought in the European Union" states, that agriculture in Europe had the highest water consumption, namely 64%. In Germany water abstraction for agriculture plays quantitatively a secondary role, with less than 1% of the total water abstraction, which is due to the climatic and geographic conditions. As figure 2.2 shows, the average water consumption of households and small business enterprises in Germany decreased immensely between 1990 and 2006; from about 147 l/(C.d) to approx. 125 l/(Cxd). It is stabilising at a

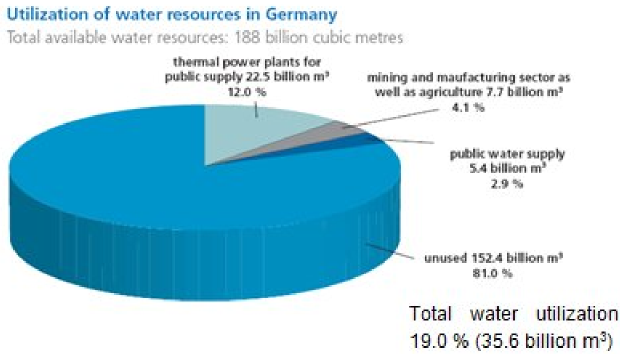

Figure 2.1: Total water utilization 19.0% (35.6 billion m^3) - Sources: Statistisches Bundesamt, Fachserie 19, Reihe 2.1, 2004 (erschienen in September 2006); Bundesanstalt für Gewässerkunde

low level. From the operation point of view, there is hardly room for any further downward margins, because adequate capacities need to be made available for peak demand. A further reduction of water consumption supported by politics is not reasonable (Branchenbild der deutschen Wasserwirtschaft, 2005; BDEW-Water Statistic of the respective year).

In comparison with other European countries only a small number of countries like Bulgaria (116 l/(Cxd), Slovakia (109 l/(Cxd), Belgium (107 l/(Cxd), Czech Republic (103 l/(Cxd), Estonia (100 l/(Cxd) and Lithuania (97 l/(Cxd) have a lower water consumption than Germany. Throughout Europe, the consumption per-capita and day varies between 97 l (Lithuania) and 294 l (Romania) (BDEW-Wasserstatistik, 2006). In order to determine the water consumption of German households, the consumption of all German small business enterprises has to be deducted. The water consumption is estimated by the Federal Association of German Gas and Water Management r. A. (BGW) to be an average handed over amount of 9%; this corresponds with a water amount of 11 l/(Cxd). Thus, the private households consume about 114 l/(Cxd) in national average (BGW, Jan. 2007). According to the Forschungsstelle Recht, Ökonomie & Umwelt, Universität Hannover, in no other European country “water saving” has such a high priority as an aim of environmentalism as in Germany.

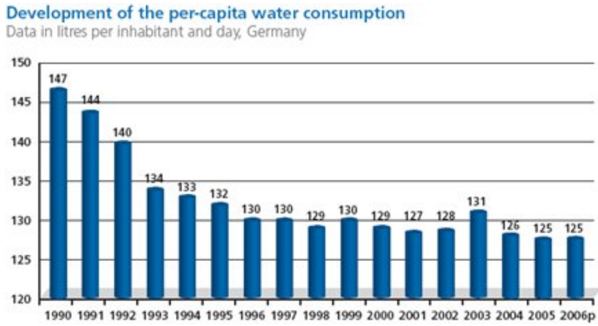

Figure 2.2: Sources: BDEW Water Statistics of the respective year, related to households and small business enterprises

From 1990 to 2005, a decrease of the water delivery volume of public water supply to the consumer was realised, by approximately 22%. That is a decrease from 5.99 to $4.65 billion m^3$ (BDEW-Wasserstatistik, 2006). Reasons for the decrease of water consumption are among others the constitution of water prices, that includes incentives for a rational use of water and are supposed to counteract lavishness of water resources; further reasons are the installation of water metres, the installation of water saving sanitary facilities, and the purchase of water efficient domestic appliances. Since the consumer has an insight into the measurement results of the water metre, which the water bill applies to, the consumer himself is able to control the costs of his water consumption and therefore he is able to readjust his usage behaviour accordingly. Moreover, the water supply utilities are permanently in contact with their clients by means of their customer and information centres; they inform their clients particularly about the following topics: rational water use, water quality and pricing. The reduction of water consumption in the industrial sector is due to the introduction of resource-friendly production processes, a decrease in water purchase, as well as an increase of self-production. In Germany, the industry covers 96% of its water demand with its own production. The effect on the supply utilities is an increasing need to act as corporate managers in industrial water supply (VEWA-Studie, 2006; Branchenbild der deutschen Wasserwirtschaft, 2005).

The EU announcementt's demand, according to which the prices should be linked directly to the amount of consumed water and to the caused pollution, is fulfilled in Germany, for both the public water supply as well as the wastewater disposal. In addition, water abstraction takes place according to ecological aspects. Equally to a discharge of wastewater, any water abstraction needs a water right allowance or a permission, which will be issued only after a careful check-up by water authorities (WHG, 2002). Besides, more and more rainwater is used in households, e.g. for watering the garden, toilet flushing, etc. This applies also to agricultural matters; in situations in which irrigation is needed, efficient methods are introduced (e.g. drip irrigation, etc.).

2.4 Cost Structure of Water Supply and Wastewater Discharge

2.4.1 Water Supply

Drinking water supply utilities are usually municipal utilities or small state-run utilities of municipalities; however, they provide only 25% of the water output. The bigger amount of water output is provided by mixed public-private companies (AG/GmbH), public-law companies (AG / GmbH), water and soil associations, special-purpose associations, municipal companies (AG / GmbH), as well as by other private-law companies. In terms of the water output, public forms of business organisations provide 36%, while the private forms of organisations provide 64% of the water output. Within the pluralistic supply and disposal structure in Germany, private and public companies do not conflict, but complement one another (BDEW-Wasserstatistik, 2005, Branchenbild der deutschen Wasserwirtschaft, 2005).

In Germany, the structure of water prices, which consist of variable and fixed price elements, relates to the structure that is proposed in the EU announcement (July 2007). The consumer pays, according to the polluter-pays-principle the water price that accrues to the water supply utilities for the provision of drinking water in their service area in a sufficient quantity and sound quality. The transparency in pricing and the corresponding disclosure of information to the consumer, which were postulated in the EU announcement (July 2007), are carried out in Germany. Water supply utilities publicise their current charges or changes in official announcements, in the local and regional press, via mail circular, PR brochures, water invoice, etc. The consumer is informed about the price level and structure.

The fixing of prices and charges is subject of up to a threefold control and strict statutory regulations. The legal check-up of the pricing takes place on several levels. Municipal utilities of water supply and wastewater disposal are controlled on the municipal level by municipal/town or local council and within the associations by the respective association bodies and by the municipal supervisory authority (the municipal supervisory authority is responsible for the adherence of local tax laws). Furthermore, pricing is controlled by representatives of the current board of supply and disposal utilities, who were democratically elected. Through the elected municipal representatives participation of users and consumers in water pricing is given (control by civil or administrative court). In addition, utilities, either public or private, are subject to the supervision of cartel authorities, as far as they invoice their services directly by price to the consumers (charge under private law) (K.E. Kappel, W. Schmidt, 2007).

In German public water supply utilities, pricing is based on five general principles, which will be discussed in the following passages. These principles were already published in the water supply report from the federal government in 1982, and are also considered in the local tax laws of the federal states:

- **Cost coverage principle**

  All costs caused by water supply and wastewater disposal must be covered by the price or charge, respectively; a long-term surplus cover is not permissible. In addition, there is the principle of equivalence, meaning: The prices or charges must not be significantly above the value of the service for the citizens, independent of the cost of the service. The concept of cost recovering enables utilities economically to ensure the necessary investments for build-up and maintaining at the right time. It also makes the long-term securing of water supply for the citizens and industry possible that is not only sufficient in quantity but also sound in quality and that is available 24/7. The different site-specific conditions, at a particular supply area, are influenced by water extraction, treatment, monitoring, storage, transport and distribution of drinking water. They are considered according to the principle of cost recovering of water prices (Branchenbild der deutschen Wasserwirtschaft, 2005; BGW, Aug. 2004; Kommunalabgaben-Gesetz NRW, 2005).

- **Breakdown of charges of consumer groups according the costs caused by specific consumer groups**

  During the supply process various conditions are calculated, which might influence utilities, because of the possibility that they might have a different financial impact on some utilities. E.g., it is cheaper to deliver an amount "X" of water through an adequately dimensioned pipeline to an industrial customer, than the delivery and accounting of the same amount "X" through a wide branched piping to several hundred small business enterprises or thousands households. There is also a difference between urban and rural areas. Another fitting example is the case of seasonally used holiday flats and buildings; the costs concerning these premises are also specifically higher because a sufficient capacity needs to be provided (Branchenbild der deutschen Wasserwirtschaft, 2005; BGW, Aug. 2004).

- **Consideration of cost structure for determination the base price and the quantity price**

  For water abstraction, treatment, storage and distribution manifold technical facilities are required, thus high plant intensity is given. The consequence is the utilitiest' high share of investment costs (new construction, extension and renewal) at the total costs. The average costs for water supply can be subdivided into 70-80% fixed costs and 20-30% variable costs. Fixed costs include the costs for operation and maintenance of facilities. Thus, the vast parts of the costs incur independently from the system's usage rate; only a relatively minor part of the costs is affected by the quantitative provision of water, these costs include costs of equipment for water treatment, electricity costs for pumping, water abstraction charges etc.. Thus, e.g. maintenance and personal costs only depend to a minor extent on the operating efficiency. Most water supply utilities' (approx. 95%)

price structure contains two components: a fixed monthly or annual base price and a quantity-dependent price (Euro/m3). In Germany, the base price amounts currently to about 10% of the total price. Thus, the structure of the water prices is inversely proportional to the cost structure of the utilities (Branchenbild der deutschen Wasserwirtschaft, 2005; BGW, Aug. 2004; Kommunalabgaben-Gesetz NRW, 2005). The German structure can be taken from figure 2.3.

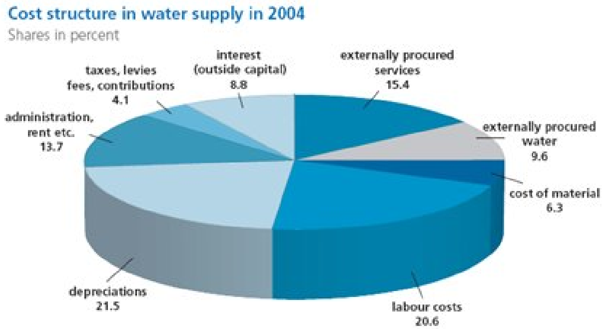

Figure 2.3: Sources: Statistisches Bundesamt, Fachserie 4, Reihe 6.1, 2004 (erschienen im November 2006)

- **Adequate interest yield for equity capital and debt capital**

  The economical stability of utilities is a prerequisite for a long-lasting securing of water supply. Water supply utilities should obtain a profit that allows at least a current market interest of the capital invested. This corresponds with the principles of an economic activity of municipalities that are stated in the municipal bylaws of the federal states. Moreover, this promotes the interest of investors to finance water supply.

- **Consideration of the principle of preservation of substance**

  Concerning long-term security of supply and disposal, the consideration of costs maintenance and renewal of technical facilities is very important. The municipal water supply system has a long service life of approx. 20 years for measurement, control and feedback control systems and up to 70 years for pipelines and hydrants. Thus, after service life, the replacement of the equipment cannot take place at the same prices as in the year, in which the system was built, caused by inflationary price development. In order to hinder a subtle depletion and a decoupling of the utility from technology development, it is essential to think in a future-oriented manner. Thus, if necessary, the financial funds are available for renewal, redevelopment or for development of the facilities (Branchenbild der deutschen Wasserwirtschaft, 2005; BGW, Aug. 2004; Kommunalabgaben-Gesetz NRW, 2005).

2.4.2 Wastewater Disposal

In Germany each producer of wastewater is obliged, to discharge the wastewater into a public system, as long as he does not have an exemption from the water authority. Wastewater disposal is the responsibility of public service of general interest, for which municipal bodies performing the function of the cities and townships are responsible. Thus, the bodies providing wastewater disposal are usually utilities under public law. E.g., municipal utilities (39%), special-purpose and water associations, as bodies of several municipalities (17%), and institutions under public law (8%). Furthermore, state-run utilities are completely integrated in the municipal organisation structure (32%) and others (4%). The percentage of the above mentioned organisation forms are rated by the number of utilities. Hence, public utilities are mainly in charge of wastewater disposal. However, they are increasingly using entrepreneurial instruments. In Germany, there are more than 6,900 wastewater disposal utilities. Private wastewater utilities are mainly active in operative business by means of operator or management contracts (BGW/DWA- Wirtschaftsdaten der Abwasserentsorgung, 2005; Branchenbild der deutschen Wasserwirtschaft, 2005; BGW, ATV-DVWK, Marktdaten Abwasser 2003).

In Germany, there are two systems to calculate wastewater charges: the freshwater standard and the split charge standard. Using the freshwater standard goes as follows: a charge is levied that depends on the used quantity of freshwater (simplified assumption: freshwater quantity = wastewater quantity). It is assumed that the quantity of freshwater obtained of the drinking water network flows completely into the sewage system. Costs for rainwater collection and treatment are included in this charge as a lump-sum. The consumer gets an invoice, which is not split up in wastewater and rainwater. The method of freshwater standard is simple, but the method does not consider the actual quantity of rainfall flows in the sewage system, which accrues from the paved parking places and roof areas. In inhomogeneous areas this method would probably lead to iniquities (BGW/DWA- Wirtschaftsdaten der Abwasserentsorgung, 2005; Dudey, J., 2002; Kommunale Steuer Zeitschrift, 2003). Alternatively, it would be possible to upraise the charges also in accordance with a split charge standard. This is already carried out in many municipalities in Germany (mainly in bigger cities). In order to use the split charge standard, the costs for disposal of wastewater must be divided equally, according to the principles of cost causation, between the sectors of wastewater and precipitation water. Hence, a charge for wastewater is raised, which is continuously calculated according to the used quantity of freshwater. In addition, a charge for precipitation water disposal is calculated. The amount of the latter charge depends on the m2 of paved and/or built-up plot area, since the precipitation water flows off that area into a public sewage system => m^2-standard (BGW/DWA- Wirtschaftsdaten der Abwasserent-sorgung, 2005; Dudey, J., 2002).

According to the decision of the Federal Administration Court, the split charge must be brought into use in NRW as off 13th May 2008 (OVG, 18.12.2007; BVerwG 13.Mai 2008). For municipalities that have not yet implemented this split charge, the decision means the following: The adjustment of their previous calculations of the wastewater charge, the amendment or adjustment of the by-law, public relation and determination of paved areas. Costs for precipitation water disposal from public streets and public buildings must be excluded. The provider of public easement of the street and buildings is responsible for the compensation of these costs, (figure 2.4). When residents pay according to the split charge standard, they receive an invoice, on which wastewater and rainwater are listed separately. With the usage of this approach an equitable redistribution of the load of charges will be achieved, since, according to the polluter-pays-principle, incurred costs are more strongly co-financed by consumers, who discharge a big amount of surface water and only a small amount of wastewater in the sewage system. Next to the legal situation, the existence of a fair and ecological wastewater charge now also leads to the changeover/ adjustment of the charge from freshwater standard to the split charge standard (BGW/DWA-Wirtschaftsdaten der Abwasserentsorgung, 2005; Branchenbild der deutschen Wasserwirtschaft, 2005; BGW, ATV-DVWK, Marktdaten Abwasser 2003; Dudey, J., 2002; Kommunale Steuer Zeitschrift, 2003).

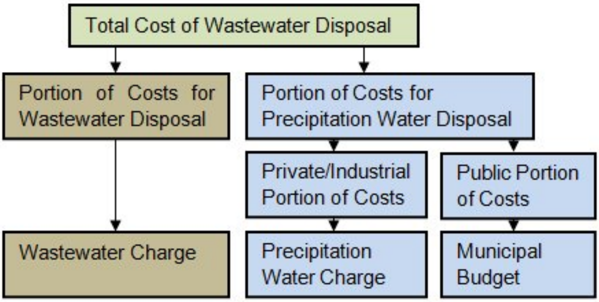

Figure 2.4: Split Wastewater Charge

Cisterns and rainwater harvesting systems have a positive effect on precipitation water charge as long as rainwater from rainwater utilisation facilities does not flow in a public sewage system. However, if rainwater was used as service water e.g. for toilet flush, and thus was discharged in the sewage system, the consumer would have to pay a wastewater charge. In that case, an additional water metre has to be installed. If the owner of a plot of land wanted to use the rainwater, which accrues on his plot, as service water, he would have to inform the municipality. It is not allowed to connect rainwater that is used as service water, with the drinking water supply network (Stadt Bonn, Regenwasserbewirtschaftung).

In either charge concepts/system (freshwater or split charge), it is possible to collect a basic charge that, as a general rule, is being levied as a fixed annual amount. Consumer- independent fixed costs caused by wastewater disposal are more homogeneous distributed among all inhabitants connected to wastewater disposal facilities through the basic charge. At the same time, the basic charge contributes as a stabilising element to cushioning the increase in charges. Fixed costs are e.g. costs for rehabilitation, operation and maintenance of wastewater facilities (e.g. sewage system or wastewater treatment plant), as well as depreciations, interest, labour costs, etc. (Figure 2.5). Approximately 75% to 85% of costs for wastewater disposal arise independently of how much wastewater is collected and treated in a wastewater treatment plant. Hence, fixed costs in Germany are comparatively high (BGW/DWA- Wirtschaftsdaten der Abwasserentsorgung, 2005; Branchenbild der deutschen Wasserwirtschaft, 2005).

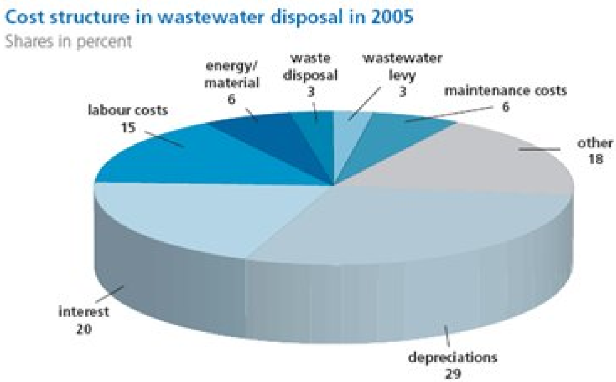

Figure 2.5: Sources: BDEW/DWA-Wirtschaftsdaten der Abwasserentsorgung 2005

The facilities of wastewater disposal are usually very durable economic goods, their purchase cost and production costs are distributed to the entire service life, the same applies to facilities of water supply. When it comes to calculation, the long service life of capital-intensive technical facilities is a particular challenge for the wastewater disposal utilities. The service life of a sewage system lies between approximately 50 to 80 years and that of a wastewater treatment plant between 15 to 20 years etc. *"The collection of wastewater charges is subject to a strict principle of cost-recovery independent whether the calculation is made according to freshwater standard or split charge standard"* (BGW/DWA- Wirtschaftsdaten der Abwasserentsorgung, 2005). Thus, the consumer pays only the costs which arise for the wastewater disposer during the collection and wastewater treatment. These costs include also the wastewater tax, which is a statutory extra fee. The state raises this fee for the discharge of wastewater into a water body. The amount of the wastewater tax depends on the residual contents of wastewater substances in the discharged wastewater. Primary the wastewater tax was a steering instrument. Due to the high standard of the German wastewater disposal, it has lost its steering effect and function (VEWA- Survey, 2006; BGW/DWA- Wirtschaftsdaten der Abwasserentsorgung, 2005).

2.5 Mean Water Price in Germany

2.5.1 Fiscal Framework

In Germany, the taxation for water supply is different from the taxation for wastewater disposal utilities. Water supply utilities are taxed with a uniform and reduced turnover tax rate of 7%. However, among wastewater disposal utilities taxation is regulated in a more differentiated manner, one principally distinguishes between the legal forms "public-law" and "private-law". Public wastewater utilities as sovereign undertakings are exempted from corporate tax and turnover tax, while the private-law utilities are subject to a full turnover tax rate of 19%; a pre-tax deduction is possible. The fiscal frame conditions of the water industry/sector are currently subject to intense discussions, both on a national and a European level. The review of the positive and negative effects of a fiscal equality of water and wastewater is available in the "report of the federal government on the modernization strategy for the German water industry/sector.." (Bundesdrucksache 16 / 1094, 16.03.2006; Branchenbild der deutschen Wasserwirtschaft, 2005).

2.5.2 Drinking Water

The quality of German drinking water seems very good in European comparison, but with an average price of $1.85 Euro/m^3$ ($1.80 Euro/m^3$ in 2002) also very expensive. Italy ($0.73 Euro/m^3$) and Spain ($0.72 Euro/m^3$) have lower water prices; even though dryness/drought occur periodically in these countries. Perhaps, water prices in Italy and Spain can be understood as indirect subventions for agriculture or farming sector, respectively. Great Britain and France have average water prices of $1.25 Euro/m^3$ and $1.09 Euro/m^3$ (DStGB, Nr. 13-2007; NUS, 2001-2002).

In the past years the rise in German water prices has decreased drastically. In 1992/1993 the rise in water price amounts still to 11.7%, however, in 2006/2007 it decreased to 0.5%. Thus, the increase in price is again far below the average inflation rate of 1.7%. To ensure high quality and nationwide drinking water supply requires a large-scale infrastructure, partly accompanied by high cost of development (e.g. construction of impounding reservoirs and regional supply systems,Ě), because there are regional differences in relation to the water resources. Hence, also in Germany water prices vary regionally, because each water supply utility has other decisive parameters for water abstraction, treatment and distribution, these parameters have an effect on the costs (BGW, Aug. 2004; BDEW-Wassertarifstatistik, 2007). Different parameters are the following:

- The distance from the area of abstraction to the consumers
- The quality of raw water and the effort for the treatment to drinking water
- The connection density of the households and enterprises provided, and the topographic particularities at running of water pipes
- The costs for quality control of drinking water
- The condition of the piping system and the necessary cost for reparation, operation and maintenance
- In addition costs occur with assurance of extinguishing water availability. Fire prevention is responsibility of municipalities, according to the statutory provisions for fire prevention applicable in the different federal states. To provide fire prevention one makes use of the public drinking water supply. In what way depends on the efficiency of the pipeline network, the availability of water resources and the supply situation. Normally, fire prevention is locally regulated between municipality and water supply utility, who signed a contract with one another

- Concession fees, which exist in many places, are paid by the water supply utility to the concerned municipalities (Branchenbild der deutschen Wasserwirtschaft, 2005; BMU, Wasserwirtschaft in Deutschland, Teil1-Grundlagen, Januar 2006).

Furthermore, in Germany, consumers are additionally charged with a compensatory payment to the agriculture/farming sector, for water-body-friendly management in water protection and catchment areas. Thus, farmers in protection areas e.g. use fertiliser and pesticides environmental friendly or avoid soil erosion by special measures. The direct cooperation between agriculture/farming sector and water supply utilities has proofed to be very effective (Branchenbild der deutschen Wasserwirtschaft, 2005).

Since the water price in Germany is dependent on the above mentioned general conditions, it varies currently between $0.52 Euro/m^3$ and $3.95 Euro/m^3$. In Germany the average payment made by citizens for drinking water daily lies at around 23 Cent (without house connection costs and wastewater), 9 Cent for a shower or 22 Cent for a bath, that complies to 0.2 Cent per liter, at a given water consumption of 125 l/(C.d). Consequently, the annual average costs amount to 85 Euro per year and per inhabitant or to 7 Euro per month. That means the proportion of costs for drinking water, compared to the annual income of the households, amounts to ca. 0.5% (BDEW- Wassertarifstatistik 2007).

2.5.3 Wastewater Disposal

Since 2000, the German wastewater charge has been relatively stable. In 2005 the charge increased by 1.4% in comparison to 2004. On an average the increase rate is below the inflation rate of 2%. At the freshwater standard the inhabitant pays an average charge of $2.28 Europerm^3$ wastewater (wastewater and precipitation water). In case of the split charge standard, the inhabitant pays an average wastewater charge of $2.05 Euro/m^3$ and a precipitation water charge of $0.88 Euro/m^2$ paved and drained plot area. Thus, at national average in 2005, the charge for collection and treatment of wastewater and precipitation water is about 129 Euro per year, that is about 35 Cent per inhabitant and day (connection costs are included) or 10.75 Euro per month. Wastewater charges are regionally very different, as are prices for drinking water. This is due to various general conditions like infrastructure, water consumption, differences in local topography, demand of rehabilitation, population density, different basis of calculation, considering the Local Tax Laws of the federal states, etc. (BGW/DWA- Wirtschaftsdaten der Abwasserentsorgung, 2005). Concerning the split charge standard, in 2007, e.g., in Cologne the citizen paid a charge of $1.18 Euro/m^2$ paved area for precipitation water and a charge of $1.32 Euro/m^3$ for wastewater, while the charge in Dortmund amounts to $0.83 Euro/m^2$ for precipitation water and to $1.81 Euro/m^3$ for wastewater, and in Siegen to $0.90 Euro/m^2$ for precipitation water and to $2.02 Euro/m^3$ for wastewater. In 2007 the citizen, living in municipalities in rural areas, paid, e.g., in Bergneustadt a charge of $1.14 Euro/m^2$ for precipitation water and a charge of $4.13 Euro/m^3$ for wastewater, in Gummersbach the charge amounts to $1.10 Euro/m^2$ for precipitation water and to $3.40 Euro/m^3$ for wastewater and in Engelskirchen to $1.31 Euro/m^2$ for precipitation water and to $3.96 Euro/m^3$ for wastewater. A town or municipality, which still accounts according to the freshwater standard, e.g., the charge in Bad Münstereifel amounts to $4.82 Euro/m^3$ (wastewater + precipitation water), to $5.08 Euro/m^3$ in Lindlar, to $4.40 Euro/m^3$ in Rösrath or $6.29 Euro/m^3$ in Waldbröl (according to the Information request among the municipalities).

2.5.4 International Price Comparison

When comparing drinking water costs per inhabitant and year, in 2003, with its 82 Euro Germany is ranking behind England/Wales with 95 Ă and France with 85 Euro. The comparisons are taking into account the higher water consumption in the other countries. However, in terms of compliance with drinking water quality, the condition of networks, interruptions of supply, water losses and subsidies etc. the different standards are not considered. Within the scope of wastewater disposal, the annual per capita burden in 2003 amounts to 111 Euro in Germany, 90 Euro in France and 93 Euro in England/Wales. The state subsidies, allowances and differences in the performance level etc. are not considered in this comparison. If one includes these factors, the wastewater charges in England/Wales are higher than those in Germany and France (VEWA-Studie, 2006). Hence, one should judge an international comparison of water price very critically, because in many cases the water prices do not reflect the real/actual costs for water supply. A comparison of costs per m^3 as indicator for efficiency and performance of the supply and disposal utilities, alone, has no relevance. In Europe, water prices are often political prices, which are accompanied by subsidies and allowances (BGW-Presseportal, 2007).

In Germany, the water consumption is generally ascertained per measuring instruments (water metre) and invoiced according to the measured quantity. Each residential building (every flat) and further buildings with water connection have a water metre, which is well-calibrated at regular intervals. That is not the case in all European countries. E.g., in England water metres are installed only in about 20% of the houses, roughly 80% of the consumers received a water bill on the bases of estimations. It is also problematic to compare the prices per m3 or the annual costs of the inhabitants among the European countries in terms of wastewater charge. In order to do so, the different models of cost re-coverage, different quality levels, state or regional subsidies, connection, maintenance and renewal rate of the sewage system as well as the connection degree to wastewater treatment plants and the quality of wastewater treatment have to be considered, too (BDEW, März 2001).

The Metropolitan Consulting Group has compiled a study on behalf of the German Association of German Gas and Water Management (BGW) to be able to conduct a comparison of the costs in water supply and wastewater disposal. The Study or comparison, respectively, is based on three sequenced levels, because there are considerable differences regardless of the uniform European rules (VEWA-Studie, 2006). The levels are:

1. Comparison of average, country-specific prices for the consumer, including turnover tax

2. Cost covering water prices: Here, in addition the subsidies and allowance are included in the calculation, which the consumer in the end financed by the taxes

3. Price at a uniform performance level: Here, it is calculated how high the costs for water and wastewater would be at a similar performance and quality level as in Germany. However, only the most important performance parameters are considered (connection degree to the sewage system and the wastewater treatment plants, renewal of the sewage system, standards

of wastewater treatment). Costs for operation of the third purification state etc., e.g., are not considered (VEWA-Studie, 2006).

The result of the study shows: If England/Wales and France reached the German quality standard, for both countries the annual costs for drinking water would amount to 106 Euro per capita and hence the costs are higher as in Germany (84 Euro/C). Concerning the wastewater disposal England/Wales (138 Euro/C) and France (122 Euro/C) are both more expensive than Germany (119 Euro/C) (VEWA-Studie, 2006).

2.6 Abstract of a contribution and charge by-laws

Now an example will be presented for a contribution and charge by-law in North Rhine Westphalia (NRW). The by-law can vary from one municipality to another, meaning that, the by-law is not the same in all municipalities. When it comes to drinking water, one generally distinguishes between a base and consumption charge and a connection contribution. Concerning wastewater one differentiates between base and service charge and the connection contribution. The example discussed hereafter, is about an abstract of a by-law from a small town with roughly 19.000 inhabitants in NRW (because of data security the name of town is not mentioned).

2.6.1 Connection Contribution (e.g. Water Supply)

The city “X” levies a connection contribution for the refinancing of the average annual expense for new construction and extension of public water supply facilities. The one-time connection contribution is levied by the size of the plot area. The following parameters define a plot area:

- If the plot area is located in the scope of a binding land-use plan, the developable area is crucial, meaning that, the area on which the binding land-use plan allow the structural or industrial use.

- If no binding land-use plan is available, the actual size of the plot area up to a depth of 40 m is crucial, metered from the street (figure 2.6a).

- If the house, which is build on the plot area, is beyond the border of 40 meters or if the plot area can be used for industrial or structural purposes in a larger depth as 40 m, then the depths of the plot area is crucial. The depth of the plot area is given by the back border of the building coverage (figure 2.6b).

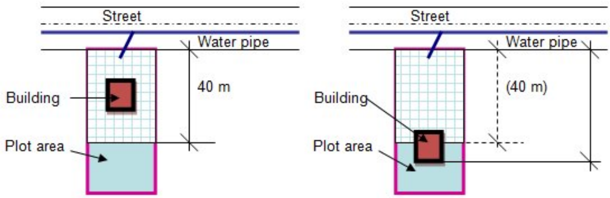

Figure 2.6: 6a; left, the building is inside the border of 40 m; 6b, right, the building is beyond the border of 40 m

The plot area is multiplied with the manifold per cent rate respectively to the utilisation.
The per cent rate particularly amounts to:

At single-storey development potential 1
At two-storey development potential 1.25
At three-storey development potential 1.5
At four and five-storey development potential 1.75
At six and multi-storey development potential 2

The connection contribution for the sewage system is levied at the same basis.

Note: The municipality "X" accounts its connection contribution for drinking water and wastewater according to the qualified charge standard, meaning that, it considers the various sizes of the plot areas, as well as the different development or development potential of the plot area, respectively. Various qualified charge standards exist. The so-called full-storey standard is used most often: the plot area is weighted according to the number of the full-storey. The so computed chargeable plot area is multiplied with the contribution rate in Ă/m2, which is stated in the by-law (Escher, der MDR Ratgeber, 2004).

E.g.: Plot area: 20 m broad, until 40 m depth, which complies 800 m2; three-storey development potential, connection contribution $1.30 Euro/m^2$. Thus, the connection costs are: $800m^2$ x 1.5 x $1.30 Euro/m^2$ = 1560 Euro

Only these plot areas are under the **liability to pay contribution** that can be connected to public water supply facilities (wastewater facilities) and are statedly for a structural or industrial usage, once they can be build-upon or industrially used. The liability to pay contribution accrues as soon as the plot area can be connected to the public water supply (sewage system). The connection contribution is to be paid one month after receiving the demand for payment.
Note: Hence, liability to pay contribution accrues not only with an actual connection, meaning that, if a building is constructed before.

Liable to contribution is the owner of the plot at the time when the liability to pay contribution accrues. If the plot is burdened with a heritable building right, the tenant under a building lease is liable to pay contribution instead of the owner of the plot. Multi- contributories are co-debtors.

The **connection contribution** amounts to drinking water per m^2 chargeable plot area that is calculated according to the permitted usable total plot area (e.g. 40 m border), e.g. 1.30 Euro. The connection contribution for the connection to pasturage and similar establishments amounts to e.g. 75 Euro per connection. The connection contribution amounts to a wastewater and precipitation water connection per m^2 chargeable plot area that is also calculated according to the permitted usable total plot area (e.g. 40 m border), e.g. 6 Euro. If there is a connection only for wastewater e.g. 70% of the charge is levied, and if there is a connection only for precipitation water, e.g. 30% of the charge is levied. At this point it must be mentioned explicitly that the connection contribution/charge differs from municipality to municipality, the above contributions/charges are just an example.

Note: It is not allowed to account the continuous maintenance and restoration of the water supply facility (wastewater facility), when calculating the connection contribution/charge. The costs for maintenance and restoration are included in the price for the basic and consumption charge in relation to drinking water or the basic and service charge in relation to wastewater.

2.6.2 Basic and Consumption Charge

The charge for drinking water is levied as basic charge and consumption charge. The consumption charge is quantity-dependent, meaning that the charge is calculated according to the obtained quantity of water. The billing unit is the m^3 water. The water consumption is measured by water meters. The basic charge of water meters with a nominal flow of (Ě) amounts to:

Nominal flow of Qn 2.5 (complies $2.5m^3/h$) 5.00 Euro per month Nominal flow of Qn 6 (complies $6m^3/h$) 9.00 Euro per month Nominal flow of Qn 10 (complies $10m^3/h$) 15.00 Euro per month Nominal flow of Qn 15-40 (complies $15-40m^3/h$) 35.00 Euro per month Nominal flow of Qn 60-150 (complies $60-150m^3/h$) 50.00 Euro per month
In this example, the consumption charge amounts to $1.25Euro/m^3$. As already mentioned in section 4.2, the charge can be lower or higher. The same applies to the basic charge as the following example shows. The water price amounts to $1.49Euro/m^3$ in Munich and to $1.61Euro/m^3$ in Cologne; the basic charge of water meters with a nominal flow of (Ě) amounts to (see figure 2.7):

Nominal Flow (Qn)	Base Charge in Munich	Base Charge in Cologne
2,5 m³/h	5,52 € per month	-------
6 m³/h	9,38 € per month	9,57 € per month
10 m³/h	15,45 € per month	18,26 € per month
15 m³/h	29,84 € per month	27,24 € per month
40 m³/h	39,78 € per month	61,81 € per month
60 m³/h	53,03 € per month	87,53 € per month
150 m³/h	79,55 € per month	194,21 € per month

Figure 2.7: Base price concerning the nominal flow of the water meter - Source: Stadtwerke München, RheinEnergie AG / Köln, ab 2004

The liability to pay charge starts with the ready-to-use preparation of the connection. For both, the water and the basic price, the reduced turnover tax rate of 7% takes effect.

2.7 Security of Supply

Long-term interruptions of water supply are unknown to Germany. That is justified by the technical standards of treatment and distribution and the very good condition of the networks as well, compared to other European countries. Germany has by far the lowest water losses. The water supply utilities succeeded, in the period between 1990 and 2004, to reduce noticeable the water losses caused by burst pipes and leakage (from $600 Mio.m^3$ to around $495 Mio.m^3$). That was enabled by investments into maintenance and renewal of the infrastructure. In a European comparison water losses are really low with 7% in Germany, followed by Denmark with 9%. In Italy and France the losses amount to 28% and 26% and in England/Wales at least to 19%, see figure 2.8 (VEWA-Studie, 2006; Statistisches Bundesamt, Fachserie 19/2.1, Heft 2004).

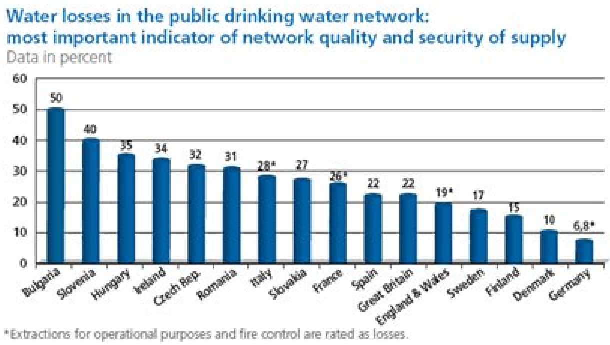

Figure 2.8: Sources: VEWA-Studie, 2006 (Italy, France, England/Wales); Statistisches Bundesamt, 2004 (Germany); Rest: EU Kommission 2007

In national average, rates of damages to water supply lines (less than 10 damages per 100 km/year), house connections and pipe-network-fittings are constantly low, related to the past few years. The total investment in drinking water supply amount annually to more than 2 billion euro. During the past few years there was no notable extension of the water network, thus the investments are mainly spent on facility maintenance. In the drinking water sector, Germany has the

highest average investments. In the period from 1995 to 2003, 0.54 Euro per m^3 were invested. At the same time period England/Wales invested 0.53 Euro per m^3, France 0.33 Euro per m^3 and Italy 0.15 Euro per m^3 - inflation-adjusted (VEWA-Studie, 2006).
The first step towards a leak-proof sewage network is the awareness of the damages to the sewer system. In the wastewater sector, 90% of the sewage network operators had documented their complete network through inspection in 2001. In fact, this percentage went up to 95% in 2004. The result of the inspection shows that around 20% of the public sewage system is in need of rehabilitation in short or medium term. Minor damages were existent for approximately 21.5% of the sewage network; these damages need to be rehabilitated in long term. It has to be noted that almost one third of the existing sewers have been constructed during the last 25 years, meaning that they are of latter age. As a consequence, two third of the existent sewers belong to the older generation (Berger, C.; Lohaus, J., 2004). Figure 2.9 shows a maintenance vehicle with a camera and a computer (EDP) on board. This vehicle is applied for the inspection of sewage systems.

Figure 2.9: Sources: left - www.rohrreinigung-egbers.de/kanalinspektion.php, right - www.consulaqua.de/abwasserwirtschaft.html

In the year 2004, the average cost for sewer rehabilitation amounted to approximately 540 Euro per meter of repaired sewer. For the rehabilitation measures an average amount of 20.34 Euro per inhabitant connected to the sewage network was spent in 2003. If one projected that to the entire federal territory with 82.5

million inhabitants, it would mean a sum off about 1.6 billion Euros only for sewer rehabilitation. In total, the investments of the waste water sector are on a very high level for many years with investments of approximately 5 billon Euros annually (Berger, C.; Lohaus, J., 2004). In the time period from 1995 to 2003, in Germany, the average investment per cubic metre waste water was 1.27 Euro, followed by England/Wales with 0.91 Euro, France with 0.72 Euro and Italy with 0.11 Euro (VEWA-Studie, 2006). In the year 2005 alone, the water and waste water utilities invested about 8 billion Euros; thereof the major part is spent on networks. As mentioned before, in Germany, all investment costs are included in prices and charges, whereas in other countries investments are financed partially by the municipalities themselves.

A major factor for a long-term supply and disposal security is the continuous investment in maintenance and renewal of the infrastructure. Therewith, one avoided investment batches or a clear sudden increase of the charges. A further step for the observance of statutory and technical requirements, as well as the customer satisfaction in terms of water supply and wastewater disposal, are correct and appropriate operation, adequate high-capacity facilities, sufficiently qualified personnel, a continuous advanced and further education of personnel, and measure and quality assurance. Measure and technical assurance are e.g. Technical Safety Management (TSM) certified by independent experts.

2.8 Benchmarking in the Water Management

In the German water industry benchmarking is a part of the modernisation concept. Benchmarking was developed and forwarded by the water industry itself in consultation with its political partners. Since 1950, in the German water supply and wastewater disposal sector a systematic comparison has been implemented. The comparison was made on the basis of indicators, related to todayt's benchmarking. In principle, benchmarking means nothing else than to compare oneself to others and to improve onet's performance by learning from the best within the comparison group. Thus, benchmarking is an efficient instrument to indentify, to get to know and to adopt successful methods and processes from benchmarking partners. Its aim is, to optimize processes and to open up potentials for improvement (Branchenbild der deutschen Wasserwirtschaft, 2005; DVGW-Merkblatt W

1100 - Entwurf, Juli 2006). [0.2cm] In 2002, the German Bundestag postulated among others things the "introduction of a procedure to compare the performance between utilities" in its resolution "sustainable water management in Germany". By the "Statement of the associations of the water industry on benchmarking in the water sector" in 2003, the water industry obligated themselves to cooperatively develop and refine a conceptual framework for benchmarking. The large-scale propagation of voluntary benchmarking shall be promoted as well. The German associations of the water and wastewater sector signed the extended "Statement of the associations of the water industry on benchmarking in the water sector" on 30th June 2005. By this statement the signing associations obligated themselves to a regularly submission of a water sector profile. The essential targets of the statement are supported by the German association of cities (DST) and the German association of towns and municipalities (DstGB) (Deutscher Bundestag, 2002; Verbändeerklärung, Nov. 2003; Verbändeerklärung, Juni 2005).

To the success of benchmarking two prerequisites make an essential contribution, namely the voluntary participation and the confidential treatment of information. A statutory prescribed benchmarking, as practiced in two EU countries for instance, cannot fulfill these conditions. In Germany, the voluntary benchmarking is realized by independent private providers. This procedure ensures a high quality standard of the benchmarking projects through free market mechanism (free selection of providers). In addition, competition and the free selection of providers lead to an optimal implementation of projects. In terms of benchmarking, the selection of appropriate comparison partners plays an important role. Due to the large regional differences in the technical, natural or legal marginal conditions, the performance indicators of the benchmark partners differ from each other. These have to be considered in benchmarking projects, otherwise it leads to incorrect results. As a result, appropriate benchmarking methods are required. One can find projects in corporate benchmarking (analysis of utilities as a whole), process benchmarking or comparison of performance indicators only. In the projects the water industry make sure that the aspects of supply security, supply quality, customer service, sustainability and economy are adequately taken into consideration (Branchenbild der deutschen Wasserwirtschaft, 2005; DVGW/DWA-Merkblatt W 1100). Benchmarking contribute to a continuous approvement, ultimately to modernization and to price stability into the German water industry. Ultimately, the approvements benefit the citizens.

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3 Rainwater Harvesting and Sustainable Energy Sources - Martín H. Bremer, Mario G. Manzano Camarillo

Building Up a Model For Sustainable Rural Develoment in the Semi-Arid Highlands Of Northern Mexico

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3.1 Introduction

The Monterrey Tech University (Tecnológico de Monterrey) aims at educating integral citizens committed to the social challenges of the Mexican community's diverse situation within the framework of sustainable development. It comes from these goals that professors and students are involved in several programs and projects at different levels to address specific problems associated with rural communities in remote regions in different climatic locations, such as the dry, semi-arid lands of Mexico's north-east. The programs described in this paper represent the projects in which the authors have been involved, and represent furthermore, the work of several colleagues and students. They have done either social work, their MSc. thesis or innovative projects focussing on water and energy issues and their associate socioeconomic impacts.

3.2 Background

One of the oldest program associated with rural development is the "Water and Life Program", located on a typical *ejido* (a rural landholding) named San Felipe, in the southern part of the Mexican state of Nuevo Leon. This project was commenced in January 1996 and it developed for several years by Dr. Hugo Velasco Molina†. The small town of San Felipe has a population of 72 people and expands over an area of 2.452 hectares. Small precipitation of about 300 mm/year characterizes the region. The project's aim was to develop and implement technology by means of applied investigation, extension and education in order to improve the quality of life of a community. This community would be a representative of the Mexican semi-desert concerning water, agriculture, cattle, employment and energy. On the other hand, it is considered that in Mexico 17% of the houses (3.653.178 according to the census of 2000) use firewood. If the consumption was to be halved, it would create a positive impact on environmental issues such as biodiversity, deforestation and CO2 emissions. Further achievements would be the improvement of the inhabitant's living conditions, as in time to collect firewood, the decrease of wastes and inhalation of smoke and others. There are several intents on making woodstoves that are more efficient and healthy than open fires in order to avoid those problems.

The projects of innovation for sustainability and integrated rural power development focus partially on the development and construction of devices that reduce sanitary problems. In addition, the production of alternative energy for cooking, heating/cooling and illumination is a major aspiration. Some of them can reduce the wood consumption for food preparation and can find substitutes taken from natural and renewable energy sources like solar, wind and organic wastes. The literature documents an infinity of devices (some more elaborated than others) for the use of alternative energy sources. Nevertheless, few scientists have documented economic and power efficiencies. Also, the reliability of operation and performance under real conditions is not proven.

3.3 Objective

In order to improve the living conditions of rural families, they are being provided with diverse energy and water sources and devices that can be constructed and maintained by the inhabitants themselves. These devices are adapted to the local socioeconomic and natural settings with an active enrolment of graduate and undergraduate students.

3.4 Specific Objectives

The development of a rural ejido as a model for rural sustainable development for communities with similar difficulties aims at working towards a culture for the sustainable use of water in the Mexican semi-deserts. The topics which are being addressed refer to water for humans, agriculture and cattle, food production for self-consume, production of autochthonous plant species, like cacti, and agave. This happens through management of surface runoff with infrastructure such as absorption terraces and water micro-catchments, long term employment and alternative energy. Furthermore, the identification, adaption and construction of prototypes to make use of diverse energy sources in order to satisfy the power need of rural families is intended.
As well as to implement technical, economic and environmental evaluation of the operation and synergies that could be obtained with the combined use of several devices under different environmental and socioeconomic conditions.

3.5 Activities and Projects

The Water and Life Program is divided into several phases, some of them have already finished, but others are still in progress.

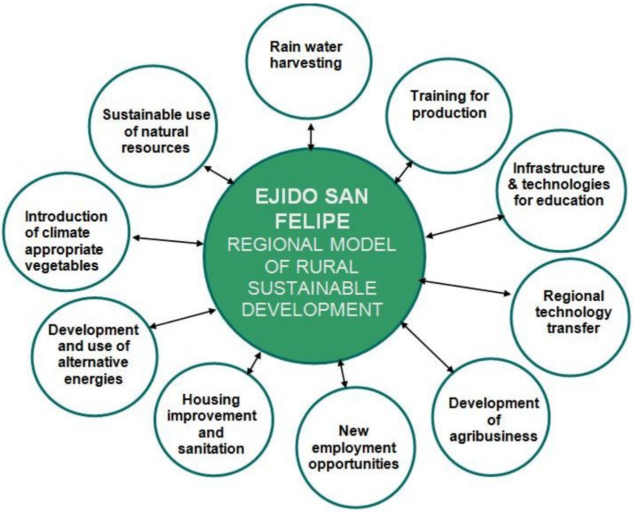

Figure 3.1:

Figure 3.2:

3.5.1 Phase 1: Potable Water Supply for Human Consumption (Roofing for Water Harvesting)

The first phase comprises the design and construction of a water permanent deposit for human consumption, which in the present case is a watershed-roof with a collector/container of pluvial water with a capacity of storage of 281.580 liters. With this container each one of the 70 inhabitants of the populace could have about $4m^3$ of water/year. This volume represents about the triple amount of what they originally have arranged to live with. The watershed-roof basin for San Felipe, with its 300 mm of annual rain, requires a metallic corrugated surface of $800m^2$. This easily offers a coefficient of runoff of 95%, which allows the collection of $200m^3$ of rainwater per year. This phase has been finished in November of 2002 and the construction time was six months.

3.5.2 Phase 2: Creation of a Source of Permanent Employment (Infrastructure for the Development of Goat and Ovine Livestock)

1. **The complete surrounding of the ejido's lands:** In order to localize the region, 21 kilometres land in perimeter were dismounted. 6.050 iron posts, of which 280 were used retained, 350 rolls of barbed wire, three gates for the ejido, four intermediate doors to put and to remove cattle, three doors next to the ejido's gate for vehicle access were erected.

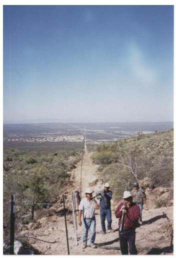

Figure 3.3:

2. **Design and construction of systems for rainwater collection (to grant 500 thousand litres):** The location of the three traps in strategically pointing towards the summer pastures of the ejido. This allows the husbandry of up to 800 herds of young animals/year. The construction period took up 18 months.

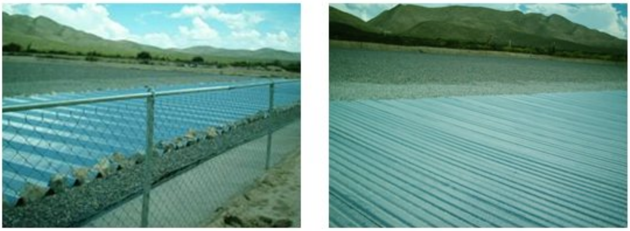

Figure 3.4:

3. **Erection of a fence for the exclusion of 500 hectares for the rehabilitation and sowing of summer pasture:** The construction of 5.64km of fences and the sowing of 300 hectares of grass, leaving the 200 hectares in-between to allow the draining of the pasture.

Figure 3.5:

3.5.3 Phase 3: Plantation of Fruit Trees: Peach Tree, Plum Tree and Apple Tree (Using Watershed Basins, Absorption Terraces and Water Taken from a Rainwater Collector System as Spare).

1. **Establishment of an orchard of peach trees in micro-watershed basins and a rainwater collection system for emergency watering:** Using the system of micro-watershed basins for an effective handling of rainwater, an orchard with 174 trees of Creole peach was planted in June 1996. The micro-watershed basins have shown a good efficiency. Nevertheless, in case of draught periods the ground can reach the permanent point of dwelling. This is prevented with the help of manual watering, using water of a recollection system. This system has a storage capacity of 220 thousand litres of rainwater per year.
   An orchard planted at the end of June of 1996, with 174 peach trees. The accumulated moisture after a rain is evident.
   Rainwater collection system with a capacity of 220 thousand litres that will allow giving water to six emergency irrigations of 200 litres, and thereby watering each one of the 174 trees of the peach tree orchard.

Figure 3.6:

2. **Design and Construction of a Solar Module of a catchment drain for the supply of plum trees:** This device consists of four absorption terraces, a draining embankment, a draining collector channel. Furthermore, a storage cistern with a capacity of 500 thousand litres of rainwater, four photovoltaic panels and a suction pump are part of the device. This suction pump elevates the water to a cistern for irrigation, with a capacity of 30 thousand

litres, with a conduction pipe that allows the irrigation of 107 plum trees. It has to be kept in mind that the efficiency of the rainwater collection module is evident and that the solar energy allows the transportation of water from the storage cistern to the irrigation cistern using gravity, in order to irrigate the orchard in times of draught. This allows to reduce the draining surface to three terraces of absorption and to increase their surface for cultivation, as to plant 44 additional plum trees, adding up to a total of 151 trees.
Aspect of the draining embankment constructed with the excavated earth of the cistern, waterproofed with polyethylene and place setting with gravel. This embankment produces 300 thousand litres of water per year, a volume that is lead through the channel prior to arriving at the sedimentation pond and finally at the storage cistern.

Figure 3.7:

3.5.4 Phase 4: Production of Vegetables for Self-Consumption (Using Water from a Rainwater Collection System and Drip Irrigation)

Construction of a rainwater collection system and a vegetable field of 1/20 of hectare: A rainwater collection system of the Vecar type was designed and constructed for 500 thousand litres of rainwater and a 500 m2 surface for vegetable planting. This enabled the population of San Felipe to learn how to produce organic compost and how to cultivate vegetable for their own consumption. The

infrastructure of this work was finished at the end of 1996 and was further worked on in 1997 and 1998.
System of irrigation using a flatted hose with space between drips of 45 cm and a flow by drips of 1.4 litres per hour with a pressure of 10 PSI. Nowadays, it is being used like a test in 10 fields cultivating tomatoes and other vegetable.

Figure 3.8:

3.5.5 Phase 5: Native Food Production (Establishment of Orchards for Legumes Cacti, Red Bishop's Weed and Agave)

1. **Establishment of an Orchard of Cacti:** An orchard with 375 plants of the cactus species Opuntia ficus-indica was established using the system of micro-catchment with soil ridges. This is a suitable technology regarding the flat land in arid zones. Each draining box consists of aligned stones in order to avoid the erosion of the ridges. The orchard has a surface of one square hectare, 100 x 100 meters.

2. **Establishment of an Orchard of Agave:** The construction of an orchard of rectangular surface (150m X 200 m) of 3 hectares was achieved. It consists of 8 terraces for absorption, to lodge 1000 plants of Agave salmiana for forage production, water honey and pulque (a drink made from Agave syrup). The orchard was successfully put up in April 2004.

3. **Establishment of a Cacti Orchard:** The orchard has a surface of 5 hectares, and 1000 plants were seeded in curves at level at intervals of 10 metres.

Figure 3.9:

3.5.6 Phase 6: Use of an Existing Saline Water Source (Desalination of the Water Using Inverse Osmosis and Aeolian Energy so as to Increase the Disposition of Potable Water)

A process of reverse osmosis using Aeolian energy (mechanical). It is still under development in order to use an existing saline (15,000 TDS) groundwater source to provide more water (1 GPM).

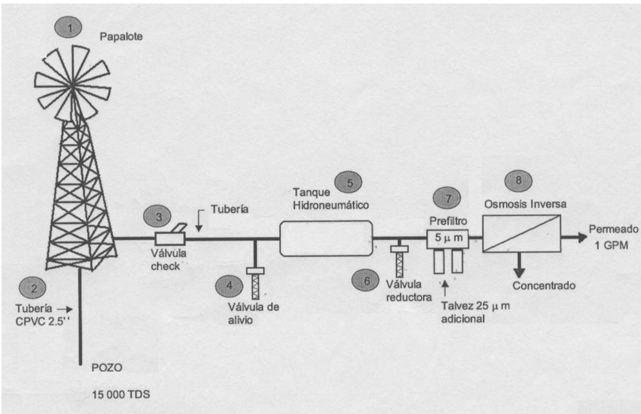

Figure 3.10:

3.5.7 Phase 7: Establishment of a Kindergarten Classroom, Creation of a Health Centre and Initiating the Building of Latrines

1. **Construction of a kindergarten, furnished and equipped with a rain-water collection system on its roof:** Children in kindergarden age of ejido San Felipe, lacked a classroom. Once the financing for the construction was managed, a hall 4.5 m x 7.0 m was built with walls, ceiling of rect-angular beams of armed concrete, a door and 2 windows. It is equipped with tables and small chairs, a blackboard, writing-desk and chair for the teacher. The ceiling has an appropriate inclination throughout its inferior edge that ends in a tube of PVC of 2 inches of diameter and is connected to 3 interconnected containers of 2500 litres of water. This small facility does not differ from the rest of the diverse infrastructure units which were already finished for this one project, as it will be self-sufficient in its water supply, as well.

Figure 3.11:

2. **Establishment of a Rural Health Centre:** The establishment of a Health Centre was needed in ejido San Felipe. The nearest place where the inhabitants were able to receive basic medical care was in ejido Santa Ana, which is 8 kilometres away. At the moment, the Project "Water and Life" maintains a small medicine dowry that was bought with a grant obtained for this intention. The small clinic is outfitted with essential medical utensils and furniture. Moreover, it is equipped with a rainwater collection system so as to be self-sufficient in the aspect of water supply.

Figure 3.12:

3. **To initiate the use of Latrines:** It was of fundamental importance to help the population of San Felipe so that each family had a latrine. This allows more hygiene and a more acceptable level of discretion. Considering a population of a total of 70 people, the construction of 20 latrines was suggested on which the three larger families living in this population centre could count on 2 latrines by family. The ecological dry latrine, allows them to adopt a better conscience on the ecology, as well as it increases life

standards.

Figure 3.13:

3.6 Inventive and Innovation for a Secure Future

Using the sustainability paradigm as motivator for product and service innovation several aims can be articulated:

- Solution should be economically feasible, socially responsible and environmentally neutral or preferably positive
- Promotion of the use of renewable materials and energies
- Reducing the material and energy consumption, as well as the waste generation
- Improving the environment and the living standards of stakeholders/clients

The goal is that graduate and undergraduate students construct, prove and document performances of the devices under different environmental and socioeconomic conditions.
Potential experimentation with devices being combined for the identification and

quantification of synergy of the combined use of at least two problems is provided.

3.7 Rural Sustainable Housing

The objective is to improve the living conditions of rural families by promoting settlements in secure areas and using diverse energy supplies. Furthermore, the development of appliances being adapted to the environment and that can be constructed and/or repaired by local people in order to contribute to the improvement of living conditions is part of the strategy.

Figure 3.14:

3.8 Requirements for the Devices

To adapt and to construct prototypes of devices the

- devices should be built out of common materials, so that they are available in commercial hardware stores
- devices have to be economic and effective
- devices have to be durable so as to amortise the investment
- devices should have a design and/or development of components that can be assembled, be constructed and/or be maintained by people with limited technical skills/ knowledge.

3.9 Activities to be Realized at each Project

Bibliographical investigation as much of the technical and economic part, like of previous experiences in the countryside, is an important part of any project in order to be inspired by more or less successful experiences.

Figure 3.15:

Some of those devices that are under development:

- Anaerobic digester: Treatment of biodegradable wastes to improve sanitary conditions, and to obtain biogas for cooking and organic fertilizer
- Wind generator: Wind energy in order to load an automobile storage cell
- Thermo solar stove: For cooking inside the house without burning wood
- Stove “without smoke”: Burning firewood more efficiently and reducing the consumption and emissions within the rooms.

3.9.1 Roof Insulation with Scrap Tires or “Tire-tiles” Over Metal Roofs

- Problem: metal roofs are hot in summer, cold in winter and noisy during rainfall
- Objective: protect the metal from climatic elements using scrap tires as “tiles”
- Results: the experiments showed that on a sunny day, the temperature 10cm under the metal roof was 38řC while the temperature under the Tire-tiles was 29řC.

Figure 3.16:

3.9.2 Wind Generator

- Problem: Commercial wind generators are expensive and can not be repaired locally due to specialized materials and work
- Objective: Construction of a wind generator with “standard” materials that can be constructed and/or repaired locally and that can charge a car battery

Figure 3.17:

3.9.3 Slope Erosion Control With Scrap Tires

- Problem: Scrap tires represent a sanitary and environmental risk, while the unplanted slopes can be easily eroded
- Objective: Using scrap tires as an abundant and 'cheap' material to reduce erosion in unplanted slopes
- Results: The measured soil erosion was reduced by 83% compared to an unprotected slope. Moreover, the protected slope developed vegetation within the observation time and the costs to implement the system ware about $1 USD/tire (Mexican costs) in which labour accounted for about 60% of it (being an advantage for the improvement of local labour). The system is being registered as a patent in Mexico.

Figure 3.18:

3.10 Expected Results of All Projects

While most of the described projects are still in progress, it is expected to become the documentation of technical, economic and environmental performance of the prototypes constructed with results of conditions of operation and proposals of improvement.
Also, it serves as a document with the required diagram, costs of material for construction, operation conditions and required maintenance of the devices.

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Case Study: Songkhla Lake Basin

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Hat Yai Songkhla Thailand

4.1 Introduction

Thailand can be divided into four main geographical regions: the North, the Central plains, the Northeast, and the South. However, in terms of geographic feature, there are a total of 25 river basins in the country. The side of the basins varies from basin to basin (Simachaya, 2002).

There are several water quality variables that can cause water pollution problems, such as BOD, nutrients (nitrogen and phosphorus), toxic substances, bacteria, and solids. Surface water quality was surveyed and a monitoring program was designed. The Pollution Control Department (PCD) has been monitoring 46 major rivers in 2005, except for the Pattani and Saiburee Rivers as for the present violence in three southern provinces in Thailand (Pollution Control Department, 2005). The results showed that the water quality ranged from good, fair, poor and very poor conditions at the rate of 17%, 49%, 29% and 5% (see Figure 4.1).

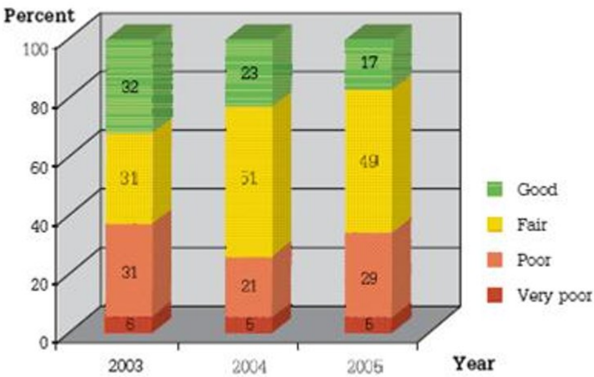

Figure 4.1: Inland Water Quality for the whole country from 2003 to 2005 (Source: Pollution Control Department, 2005)

It was found that the share of water with good and fair quality had been decreasing between 2003 and 2005. In Thailand, water pollution is mainly caused by urbanisation, industrialisation and agricultural activities. The observation of water quality for the received waters was carried out in terms of dissolved oxygen depletion, high coliform bacteria and the occurrence of an eutrophication phenomena (Simachaya, 2005).

Not only is the water quality a problem, since Thailand has also suffered periodical floods and droughts. The sum caused by those damages was at times higher than 70.000 million Baht, with an average sum of 23.700 million Baht between the years 1989 and 2001. The worst year for Thailand, regarding natural disasters, was 2005. 50.000 people were affected by several serious floods with average floodwater levels of 50 to 200 centimetres. More than nine million people in 71 of Thailand's 76 provinces have been affected by water shortages. In the same year, the major flooding throughout Thailand destroyed agricultural land, farms, houses and, as a result, affected the national product.

The Royal Thai Government (RTG) imposed policies on water resource management. The solutions for the development or rehabilitation are verified and divided into three main categories. Those are based on area functions, meaning the upper (forest area), middle (agricultural area and community), and lower (downstream, including coastal area) river basin. Integrated Water Resource Management (IWRM) is an effective tool that can be applied to all 25 river basins (Hungspreug, 2006). Various management approaches have been employed by the PCD and other governmental sectors in order to deal with water pollution problems in Thailand, such as:

- The construction of municipal treatment plants, especially in municipalities located along the main riverside
- The monitoring of water quality and effluent from point-source pollutions
- The implementation of public awareness programs
- The setting up of a restricted zone so as to protect the source of water supplies
- The promotion of public participation in water quality management plans

4.2 Case Study: Master Plan for Songkhla Lake Basin (SLB)

The Songkhla Lake is the only natural lake, or lagoon, in Thailand which has a very unique characteristic - the *3-water ecosystem* (see Figure 4.2). The mixing of fresh water runoff, overland flow and saline water from the sea causes the salinity of lake water out of the Songkhla Lake to vary spatially and temporally. Three distinct elements of the Songkhla Lake can be distinguished: fresh water, brackish water and saline water. Understandably, the rainy season results in a larger amount of fresh water, whereas the dry season causes more saline water to intrude further north into the lake (Ratanachai et al., 2005). The salinity profile is shown in Figure 4.2, depicting the flow of fresh water in Thale Noi at the northernmost part of the Songkhla Lake, through the lower part of the Songkhla Lake, thereby varying seasonally within the 23-30 psu range, down to the Gulf of Thailand. Major economic activities at present times include rubber plantation, paddy rice farming, fruit tree orchards, fishery, aquaculture and husbandry. The SLB is also a source, storage and sink for a vast amount of fresh water supply which, if properly managed, can be used for agricultural, industrial and domestic purposes.

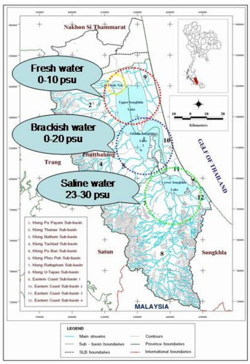

Figure 4.2: Map of Songkhla Lake Basin and salinity profiles (Ratanachai et.al., 2005)

The PCD reported in 2005 that the water analysis quarried a constant high percentage of highly contaminated water in the Songkhla Lake, presumably around the estuary of Sumrong Canal, Muang District, Songkhla Province. The water showed coliform bacteria, high ammonia, high BOD and low dissolved oxygen (DO was lower than 2.0mg/L).

4.3 Water Use Conflict

1. **Paddy Rice Field**

   Paddy rice fields in SLB cover the central plains of the Phattalung Province and large plains in the Satingpra peninsula, therefore long being considered as the rice bowl of southern Thailand. A study by the Land Development Department (LDD) indicated that the quantity of paddy rice fields in SLB have decreased from 1.412.916 rais in 1993 to 1.126.211 rais in 2002, a decrease of 20.3%. The same study showed that there were 83.340 rais of abandoned rice field.

2. **Rubber Plantation**

   The area of rubber plantation in SLB has increased from about 2.286km^2. (1.428.753 rais) in 1993 to about 3.401km^2. (2.125.775 rais) in 2002. This can be translated into an increase of 286,705 rais, or approximately 48.8% in 10 years, or an increase rate of about 28.670 rais/year. Rubber has been a very popular economic plant in SLB for a long time, despite the latex price fluctuation. Since the year 2004, the price for latex rose and became more stable, therefore the plantation area was expected to rapidly increase. Besides forest encroachment, the past few years have seen a transformation of paddy rice fields in the highland into rubber plantations, reasoning further decrease of rice farming areas.

3. **Palm oil plantation**

   In the past few years, palm oil plantation was more and more noticed, since the Thai government has set new policies on producing biodiesel based on palm oil as a renewable energy. As a result, a variety of discourses on palm oil has emerged to promote its plantation as a renewable source of energy since 2006. Such active promotion resulted in a rapid expansion of the plantation areas, especially in the watershed forests, wetlands, community public forests and rice fields, since not a lot of space had been available for this crop plantation and since the oil palm needs a lot of water.

4. **Shrimp Farming**

   Shrimp farming is a highly profitable business. However, it is risky as it requires high investment. In addition to that, shrimps are susceptible to viruses. Some of the impacts of shrimp farming include: (a) The possibility of destroying the mangrove forest; (b) The discharge of saline wastewater from shrimp farms contaminates other agricultural activities, as well as water resources; (c) Abandoned shrimp farms contain saline soil which is difficult to rehabilitate.

5. **Pig breeding**

   Pig farms are currently a major source of agricultural pollution in the SLB. There are 108 registered pig farms scattered throughout the country, yet they are largely located at the Phatthalung province. The rate of generated wastewater is valued at 20 litres/swine/d in smaller farms (6 - 60 uoa.(unit of animal)) , with a BOD of 1.500 mg/l. In larger farms (61 - 600 uoa.), the rate is expected at about 15 l/swine/d with a BOD of 2.000 mg/l. Most pig farms discharge wastewater directly into the basin.

6. **Municipal water demands**

   Settlements in the SLB region are sporadically spaced with high-density clusters within major towns. Hence, the amount of generated wastewater differs. The sub-basin water quality that is mostly affected is the Klong U-Tha Pao Catchment, followed by the Sathing Pra Peninsula. The total amount of caused wastewater in the SLB in 2004 was roughly 100.000 cu.m/d. with a BOD of approximately 17.000 kg./d.

7. **Water Demand for Industrial Activities**

   Water demand for industrial purposes for all SLB sub-basins adds up to about 40 MCM/year. Main industries are agro-based industries. Most of them are located on the main street of the “upper” sub-basin.

8. **Fishermen community**

   Most of the fishermen in the SLB are local indigenous people. They generally install stationary fishing gears, such as sitting cages, set bag nets, stationary lift nets and bamboo stake traps. The strong tidal effect in the Lower Songkhla Lake makes the use of set bag nets and sitting cage fishing highly effective. Thus, it seems that fishery zoning has been drawn by the advantages of the lake's features. In the Lower Songkhla Lake fishing is practiced all year round. There are 5.199 fish cages owned by 1.433 fishermen summing up to a production of 910 tons/year. In 2003, around 25.000 units of sitting cages were located in the Lower Songkhla Lake.

Adapted from these various kinds of water demand, a variety of diverse water qualities and quantities is required for the SLB. They differ spatially and temporally. SLB water problems can be depicted as in the following:

1. **Lack of integrated water management**

   The water demand for domestic consumption, industrial uses, irrigation uses, as well as for the ecological system, totals up to approximately 1.454 MCM (Million Cubic Metres) per year, a figure which is gradually increasing. Thus, there is an urgent need for the establishment of an effective mechanism for integrated water resource management.

2. **Freshwater over-pumping / saline intrusion**

   An average of 58 MCM of freshwater per year is extracted from Songkhla Lake for the irrigation of paddy rice farms. In the dry season, salinity permeates the upper Songkhla Lake up to the northernmost part. In severe dry season, salinity in the Upper Songkhla Lake reaches up to 10 psu.

3. **Groundwater overuse**

   The yield of groundwater being extracted from the "high density" sub-basin has been estimated at approximately 35 MCM per year, or 96.000 cubic metres per day. In comparison to that, 75.600 cubic metres per day of groundwater per day had been extracted in 2004, which is considered to be a critical figure. Furthermore, data from 2002 suggested that an area whose groundwater level is more than 8 metres has expanded as to now cover approximately $103 km^2$, and it is still expanding. This will affect the groundwater basin, since it will induce the intrusion of salinity up to a point where the basin becomes unusable.

4. **More severe flooding**

   Flood regimes in the SLB vary in different parts of the basin. In the upstream and midstream zone, flash floods are usually associated with heavy rain and overland flow, whereas in the downstream zone, inundations are usually caused by either a prolonged impounding in the lowland area or an overflow from waterways.

5. **Insufficient wastewater treatment facilities**

   In 2003, there are only two central wastewater treatment plants located in the SLB: One in the Hat Yai City Municipality, another in the Songkha City Municipality. The service area, however, does not cover the total area of both municipalities. Only about 100.000 inhabitants, or 7% of the basin's population (approx. 100.000 inhabitants of an overall population of 1.6 million), were being serviced by these two existing facilities. In 2006, another two smaller central wastewater treatment plants were installed in order to oversee small groups in SLB (pilot scale projects).

6. **Wastewater pollution problems**

   Major wastewater pollution sources are composed of (i) domestic wastewater sources, (ii) industrial wastewater, (iii) wastewater from pig farms and (iv) wastewater from shrimp farms which widely fluctuate. Apart from simple organic waste, the wastewater also discharges nutrients (Nitrogen and Phosphorus), thereby contributing to the Eutrophication problem.

7. **Deterioration of water quality in waterways and lake**

   Major wastewater sources are (i) domestic wastewater sources, (ii) Industrial wastewater source, (iii) wastewater from swine farms and (iv) wastewater from shrimp farms. All these contribute to the pollution problems in waterways and Songkhla Lake.

In 2005, a **"Master Plan for the Songkhla Lake Basin Development"** was developed by the Office of Natural Resources and Environmental Policy and Planning (ONEP) in Thailand, in cooperation with three universities of the Songkhla province. Five strategies, 26 measures and 57 project ideas have been designed to meet public demands, such as:

1. Reduction of discharge nutrients from wastes into the lake
2. Installation of appropriate waste treatment systems for municipalities
3. Campaign for environmental awareness in pollution problem
4. Controlling land use and pollution source
5. Improvement of environmental quality along selected waterways.

The project ideas are the outcomes from public consultation process involving all sectors of the public. It is anticipated that, after 10 years (AD 2006-2015) of implementation of this Master Plan, there will be, at least, Songkhla Lake water quality will be at least of Type 3, as classified by National surface water quality standards (one of seven indicators).

Within this master plan, a "SLB committee from a public sector" intended to allow strong public participation in decision-making for a sustainable development of the SLB. Figure 4.3 shows the proposed "model" for an ideal SLB committee. The objectives of this model are:

- Issues and demands of each beneficiary group are borne by its network or interest group. Therefore, its problems will be recognized and solved.
- Demands of each representative in the SLB board will be registered by the SLB board.

4.4 People Sector in the Three Provinces of the SLB

The regional environmental office 16 illustrated the surface water quality from 2004 to 2006 for the SLB, as a result of several projects, both engineering and

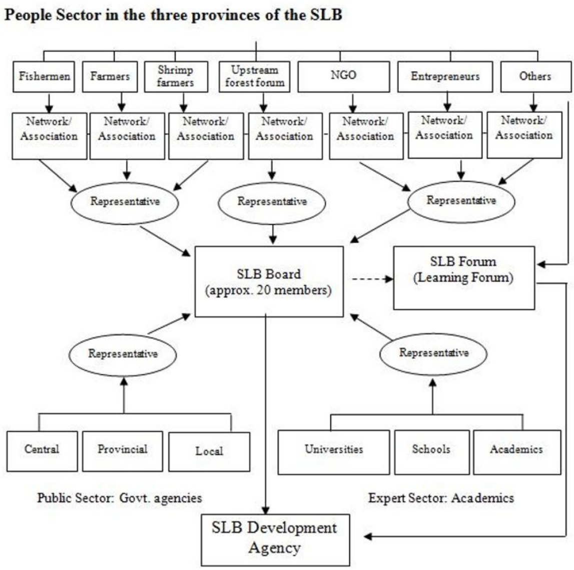

Figure 4.3: Component of the proposed SLB Committee (Ratanachai et. al.,2005)

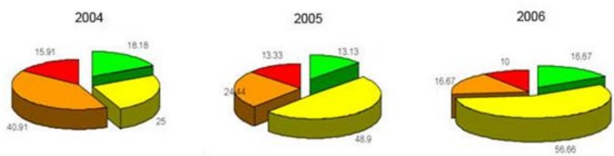

Figure 4.4: Surface Water Quality for the Songkla Lake Basin from 2004 - 2006

public awareness programs, as shown in figure 4.4. It is evident that the surface water quality of the SLB had improved.

Commune based participation in resource management had proved to be powerful for achieving a sustainable management. Figure 4.5 shows an example of public participation in a water quality management action plan.

Figure 4.5: Commune based participation in a sustainable management plan

However, Ratanachai *et. al.* (2005) highly recommended this master plan to be dynamic, so that responsible agencies will have to adjust themselves according to the actual tasks when more information is available. Under these proposed projects, the SLB's problems and issues should be efficiently and effectively corrected, so that rehabilitation and restoration will be carried out within the next ten years (2006 - 2015) of this master plan.

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5 Shallow Wells: General Aspects, Building and Protection - Cristiano das Neves Almeida

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5.1 Introduction

Considering the situation of some countries in Africa or in some regions of the world where the amount of water is not sufficient to guarantee basic needs such as cooking for instance, the well-known sentence “The cause of the Third World War will be water” can be considered assertive. In these regions, conflicts over water have already occurred, they are the order of the day. According to Beekman (1999) the minimal amount of water for basic needs is 1.700m^3/inhab.year, amounts under this value indicate that a region can be under hydraulic stress (1.000 to 1.700m^3/inhab.year), under chronic scarcity (500 to 1.000m^3/inhab.year) or under absolute scarcity (less than 500m^3/inhab.year). In some parts of Africa and in the semi-arid region of Brazil, the minimal amount of water, according to Beekman (1999), is not available for basic demands. What has happened in these regions is an increase in migration from rural areas to urban areas. In some urban regions, the rates of this migration are so high that the cities cannot offer adequate framework conditions to support this situation, so that problems are bound to occur. These include the lack of water, problems with wastewater supply, guaranteeing school education for children, and the like. As a result, social problems like violence as well as environmental problems arise.

The lack of water in terms of quantity and quality, that is to say the scarcity of basic sanitation services and safe drinking water, results in people living below basic life conditions. According to the World Health Organization WHO (2005) the relations between water and health cannot be denied. Water without an adequate quality is the cause of several diseases such as diarrhoea, cholera and hepatitis. The number of illnesses related to dirty water mentioned in the WHO report “Water for life - Making it happing” (2005) should impress everyone since 80% of all illnesses are caused by water-borne diseases. At any point in time, over two billion people are infected by water- or soil-borne diseases and 300 million of them are seriously ill. Another impressive number is that 90% of deaths from diarrhoeal diseases in today’s developing world affect children under 5 years. The worst point is that these children do not have the appropriate physical condition to avoid these diseases. Normally, this situation occurs in rural areas due to the lack of basic sanitation measures and safe drinking water. Thus, it is understandable that one of the causes of the high immigration taxes consists in the lack of basic water and sanitation conditions in rural areas.

The WHO report cited above also recommends that improved water and sanitation resources will accelerate the achievement of all eight Millennium Development Goals, helping to eradicate extreme poverty and hunger; achieve universal primary education; promote gender equality and empower women; reduce child mortality; improve maternal health; combat HIV/AIDS, malaria and other diseases; ensure environmental sustainability; and develop a global partnership for development.

In order to solve or, at least, to minimise the problem caused by the migration, the creation of good life conditions in rural regions is indispensable. Maybe, the first and most important condition is to supply water for human activities. In this context, "supplying water" implies providing water in terms of quantity and quality. Due to the dispersed location of rural communities, supplying water in quantity and quality is not easy. The construction of water supply systems (water storage, pumping, cleaning and distribution) for populations characterised by a dispersed location charges a high price, which is sometimes impracticable. It can be considered a challenge to provide these populations with water.

In some areas, a possible solution which can be applied to the population of rural areas lies in the use of groundwater. Groundwater has two main advantages. The first one is quality, since normally the quality of the groundwater is good enough for water supply and can immediately be used after some basic treatment. Sometimes it can even be used without chlorination. The second advantage is the distance of the village or settlement. The well can be buried near the location where it will be used.

In Europe, for instance, there are a lot of cities which are supplied by groundwater sources. As can be seen in figure 5.1, in some countries the use of groundwater for supply amounts to almost 100%, which means that the countries are dependent on groundwater nearly in their entirety. This shows how important groundwater is for some countries, in particular when the dependency rises over 60%, which is the case for ten European countries.

In this context, the present article deals with some issues related to groundwater for the supply of rural areas. However, since the groundwater topic is extensive, this article will only consider the wells located in the free aquifer, which are

Country	Proportion	Country	Proportion
Austria	99%	Bulgaria	60%
Denmark	98%	Finland	57%
Hungary	95%	France	56%
Switzerland	83%	Greece	50%
Portugal	80%	Sweden	49%
Slovak Republic	80%	Czech Republic	43%
Italy	80%	United Kingdom	28%
Germany	72%	Spain	21%
Netherlands	68%	Norway	13%

Figure 5.1: Use of groundwater in some European countries (Source: WHO, 2006)

known as shallow wells. Firstly, some concepts of the hydrological cycle are displayed, followed by the differences between contamination and pollution and their sources. Secondly, discussions about protection measures are presented as well as a successful study case which shows how to use water for different uses, reducing the potential impacts on the water quality. Finally, the main concluding remarks are presented.

5.2 General Aspects

In order to discuss the potential risks of the contamination or pollution of the groundwater, it is necessary to present some basic concepts. The first and most important one is that of the hydrological cycle. For some tropical and semi-arid regions, the hydrological cycle can be represented as shown in figure 5.2. The two most important phases of the hydrological cycle are the infiltration and the groundwater flow because through them substances are carried from the soil surface to the ground, and by means of this process water movement substances can reach the shallow wells. This concept is related to natural issues so that infiltration and groundwater flow, for instance, cannot be changed easily.

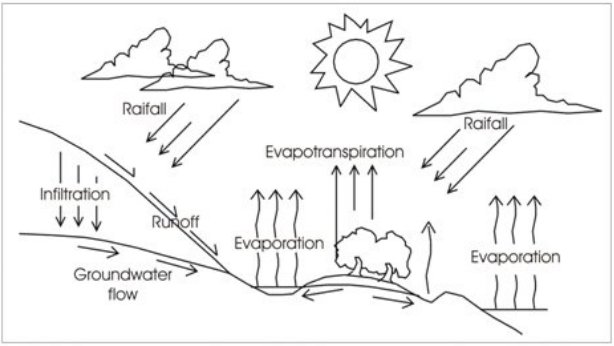

Figure 5.2: Hydrological cycle

Another concept which bears a relation to the hydrological cycle and to the risk of contamination is that of aquifer types. There are two possible types. The first one, the confined aquifer, is characterised by two confining layers, one above and one below. Between these there are different types of soil and water, forming the confined aquifer. The recharge of this type of aquifer takes place by means of the rainfall which enters into the aquifer through permeable layers at a high elevation. Thus, at the lower elevations the groundwater is under pressure. In other words, the pressure is higher than the pressure of the atmosphere. A well buried in this region will not need a pump because the water can reach to some metres above the surface, depending on the local pressure situation. The other aquifer type is the unconfined one, which is not confined by an upper layer. The matter of this type of aquifer is normally composed of a mixture of sand and gravel (sand with small stones) which has spaces that can be filled with water and/or air. This matter is called alluvium and lies under a permeable layer, but does not have a confining layer above. In this kind of aquifer the level at which the soil is saturated is the water table. Wells buried in unconfined aquifers are more sensitive to seasonal changes and may dwindle during dry periods. The variation of the water level is more dependent on infiltration caused by rainfall than on groundwater flow. Another important feature of the unconfined aquifer consists in the boundary between the saturated zone, where the spaces are filled with water, and the non-saturated zone, where the spaces are filled with water and air. This boundary indicates the static level or the water table. Due to the possibilities to bury a well in the unconfined aquifer, this aquifer type will form the main focus of the present text.

As far as the problem of well contamination is concerned, two other concepts are important. Since this text only addresses shallow wells, it is essential to understand the differences between an artesian and a shallow well. The artesian well is a well buried in the confined aquifer. Normally, its construction requires specialised staff and construction techniques. This well type usually has a depth of 80 metres but can reach depths of more than 1.000 metres. In comparison, a shallow well is simpler and marked by a hole in the ground which has a diameter of 1.5 metres and a depth of about 20 metres. Normally, the source of this type of well is a free or unconfined aquifer whose matter is the alluvium. In contrast to the artesian wells, the construction of shallow wells does not require specialised techniques or staff, but nevertheless some protection measures must be carried out. Figure 5.3 illustrates the aforementioned features (unconfined aquifer, permeable layer, shallow well, saturated and non-saturated zones, static level).

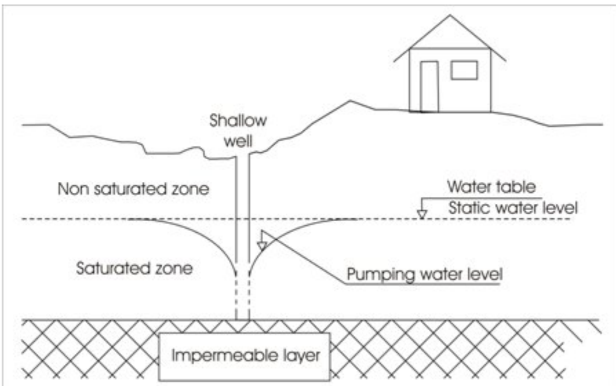

Figure 5.3: Shallow well and unconfined aquifer

Another important aspect that has to be addressed is the difference between pollution and contamination. Pollution occurs when the level of the contaminant concentration restricts the potential use of groundwater. A practical example is that of a lake with fish, in which the temperature of the water is a little bit above the normal water temperature. This can have some negative effects on the pisciculture since fish might die, but not on irrigation so that contamination causes some restrictions on just some uses. On the other hand, contamination occurs when soluble or insoluble substances are introduced into the hydrogeologic environment as a result of human activities. The use of contaminated groundwater can lead to serious health problems. This article will focus on problems which arise from contamination.

Contamination can be spread in three ways. The first way consists in linear sources and occurs when the source of contamination is a river or a channel. The second way is a nonpoint or diffuse source which occurs when the source is spread over a large area such as an irrigation area. As for this kind of contamination, either the infiltration or the groundwater flow play an important role. Thus, it is more difficult to control this source. The last way of spreading contamination is a point source and occurs when the source of contamination is concentrated in a small area or even in a point like inoperative wells and septic tanks. It is much easier to control this point source because it is only necessary to isolate the point. Figure 5.5 shows a shallow well and its sources of contamination.

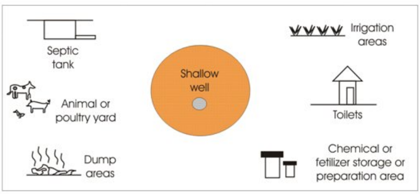

Figure 5.4: Shallow well and sources of contamination (adapted from Feitosa et al., 1997)

Figure 5.5 depicts how the infiltration and groundwater flow can transport substances from the sources of contamination to the shallow well. A similar case is shown in figure 5.6 where the inadequate disposal of waste can be transported to the shallow well. What is important to note is that in both cases the contamination depends not only on the infiltration and groundwater flow but also on hydrogeologic features. Thus, if an aquifer matter is more permeable, the groundwater flow as well as the transport of contamination substances will be faster.

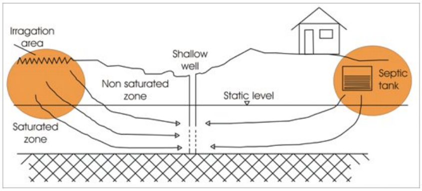

Figure 5.5: Shallow well contamination: irrigation area and septic tank (adapted from Feitosa et al., 1997)

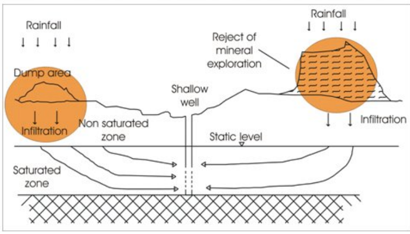

Figure 5.6: Shallow well contamination: dump area and rejects (adapted from Feitosa et al., 1997)

5.3 Aspects of Construction - Shallow Wells

When the aspects explained above are well understood, it will be easier to protect shallow wells against the sources of contamination. The first step is to take some measures during the construction of the shallow well. Before building a shallow well it is important to consider the distances from the possible sources of contamination. It is recommended to keep a distance of at least 30 metres from any source of contamination (see figure 5.7). During the phase of well location the main and potential sources of contamination must already be known in order to keep the minimum distance. In the case of villages and settlements it is important to know the location of septic tanks, bathrooms, poultry yards and waste disposal. These are the most common facilities which can be found around shallow wells in villages.

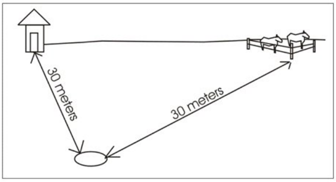

Figure 5.7: Location of the construction point

Then the construction of the shallow well can begin. A hole with a diameter of 1.5 metres must be dug until the 2-metre water level is reached. When it is reached, the bottom of the well must be filled with stones, which have the function of facilitating the filtration process. Above this level, a wall around the hole must be constructed. In this connection, the first five layers of bricks are laid without mortar (a kind of workable paste made of lime, cement, sand and water). These layers are built without mortar in order to make the water run into the well. The rest of the wall must be built with mortar and reaches until about 80 centimetres above the surface of the ground. This part that is above the ground surface must be well-sealed with mortar. Finally, the outside of the shallow well has to be sealed and cased with plaster. Normally, a circular plate of concrete is employed in order to case the well.

The area around the well must be sealed with concrete to avoid the direct infiltration of substances into the well and the discharge of the rest of the water or any other substances into the area where the well is built (Figure 5.8). Finally, a pump can be installed otherwise to facilitate the trapping of water. There are different types of pumps which depend on solar energy, wind or human effort (a system formed by a bicycle system, for instance).

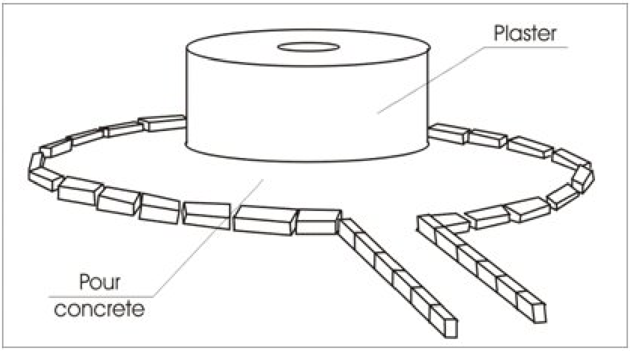

Figure 5.8: Forming the apron and the drain; pouring concrete

5.4 Protection Measures

The constructional measures do not suffice to guarantee the protection of shallow wells. That is to say, some additional measures must be taken in order to protect shallow wells. The operation of the wells is as important as the construction. In order to guarantee an adequate operation of shallow wells, the community must be involved, from the start, in all of the building phases, mainly in the beginning. Thus, people will learn that some kind of protection perimeter has to be taken into consideration. Therefore, they will not be allowed to carry out any activities in the area mentioned above. Discussions must at least seize on the following issues: the importance of water for guaranteeing good life conditions, relationships between drinking water and health conditions, the main sources and causes of contamination, basic considerations about the hydrological cycle focusing on the infiltration and groundwater flow processes, and the operation and maintenance of shallow wells.

An important aspect before the beginning of any discussion is to teach protection measures mainly to women and children because it is well known that they are the best “multipliers”. When children understand information well they tend to quickly pass on these pieces of information to others. Women can also be considered “multipliers” because they tend to teach their children and to take care of them. Presenting a very simple action such washing hands with soap and water to the children can reduce diarrhoeal diseases by 40%. Discussing these issues with the community will ensure that the maintenance and operation will be carried out properly. This means that two procedures must be implemented: water testing and disinfection. Water testing programmes have to analyse the water to find out if there is contamination due to human activities. Thus, at least every year a coliform analysis has to be carried out, and at least every 36 months a nitrate analysis has to be done. Disinfection is another procedure which has to be employed annually with wells after construction and reparation processes or when the coliform tests are unsatisfactory. The execution of these procedures along with other measures can ensure a good quality of the water and avoid the spread of diseases.

5.5 A Successful Study Case

In Brazil, a non-governmental agency called Mandalla (www.mandalla.org.br) has been working on the topic of sustainable agriculture. Thus, the development of a simple irrigation system called Mandalla allows for growing animals and fish. This solution can also be seen as a way to protect shallow wells because some sources of contamination related to human activities can be dislocated from the area where the shallow well was buried. The Mandalla system does not require specialised staff of techniques to be built so that the community can build this system itself. It is made up of a simple tank where fish can grow; around it some animals can grow. Then, irrigation activities can be developed. Figure 5.9 presents a general view of the Mandalla systems which uses rational and simple irrigation systems such as micro-aspersion. The area required measures at least 10 x 10 metres, including the area for the tank, which has a diameter of 6 meters and a depth that can vary from 1.5 to 1.8 metres in the centre. What is important to note is that this system can be a source of income for the local community, and a part of this income can be used for the maintenance and operation of the well. All of these issues lead to a sustainable environmental system.

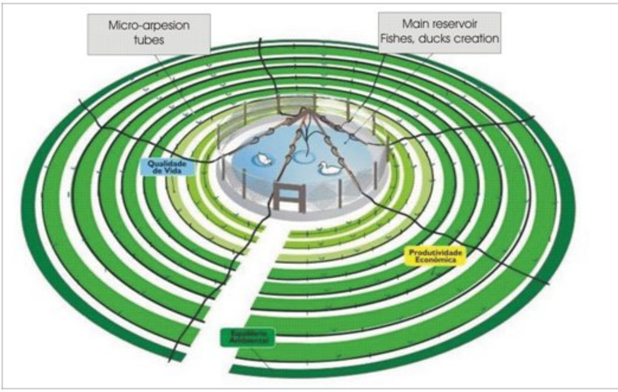

Figure 5.9: Mandalla system (adapted from www.mandalla.org.br)

5.6 Conclusion

One of the main conclusions consists in the fact that in order to protect a shallow well against contamination, a direct protection of the well is not enough since it depends on sources of contamination which are sometimes not located close to the well. Contamination also depends on the hydrological cycle, in particular on infiltration and groundwater flow. Hydrogeologic features also play a crucial role in this context.

But the previous points are not the only issues to be considered in order to protect wells, the maintenance and operation of shallow wells have to involve the community which will use the water from this source. Some issues have to be discussed with the community: water and health, the preservation the water resources, the main sources and causes of contamination, the hydrological cycle, etc. Another aspect which must be considered to preserve the water quality are the mode of operating the well as well as water analyses which must be carried out every year. If all of these issues are followed, the likelihood of contamination will be minimised. Finally, two important aspects have to be considered as well: i) If rural communities have high-quality water, life conditions tend to improve. It is important to avoid social problems caused by immigration, for instance. ii) It is important to take into consideration the local knowledge about the protection of water sources. The Mandalla system is a measure which was successfully developed for the semi-arid region of Brazil.

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6 Economical Application of Pumps in Wells? - Mario Hübner

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6.1 Introduction

25. International Water Supply Specialists at the Geofora and at WILO EMU GmbH in Hof

With this project the DAAD (German Academic Exchange Service) accesses the contacts and expertise of the German Alumni Water Network - GAWN. In this network, representatives of six German universities attend to water supply specialists of developing countries who have studied in Germany. German Alumni actively use the advanced training offers and cooperation possibilities of GAWN - which was also proven by the great response to Geofora. On September 6, 2007, these experts from four continents also visited the company WILO EMU GmbH in Hof.

Figure 6.1:

Figure 6.2:

A basic requirement for the development of water sources covering the water demand of ground water is the efficient operation of vertical filter wells, the so-called "good spirit" of water supply out of horizontal wells - also considered the "barn door" to ground water.

6.2 Climate Protection

In Germany and all over the world climate protection is developing dynamically. Politics and economy focus on a mixture of actions and tools. The national climate protection policy is linked with the role model of an effective development because it is obvious that for the protection of the global climate action at national, regional and local levels is absolutely required. The efforts to save energy and reduce C02 are the sources of state-aided efficiency improvement for electric motors. The CEMEP efficiency classes EFF 1, 2 and 3 throughout the EU are supposed to support the EU countries so that these can achieve their main objective, the reduction of C02. It is even more important - and this article is intended to show this - to have the pumps work at the correct duty point, with the intention to achieve a good LCC reflection, that is to say to use as little energy as possible for the pumping of ground water. As a result, frequency converters should be used in some ranges since the biggest saving potential is the variable speed drive.

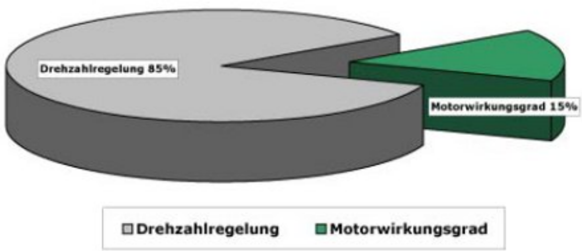


Figure 6.3: Energy savings potential

In the Federal Republic of Germany alone about 25.000 wells are used for the supply of drinking water. Additionally, there is a multitude of wells serving as ground water lowering wells, infiltration wells, industrial water wells, fire-fighting wells and emergency water wells. Consequently, we are also responsible for contributing to the reduction of energy.
Our targets regarding well and pump management are the following:

- duty increase;
- reduction of the operating costs; and
- optimisation of operating time.

We need a strategy to stop climate change. Climate protection can only be realised by means of a consequent technology strategy, which alone allows us to maintain the standard of living achieved and at the same time to reduce greenhouse gas emissions appropriately. Effective growth is only compatible with the climate protection with the help of further innovations. Therefore, also in the water pumping business, strategies must be developed and realised, according to the motto: "Partnership with our common effort to further improve the energy efficiency." This is also a reason why we gathered here in Hof - at the top end of Bavaria - to meet representatives of politics, companies and universities for an open exchange of information because global challenges require global commitment.

Due to rising temperatures on the earth, there is an intensification of the water cycle, that is to say globally averaged, more precipitation, but also more evaporation. Today, functioning wells are the basis for an efficient water supply. In the Federal Republic of Germany 80% of the water supply is provided by wells. But studies prove that worldwide a lot of wells work inefficiently with regard to water supply. As all wells lose efficiency in the course of time, we should set the following target: **to keep the service life of wells as long as possible.**
This will be more and more the job of the responsible technicians, engineers and municipal staff.
Reasons for the aging of wells are physical, chemical and bacteriological actions leading to a clogging of the well with sand, sintering, formation of ochre and corrosion. In most cases we are dealing with a biological formation of ochre. In

practice, aging means a sedimentation of substances which results from chemical precipitation, mechanical alluvium or biological metabolites. One can find these inside the filter pipe, in the filter slots and in the hollow space of the gravel filling.

The most important aspect of the rehabilitation process should be the correct timing. The action is supposed to be carried out before a significant reduction of the flow rate is ascertainable (decline of flow rate > 20% compared with new condition).

In order to solve the problem of aging wells, that is to say to re-establish the original flow rate, different processes have been developed. The use and effectiveness of the different methods is mainly dependent on the type of well aging and on the type of well construction materials. Reaching a high well age, that is to say an optimum service life with maximum efficiency, should have top priority for each operator and person in charge of wells.

All wells have the unpleasant feature that their efficiency is more and more decreasing in the course of time, until you get to a point where the flow rate the well was originally built for is no longer achieved. Actually, the recording of the well efficiency is essential. Almost everywhere where records are made, one can recognise a decrease of the efficiency in the course of time. In case of an above-average lowering of the operating water level, wells can be considered sick. Due to the lowering which changes the static head of the system, pumps must pump up to a higher level and are consequently working in the partial load range of the machines with a worse efficiency at the same time.

The beginning of the well operation is also the beginning of the well aging. Important assessment criteria are among others the hydraulic performance, the filter entry resistance, the test sand content and the condition of the raw water. The operation control includes regular measurements of the parameters mentioned above to evaluate the performance characteristics and the corresponding initiation of counteractive measures.

A basic tool to control the structural condition in the well is an inspection by TV cameras.

All well drilling companies and some pump manufacturers are prepared for carrying out such inspections.

The following figures show that some aspects must already be taken into account

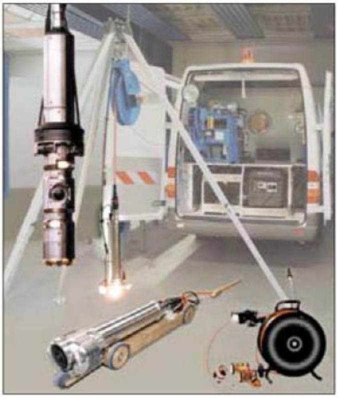


Figure 6.4:

when a new well is built. The control panel of the pump should be easily accessible and located near the well. So the relevant values can be measured which contribute to the evaluation of the well system. There is not always mutual consent among experts regarding the extent of monitoring devices close to the well.

Figure 6.5:

It should be obvious that enough monitoring places must be available for testing the capacity by means of a pump test in order to document the necessary data. An important point for this is the sounding pipe in the well. For some well drillers

Figure 6.6:

sounding pipes in the well, that is to say in the gravel filling, are a disturbing factor while inserting the filter body. But there are also reasons for checking this application. In particular where the entry resistance could be of importance, a sounding pipe is installed to control the position of the water level in the annular chamber.

The next figures show a roller guide in the well. Here, the roller guide was installed at the rising main with tension proof push-fit socket. Additional pipe clamps were used to guide the individual cables. With this design the sounding pipes were installed at the same time. This prevents the sounding pipes from touching the filter gravel and consequently guarantees a higher process security in the well.

Recently, so-called data loggers have been used more and more. They can be easily programmed for the respective well system und are very useful for the monitoring process.

In the following lowering diagram (recorded in 2006) a lot of aspects can be detected with respect to the worsening of the well. Thus, the still-water-level and the filter sections were recorded. At the same time the values before and after the

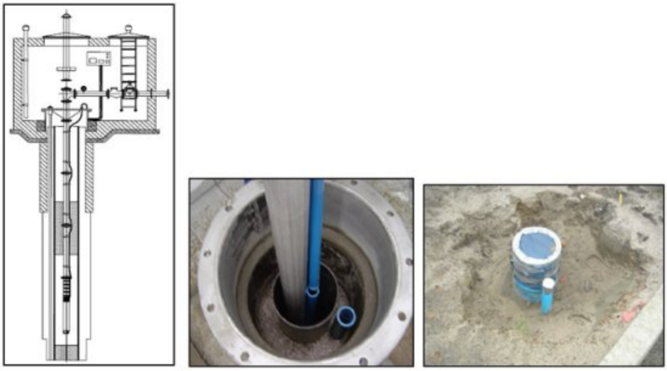


Figure 6.7:

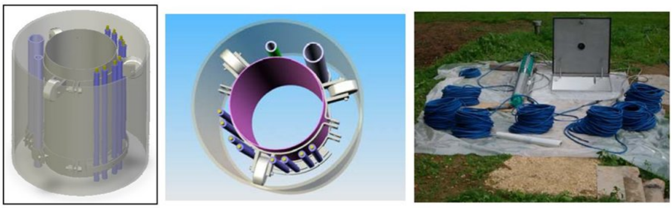


Figure 6.8:

rehabilitation were determined. In the well, differences of more than 8 m were measured with a pump flow rate of $20m^3/h$.

The diagram indicates that an inspection was necessary and that measures have to be taken. The decline of the flow rate in the well can be compensated by using different methods, on the one hand by hydro-mechanical rehabilitation procedures and on the other hand by chemical rehabilitation processes. The components of the well rehabilitation are shown in the DVGW (German Technical and Scientific Association for Gas and Water) - process sheet W 130 (status: July 2001) and - process sheet draft -W 130 (status: August 2006).

Figure 6.9:

The separation of the composites in the filter pipe and the filter gravel, the removal and discharge of the dissolved deposits as well as the monitoring of the rehabilitation progress are important aspects.
Regarding the hydro-mechanical well rehabilitation procedures used in practice there are mainly two groups of processes: procedures where mechanical or flow-mechanical forces permanently act on the environment (e.g. brushes, pistons, high- or low-pressure nozzle systems) and procedures where flow-mechanical forces act on the environment as an impulse. The latter are called pressure wave-impulse procedures.
Many years of practical experience in well rehabilitation by means of the impulse procedure have proven that this method meets the expectations. The rehabilitation is effective and can be used broadly. In most cases one can do without the addition of chemicals. Consequently, the procedure is environmentally sound. The well rehabilitation with pressure wave application requires only a few minutes for each filter section. Therefore it is very economical. In addition, it leads to almost no mechanical stress of the well structure although we work with high water pressures up to 500 bar. Thus, it is a very gentle method.

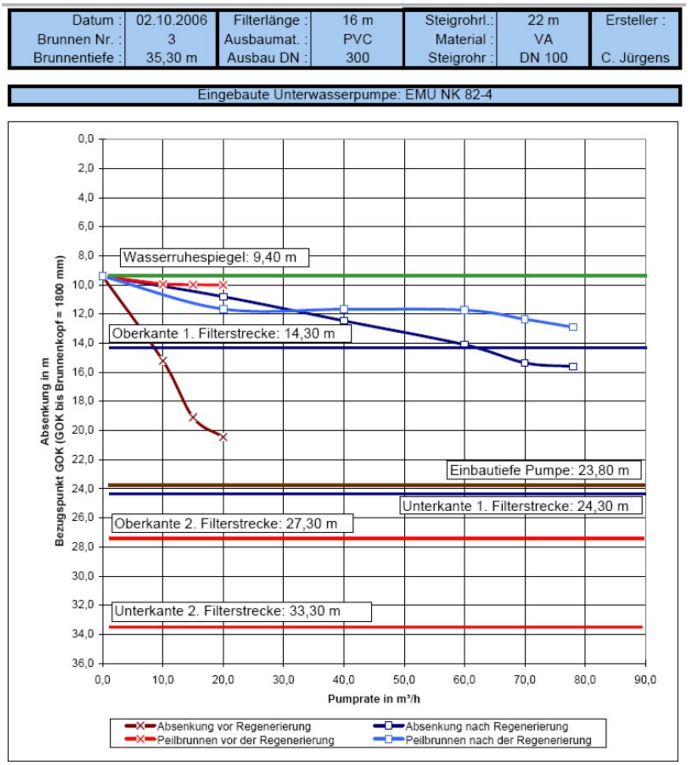


Figure 6.10:

Normally, slightly or medium-cohesive deposits - as with other method, too - can be removed by ultrasonic action. Strongly cohesive deposits can be removed by repeated ultrasonic action on the same spot. Tests have shown that a radical effect can be recognised not only in the close-up range but also in the long distance range behind the filter pipe. The ultrasonic procedure owes its relatively broad range to the fact that the sound waves are only subject to a small damping while passing the filter gravel.

Messwerte vor der Regenerierung - am 30.09.2006

Pumprate m³/h	0,0	10,0	15,0	20,0		
Absenkung in m	9,40	15,21	19,10	20,45		
Peilbrunnen	9,40	9,95	9,98	10,00		
Uhrzeit	09:15	09:20	09:25	09:30		
Druck in bar		8,8	8,2	7,4		

Messwerte nach der Regenerierung - am 02.10.2006

Pumprate m³/h	0,0	20,0	40,0	60,0	70,0	78,0
Absenkung in m	9,40	10,80	12,46	14,10	15,35	15,60
Peilbrunnen	9,40	11,65	11,67	11,72	12,35	12,90
Uhrzeit	13:00	13:10	13:20	13:30	13:40	13:50
Druck in bar		6,5	5,2	3,9	3,1	2,4

Figure 6.11:

Figure 6.12:

For the selection and application of the mechanical rehabilitation procedures the mechanical resistance conditions of the construction material must be taken into account. Corresponding to the actual conditions of the well to be rehabilitated, it might be useful to apply different mechanical processes subsequently. Additionally, we found out that in case of a thorough rehabilitation by mechanical methods in sufficient time, a chemical rehabilitation is not required.
Well rehabilitation aims at the re-establishment of the initial flow rate by a long-lasting removal of deposits reducing the flow rate, such as incrustations, sedimentation or biological deposits. The result checking should be absolutely carried out in a well- and location-specific manner. The pump test with comparison of capacity as simple result checking is absolutely necessary.
In other words, if all aspects relevant to the well are taken into consideration, the

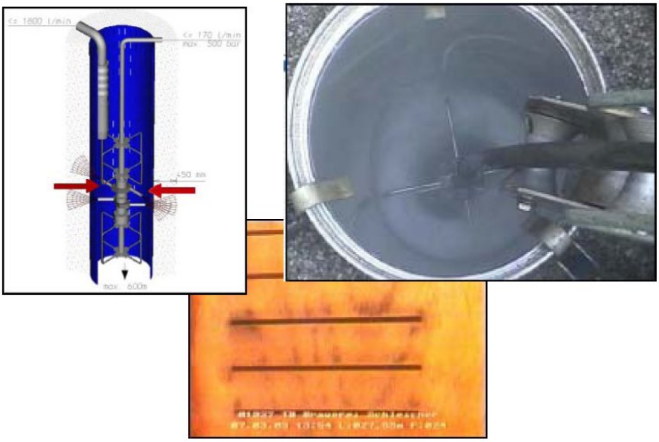


Figure 6.13:

rising main sand ground pipes have to be checked for deposits as well, of course. The following figures show new rising mains and pipe lines and how they can look after some years.

Figure 6.14: a) New rising mains; b) Rising main with ochre deposits; c) Old ground pipe laying

For consulting service, all well drilling companies with their specialists are always at your disposal. The actions mentioned above are meant to provide a pump operation in a good efficiency range.

6.3 When Do Submersible Motors Work Economically?

Submersible motors only work economically if the right pump is operated with the right speed at the best efficiency point and if this is possibly controlled by a remote monitoring system. As the cost evaluation is calculated according to the LCC procedure,

$$LCC = C_{ic} + C_{in} + C_e + C_o + C_m + C_s + C_d + C_{env}$$

the following pipe laying should be emphasised, that is to say the question which diameter shall be chosen for the discharge pipeline. This has a considerable influence on the pump duty.

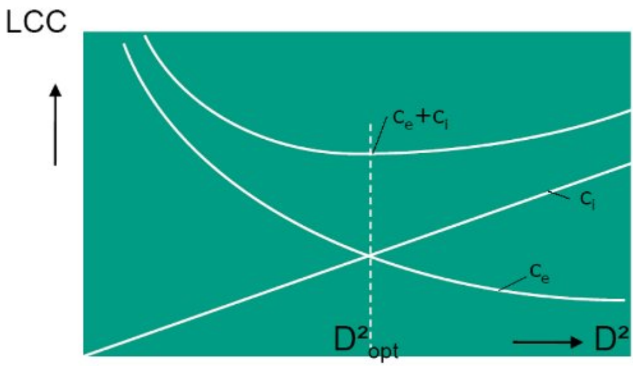


Figure 6.15:

The following table shows the pumping of 8,3 l/s through different pipeline diameters. One can easily recognise that due to the different flow velocities the pipe friction losses rise accordingly.
The calculation shows that if an 80 m pipeline is chosen instead of a 100 m pipeline with a flow rate of 8.3 l/s, there will be an additional head loss of 2.8 m on 100 m stretched pipe length. When calculating the duty, the pump must have a bigger man. head with an estimated overall efficiency of 50% of the unit, 0.5 kW/h will be additionally required for this higher inside friction per 100 m pipe

	DN 80	DN 100	DN 150
Q [l/s]	8,3	8,3	8,3
V [m/s]	1,6	1,06	0,47
Hv; k 0,1 100 m length	4 m	1,2 m	0,3 m

Figure 6.16:

length.

$P_1 = \frac{498[l/min]x4-1,2[m]}{61,1x50\%estimated} = 0,5kW/hper100mpipeline$

6.4 Product Selection

When buying a submersible pump, one has to take into account that all manufacturers have different qualities. Consequently, there are high price differences. On the one hand, this depends on the structure of the pump: from submersible pumps in stage construction to tie rod design for pumps in deep drawing technology.

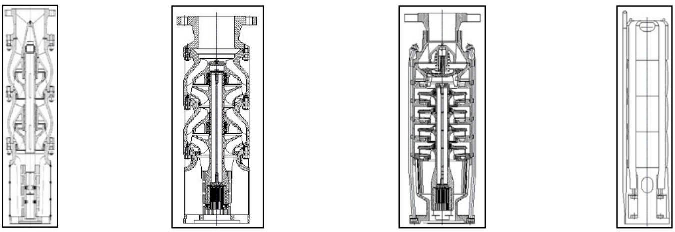


Figure 6.17:

In water works the stage construction is mainly used. Another criterion is the material or coating technology. In case of a higher sand content, corrosive pumped liquids or media tending to deposits, the pumps should be equipped with materials meeting the requirements.
As of a pump size bigger than 10", a Ceram C0-coating can be applied. Pump casings and impellers with this highly efficient two-component coating of poly-

mers and ceramic components have a considerably longer service life. This reduces the maintenance work and costs. Additionally, the Ceram-coating has a lower surface roughness, increasing the efficiency of the pump. This results in a significant improvement of the overall efficiency through the compl. life cycle.

Figure 6.18:

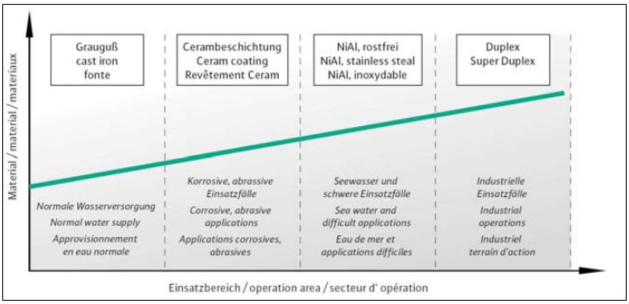


Figure 6.19:

A new motor generation is "CoolAct" with active internal circulation cooling, where a permanently driven impeller on the motor shaft leads the cooling liquid directly through the bearing and the winding. So the lost heat of the motor winding can be optimally absorbed and dissipated to the circulating pumped liquid via the external shroud. Due to the improved cooling a power increase of up to 25% can be achieved with reduced motor operating temperatures at the same time. Thus, even in case of smaller boreholes, pumping with maximum output is possible, which has a positive effect on the installation costs of the compl. system.

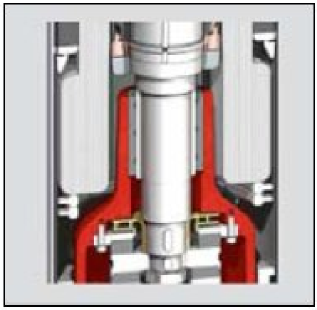


Figure 6.20:

6.5 Energy Consumption

The typical energy consumption of drinking water pumps over their life time shows that the purchase costs are relatively small compared with the maintenance and energy costs.

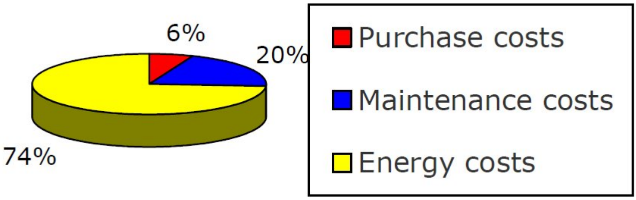


Figure 6.21:

Therefore, in case of different head and flow rates, one has to think about using frequency converters. These can be used to control the head and flow rate as well as to reduce the current consumption. At the same time, a cost comparison with alternative solutions should always be taken into account. Processes should be recorded over a period of several days to achieve a representative distribution.

6.6 Thoughts Regarding Frequency Control According to the Law of Similarity

When changing the speed, the triangles of velocity remain similar, that is to say it does not matter whether to reduce the head by using a frequency converter or by trimming the impeller diameter. However, a trimming of the impellers worsens the efficiency significantly. In case of frequency control the efficiency is also shifted and one achieves high efficiencies for each different duty point.
For us as pump manufacturers it is important that the actual duty point is at the best efficiency point of the machine.
The pump efficiency is calculated according to the following equation:
$\eta_p = \frac{Q[l/min]xH[m]}{45x1,36xP_2[kW]}$

When recalculating the hydraulic curve for lower heads, the kW-power declines in the 3rd power - this has normally a very positive effect on the application of frequency converters. We can achieve high energy saving, have a gentle opera-

$$Q_{neu} = \frac{n_{neu}}{n_{alt}} \times Q_{alt}$$

$$H_{neu} = \left(\frac{n_{neu}}{n_{alt}}\right)^2 \times H_{alt}$$

$$P_{neu} = \left(\frac{n_{neu}}{n_{alt}}\right)^3 \times P_{alt}$$

Q_{alt} = actual flow rate
Q_{neu} = new flow rate
H_{alt} = actual head
H_{neu} = new head
P_{alt} = actual power
P_{neu} = new power
n_{alt} = actual speed
n_{neu} = new speed
f_{alt} = actual frequency
f_{neu} = new frequency

$$Q_{neu} = \frac{f_{neu}}{f_{alt}} \times Q_{alt}$$

$$H_{neu} = \left(\frac{f_{neu}}{f_{alt}}\right)^2 \times H_{alt}$$

$$P_{neu} = \left(\frac{f_{neu}}{f_{alt}}\right)^3 \times P_{alt}$$

Figure 6.22:

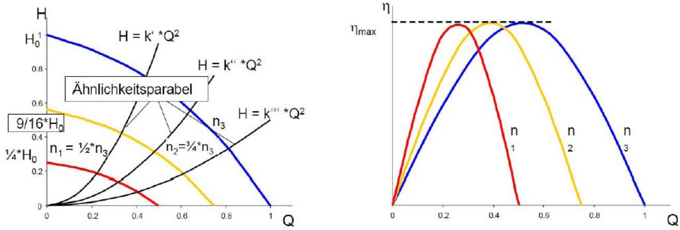


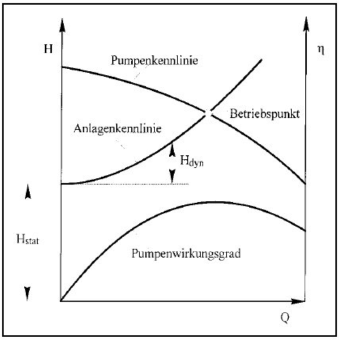
Figure 6.23:

tion of the well, can observe the requirements of the water law more easily and can avoid pressure peaks in the pipe system.

All this also contributes to a longer service life of the well and of the unit, respectively. However, sometimes an increased formation of ochre deposits can be recognised in the pump. In case of bigger pumps a Ceram-coating (as described above) can possibly avoid this. At the same time the system curve must be also checked in detail because a very flat system curve allows only a small correction of the flow rate.

Figure 6.23 shows how fast one can leave an optimum duty point.

As 20% of the energy costs worldwide are caused by pumps - for industry this



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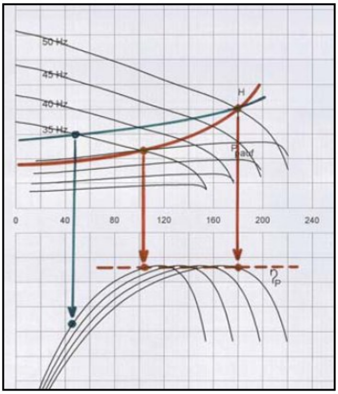


Figure 6.25:

figure amounts to 35% - we have to solve a crucial problem. Other studies show that if only 35% of the pumps used in German industry were equipped with frequency converters, savings of 16 billion kWh/year could be achieved. The C02 emissions reduced by this action would already contribute to climate protection. Thus, well measurements and well rehabilitations are the right steps on our way

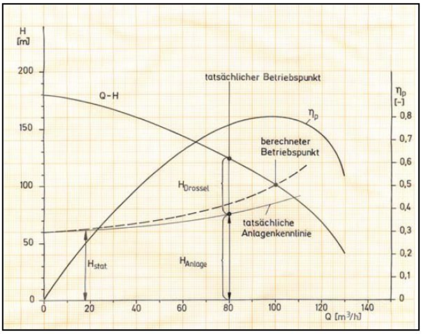


Figure 6.26:

to save energy. The question whether pumping of ground water is economical, cannot always be answered with a clear "yes".

The question regarding the total efficiency of a submersible pump is not always answered promptly.

Tests of renowned pump manufacturers have shown that the submersible pump in the station often reaches a total efficiency of only 36% - 48%, although it could have an efficiency of 70% at the best efficiency point. Consequently, it is a must to have a look at the economy of the ground water pumping from a well.

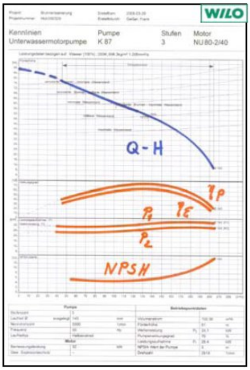
Wells are one of the most important assets of water supply companies. The better the condition of the well, the better the application of the pump and the more effectively the system works.

If all data are determined, the values can be entered in a pump selection programme, which is offered by all pump manufacturers today. A payback period calculation can be made according to business rules. We found out that the investment for an optimised drinking water pump or a well rehabilitation amounts to about 2% of the energy costs (calculated over 10 years). If we assume an improvement of 20 percentage points, the amortisation costs will pay off within one year. The following break-even point curve shows this as well.

Together with the customer we calculated the figures for a 28-year-old, 100-m-deep well with heavy ochre deposits. All data were collected and calculated.

Figure 6.27:

Additionally, the different man. heads were measured and entered into a diagram.
The P1 values were calculated before and after the well rehabilitation and in addition to that the savings per year. As the pump duty clearly rose again due to the smaller lowering of the operating water level and as the pump again pumped a bigger capacity with better efficiency, a saving of $5465 Euro/year$ could be achieved. The well rehabilitation cost amounted to 11654 Euro and the theoretical payback period was 2,13 years.



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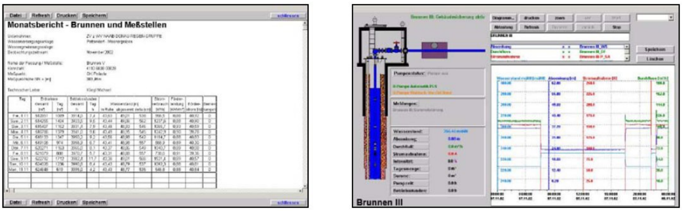

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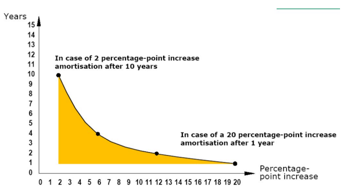

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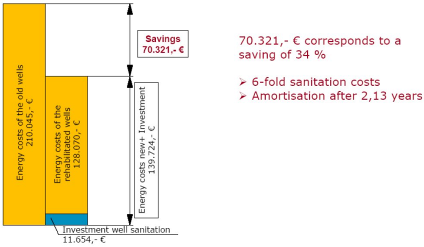

Figure 6.31:

During the 15-year-period shown here, clear changes of the well condition have of course become obvious. Even more important, however, is the question whether the pump can work for 15 years. The answer is a clear “yes”, if suitable pumps were installed, that is to say pumps in solid design with a customer-friendly repair possibility. If this system is coupled with a modern, efficient, cost-effective remote monitoring system, you are definitely on the safe side.

6.7 Conclusion

Starting from the well measurement over the well rehabilitation to the hydraulics many things have to be taken into consideration. The application of frequency converters can pay off in many cases. Concerning water supply, drinking water pumps are long-lasting assets with a high percentage of energy, operating and maintenance costs. Not low investment costs, but the reflection of the total costs over the service life of the wells and stations - the life cycle costs (LCC) - should be the basis for decisions regarding new constructions and renovation.
The three main targets of the LCC reflection for pumps with and without use of frequency converters are the following:

1. decision support for initial investments;

2. decision support for renovation investments - wells and pumps, respectively;

3. recognising actions to reduce costs in view of wells and stations in operation.

We are of the opinion that together with operators, well construction companies, engineering consultants and pump manufacturers it should be possible to guarantee an efficient well system in the long term, aiming at making a contribution to climate protection.

7 Nitrate Accumulation in Groundwater and Water Wells in Syria - Bachar Ibrahim, Abdallah Yakoub

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7.1 Abstract

A system for analysing major issues, including environmental problems, entitled "The Material flow Analyses (MFA)" was used in this study - serving as a management tool to assess the nitrate (NO3) problem in the groundwater basin of the Gota farming area (Marj Alsultan) adjacent to the major City of Damascus. The area of Marj Alsultan was selected for the study because its well's water has more than 100 mg/l nitrate (NO3).
The MFA tool brought to light the need for proper immediate and long-term planning, to put a detailed description and outline for a long-term program to mitigate the NO3 problem of the Gota area and to implement the measures to mitigate the present nitrate (NO3) problems in the aquifer. This eventually resulted in long-term improvements to the environment: (a) improved farming operations yielding cleaner surface water and groundwater, (b) better management of animal waste, plus, (c) better municipal sewage treatment; and (d) improved solid waste management for the Algota area.

7.2 Introduction

This paper is an investigation of nitrate (NO3) accumulation in the surface water bodies and aquifers in and around Algota, Syria (a rural area near the major City of Damascus). The case study will address the nitrate (NO3) being released from agricultural operations, i.e., farming the soils and animal husbandry, resulting in the build up of NO3 in the surface and groundwater systems at higher rates than normally resulting from natural resources.

7.3 Geography and Demography of Syria

A part of Syria is located along the East coast of the Mediterranean Sea between Lebanon and Turkey, the inward part of the country is boarded to the west by Lebanon, to the north by Turkey, to the east by Iraq and to the south by Jordan and Palestine. The total area of Syria sums up to 185,200 km2, subdivided into fourteen governorates. Syria's fourteen governorates and the number of cities, small cities, and villages can to be seen in figures 7.1 and 7.2.

Governorates' Name	Population	Cities Number	Small Cities number	Main Villages number	Villages number
Damascus City	1,627,097	-	-	-	-
Rural Damascus	1,850,618	20	32	26	75
Aleppo	3,912,857	14	38	28	106
Homs	1,827,893	10	17	15	105
Hama	1,878,185	9	21	21	121
Lattakia	1,102,580	4	18	3	98
Idleb	1,460,918	13	22	34	71
Al-Hasakeh	1,428,284	6	10	6	105
Deir -ez-zor	1,359,815	9	27	35	20
Tartus	634,722	5	22	1	53
Al-Rakka	1,311,690	2	8	8	51
Dara	973,688	11	19	16	31
Al-Sweda	432,568	3	9	9	40
Al-Qunaitra	669,004	2	5	4	19

Figure 7.1: Syria's Governorates and Cities, Small Cities & Villages of the Study Area

The deviations and classifications in the Governorate were made according to the availability of information from the Governorate Administration Centre and Mayor's offices.

- City: Mayor's Office; Administration Center and Directorate
- Small Cities: Mayor Office; some Administration Center
- Main Village: Mayor Office; a few Administration Center
- Village: with Mayor Office; other small villages that are interrelated to the village (MOLA&E, 2006)

Currently, over 67% of the Syrian populations live in large cities, such as Damascus, Homs, Hama, Aleppo and the coastal-zone cities. This is attributed to the high population growth rate and internal migration from rural areas towards urban centres.
As a result of the high population growth rate, the needs of inhabitants for food and water supplies increased. This resulted in the over-exploitation of local natural resources, thus causing disorder in the overall environmental balance. Con-

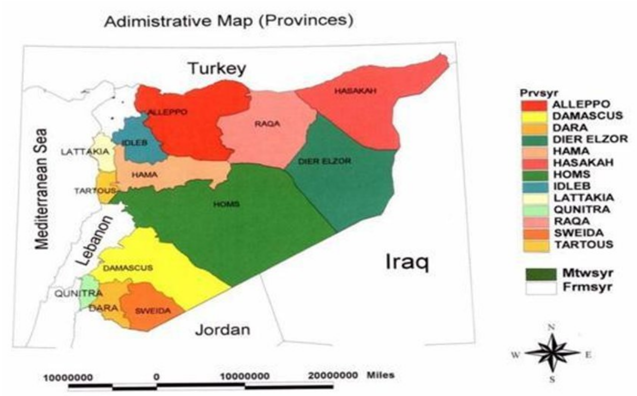

Figure 7.2: The boundary of the 14 Governorates in Syria (FAO, 2002)

sequently, the demographic problems evolved into environmental issues with developmental and cultural dimensions, which manifested themselves in the ever-increasing gap between the needs of the inhabitants in terms of: (1) food, (2) water supplies, (3) infrastructural services, and (4) environmental protection. Since the 1990s, Syria has attempted controls, through preparation and implementation of its “Five-year Development Plans”, regarding all environmental development thereby affording a good life standard to all its citizens. To identify environmental priorities, a national strategy and an environmental action plan were introduced (UNDP, 2003).

7.4 The National Strategy and the Environmental Action Plan

The strategic objectives specified in the “National Environmental Action Plan” are as follows:
The incorporation of environmental aspects into governmental policies, plans and national programs; the protection of natural resources, biodiversity, cultural heritage, public health; the promotion of the use of clean and renewable energies in the framework of sustainable development.

The National Action Plan aims, through the proposed measures, at improving environmental performance continuously. Gradually, environmental priority problems are to be addressed by the year 2015. Implementation of the Plan is to be achieved by means of specific mechanisms and measures with strategic objectives. Strategic "indicators" will be monitored in order to evaluate the progress made towards achieving these national objectives.
A number of environmental problems with priorities were determined by the national committees which evaluated and analysed available data and information on environmental conditions in Syria.

The determined problems with higher priority are:

- Depletion and contamination of surface and groundwater resources
- Land degradation
- Air pollution in large cities
- Inappropriate practices in solid waste disposal
- Growth in illegal areas (residential and industrial), (NEAP,2003)

Sustainable water resources, to meet the needs of future generations in 50 to 100 years have to be based on an integrated water management system. This sustainable program can only be achieved through (1) water conservation programs, (2) identification of water pollution sources and mitigations of such conditions, and (3) water monitoring. These achievements play an efficient roll. "Nutrient water pollutants" cause health problems among the aged and new-born human population. Well water that is polluted with Nitrate (NO3) is one of the main contaminates in the rural areas of Syria and can be seen in intensively used agriculture areas. This study will identify a specific area with NO3 issues.

7.5 Nitrate (NO3) as an Acute Contaminant

Nitrate (NO3) is a naturally occurring chemical composed of nitrogen and oxygen. Nitrate can be found in air, soil, water, and plants. Much of the nitrate in our environment comes from decomposition of plants and animal wastes. People also add nitrate to the environment in the form of fertilizers.

Nitrate is an acute contaminant, meaning that a single exposure can affect a person's health. It causes serious health problems for young infants such as the "Blue Baby Syndrome."(Encyclopedia, 2006).
Blue Baby Syndrome is an illness that is involved when large amounts of nitrates in water are ingested by an infant and converted to nitrite by the digestive system. The nitrite then reacts with oxyhemoglobin (the oxygen-carrying blood protein) to form metheglobin, which cannot carry oxygen. If a large enough amount of metheglobin is formed in the blood, body tissues may be deprived of oxygen, thus causing the infant to develop a blue coloration of their mucous membranes and furthermore, possibly digestive and respiratory problems. This condition is also known as methemoglobinemia.
The majority of cases of methemoglobinemia have occurred when nitrate levels have been over 100 mg/ litre (Uk/bluebabs, 2006). Nitrate accumulation in the water bodies in Algota, (the rural area by Damascus) - as well as discharges from the soil and animals - move into both surface and groundwater systems at higher rates than usually expected. Agriculture and livestock is considered to be the primary source of water pollution with nitrate. Materials used in agricultural production - such as fertilizers, pesticides urine and faeces are causing problems of nutrient and microbial contamination and sediment accumulation.

7.6 Well Water Polluted With Nitrate (NO3) in the Algota Area

Nutrient contamination of groundwater from agricultural operations is pronounced in some regions of Syria, particularly in areas of processing, intensive livestock horticultural and cropping activity. Research shows that trends of nitrate build-up in groundwater are difficult to evaluate on because data is fragmentary for some areas and regular sampling over long periods of time is not yet available. However, the available data indicates that nitrate contamination is becoming a major problem in many regions of Syria. In addition, nitrate "hotspots" will increase in future if not controlled through improved practices in agricultural operations, municipal wastewater and solid waste management and operations. In order to protect the groundwater and wells as a source of potable water from nutrient contamination, it is important to identify:
(1) the significant sources of nutrient contaminants, (2) to manage activities caus-

ing contamination of the surface waters and ultimately the aquifers; and (3) to identify and approve appropriate land uses for properties located in the protective parameter around all potable water wells. (Hila, 2004)
The Gota is a part of the countryside near Damascus, through which the River Barada flows. Most of the irrigated land bordering the river is separated into two parts. The main part is Gota Sharkiah which comprises the land in the northeast and southeast of Damascus. The dimensions thereof are 30 km north of Damascus and 50 km southwards. Agricultural activities are intensified in this area due to its vicinity to the market of Damascus.
The Algota forms an oasis in this dry area, accommodating one million inhabitants. The River Barada flows though many villages, recharging the upper level aquifers along its path. The water being pumped from the aquifers is the main resource for potable water supply and agricultural uses. To preserve the natural environment and protect the water resources in this area it is important to identify the primary and secondary pollution sources. Moreover, it is essential to regularly monitor both the surface water and groundwater quality. The groundwater, in many parts of Algota, has a high Nitrate (NO3) concentration; in many locations the NO3 is higher than 100 mg/litre (Abed Rabou, 2000). In the two study areas (1) Arihan and (2) Hosh Alzawaher the groundwater monitoring has shown tests results from well water monitoring with high levels of nitrate exceeding 100 mg/litre.

7.7 Description of the Study Area and Study Procedures

The objectives of the study were to:

- Identify the study area
- Describe the main activities in the study area
- Describe the interrelation within the activities
- Evaluate the pollution's impact from each activity on the groundwater
- Calculate the value of the nitrate (NO3) leached into the groundwater from each activity
- Compare the impact on the groundwater from each of the impacting activities.

In order to achieve these objectives, the community of Marj Alsultan was chosen where water quality data and other demographic information were immediately available. The boundary of the study area was identified and the "Material Flow Analyses" (MFA) approach was implemented to evaluate the impacts of respective human activities, i.e., agricultural, municipal, and family home life.

7.8 Socioeconomic Analyses of the Study Area of Marj Alsultan

The selected study area was Marj Alsultan, being located in the east Gota and belonging administratively to Haran Alawamid. The area of Marj Alsultan was selected for this study as its well water has more than 100 mg/l nitrate (NO3). The Marj Alsultan inhabitable living area can be appraised to $125km^2$. The population of Marj Alsultan is approximately 3.000 inhabitants, 51% of which are male and 49 female; about 30% are children under the age of 14 with 7% being younger than 12 months.
All houses in Marj Alsultan have a sanitary system, electricity, water supply systems, and a communication system. Both, primary and secondary schools are available. About 44% of the inhabitants finished primary school and 11% have a completed higher education.

However, the municipal infrastructure of the community is not well developed in order to provide for the general health needs of the inhabitants. Hygienic facilities are available in all parts of the community. The sewerage system is available but no wastewater treatment facility is available. Furthermore, no proper solid waste recycling or landfill operations are performed.

7.9 Materials and Methods

The study's aim was to evaluate, recommend and apply the needed solution or solutions to prevent increasing groundwater pollution and to protect the potable water wells from nitrate, being the primary pollutant source discovered accumulating in the wells.
The identified contamination sources of well water in this area are:
(i) the improper applications of nitrate fertilizers, (ii) animal feedlot wastes, i.e., urine and manures, (iii) improper municipal wastewater management and treatment and (iv) solid waste management and landfill operations.
The accumulative impact of these four activities, with their different gradations of pollution, constitutes the main sources of nitrate accumulation in the groundwater and, ultimately, well water.
In order to protect the groundwater and the potable well water a series of improvements, both physical and managerial, are needed:

- Education of farmers in (1) the proper applications of nitrate fertilizers and (2) monitored irrigation preventing over-watering of crops resulting in seepage of excess irrigation water down to the aquifer carrying with it the dissolved nitrate fertilizer.

- Improved animal feedlot solid and liquid wastes controls by (1) controlling the leaching and seepage of manures and urine, (2) preventing surface runoff and seepage of leached nitrate from the animal waste by collecting and retaining the liquids in a holding pond; then (3) pumping and hauling the wastewater to a Municipal Wastewater Treatment Plant for proper treatment, thereby preventing seepage of the feedlot waste from reaching the aquifer.

- Improved municipal wastewater management and treatment through construction of a wastewater treatment facility with nitrogen removal capabilities, plus, total disinfection of effluent released from the facility, thereby preventing nitrate from the human waste reaching when the effluent is recycled for irrigation (see improved irrigation practices, first item above); and

- Establish new procedures for solid waste management: (1) provide municipal solid waste collection, (2) implement recycling of reusable materials, (3) then establish proper landfill management and operations preventing storm water from flowing onto the landfill site; and (4) then collecting and treating the leachate that seeps from the land filled materials at the municipal wastewater treatment plant;

- Establish a 180-meter protection buffer zone surrounding each well used for potable water; procedures established in the first item (above) must be strictly maintained for fertilizer control and the irrigation water source monitored for nitrate and other pollutants preventing seepage of contaminates into the groundwater.

7.10 Material Flow Analyses (MFA)

The Material Flow Analyses (MFA) is an appropriate tool to investigate the flow and stocks of any material-based system. It gives insight into the performance of the system. And, when combined with other disciplines, such as (1) energy-flow analyses, (2) economic analyses and (3) consumer-oriented analyses, it facilitates the control of an anthropogenic system. (P.Brunner, 2004).
An MFA consists of several steps, generally commencing with the definition of the problem and the adequate goal. In the following, the relevant substance and appropriate system boundaries, processes and goods are selected. Then, the mass flows of goods and substances and the concentration in these flows are assessed. Substance flows and stocks are calculated and uncertain considered. Closing, the results are being presented in an appropriate way so as to visualize conclusions and facilitate implementation of goal-oriented decision.

It is important to note that the procedures most not be executed in a strict way. The procedures have to be optimised intuitively.

7.11 Study area boundary

The boundary of the study area was defined as follow:

- Inhabitants: 3000
- Planted area: 390 Hectare
- Duration: 1 year

Existing Activities:

- Agriculture activity
- Livestock activity
- Household activity
- Activities description and calculation of Nitrate (NO3) flow within and out of the activities.

7.12 The Activity of Agriculture

Wheat and vegetable are the main products. In addition, fruit trees are being cultivated.

The planted area with vegetable is approximately 148.4 ha

The planted area with Wheat is approximately 204.5 ha

The planted area with Fruit trees is approximately 36.7 ha

The usual fertilizer amounts for the various plants are as follow:

The amount of the Nitrate (No3) for wheat is 250 Kg/ha

The amount of the Nitrate (No3) for the vegetable 200 Kg/ha

The amount of the Nitrate (No3) for the fruit trees 150 Kg/ha

Plant Art	Wheat	Vegetables	Fruit trees
Area/ ha	204.5	148.8	36.7
Fertilizer rate Kg No3/ha	200	250	150
N kg/ha	45.1	56.5	33.8
N kg/ ha	9223	8407.2	1240.5
Total amount of the N/ 390 ha	18871.2		

Figure 7.3: Table 2

Figure 7.3 illustrates the planted areas and the related fertilizer rate.
The total amount of N as a material flow in/within this activity is about 18871, 2kg/390ha is assumed as 19 ton per hectare per year.
The assumption regarding the N-Flow in this activity it has been assumed as follows:

- A part of the Nitrogen is used by the plants
- A part evaporated to the atmosphere
- A part leached into the ground water

The N-part evaporating to the atmosphere was assumed to flow back into the soil with the precipitation.
In order to calculate the leached amount of Nitrate into the ground water the following equation was used:
$A = K.Ns.M0/T$ (Herbert et al. 1982)

A: Leached Amount of N in %
K: Soil conductivity 0, 2-0.7cm/hour
T: Depth in cm
Ns: Rainfall in mm
M0: N-amount in the beginning of the metering
A = $0.3150 * 18.9/100$
A = $8.5 ton = 44\%$
A = $0.315019/100$
A = $8.5 = 45\%$

This means that 8.5 tons of NO3 may be leached to the groundwater

7.13 The Livestock Activities

The main figure in this activity is the cow. The number of milk cows is 350. The flux (input and put) was calculated in relation to the amount of proteins in the feeds. The amount of N was calculated according to the equation:
N = Protein/6.2
The basic feed in kg per cow is 77g
The basic feed is 432g
The productive feed is 770
The total was 1202g
The total amount of protein for 350 cows is 152.5tons
The total amount of N for 350 cows is 24.5 tons per 350 cows per year

Regarding the flow, flux within the activities can be marked as follows:
2.7 tons flow to the household and 19.5 tons flow as solid and liquid waste - 15.3tons of which flow as urine and 4.2 tons as faeces, being used as biomass manure.
The flux of the biomass is as follows: 0.7 tons of it was quickly solved. It was assumed that the amount of urine which evaporated into the atmosphere recurred with the precipitation. The urine has 18% N of the total amount of the nitrate and the faeces have 20% Nitrate (P.Baccini, 1992), 0.05%, or 1/7, of which is quickly leached Nitrate.

7.14 The Household Activities

The nourishment that flows to the household consists of agricultural protein and animal protein. It was calculated according to the consumption of the inhabitants based on the information gathered with the help of questionnaires. The amount of the nitrate was calculated according to the standard amount of N in the nourishment. The calculation shows that 2.7 ton N input flows from the animal activity and 3.5 ton from the agricultural activity to the householder activity. The produced waste within the activity was urine faeces together with municipal

waste. The assumption of the nitrate in the waste was calculated according to the assumption that (1166.6g N in urine 360g N in faeces per inhabitant and year) 3.5 in Urine und 1.1 ton N were within the faeces and flowed in the groundwater (P.Baccini,1992).
The solid waste from the households flows to the whereby the N-amount in the solid waste is about 1.5 ton.

7.15 The Dumping Site Activities

The municipal solid waste is 1.500kg regarding 3000 inhabitant per day. The amount of organic waste is 60% or 540 tons which have 40% moisture or 216 tons of solid waste and 86.4 tons of adsorbed liquid organic waste per day that could eventually seep into the groundwater with its nitrate content. The N-amount is 1.5 Ton as it was calculated according to P.Baccini,1992.

7.16 Results and Discussion

The following diagram illustrates the flow flux of the appointed activities in the study area.

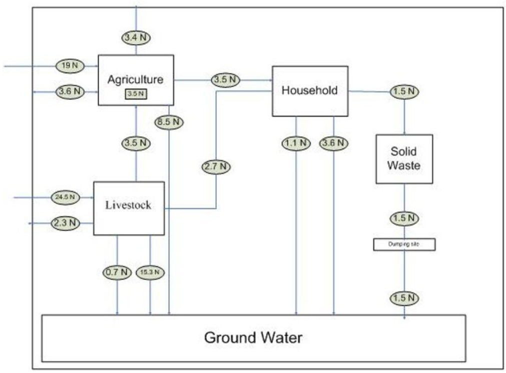

Figure 7.4: Material Flow Analyses Diagram (MFA)

7.17 Result and Recommendation

The Diagram clearly shows that all activities are playing a quantitative role in polluting the ground water and potable well systems. The quantity of the leached Nitrate found in the groundwater from the illustrated activities in the diagram is varying.

The leached amounts of Nitrate from the activities that are illustrated in the diagram are as follows:

Agriculture activity is 8.5 tons per year

From the Household is 4.7 tons per year

From the dumping site is 1.5 tons per year

From the Livestock is 16 tons per year

The Livestock activities were identified as the main source for groundwater contamination with nitrate.

The first priority in managing the ground water contamination with nitrate is to start controlling the usage and treatment of organic manures. The treatment of animal manure in the study area is proceeding without any regard of the environmental protection and groundwater saving. By handling the manure, the goods are accumulating in an open area without any kind of isolation on the surface or on the bottom. In few cases, only a surface covering is present. The leaching liquids of the manure body are flowing into the groundwater and to the well water. The leaching rate and the leaching time are related to many factors.

In order to save the water well from nitrate pollution throughout the livestock activity, it is very important to allocate a saving zone where the animal manure can be accumulated and treated. Guideline for the treatment site of the manure should be an indispensable use of an impermeable layer and the separation of the treatment site from water sources, especially the water well which could be use in dry time for drinking water. For these objectives it is important to carry out hydrological studies in order to conduct a guideline for the environmental production of organic manure and conduction of a fixed dimension of saving zone of the water well.

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8 Water Supply in Beijing: History and Development - YE Jian-Zhou

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8.1 Introduction

It can be ascertained that potable water is a highly valuable good. The settlement of people took always place close to rivers and springs so as to provide people with a basis for living. With this article I would like to communicate to you the history and development of Beijing's water supply and give you an overview of the modern waterworks No. 9.

8.2 History and Development of Beijing's Water Supply

- *- 1908*

  Almost all inhabitants took their water supply out of the lighter soil layers of clay wells. The water quality was very poor and the water tasted bitterly and tartly. The water quantity from the wells was still insufficient for the supply of all the inhabitants. One exception was the Emperor's Palace which was supplied with fresh water out of mineral wells. These wells were located in the north-west of Beijing in a small suburb called Yu-Quan-Shan (Jade-Spring Mountains).

- *1908-1910*

  In 1908, the first "Beijing Water Supply Corporation" was founded with the consent of the Emperor's widow Cixi and was commissioned in 1910. The plant layout and the construction plan of the first waterworks were created by a German engineer. Moreover, the equipment, such as pumps and steam engines, were provided by Germany. The river Sun-He, situated 20km from the city centre, was utilised as a raw water source for the city of Beijing. A water treatment plant was built on the riverside and simultaneously a waterworks facility was erected in the north-west of the city centre.
  First of all, the raw water was treated cursorily and afterwards it was transported via a water pipe into the waterworks. After disinfecting it with powdery CaOCL2 (Calciumhypochlorination), the treated water was fed into the piping network as potable water. The Water Supply Corporation employed two engineers, of whom one was German and the other Danish. They were responsible for the system operation as well as for the machine's

maintenance and overhauling. In 1910, Beijing's piping network spanned 152km and achieved a pumping amount of $3.300m^3/t$. The corporations' turnover was very narrow since the Emperor's family, as well as the population, did not believe that water could apparently come out of the conduit itself, due to their superstition. Actually the Emperor's family did at first not approve the planting of water pipes within the palace.

- *1910-1949*

  As a result of war and political turmoil Beijing's water supply developed only very slowly. In 1942 the run-off quantity of the Sun-He river was no longer sufficient for water supply. Therefore, the treatment plants were entirely decommissioned so that the groundwater had to be exploited. For this reason, 26 wells were drilled in the city centre and the suburbs for the first time in 1939 so as to feed the waterworks with ground water. Until the end of 1949, still only one waterworks facility existed in Beijing. The piping network at that time already spanned 364km and achieved a pumping amount of 86.000m3/t so that 600.000 inhabitants could already be supplied with potable water. Even so, this was only a share of 30% of the overall population. The other 70% of the population still took their water out of clay wells or water trucks.

- *1949-1979*

  Beijing's water supply system expanded rapidly after China's reestablishment. The urban development, the initiating industrialisation and the constant population growth necessitated the drilling of approximately 200 wells in various suburbs of Beijing and the construction of six water works all around the municipal area. Numerous extensions of the water catchment and water pumping facilities followed.

  In this context, some general information about Beijing will be provided. The city of Beijing is located at 39°56'N latitude (comparable to Madrid) and 116°20'E longitude. Today, it spreads over an area of $1680km^2$ (a bit larger than the German Federal Land Schleswig-Holstein) and its city centre situated at 44m above sea level. Approximately 62% of the area, in which the rivers Yongding, Chaobai, Juma and the Northern Canal flow, is downs. The city is situated in the vicinity of a low mountain ridge, which comprises Taihinag Shan in the west and Yan Shan in the north-west. Southwards and south-eastwards, Beijing opens up to the North-Chinese plain. Beijing's administrative district is subdivided into ten districts and nine rural districts. Since the beginning of the 1950s, the following situation arose owing to the development and exploitation of the ground water. Due to increased water resources, Beijing was situated in the alluvial cone of the rivers Yongding and Chaobai: This alluvial cone bestrode several suburbs of Beijing, whereas most of the suburbs were located in the north and west. Since the geodetical height in the municipal area slopes from north-west to south-east, the ground water flowed into the north-west and south-east direction as well. The establishment of several wells, galleries and waterworks was carried out in the alluvial cone of the city district and in the north-western suburbs, respectively. The arrangement of the wells, galleries and waterworks was horseshoe-shaped. Two advantages result out of this:

1. The well galleries were exactly sited in the area where the amount of groundwater was sufficient. In the 1950s and 1960s, for example, the water supply rate of only one well amounted to $300-500m^3/h$.
2. The waterworks were able to use the convenient geodetical height so as to supply the city's inhabitants with potable water, from upper reaches to lower reaches, with little energy input.

In the 50s and 60s, the water quality was excellent and the wells' water supply rate quantitatively sufficient. Since the beginning of the 1970s the water quantity out of wells decreased significantly, which led to a fast lowering of the ground water level. In addition to that, the water quality deteriorated as result of the following aspects:

1. Several well galleries were situated in vegetable growing areas which were irrigated with wastewater by the peasants.
2. Some wells were polluted with industrial waste (oil, paint, varnish and fertiliser).
3. In order to increase the production output of the vegetable crop, the peasants employed too many fertilisers and pesticides.

The aforementioned reasons led to a considerable pollution of the ground water. Its nitrate and nitrite levels were very and even exceeded the threshold of the national drinking water standards. Thus, the wells had to be partially decommissioned.
In the meantime, Beijing developed at a virtually explosive rate. The city's increasing water demand, resulting from a population of six million inhabitants already, could only be satisfied with the use of extensive methods, e.g. with the conveyance of 1.03 million m^3 per day in 1978. The water work's water catchment of wells and galleries and the release capacity of potable water reached the limits of their productivity by that time. The groundwater table fell rapidly as a result of the high amount of extraction and consequently many wells had to be put out of operation.

- *1975-1982*

  For that reason the planning and construction of water works facility No 8 was carried out in order to cover the severely increasing water demand. This facility had been the biggest and last facility for ground water pumping to be built in Beijing. 36 wells were dug in the farther rural district Shun-yi, or rather at the bank of the Chao-bai river (within the alluvial cone), with the purpose of further water catchment. The water quality of the well's water was excellent so that only little chlorine had to be added. Moreover, the output of those wells was sufficient. The transmission pipelines leading from the wells to the waterworks facility No 8 have a length of 40km and a diameter of 2*DN1400mm. This facility has a daily water supply productivity of 480.000m^3.

- *1982-2009*

  From this time on, one had to revert to the surface water, since the ground water was no longer available in the required quality and quantity. The construction works for the project "waterworks facility No 9" were initiated in 1986 after ten years of planning. The first building phase, with a water catchment capacity of 500.000m^3 per day was put into operation in 1990. The Hoai-Rou reservoir is utilized as the main water source (fresh surface water). For the first building phase, the withdrawal of water is carried out through a steel pipe with 42km in length and 2200mm in diameter. The freshwater is being transported from the reservoir to waterworks facility in the northern periphery via this pipeline. The second and thirst building phase concluded in 1995 and 2000 respectively, with a daily output of 500.000m^3 each. The freshwater for those two building phases is withdrawn directly from Mi-yun reservoir. The water transportation pipe, which serves the headwaters between the Mi-yun and Hoai-Rou reservoirs, has a total length of 32km and a diameter of DN2600mm(GGG). For the lower reaches, between the Hoai-Rou reservoir to the waterworks facility No 9, further two pipelines were passes parallel to the first steel pipe, each with a diameter of DN2200mm. Every day 1.5 million m^3 of freshwater are transported to Beijing's waterworks facility No 9 through these massive water pipelines. Japan, the USA, Great Britain and Germany served as subcontractors for the plant.

8.3 Detailed Data on Water Catchment and Water Treatment - Example: Third Building Phase of Waterworks Facility No 9

The entire water being treated in waterworks facility No 9 is withdrawn from the Mi-yun reservoir.

8.3.1 Data on the Reservoir

Freshwater source: Mi-Yun reservoir

Sources: Rivers Chao-Be and Bai-He in the province of He-Bei.

Total volume: 4.3 billion m^3 with 143 metres above MSL.

Current volume: 0.776 billion m^3 with 130 metres above MSL.

Constant volume: 0.4267 billion m^3 with approximately 120 metres above MSL.

Water temperature: $-0.3\,^{\circ}\mathrm{C}$ to $20\,^{\circ}\mathrm{C}$.

State of freshwater: Adapted to national Chinese "Water Quality Standard for Drinking Water Sources". The withdrawal of water for the waterworks facility

No 9 (approximately 50 metres above MSL) is carried out after a pipeline course of 77km. The annual amount of withdrawn water adds up to 0.5 billion m^3. The difference in altitude between the Mi-Yun reservoir and the water treatment plants amounts to about 80 metres, so that the freshwater can be transported to the facility with the help of gravitation.

8.3.2 Procedural Steps

1. **Pretreatment** The freshwater is pretreated with chlorine CL2 and with potassic permanganate directly at the water intake point at the Mi-yun reservoir. This pretreatment is performed in order to abate algae in summer if the reservoir's water quality necessitates it.

2. **Flocculation, Reaction and Sedimentation** The freshwater is transferred to the distribution basin after the long transmission through pipes. From this basin the freshwater is arrives at a comprehensive basin. Here, aluminum salts are added which serve as flocculants. In this process, the floc sediments at the bottom of the basin.

3. **Filtration** The filtration process completely removes particles clouding the water. During the quick filtration the water is filtrated through a one-layer filter. This layer consists entirely of anthracite. In case the filter is clogged, it is being purged with the help of a three-phase stripping, each procedure (water / water plus air / water) taking ten minutes. For each purge approximately 1000m^3 of purge air and about 2000m3 of water, which are taken from the pure water basin, are necessitated.

4. **Disinfection** At the inlet the filtrated water is chlorinated (CL2) and thereby disinfected. The pure water storage basin has a volume of 100.000m^3.

5. **Conveyance of Potable Water** After the disinfection process, pure water is inducted into the water pipeline network via the pumping station and its centrifugal pumps (frequency regulation 30-60Hz). To ensure an impeccable water quality, the water is being slightly chlorinated within the inlet (low dosage).

6. **Mud Treatment** The mud reaches the conditioning via a mud sedimentation tank. Subsequently, the mud is inducted into a pressing facility though a high pressure nemo pump. In this step, the chemical PAM is added. Concluding, the mud cake is loaded on a lorry and transported to the landfill site.

8.3.3 Analysis of Freshwater State

The facility offers its own water laboratory. The data for the limit values of the water's substances of content are mandatory and can be inferred from figure 8.1.

Parameter	Limit Value - 98/93/EC	Limit value Chinese national "Drinking water Standard" GB5749-85	Limit value No.9 Waterworks Water Rule
Turbidity	1.0NTU	3-5NTU	0.5-2NTU
Color	none	15 TCU colorless	5 TCU colorless
Residual Chlorine		- 0.3mg/l after 30min contacting water, 0.05mg/l at ends of distribution system	0.8-1.2mg/l (water delivery location)
visible Material	none	none	none
Oder and Taste	acceptable	No objectionable or/ and taste	No objectionable or/ and taste
Total Bacteria	No sudden change	100/ml	100/ml
Total Coliform	0/100ml	3/l	3/l
PH Range	6.5-9.5	6.5-8.5	6.5-8.5

Figure 8.1: Table

8.3.4 Electric Control and Surveillance of the Plant

The process control is carried out fully automated with the help of the electronic control system CENTRUM DCS 3000 by the Japanese manufacturer YOKOHAWA. The man-machine dialogue happens by means of monitor control. Set-point factors (e.g. amount of filtrate, limit value of turbidity) and control commands are entered. Electronic readings recorder are used in order to gauge process factors. The real-time data processing is carried out by a computer.

8.3.5 Representative Data on the Line Operation of Waterworks Facility No 9

Pretreatment: Chlorine gas: 1.5mg/l; In summer: potassium permanganate: 1mg/l.

Flocculent: $< 3g/m^3$ AL3+

Filter system: One filter hall, two systems (series) per each 12 quick filters with a filter area of $117m^2$ each and a filter velocity of 7.5m/h.

Buildup: Open one-layer filter, complete anthracite (anthracite coal): graining (average value) 1.1mm and a layer thickness of 1500mm. Supportive stratum (flint): 1-8mm and a layer thickness of 400mm.

Ground nozzles: 64 nozzles per m^2 out of PE (or ABS), 1mm slot width.

Stripping criteria: Automatic, depending on turbidity, time, pressure difference.

Turbidity: < 0.5 NTU

Time: < 24-48h

Pressure difference: < 2m Ws.

Stripping pumps: Three pumps with $2800m^3/h$ each, Capacity: 1500kW.

Disinfection: CL2, Dosage: $1.4g/m^3$. Delivery: As liquid chlorine in a steel barrel.

Feeding pumps: Six centrifugal pumps with $14760m^3/h$ each, pressure head: 56m, electric capacity 2550kW (frequency regulation: 30-60Hz).

Current problems: Scarcity of adequate raw water sources for the production of potable water and leakages within the water pipeline network. Estimated loss of water: 20-30%.

9 The Potential Impacts of Human Settlements on Groundwater Quality - Dr. Caleb Mireri

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9.1 Abstract

The main theme of this paper is to show the strong relationship between human settlements and groundwater quality. Human settlements, and the associated activities, represent a serious threat to groundwater quality because of the increasing demand for water as well the increase in effluents which find their way into such water bodies, thus causing contamination and pollution. The paper further shows that proper planning of human settlements and infrastructural development can contribute to a conservation of groundwater resources. This can be achieved by reducing pollution risks from human settlements, conserving watersheds and protecting groundwater aquifers through planning interventions.

9.2 Introduction

Human settlements are broadly defined as spatial arrangements of various land uses and their functional interrelationships. Human settlements include housing, agriculture, industry, mining, forestry, transport and communication, services and amenities. During the United Nations Conference on Human Settlements in 1976 in Vancouver, human settlements were defined as the totality of the human community - whether city, town or village - with social, material, organizational, spiritual and cultural elements sustaining it. The fabric of human settlements consists of physical elements and services to which these elements provide the material support. The physical components comprise shelter, infrastructure and services. The concept is that human settlement has been broadened to become a framework for an overall national, socio-economic development. It is now being contended that human settlements are the spatial dimension as well as physical expression of economic and social activity (http//www.unescap.org).

From the above definition, human settlements are linked to groundwater quality at three key levels. Firstly, human settlements demand water for various uses and groundwater sources usually represent one of the important water sources. Therefore, depending on the available groundwater resources and rate of abstraction, human settlements can lead to groundwater depletion and trigger sea intrusion. Secondly, growing human settlements demand space and in the absence of planning and developmental control, sensitive watersheds and aquifers may attract

settlements resulting in the degradation of groundwater quality. Thirdly, human settlements are associated with the consumption of resources and discharge of residuals into the environment. In the absence of appropriate infrastructure in order to manage residuals from human settlements, groundwater resources are one of the recipients of wastes from various human settlements' activities causing either contamination or pollution of such water sources. These factors exemplify the strong relationship between human settlements and groundwater. Therefore, there is the need to strengthen human settlements and the provision of infrastructure so as to support groundwater quality management.
The rapid growth of cities leads, especially in developing countries, to serious burdens for the health, the environment and thus resulting in social problems. In industrial societies a massive exploitation of natural resources and harmful emissions into the air, water and soil takes place in urban settlements. Some of the guidelines of urban planning oriented to ecological objectives are:

(1) sparing use of building land (high density and good quality accommodation, space-saving building forms and access facilities, multiple use of areas, mixture of uses); (2) urban green space (conservation and enhancement of the countryside, establishment of a 'green cycleway network', many alleys); (3) reducing energy consumption (highest feasible building density, compact development, building orientation for passive uses of solar energy); (4) economic use of water in the project planning (minimising paved areas, rainwater infiltration, green roofs, collection of rainwater in cisterns, water-saving taps); (5) planting of open space with vegetation, climbing plants on walls, green roofs (Agenda 21-Bureau of the City of Hannover, 2004). The above stated, ecologically oriented planning objectives demonstrate the strong relationship between planning and natural resource management and, consequently, groundwater resources.
Regarding Kenya, urban infrastructure has witnessed rapid deterioration during the last two decades, especially of roads, water and sewerage systems. The existing infrastructure has not been able to cope with the rise in population and is therefore overused or overcrowded and thus unable to guarantee the expected life quality. The services are similar in their pathetic state, for example persistent water shortages, limited sewerage system coverage, uncollected garbage, public health and persistent power failures. Some factors being responsible for the depicted scenario include inadequate and skewed resource allocation for the

construction, maintenance and rehabilitation of the facilities; poor contractual work; rapid urbanisation; high population growth and adverse weather conditions (Mireri, 2006). At the beginning of the 21st century, the greatest water quality problem in the developing world is the prevalence of pathogenic waterborne diseases. These are induced in large measure by faecal pollution of drinking water, resulting from inadequate sanitary protection (Foster, 2006). Only 30 per cent of the gazetted urban centres in Kenya have sewerage systems. This has posed serious environmental and health problems. Where they exist, most systems suffer from constant breakages or leakages and an inadequate capacity to handle their full sewage load. A number of factories and enterprises are known to discharge effluents to mainstream rivers and valley depressions causing high pollution levels. Effluent pollution makes rivers, streams and dam water unsafe for domestic and livestock consumption. Management of solid wastes in urban areas is increasingly of major concern. Human activities, particularly in water catchment areas, have increasingly threatened forest cover and in some areas have resulted in diminishing water availability (Mireri, 2006).

9.3 The Drivers of Human Settlements

Human settlements can grow or decline during certain periods of time. The growth and decline of human settlements is influenced by different factors such as demographic characteristics, the existence and demand for natural resources, urbanization, politics and institutional arrangements and socioeconomic and political stability. Population growth rate has a direct bearing on the demand for environmental resources, including groundwater. In Kenya's case, the population has been growing at about 3 per cent during the last four decades, while the urbanization rate has been about 6 per cent during the same period. The growth of slum settlements in Kenya has occurred at very high rates (7 - 12 per cent per year), one of the key features of slum settlements being the lack of basic infrastructure, such as water and sanitation facilities. Against the growth of population, informal settlements as well as overall urbanization, wastes generated from urban settlements find their way into water bodies, including groundwater. The problem is vividly demonstrated in the Kisumu municipality (Kenya) where 90 per cent of the municipal residents use pit latrines to dispose of human waste, although shallow wells are often located in the proximity, thus creating a serious risk of cross contaminations of groundwater sources. In the Kisumu municipality, 60 per cent of the population lives in the informal settlements where shallow wells constitute an important source of water.

Human settlements are influenced by the existence and enforcement of politics and institutional frameworks. Policies and institutional frameworks should specify the manner in which land uses should be organized in the country. Since her independence in 1963, the successive governments in Kenya have failed to develop a human settlement policy, although the country has a legislative framework on settlement planning (Physical Planning Act, 1996). The government has not effectively implemented the Physical Planning Act as evidenced by the massive growth of informal/slum settlements. For example, 70 per cent of Nairobi City's residents live in slum/informal settlements. A policy is very important in galvanizing the population to accept a certain ideological position on human settlements, such as patterns of human settlements and conservation of strategic areas, for instance watersheds and groundwater aquifers.

The level of economic activities in a country determines the demand for natural resources and thus the amount and rate of extraction, as well as the generation of wastes. Rapidly growing economies demand strategic resources to drive the growth, compared to the stagnating ones. Water is a strategic resource in industrial, agricultural and commercial activities. The demand for both surface and groundwater resources to drive rapid economic growth puts pressure on hitherto fixed water resources, which may lead to resource depletion in resource-poor economies. As economies seek to modernize and improve their performance, the risks of water resources' degradation increases.

High levels of water use cause both environmental and economic problems. On the environmental side, high consumption puts stress on rivers, lakes and groundwater aquifers and may require dams and flooding with serious ecological impacts. On the economic side, high levels of water use require ever-increasing and expensive investments in water system infrastructure. These are needed to gather, deliver and dispose of water (dams, reservoirs, water treatment facilities, distribution networks and sewage treatment) (http://www.environmentalindicators.com).

Political stability is a key determinant of the rate and structure of human settlements. Regions which have experienced political stability over a long period of time have relatively stable settlements, unlike areas with political instability. Political instability results in sudden increase in human settlements beyond the capacity of existing infrastructure, thus causing environmental degradation. Typical examples are the (1) rapid rate of urbanization in independent Kenya, which has led to a rise in the urbanized population from 8 to 27 per cent in 1967 and 1999 respectively. Another example is the (2) political instability in the East Africa region which resulted in the creation of refugee camps and leading to an increase in demand for the key natural resources around the camps, especially water and energy. Also, refugee camps have been established without requisite sanitation and solid waste management system creating risks of groundwater pollution.

9.4 Human Settlements as Potential Sources of Groundwater Pollution

Human settlements are important consumers of natural resources (land, water and energy) and they, in return, discharge wastes in the environment. Depending on the type of wastes generated against the nature of infrastructure and governance structures, human settlements are potential sources of contamination and pollution of both surface and groundwater resources. The quality of sanitation and solid waste management infrastructure are key determinants of the levels of contamination and pollution risks from human settlements.
A number of water quality problems are associated with dense settlements. The most important of these are (Republic of South Africa, 1999):

- *Microbiological Contamination* by faecal pathogens, which has severe health implications for water users and the community. These mostly come from human excreta, and dirty washing water (grey water). However, high concentrations of faecal bacteria may be found in storm water runoff, and in livestock faeces.

- *Nutrients*, mainly phosphorus and nitrogen, which cause eutrophication and increase the costs of treating water to potable standards. These mostly come from human excreta and grey water, but may also be present in high concentrations in storm water runoffs.

- *Solid waste (litter)* from public spaces and from household refuse, which causes ecological, aesthetic and health problems, and affects the functioning of storm water and sewage services.
- *Sediment* from unpaved areas in the settlement that accumulates in rivers and dams, affects aquatic habitats and reduces storage of storm water runoff.
- *Habitat destruction* mostly by building in the riparian zone which affects the natural functioning of river ecosystems, and allows waste to get into the rivers.

These waste streams interact, e.g. faecal matter from blocked sewers or litter may be washed into the water resource by storm water runoff, while solid wastes may block sewer systems. Water quality problems result from the *physical* breakdown or inadequacy of one or more of the waste streams and are mostly associated with inadequate, or poorly functioning, services. These *physical* causes of water quality problems include inappropriate sanitation for the density of the settlement, no facilities to dispose of grey water, sewer blockages due to inappropriate design, and poor design of solid waste removal services. The encroachment onto, and destruction of the riparian zone, also impacts on the water environment and can be considered as a physical problem. However, these *physical* causes of pollution are situated amongst the *social* and *institutional* environment within the settlement. These exacerbate or directly cause the physical problems. Important *institutional* concerns are a lack of funds within the Local Authority to address the problems, a lack of capacity to maintain the services, and the diversion of resources to other priorities. *Social* issues include non-payment or illegal use of services, vandalism and a lack of awareness with respect to the proper use of the services. Pollution in settlements must be managed by addressing all three of these components. This requires addressing the *physical* factors which contribute to the problem, usually by direct intervention within one of the four waste streams. Moreover, the underlying *institutional* and *social* issues, usually by softer intervention options like capacity building and education, have to be attended to. (Republic of South Africa, 1999).
Due to the fact that there is a lack of sewerage collection systems in many urban areas in Cyprus, a substantial amount of sewage is collected in septic tanks/cesspools, potentially causing pollution to both groundwater and surface

waters. The main pressure of industrial pollution takes the form of industrial wastewater which may contain several substances. Those effluents are disposed to the surface water or groundwater either after treatment or untreated. Storm water runoff originating from precipitation mainly on impervious areas may be a significant source of pollution that can put significant pressures on the water quality of surface and groundwater, either as point source or usually as a diffuse source. Urban areas are, as being mostly impervious due to the constructed environmental produces, considerable volumes of storm water runoff. For the same reason industrial areas and transportation infrastructure, like highways and airports, produce also important storm water runoff volumes. Moreover, due to the various land uses of those areas as well as the fallouts, originating from effluents, may include various pollutants like organic materials, nutrients, certain heavy metal and hydrocarbons. Thus, runoffs may pose a significant problem to the surface waters and probably groundwater (ENVECO, 2004).

The main pressures, as a result of agricultural activities, are in the form of pollution due to nutrients (nitrogen and phosphorous), oxygen demanding compounds (BOD, COD) and pesticides. With respect to solid wastes, current practice involves mostly uncontrolled or, in some cases, semi-controlled dumping of municipal solid wastes. The most common water quality problem in Cyprus is in the contamination of groundwater caused by sea intrusion. Intensive agricultural practices and excessive use of fertilizers resulted in raised nitrate pollution of some aquifers. Overexploitation of those aquifers resulted in the depletion of all inland aquifers and the deterioration of groundwater quality in most of the important coastal aquifers of sea intrusion (ENVECO, 2004).

Salinisation is a persistent water quality problem in South Africa. Salinisation refers to the natural or anthropogenic processes that increase salinity within a water system. Anthropogenically induced causes of salinisation include: discharge of municipal and industrial effluent, irrigation return flows, urban storm-water runoff, surface mobilization of pollutants from mining and industrial operations and seepage from waste disposal sites, mining and industrial operations. Another problem affecting water quality in South Africa is eutrophication. Eutrophication refers to the process whereby excessive algal and macrophyte growth encouraged as a result of the environment of water with the plant nutrients, particularly nitrate and phosphate forms. As nutrients are present in sewage effluent, the problem is accentuated wherever there is a concentration of humans or animals. Human settlements and overloaded sewage systems are the major sources of deteriorating microbiological water quality. Micro-organisms and parasites may enter the water system in partially treated sewage effluents, seepage and runoff from inadequate sanitation and waste disposal. Water contamination by faecal matter is the medium for the spread of diseases such as dysentery, cholera and typhoid (DFID, 2002).

9.5 Sanitation and Solid Waste Management in Kisumu Municipality, Kenya

The Kisumu municipality is the third largest urban centre in Kenya. Its current population is estimated at 500.000, having risen from 32.431 in 1969. The municipality is located at the shores of Lake Victoria (the second largest freshwater lake in the world) with a total area of $417km^2$, out of which $120km^2$ is covered by the lake. The incidence of poverty in the municipality is estimated at 60% and a similar proportion of the municipal residents live in the informal settlements. The municipality suffers from inadequate sanitation infrastructure and services, predisposing groundwater to contamination. A significant proportion of urban residents live in the informal settlements, covering just eight per cent of the municipal land area measuring $297km^2$. The municipal water supply is not only inadequate but has a small spatial coverage (40 per cent). The municipal water supply is estimated at $20.000m^3$ against a project demand of $50.000m^3$. The conventional sewerage system has a spatial coverage of about eight per cent, while the rest of the municipality is served mainly pit latrine. The above figures indicate that human settlements in Kisumu municipality are putting pressure not only on the existing infrastructure, but are a threat to groundwater quality. Inadequate infrastructure (water and sanitation) in most settlements indicates that wastes from settlements may find their way into the groundwater aquifers.

In a situation where water supply from conventional sources is far below demand, consumers are forced to look for alternative water sources including groundwater. It is unlikely to expect groundwater sources to be safe in a situation where pit latrines are the main means of human waste disposal. Given the small land

sizes in the urban areas it would not be uncommon to find pit latrines located in the proximity of shallow wells, thus heightening the risks of cross contamination. The predominant use of pit latrines poses a real threat to groundwater quality given that most parts of the Kisumu municipality are characterized by a high water table. In addition to that, the sewerage system often malfunctions because of breakdowns associated with poor operation and maintenance. Therefore, waste water emanating from sewerage systems is below acceptable standards. The poorly treated waste water from the sewerage system is a threat to environmental quality, including groundwater resources.
The conventional sewerage system covers about 10 per cent of Kisumu municipality. The rest of the municipality is served by either pit latrines or septic tanks. Unfortunately, the conventional sewerage system broke down over 10 years ago, resulting in not properly treated sewage. Discharge of untreated or improperly treated waste into the environment because of malfunctioning sewerage system poses serious pollution risks. In most of the low-lying areas, constituting about 50 per cent of the land area, pit latrine construction and management is complicated by the high water table (Mireri, et al, 2007).

Poor solid waste management is a threat to groundwater quality. Solid waste can be broadly classified as organic and inorganic. The main sources of solid wastes are households, commercial, industrial and agricultural activities. Although inorganic waste is more problematic to handle, organic waste is also a potential source of pollution. With good management structure, organic waste can easily be recycled for use but it is an important source of disease causing pathogens. Environmentally related diseases such as cholera, typhoid and hepatitis are easily spread through organic wastes. The Kisumu municipality has a weak solid waste management system. About 70 per cent of municipal waste is organic in nature, but only 30 per cent of it is collected. Therefore, most of the waste remains uncollected from various sources. Unfortunately, the municipality does not have a working waste disposal system. Wastes are haphazardly disposed off in different dumpsites some of which are illegal. Since there is no mechanism to either pretreat or sort wastes, hazardous wastes may find their way into the water cycle. During the rainy season, some of the poorly disposed of wastes are washed away by storm water into water bodies. Such waste percolates into the ground, leading to either contamination or pollution of groundwater.

Pollution analysis of irrigation water, yams and kales in two sampled farming areas in the Kisumu municipality indicates that they have concentrations of iron, lead, cadmium, copper and chromium. While the concentrations of pollutants are still within the permissible Kenyan national standards, some of them have exceeded WHO permissible limits. In addition, the farms are exposed to continued pollution by the municipal waste, suggesting that the pollution levels are likely to increase in future. The existence of traces of pollutants in both irrigation water and crops indicates that urban agriculture produce predisposes consumers to health risks (Mireri, et al, 2007). Since the pollutants exists in irrigation water and crops in the municipality, it is plausible to expect that such wastes can find their way into groundwater resources.

9.6 Conclusions and Recommendations

This paper has shown that human settlements are not only consumers of natural resources including water but are also important sources of pollution. Human settlements encompass shelters, infrastructure, services and the socio-economic activities. Poor infrastructure, characterized with inadequate sanitation and solid waste management, gives room to serious sources of contamination and pollution of both surface and groundwater sources. Slum/informal settlements as well as poorly managed agriculture, industries, commerce and other services are potential sources of groundwater pollution. The case of the Kisumu municipality (Kenya) shows that 60 per cent of the urban residents live in the informal settlements while at the same time some of them obtain domestic water supply from shallow wells, often located in the proximity of pit latrines indicating the risks of groundwater contamination. Also, inadequate and malfunctioning sewerage system and solid waste management system are clear pointers to groundwater quality problems. Groundwater contamination and pollution are closely related to waterborne diseases such as typhoid, cholera and dysentery.

Measures geared towards addressing groundwater quality problems must include effective settlements' planning, infrastructure development and management of wastes. At the same time, the strategic watersheds, as well as aquifers, must be protected from any form of settlements. Human settlements remain potential sources of groundwater pollution, partly because of weak local authorities' governance structures leading to ineffective enforcement of legal regulations. There is need to harness adequate resources to develop requisite infrastructure and supportive service to safeguard groundwater quality from human settlements-related contamination and pollution.

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10 Participatory Approach to Meet Water Demand and Supply - Andrew Jacob Ngereza

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10.1 Abstract

Water availability is linked to human welfare and health by means of affecting the nutrition status as well as the quantity of drinking water, especially with regard to the poor people. This has impacts on household labour because of the time and energy spent on obtaining water. Water scarcity is an important environmental constraint to development, leading to problems for the poor households and for the agricultural subsistence economy. The demand for water has been increasing due to rapid population growth, economic development and climatic change. As a result, social conflicts between various water users are raised. The latter comprise individuals, communities, industries, livestock, wildlife, agriculture etc. Local communities have evolved strategies for coping with water stress and drought, which include the use of various sources of water, inaction to strict by-laws regarding the use of water, crop diversification, wage labour, and possibly seasonal migration. These strategies vary from one area to another and some of these actions have measurable long-term demographic consequences, particularly if water stress is severe or repetitive. Although most governments and donor organisations often put much emphasis on the provision of water for drinking purposes, there is clear evidence that the supply of water for other uses has equal importance, especially among rural communities. The presence of other water uses necessitates the provision of multi-purpose water sources that can serve a number of contrasting functions. This demand-responsive approach can enable the local communities and the poor households to choose the type of services they require on the basis of perceived needs and their ability to manage the water scheme.

10.2 Introduction

Water supply is important for human, animal and plant life. The provision of water services is one of the most crucial prerequisites for improving the quality of people's lives, which is the long-term goal of almost all development policies and strategies in Tanzania. This argument suggests that *"water is life"*. Realising the importance of water, Tanzania adopted a 20-year programme in 1970 with the objective of supplying clean and safe water to every citizen within a walkable distance of 400 metres from their homes. Similarly, the National Water Policy had a long-term goal of ensuring access to safe water for all people and proper sanitary facilities for about 95% of the population by the year 2002 (URT, 1999). However, recent estimations by the Ministry of Water indicate that only 50% of the rural population and 69% of the urban population in Tanzania have had access to reliable water supply. Moreover, about 30% of the rural water schemes do not function properly, basically because little emphasis was placed on sustainability. A sharp decline in the proportion of households using piped water could be noted during the 1978/88 decade as compared to the 1967/78 period (Zaba and Kiwasila, 1995). However, there is evidence to suggest that the water supply services have been declining since 1978. The 1991 Water Policy indicated a clear departure from the era of free water launched in 1967 by introducing the principle of cost sharing in the Operation and Maintenance (O&M) of water schemes (URT, 1991). The revised Water Policy puts emphasis on a demand-responsive approach as well as on community participation in the management and maintenance of water schemes (URT, 1999). The policy re-emphasises the importance of the *3rd WaterNet/Warfsa Symposium 'Water Demand Management for Sustainable Development', Dar es Salaam, 30-31 October 2002 Poverty, Conflicts and Water Resource Use in Tanzania* with respect to community involvement in the planning and provision of water services to the population. It also opts for technologies that require low cost investments with the least operation and maintenance costs. Tanzania is characterised by natural water scarcity alongside a growing demand for water due to population growth. The ever-widening gap between supply and demand for water calls for the search for new water sources. In most rural communities, domestic water availability is determined by the communities' own efforts to invest in improving, maintaining and developing water sources and not just by its physical abundance (Drangert, 1993). In Tanzania, local communities are increasingly expected to contribute to the costs of improved water provision. There is need to identify various conflicts that emerge due to competing interests and demands from various water users. This will help in the planning of water source development, so that investment in rural water supply schemes can take account of the community needs and the likely impacts of population pressure on future water demands.

10.3 Water Demand and Supply

Access to clean water is an essential necessity for the well-being of all people. Water availability has been identified as an important environmental constraint on development and ultimately as a limiting factor for population growth and food production (World Bank, 1992). Falkenmark (1989) explained that the population experiences water stress if there is not enough locally available water for food production and basic hygiene. Water availability is closely linked to human welfare since it affects nutrition through food production and people's health through the quantity and quality of drinking water. Scarcity of water also affects household labour costs because of the time and energy spent on obtaining water. In Tanzania, despite significant investments in the provision of rural water since the 1970s, only about 50% of the rural population has access to reliable water supply. The main causes of this alarming decline have not yet been fully analysed. However, some of the causes of this decline undoubtedly consist in the drying out of sources, which is probably due to rapid deforestation and climatic change, and in maintenance failures of water provision schemes, especially those constructed in the past. Moreover, support in the water sector was provided in a fragmented fashion, and little emphasis was placed on sustainability. This understanding served as a basis for the 1991 National Water Policy (URT, 1991). Methods for providing water to the rural people in Tanzania have changed over the years and emphasis has been directed to more user-friendly demand-driven programmes, with emphasis on local community involvement, especially in the planning and management of improved water provision costs. On the one hand, the decline in the proportion of used piped water, for example, reflects the impact of rapid population growth on water supply. On the other hand, this decline can be considered a reflection of an absolute decline in the number of households using piped water. Varying socioeconomic developments, environmental and climatic conditions, and the non-availability of reliable water sources such as lakes, rivers and dams in particular locations causes regional and district variations with regard to water accessibility. Even at the village and household levels, the economic status of the individual household is a significant explanatory factor of water availability, quality and type of source used.

10.4 Water Sources

Different water sources are sometimes employed for different uses in different seasons. The most common uses, however, are drinking, cooking, washing, and crop cultivation. There are often major disparities as far as the number of water sources at the village, district and region levels is concerned. This situation can be mainly explained by researchers' neglect of the small ponds and dams that are used principally for washing or for water cattle. Various studies (e.g. White and Bradely, 1972) have shown that even when water is scarce or has to be carried from long distances, people use more water for washing (bodies, clothes, utensils etc.) than for direct consumption (drinking and cooking). Generally, water sources that are not fit for human consumption are overlooked when estimating the total number of available water resources because of the focus on the "drop to drink" at the expense of the "bucket to bathe". In many villages, about half of all traditional and improved water sources run dry for three or four months a year. Thus, many households cannot use their nearest source throughout the year. In other areas, a trip to and from a water source to fetch water or to send cattle to a watering point takes an entire day (Madulu et al., 1990). Another important and controversial use of village water resources lies in water for livestock. Ownership of livestock in many pastoral areas is an essential investment and a traditional wealth indicator (Malcolm, 1953). Problems of water especially for livestock are eminent in the pastoral areas and have often resulted in serious conflicts leading to seasonal or permanent migration. Such problems have to be faced by the Masai, the Sukuma, and the Barbaig, to mention only a few. It is hard to find a widely accepted "minimum water need" figure for livestock. A rough estimate of 30 litres per day per LU has been given for Mwanza region (Brokonsult, 1978). This figure exceeds the human per capita target for all domestic uses. Drangert (1993) gives current use rates between 15 and 20 litres for Mwanza region, though there have been efforts to improve or develop water sources under the self-help initiatives. Most cattle are watered at the specially constructed charco dams (bwawa) which account for 51% of the dry season use and 58% of the wet season use (Zaba and Madulu, 1996). Other sources of water for livestock include traditional wells, rivers and lakes. In many areas like the Usangu plains in the Mbeya region, serious conflicts that centre around water resources have emerged especially between local communities and the pastoralists.

10.5 Integrated Water Demand Management

The important aspect that needs to be considered in order to ensure that the poor are not marginalised consists in having proper water resource management plans. This is a management approach which aims at conserving water by controlling demand. It involves the application of selective incentives to promote an efficient and equitable use of water. Moreover, it considers the demand and usage of water. In order to ensure sustainability, there is need to emphasise "demand-driven" and "community participation" approaches. Experiences from the HESAWA project suggest that small-scale projects like improved wells are both cost-effective and easily managed by the villagers themselves through their own water committees (Zaba and Madulu, 1996). The focus here should be placed on village/user ownership and on strengthening women's participation in planning and decision-making. This approach aims at reaching the poor and making them responsible for searching solutions.

Another good example is the Uroki-Bomang'ombe Water Scheme (UBWS) in the Hai District, which serves eight villages, namely Roo, Uswaa, Maube, Shari, Kyeeri, Kware, Kwa Sadala and Boma Ng'ombe. The project goal is to provide clean and safe water to 90.000 people by the year 2010. The main lesson to learn from the UNWS is the willingness and importance of community involvement in solving water problems. In the UBWS, the local communities were involved in all stages from the project initiation through the planning process to the final implementation. During the project implementation, the villagers arranged self-help support in terms of labour for digging trenches, transporting materials and providing security. Efforts to ensure cost recovery have been taken into consideration in the project operation mechanisms. Water tariffs have been calculated to ensure full recovery of the Operation and Maintenance costs (O&M) and the replacement costs of major assets.

10.6 Water Use Conflicts

Observations from the Kilimanjaro and Arusha areas indicate that the rural populations are generally aware of the changes in the water levels in rivers and other sources, especially for irrigation purposes. However, noticeable differences exist in the perception of the main causes of the decline in water levels (Mwamfupe, 1999). The causes vary from increase in demand and uses of water; to the greediness of upstream users who deny water to people in the lower slopes; to prolonged drought, poor maintenance of furrows and insufficient design of furrows. According to Mujwahuzi (1999), water use conflicts in the Pangani Basin exist because different people have different goals and interests while using the same water source. The existence of competitions as well as changes in the use of a resource may trigger conflicts between various source users. Mujwahuzi (1999) lists a number of factors that trigger conflicts in the Pangani Basin.
These factors include:

- the competition for a scarce resource,
- differences in organisational status and influence,
- unmet expectations,
- unequal power or authority,
- incompatible objectives and/or methods,
- jurisdictional ambiguities,
- communication distortions,
- misperceptions.

HESAWA refers to the *Health through Sanitation and Water programme* which propagates the principle of people's participation in planning and implementation of the village projects. *(3rd WaterNet/Warfsa Symposium 'Water Demand Management for Sustainable Development', Dar es Salaam, 30-31 October 2002 Poverty, Conflicts and Water Resource Use in Tanzania)*. The interdependence of people, tasks and conflicts exists between small-scale and large-scale irrigators;

between upstream and downstream riparian irrigators; and between domestic water use and other uses (agriculture, livestock, industry, municipality etc). Other conflict areas include industrial and environmental uses (pollution, environmental protection, ecosystem management etc) as well as agricultural and industrial uses (power generation, consumption versus non consumption).

10.7 Conclusion and Recommendations

There are notable variations in terms of water availability, access and use between individuals and communities, which show significant variation in water access and uses according to levels of wealth and economic status. In most cases, the poor users suffer much or are denied the right to access water. Hence, they are forced by circumstances to use water sources that are not safe for human consumption. It was also noted that though much emphasis is put on improving water sources for drinking/domestic water uses, evidence seems to suggest that much more water is used for other uses (bathing, laundry, livestock and cleaning) than for drinking and cooking alone. In fact, rural communities often do not abandon their traditional sources even after having improved water sources. The health benefits of water used for these other uses are just as important as any different uses. It has also been observed that local people are sometimes compelled to go far outside the village to access water, especially for livestock and other uses. There is need to redirect resources and investment in rural water supply towards multiple-use sources like dams and boreholes rather than just putting emphasis on drinking water. However, local communities should be given the choice to select the type of water source they can manage to maintain. This omission influences the development of water use conflicts because other interests are underestimated. Generally, there is need to adopt demand-driven approaches in the provision of water services, particularly to the poor rural communities.

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11 Methodologies for Solving Environmental Conflicts between the Poor Community and the Water Supply Company: A Case Study of Vietnam - Nguyen Trung Dung, Nguyen Tuan Anh

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11.1 Abstract

In Vietnam, a number of cases related to environmental issues cannot be brought to the court of justice and solved by the latter. In the article *"Why the people avoid doing legal proceedings to environmental cases"* (TNVN) two main reasons for this problem are listed: the high fees/charges of the court and the small chance for the poor communities to win in the court of justice. Therefore, the idea of the Coase Theorem with regard to the negotiation between two parties (polluter and poor community) without the legal (state) intervention can be applied in such cases.

This paper reports the environmental issues caused by the groundwater exploitation on the part of the "Bac Ninh Water Supply and Sewage Company" (operation of ten deep drill wells, each with a capacity of $70 - 100m^3/h$, along the bank of the Cau River). Some significant negative externalities such as the drying problem of shallow wells for households, the reduction of paddy yields, additional irrigation costs (more time for irrigation and energy used for pumping) occur to the poor farmers of the villages Huu Chat, Viem Xa and Dau Han (Hoa Long commune, Yen Phong district, Bac Ninh province). However, the households of Huu Chat village are provided with clean water. Nevertheless, the water price is the same as the one applied in Bac Ninh Town. The study hypothesis is to find out whether the compensation is high enough or the Bac Ninh Water Supply and Sewage Company needs to provide more support. The statistical cost and benefit analysis is applied and the results can be used for the negotiation process.

Keywords: *Environmental conflicts, water supply, statistical cost and benefit*

11.2 Introduction

In order to supply clean water to Bac Ninh Town, the "Bac Ninh Water Supply and Drainage Company" (henceforth called "water company") constructed - since 1997 with the financial aid of the Australian government (AUSAID) - a river bank infiltration system with deep drill wells along the bank of the Cau River[3]. These wells are for the most part located in Huu Chat village, a few of

[3] The water quality of the Cau River degraded during the last ten years.

them also in the villages Viem Xa and Dau Han (Hoa Long commune, Yen Phong district, Bac Ninh province (Figure 11.1)). The Hoa Long commune is located about 4 km from Bac Ninh Town.
The water is exploited and then transferred by a pumping station to Bac Ninh Town for treatment and delivery. The drill well system comprises ten wells, eight of them constructed in 1997 with a pumping capacity of $70-80m^3/h$ per well, and two additional wells built in 2005, each with a capacity of $90-100m^3/h$. Up to now, the whole system has never fully operated (mostly 60-70%). The annual amount of clean water produced by the water company is listed in figure 11.1. After some years in operation, the wells number 1 and 3 have a water level problem. Especially during the dry season the water level is always in the warning area.

Year	2002	2003	2004	2005	2006
Clean water produced (in 10^6 m^3)	2.80	3.15	3.48	3.74	3.98

Source: Bac Ninh Water Supply and Sewage Company

Figure 11.1: Clean water volume produced by the water company

After the construction and operation of 10 wells, some *significant negative externalities* occur to approximately 800 households in the affected area of the villages Huu Chat, Viem Xa and Dau Han:

- Before 1997-1998, the shallow wells and drill household wells were about 20m deep and there was no problem with water. But during the operation of 8-10 wells by the water company the household wells got dry and dryer. In order to get water, some villagers tried to dig their well for additional 5-10 metres; the costs amounted to about 1 million VND. But the drying problem of the wells could not be solved.

- Because of the relatively high water loss as far as the paddy fields are concerned, the costs for agricultural production are significantly rising: (i) additional irrigation costs (volumetric frequency) and (ii) use of more fertilisers.

- The paddy yield is decreasing in comparison to the other villages with the same conditions (seed, soil, etc.).

However, as a compensation for the villagers in the affected area, the water company constructed a 800-900m concrete road with a width of 8-10m through Huu Chat village. Moreover, all households of Huu Chat village were connected to the piped water system of Bac Ninh Town. The clean water price amounts to $2.500 VND/m^3$, the same price as the one paid by the inhabitants of Bac Ninh Town whose income per capita is higher.[4]
It is notable that three villages located in the affected area belong to the poor communities. Figure 11.2 shows the crucial figures for these villages. As per the latest poverty line[5] of the MOLISA (Ministry of Labor, Invalids and Social Affairs of Vietnam) the Huu Chat village has the highest poverty rate in the Hoa Long commune because in-farm production is the only household income source.

Village	Households	Inhabitants	Poverty rate (%)
Huu Chat	387	~ 1300	24.5
Viem Xa	724	~ 3200	10.4
Dau Han	315	~ 1700	13.2

Source: Hoa Long commune

Figure 11.2: Crucial figures for three villages of the Hoa Long commune

Furthermore, there is a *negative externality from agricultural production for the water company*[6]. Farmers still consider nitrogen fertilisers as “cheap insurance”

[4] The clean water price is based on the Circular 104/2004/TTLT-BTC-BXD (08.01.2004) of the Financial Ministry and the Ministry of Construction as well as on the Decision 38/2005/QD-BTC (30.06.2005) of the Financial Ministry

[5] According to the new poverty line, an urban resident who earns VND 230.000 or less a month and a rural resident who earns VND 200.000 (US$ 12.7) or less will be considered poor. The current poverty line for the 2001-2005 period has three levels, and an urban resident is considered poor if he earns VND 150.000 a month. For people in rural areas the sum amounts to VND 100.000/month and for those residing in mountainous regions and islands to VND 80.000/month. The exchange rate in January 2008 accounts for 1 Euro = 23.500 VND.

[6] The number of poor households in Vietnam will increase from currently 8.3% to 26.7% if the Prime Minister approves of a plan of the Ministry of Labour, Invalids and Social Affairs (MoLISA) to introduce a new poverty line for the 2006-2010 period. Source: http://vietnamnews.vnanet.vn/showarticle.php?num=08SOC210305

Figure 11.3: Location of Huu Chat village

against crop failure. Obviously, the more nitrogen fertilisers the farmers use, the higher will be the probability of nitrate pollution of the groundwater. The overuse of fertilisers on the fields of Huu Chat village can be considered a risk for nitrification in the groundwater bodies and a danger for human health. The current nitrite and nitrate value are still under 10 mg/l, also under the safe level. Concerning groundwater protection against nitrification in the future, the water company needs to (i) set up strategies for the protection of groundwater bodies and step by step negotiate with the farmers of Huu Chat in the form of "buying the right to fertilisers" and compensate the yield reduction; or (ii) install nitrate removal technologies. However, these are very costly.

It is evident that the villagers of Huu Chap have got better traffic conditions and health benefits by using the clean water. However, the external costs caused by the construction and operation of the drill wells are relatively high and permanent.

Thus, the study hypothesis is to find out whether the compensation is high enough or the water company needs to provide more support. The statistical cost and benefit analysis is applied and the results are used in the negotiation process.

11.3 Methodologies and Results

Environmental Conflicts in Vietnam - Rarely Solved by the Court of Justice

Industrial zones (IZs) in Vietnam have greatly grown in both quantity and quality. Beside a number of social and economic benefits from the operation of IZs, there have been several problems related to environment, which include the treatment of water pollution and effluent; the treatment of emissions and air pollution; the treatment of solid and hazardous waste; the depletion of natural resources as well as the degradation of the environment. Environment management within an IZ does not meet the requirements. A number of communities suffer from the environmental impacts and the pollution of IZs, among them the cancer village of Thach Son[7] (Lam Thao district, Phu Tho province) and Minh Duc village (Thuy Nguyen district, Hai Phong).
It is well known that in Vietnam a number of cases related to environmental issues cannot be brought to the court of justice and solved by the latter. According to the article *"Why the people avoid doing legal proceedings to environmental cases"* (TNVN) the fees and charges of the court are a relevant issue to bring the case to the court of justice. For example, for the environmental damage of 1 billion VND, the people who bring the case to the court have to pay 14 million VND as a court fee/charge. This amount can be paid back if they win. But, in the bad case (and unfortunately in most cases) they lose the money because the industries in the developing countries always hold the take-win position. This amount is relatively high for the poor farmers in Vietnam.

Thus, from 2001 up to now, the Vietnamese court of justice had to judge 262 criminal and tort cases related to environmental issues, among them 170 cases related to forest deterioration, 76 cases in connection with the violation of regulations for the protection of wild animals, 3 cases in connection with spreading

[7] Article "Environmental cleanup key to health in cancer village" Source: http://vietnamnews.vnagency.com.vn/showarticle.php?num=01HEA250106

hazardous epidemic diseases for human life, and 10 cases with regard to the deterioration of aquacultural sources[8]. Furthermore, most of the cases were related to the destruction of natural resources and rarely to the pollution caused by industries.

Solving environmental conflicts - looking for a simple way in many cases
There is a large number of literatures about the *external effect* or *externality* . In economics, such an effect is said to exist if an economic agent's decisions impact on another agent's well-being or production possibilities and the former does not (properly) take these effects into account in his economic behaviour. The classic example of an external effect is that of an upstream factory polluting a river, which has a negative impact on catches in a downstream fishery. When deciding upon how it will produce and consequently upon how many pollutants it will emit into the river, the upstream factory will not take this effect into account. This is an example of a firm-firm externality where one firm's economic actions affect another firm's production. Externalities can be both negative and positive. The "internalisation" of negative externalities can be solved by using the Pigouvian taxation or the Coasian bargaining. In practice, obstacles to bargaining or poorly defined property rights can prevent Coasian bargaining. The other point of criticism often targeting at the Coase theorem is to say that transaction costs are almost always too high for the appearance of efficient bargaining. However, the basic idea of the Coase theorem is valid and can be used in solving the conflict between the poor community and the water supply company.

The "efficient" level of exploited water is defined as that level at which marginal damages are equal to marginal abatement costs (see Figure 11.4, areas a and b under the marginal curves MAC and MD). In this case, the marginal damages for the villagers caused by water exploitation are presented above (costs for agricultural production, low paddy yield etc.) and the marginal abatement costs are those costs paid by the water company. These include for example the costs for the construction of infrastructural measures such as roads and irrigation canals. In order to meet the demand, the water company cannot reduce the water amount exploited from Q' to Q. Therefore, the remaining damage (RD) for the villagers is the difference between the total damage (TD) and the costs given by the water

[8] Source: People's Supreme Court of Vietnam

company to the villages (C), that is to say RD = TD - C. Thus, the identification and quantification of the external costs and benefits caused by constructing and operating drill wells in the villages Huu Chat, Viem Xa and Dau Han are the main subjects of the study.
It can be said that this research study has practical, scientific and policy relevance so that the study results will contribute to the solution of the identified problems.

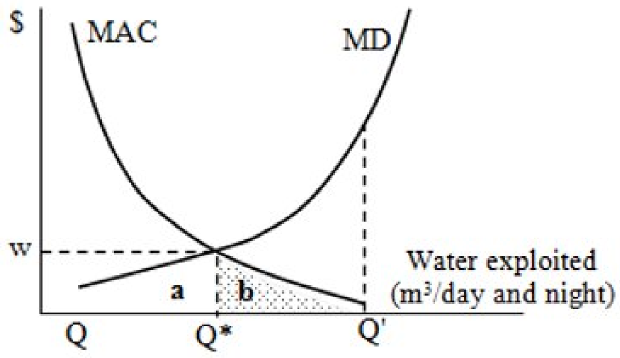

Figure 11.4: Efficient level of waterexploited in Huu Chat village (Field, B.C. & Field, M.K., p. 10)

The following main methodological approaches were used:

- the statistical cost and benefit analysis by using the survey study; and
- the Contingent valuation (CV) method for valuating the piped water.

a) Statistical cost and benefit analysis by using the survey study

Firstly, the *area affected by the drill well system* is determined by different integrated methods: (i) statistical analysis of the daily data series of the water level of the drill wells and mapping of the affected area; and (ii) determining the area by interrogating village and commune leaders as well as households about their experiences.
In this survey study, *the comparison between two groups* (a treatment group and

a control group) as well as the "with/without" and "before/after" principles are used. The treatment group is a group of households in the affected area of three villages. The control group consists of a comparison group of households not located in the affected area. But the control group has characteristics similar to those of the treatment group. The control group consists either of the other villages of the Hoa Long commune or of other villages of communes nearby. There are two ways to set up the control group: the experimental design (randomisation design) and quasi-experimental design as well as the randomisation design were applied.

A total number of about 800 households are located in the affected area and it is impossible and not necessary to conduct such a big survey. Thus, determining the *sample size* is of importance. The simplest form of probability sampling is simple random sampling (SRS)[9] . With this method, every possible sample of equal size - as well as each individual element in the population - has the same non-zero probability of being selected: the *Epsom* (equal probability of selection) design. The sample size in SRS depends on three factors: (i) the population size, (ii) the variability of the parameter one wishes to estimate and (iii) the desired level of precision and confidence.

Identifying and quantifying the external costs. In the affected areas (Huu Chat village, a part of Viem Xa and Dau Han village) the external costs should be identified by using the survey methodology. Generally, there are the following main losses/costs (hereafter *L*):

L_1: Loss of asset (asset which cannot be used because of the operation of ten drill wells of the water company: drill or shallow well, water tank, etc. of villagers) (VND/household)

L_2: Initial costs for piped connection of household (costs for installing water pipe, metre, tap, etc.) (VND/household)

L_3: Additional costs for agricultural production (fertilisers, irrigation, etc.) (VND/ha year)

L_4: Yield reduction due to high water loss (paddy, vegetables, potatoes, etc.)

[9]Iarossi, G., p. 112-116

(VND/ha year)

L_5: Other costs (VND)

$C = H(L_1 + L_2) + F.n(L_3 + L_4) + L_5$

where
C indicates the total external cost.
H the total estimated number of households in the affected area
F the agricultural area affected by drill wells
L_i the external costs/losses i briefly described above
n the life period of drill wells of the water company

The variables *L1, L2, L3* and *L4* are estimated by using single and double differences between the treatment and control group. However, the yield reduction *L4* will be estimated for the common seed and under the average conditions.

Identifying and quantifying the benefits from supplying piped water. In the affected areas (Huu Chat village, a part of Viem Xa and Dau Han village) the external costs should be identified by using the survey methodology. Generally, there are the following main benefits (here after *B*):

B1: Benefit from better infrastructure (roads, irrigation canals, etc.) (VND/household)
B2: Benefit from reduction of medicine, medical treatment, etc. (VND/household)
B3: Benefit from reduction of drainage costs (pumping costs) (VND/ha year)
B4: Other benefits (VND)

$B = H(B_1 + B_2) + F.N.B_3 + B_4$

where
B indicates the total benefit
H the total estimated number of households in the affected area
F the agricultural area affected by drill wells
B_i the benefit i briefly described above
n the life period of drill wells of the water company.

The variables *B1, B2* and *B3* are estimated by using single and double differences between the treatment and control group.

b) Contingent valuation (CV) method for valuating the piped water

The contingent valuation method is a survey technique that has been used to elicit people's preferences by asking them directly to report their willingness-to-pay (WTP) to obtain a specified good or service, or their willingness-to-accept (WTA) to give up a good or service, rather than inferring these values from observed behaviours in regular market places. This method is called a "contingent" valuation because it uses information about how people state how they would behave given certain hypothetical situations.

The CV method has been widely applied to valuing public goods and environmental resources where markets for such goods or services do not exist or their transactions are not easily observable. Although the CV method has its basis in economic theory (Cameron & Carson, 1989) , its use is subject to some controversy. Critics of the CV allege that the quality of stated preference data is inferior to that obtained by observing revealed preferences, since people are asked to evaluate goods and services they have never purchased or never thought of with regard to purchasing.
The value of public services can be estimated on the basis of the sampling provided by valid responsive answers. The average WTP is calculated. Depending on the question, of course, the amounts that the respondents are willing to pay on a per-household basis will be asked in many cases, the number of households. Naturally, the questionnaire uses the expression. Despite these points of criticism, CV has gained institutional acceptance and has formed the basis for policy-making in the United States and more recently in Europe.

In this study, the respondents in both groups resemble each other highly as far as gender, age and education are concerned. They are mostly farmers and have the same income structure and level. Therefore, the WTP has a low standard deviation. However, the WTP of the control group is higher and reflects the real situation in the water supply of the commune. The water quality of the Cau River and of shallow household wells is getting worse from year to year because the paper production village, located about 7 km upstream, releases every day approximately $4.000 - 5.000m^3$ of wastewater without any treatment into the Cau River. In comparison, the WTP of the treatment group is lower because the farm-

ers always want to pay less than $2.500 VND/m^3$. Therefore the WTP of treatment group can not be considered in the further study.
The results of the statistical cost-benefit analysis and of valuing the benefits of the piped water supply in the Hoa Long commune are shown in figure 11.5. The difference between benefits and external costs of one household amounts to approximately 260.103 VND/hh year. Thus, it is evident that the water company has to support the farmers in the affected area.

Item	Unit	Treatment group	Control group
Households interviewed (error 5%)	hh	266	254
Gender/age of interviewees			
Male (age)	%	37.4 (43.3)	52.9 (44.3)
Female (age)	%	51.8 (43.5)	47.1 (47.8)
Education of interviewees			
Primary school	%	20.6	25.0
Secondary school	%	67.9	64.7
High school	%	6.1	10.3
College, university studies and higher	%	0.8	0.0
Average piped water consumption per capita per month	m^3/capita month	1.43	-
Water costs per capita per month			
Average	VND/capita month	3.98	-
Max	VND/capita month	10.7	-
Min	VND/capita month	0.9	-
Percentage of water costs in household income	%/month	3.81	-
Additional irrigation (estimated)	Times/season	7	0
Paddy yield	tons/ha year	14.3	15.5
Willingness to pay for piped water			
Max	VND/m^3	2500.0	3000.0
Min	VND/m^3	500.0	1000.0
Average	VND/m^3	1603.8	2382.4
Median	VND/m^3	1500.0	2500.0
Standard deviation	-	578.7	458.1
External costs	10^3 VND/hh year	346.6	-
Benefits	10^3 VND/hh year	87.7	-
Difference between benefits and external costs	**10^3 VND/hh year**	**258.9**	-

Figure 11.5: Characteristics of the survey study and some results

11.4 Conclusion

The construction of a drill well system by the water company causes a number of damages, but also brings benefits of clean water supply to the poor villagers of the Hoa Long commune. The external costs and benefits are estimated by using the survey methodology as well as a statistical cost and benefit analysis. The valuation of the piped water supply was implemented by estimating the WTP in the treatment and control group. It is interesting to see that the WTP of the control group is in some cases higher than the current water price. This means that the WTP reflects the real situation of existing environmental issues and of the degradation of the water quality (surface- and groundwater used for household purposes). The difference between benefits and external cost of one household is approximately $260.10^3 VND/hh$ year, and shows that the financial support from the water company is unbiased.

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12 Socially Acceptable Distribution of Water for Poverty Alleviation in Rural Areas of Zambia - DCW Nkhuwa (PhD)

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12.1 Abstract

Despite the country's significant investments in Rural Water Supply and Sanitation (RWSS) since the early 1970s, the actual number of poor Zambian people that are effectively provided with safe drinking water and adequate sanitation has remained very low. Both the *Living Conditions Monitoring Survey of 2002/2003* and the CSO Census of 2000 estimated access to safe water supply in rural areas of at only 37% of the Zambian population, while access to sanitation amounted to only 13%. This severe deprivation of basic human needs, including *food, safe drinking water, sanitation facilities, health, shelter, education and information* has entrenched and characterised rural poverty.

Therefore, to tackle poverty directly, there will be need for policy formulation that shifts emphasis from providing rural populations with just *water from safe supplies* for household needs to *productive water*, which must enable families to increase their income generation. Such income benefits may result from gains in productivity and a reduction in the costs of health treatment resulting from a decline in water- and sanitation-related illnesses. If the provision of safe water also takes into consideration quantity, quality and distance, productivity gains are likely to stem from time saved from collecting water. By including the provision of *productive water* to rural communities, households and communities with increasing incomes would be better placed to take care of their safe water and sanitation needs, thereby taking care of sustainability issues of past rural water supply and sanitation programmes. Only then will an environment be created, in which rural communities are able to enjoy a life of quality and dignity.

12.2 Introduction

Although Zambia has made significant investments in the rural water supply sector since the early 1970s, the actual number of people that are effectively provided with safe drinking water and adequate sanitation still remains very low. Both the CSO Census of 2000 and the *Living Conditions Monitoring Survey of 2002/2003* estimated access to safe water supply in rural areas at only 37% of the population, while access to sanitation was only 13%.

The major problems of water supply in rural Zambia include (i) walking long daily distances of about 2 to 3 kilometres to public water points, (ii) carrying heavy containers of 20 to 25 litres per trip on one's head (Figure 12.1), (iii) long queues at water points, and (iv) if there was contamination at this common point, the whole village would usually be at risk. This scenario is exacerbated by the fact that Zambia has not yet developed the required capacity and clear management arrangements to provide better access to water supply and sanitation (WSS) services in the near future, when the competition for available water resources in the country is likely to increase against the backdrop of a heightened economic development.

12.3 Coverage Levels for Water in Rural Zambia

This paper discusses what water distribution systems would be considered socially acceptable to alleviate poverty in rural areas of Zambia.

Figure 12.1: (a) Walking distance to a water point, (b) Zambian woman carrying a heavy water container

12.4 Definition of Safe Water

An appropriate definition of safe water ought to include consideration of:

- *Quantity*, expressing the average volume of water used by consumers for domestic purposes, and expressed in litres per capita per day.
- *Quality*, which indicates the safety of water for drinking purposes.
- *Distance*, a major factor in determining the amount of time spent on collecting water.

There are appallingly low levels of access to water for Zambia's rural population. Available coverage figures mask wide temporal and spatial variations in access across the country due to the fact that many water points (about 30-40%) recorded as part of these figures are either dysfunctional or function intermittently on a daily or seasonal basis. Real coverage figures may therefore be significantly lower than the 37% mentioned before.

Improved access to water supply services to poor households would to a large extent contribute to promoting dignity, equity, compassion and solidarity, thereby playing an important role in reducing the burden of poverty among the poor Zambian population. In addition to improvements in people's health and well-being, increased access to water supply services would also lead to a reduction in expenditures on medical services, to an enhancement of their capacity to work and the provision of opportunities to develop productive and sustainable livelihoods. Thus,

- households with improved services would be found to suffer less morbidity and mortality from water-related diseases;
- better services resulting from the relocation of a well or a borehole to a site closer to user communities, the installation of piped water supply in houses, and latrines closer to home yield significant time savings;
- girls, children (Figure 12.2) and women have better educational and productive chances when they have water facilities nearby, because they can save time when fetching water;

- the availability of water may also be used to start or expand small enterprises and thus increase disposable household incomes.

Figure 12.2: Children carrying water buckets - their major pre-occupation in rural areas.

However, the strategies that have been pursued by the country's Poverty Reduction Strategy Paper (PRSP) [2]in the recent past have placed emphasis on building a standard physical infrastructure *(boreholes for rural water supply, dams and*

[2]The Poverty Reduction Strategy Paper (PRSP) was a national document that analysed causes of poverty in the country and set out a strategy to overcome these. As a national process, it was steered by the government and involved domestic stakeholders as well as external development partners. It also became the basis for the multi- and bilateral donors' aid allocation, which was seen as a means of improving the effectiveness and efficiency of development assistance.

weirs for irrigation purposes). The landmark indicator of the PRSP period has thus been the number of physical water points constructed, which has not been complemented by similar attention to create social organisations - such as user groups - in order to help ensure sustainable operation and management of the built facilities.

Regrettably, Robinson (2003) notes that current national and international trends do not appear to earmark budgetary allocations for the maintenance of the rural water infrastructure. The rationale behind these cuts has been to assign maintenance activities to the community, a measure that sadly comes at a time when the communities' resources are more stretched than ever before to support such activities. Consequently, rural water and sanitation programmes, which are intended to eradicate rural poverty, are themselves threatened by possibly worsening poverty.
Therefore, to tackle poverty directly, there will be need for policy formulation to shift emphasis from just *rural water from safe supplies* for household needs to *productive water*, which must enable families to increase their income generation. For instance, a community with a protected well (Figure 12.3, route 1) is able to be provided with safe drinking water with some assured level of sustainability arising from a sense of community ownership, from proximity to the homesteads and commitment to the technology, thereby ensuring high usage of water for both domestic uses and gardening in order to produce some fruits and vegetables for home consumption.

Such income benefits may result from gains in productivity and a reduction in the costs of health treatment. The gains in productivity are likely to accrue from time saved from collecting water, from the availability of water as an input to the productive sector, and from a decline in water-related illnesses.

However, by putting *productive water* first (Figure 12.3, route 2), the community would be enabled to produce high-value crops for export and to increase its incomes. Consequently, the community would be better empowered to take care of its safe water needs, thereby taking care of sustainability issues of past rural water supply programmes.

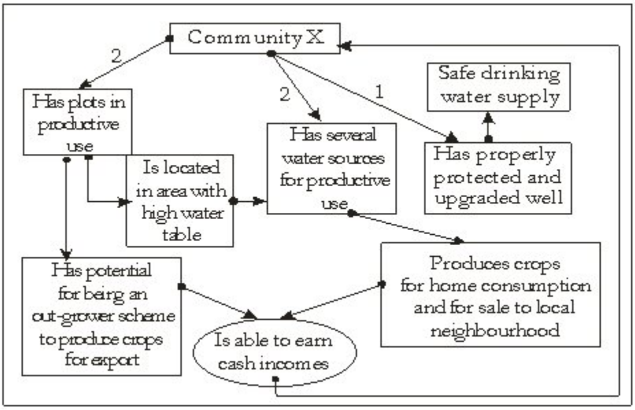

Figure 12.3: Possible community benefits from provision of both safe drinking water (route 1) and productive water (route 2).

Recent studies in rural communities of Zambia have indicated that the economic impacts of improved water are often more significant to communities than the mere health improvements that sector programmes often focus on. Through such arrangements, the sector is able to contribute directly to poverty alleviation efforts within the country along with all the health benefits, thereby creating environments in which all members of the society are able to enjoy a life of quality and dignity.

12.5 Challenges of the Perception of Water as an Economic Good

Increased access to water as well as hygiene promotion create improvements in people's health, but they also have an indirect positive effect on educational opportunities, gender equality, and the empowerment of women and children. Studies in Zambia have demonstrated that school enrolment of girls has increased with easy access to safe water sources as this has freed them from spending many hours every day on drawing and carrying water home.

However, the adoption of the concept of water as an economic good may be an approach that is purely economic, which would create the risk that the poorest and most vulnerable members of the society may be denied access to a critical basic social service. At the same time, taking an entirely *demand responsive* approach to service provision within the sector would raise significant barriers to the extension of these services to poor communities as it would entail cost recovery, capital cost sharing and placement of the management responsibility for operation and maintenance (O&M) on the community.

12.6 Financing of the Rural Water Supply for Poverty Alleviation

The distribution of expenditure by source of funds shows that donors account for a substantial part of funds spent in the water supply sector (GRZ, 2004). Exacerbated by fragmentation in channelling resources in the sector, rural communities have usually ended up receiving too many water points, while other communities are neglected. Furthermore, the lack of clarity on the kind and amount of investment required to raise the coverage to acceptable levels has been difficult in so far as these levels have not been adequately defined. This has been further affected by the lack of clear information on what facilities are available as well as on their state of operation.

More importantly, domestic investment into the water supply sector currently accounts for about 2-3% of the national budget. Even the funding for the Fifth National Development Plan (FNDP) is largely dependent on external funding agencies. For Zambia to effectively tackle rural poverty, it is imperative that the government commits enough internal resources to its budgetary allocations towards the implementation of rural water supply.

Whilst it is appreciated that the FNDP is intended to be a broad frame document and an outline of specific sector activities, it does not offer an in-depth analysis of water issues such as linkages between *inadequate participation by consumers in the design and implementation of water supply programmes and the poor infrastructure in the sector*. The use of inappropriate technologies (usually selected by implementers and not by users) and the provision of inadequate operation and maintenance skills training for communities contribute significantly to the short lifespan of many installed water points in rural areas.

12.7 Possible Strategies for the Development of the Water Supply Sector

The National Water Policy, the Water Supply and Sanitation Act, and the Water, Sanitation and Health Education (WASHE) Concept are currently the cornerstones of the water and sanitation sector activities in Zambia. Additionally, there are three national sector strategies - *the Community Water Supply and Sanitation Strategy, the Environmental Sanitation Strategy, and the Peri-Urban Water Supply and Sanitation* - each of which is a product of admirably consultative processes. The implementation of elements of these strategies may be a good starting point in tackling rural poverty.
Some of the strategy elements include

1. the consideration to provide water for productive uses and development of low cost, affordable and acceptable projects with sustainable technologies, which respond to community needs, software and hardware for adaptive uses;

2. placing communities at the forefront of their own water development activities and enhancing their capacities to contribute effectively to project planning, design, implementation, management, operation maintenance and monitoring in their respective operational areas;

3. focussing on capacity building within the sector rather than on infrastructure construction. This capacity must be within the government, the private sector, Non-Governmental Organisations (NGOs), Community-Based Organisations (CBOs) and communities to plan, design, implement, monitor, operate, maintain and evaluate sustainable water supply projects;

4. considering, promoting and protecting the interests of women and children in project design and implementation.

12.8 Concluding Remarks

In order to be socially acceptable and to facilitate the alleviation of poverty, the plan of distributing water in rural areas must

- shift emphasis from just rural water from sustainable supplies for household needs to productive water. In this way, families will be enabled to increase the generation of incomes, which would in turn provide resources for operation and maintenance (O&M) with regard to water sources. This would allay concerns of the sustainability of most rural water programmes;
- receive enough support from the government through the commitment of internal resources in its budgetary allocations to implement rural water supply programmes;
- get communities to be at the forefront of their own water development activities, to be able to select appropriate technologies and to be provided with adequate operation and maintenance skills training in order to significantly contribute to a long lifespan of installed water points;
- ensure secure water supplies across seasons and between wet and dry years.

Unless the government, the non-governmental and private sectors develop the skills and capacities to effectively facilitate and respond to community-led water development initiatives, any interventions in the sector will continue to exert less than their full potential impacts on poverty.

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13 Shallow Wells: A Sustainable and Inexpensive Alternative to the Drilling of Boreholes in Semi-Arid Kenya - Chris A. Shisanya

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13.1 Abstract

Water resources in the semi-arid areas of Kenya are under increasing pressure as service is extended to rural populations and land use shifts to more intensive production of crops and livestock. As millions are invested in water systems to meet these demands and competition among users grows, information about groundwater resources is increasingly important. Reducing drilling costs in sub-Saharan Africa must be of high priority of the region's governments, if the Millennium Development Goals (MDGs) or national water supply targets are to be met. Worldwide, the drawing of water is rising faster than the growth in the world's population. Between 1900 and 1990 the world's population increased from 1.7 billion to 5.5 billion, while the total consumption of water in that time went up by a factor of 10, from 500 to 5.000km^3. This explosive rise is not just due to higher human consumption of water but is also the result of an increased supply. Another factor is the expansion of existing economic activities and the introduction of new projects. By describing the water situation in the semi-arid Kajiado District in southern Kenya, this paper highlights the way specific interactions between political and economic process have contributed to an upsurge in the pressure on natural water sources and available groundwater reserves. A comparison is made between the efforts proposed and implemented to solve the numerous problems in water provision in the area, focusing in particular on two types of water facilities - boreholes and shallow wells.

Keywords: Borehole; Drilling; Kajiado District; Semi-arid; Well

13.2 Introduction

Throughout the world, regions having sustainable groundwater balance are shrinking by the day (Shah et al., 2000). Three problems dominate groundwater use: Depletion due to overdraft; water logging and salinisation mostly as a result of inadequate drainage and insufficient conjunctive use; and pollution owing to industrial and other human activities (UNESCO-WWAP, 2003). Water use can be divided into three major categories: agriculture, industry, and domestic. Domestic use includes drinking water, private homes, commercial establishments, public services, and municipal supplies. Agriculture is by far the biggest water user, accounting for over 85 percent of the withdrawals in Africa (figure 13.1).

Region	Withdrawals by sector					
	Agriculture	Municipal	Industries	Total	As % of total	As % of internal resources
			($x10^6 m^3/yr$)		*(percent)*	
Northern	65,000 (85%)	5,500 (7%)	5,800 (8%)	76,300 (100%)	50.9	152.6
Sudano-Sahelian	22,600 (94%)	1,200 (5%)	300 (1%)	24,100 (100%)	16.1	14.2
Western	3,800 (62%)	1,600 (26%)	700 (12%)	6,100 (100%)	4.1	0.6
Central	600 (43%)	600 (43%)	200 (14%)	1,400 (100%)	0.9	0.1
Eastern	5,400 (83%)	900 (14%)	200 (3%)	6,500 (100%)	4.3	2.5
Islands (I.O.)	16,400 (99%)	200 (1%)	20 (-)	16,620 (100%)	11.1	4.9
Southern	14,100 (75%)	3,000 (16%)	1,800 (9%)	18,900 (100%)	12.6	6.9
Total	127,900 (85%)	13,000 (9%)	9,020 (6%)	149,920 (100%)	100.0	3.8

Figure 13.1: Regional Distribution of water withdrawals in Africa (Source: FAO, 1995)

The number of people without adequate access to safe drinking water in sub-Saharan Africa (SSA) is 287 million, despite a small increase in water coverage over the last ten years (WHO/UNICEF, 2005). This is still a challenge in achieving the Millennium Development Goals (MDGs) for the African continent. Since the year 1993, the bilateral aid to the water and sanitation sector has been decreasing and the water and sanitation sector is featuring the lowest aid in the strategies for the poverty reduction in most African countries (Benn, 2003). RWSN (2005) reports that the progress to meet the MDGs and the World Summit on Sustainable Development (WSSD) targets for the provision of water supply and sanitation is slow in SSA and points out that "although considerable additional resources are required in order to meet the targets, more effective use of existing resources can make significant contribution".

Water resources in the semi-arid areas of southern and eastern Africa are under increasing pressure as service is extended to rural populations and land use shifts to more intensive production of crops and livestock (*http://www.iaea.org*).

Groundwater sources with hand-pumps have increasingly become the viable option of the provision of safe drinking water due to its relative purity and the almost ubiquitous nature of groundwater (Arlosoroff et al., 1987). Multilateral and bilateral donors have extended considerable funding to developing countries through Official Development Assistance (ODA) for provision of safe drinking water using groundwater sources for the community (RWSN, 2005). Africa has benefited from such assistance used for drilling programmes "implemented by National and Local Governments, as well as NGOs" (RWSN, 2005). By describing the water situation in the semi-arid Kajiado District in southern Kenya (Figure 13.2), the objective of this paper is twofold: (a) to explain the factors contributing to the high cost of borehole drilling in sub-Saharan Africa and (b) to highlight the way specific interaction between political and economic process has contributed to an upsurge in the pressure on natural water sources and available groundwater reserves. In addition, a comparison is made of the efforts proposed and implemented to solve the numerous problems in water provision in the area, focusing in particular on two types of water facilities - boreholes and shallow wells.

13.3 Factors Affecting Drilling Costs in Sub-Saharan Africa

There are several factors affecting the variation of drilling costs in the sub-Saharan Africa. RWSN (2005) points out that, in order to achieve significant reduction in borehole construction cost and for the purposes of comparisons of the water drilling costs, it is imperative to identify and evaluate the key factors influencing borehole construction cost. RWSN (2005) clearly illustrates this as shown in figure 13.3. This forms the basis for division of mobilisation and demobilisation, drilling, casing, completion and development and test pumping into depreciation, transport, consumables and manpower. Carter et al. (2006) have elaborated on how to reduce drilling costs in Africa. Wurzel (2001) points out that the cost of water well drilling in Africa is very expensive compared to the cost of hand-pumps used for the abstraction of water. Based on the experiences in rural Africa and India, Wurzel (2001) argues that drilling costs in Africa could be reduced significantly by drilling appropriate depths and diameters for the hand-pumps using appropriate construction methods (hand-dug, hand-drilled or machine drilled) coupled with the citing techniques, and very short periods of test pumping.

Consequently, a number of African countries (Sudan, Ethiopia, Zambia and Nigeria) have achieved a considerable reduction of the water well drilling costs. Wurzel (2001) adds that achieving cost saving also requires "a proper management to en-

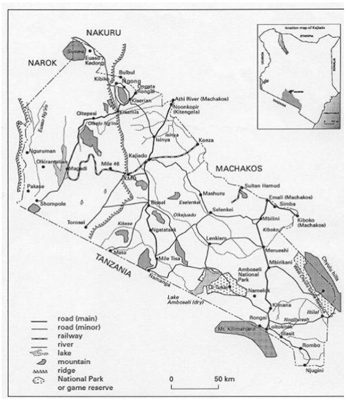

Figure 13.2: Location of Kajiado district in southern Kenya

sure maximum utilization, with technically competent and experienced crews and good logistics". Ball (2001) supports Wurzel (2001) in advocating for the shallow depth, small diameter and use of lightweight drilling equipment which has low capital value and low depreciation cost.

13.4 Shallow Wells in Kajiado District, Kenya

The development of boreholes in this district is primarily the business of donors, the government and churches. In addition to that, wealthy individuals have been drilling their own boreholes and others have organized themselves in groups. The costs involved in the drilling and equipping of a borehole (100m deep) are high and worked out (in the early 1990s) at some Ksh 2 million (ca. USD 40.000). Figure 13.5 provides a detailed overview of borehole construction based on the Ministry of Water Development's borehole register. Unfortunately the borehole register does not give information about the operational condition of the boreholes.

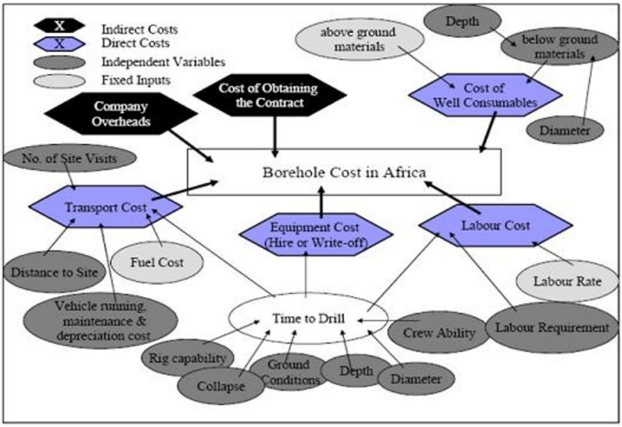

Figure 13.3: Factors which affect the costs of borehole construction (drilling and pump) in sub-Saharan Africa (Source: RWSN, 2005)

13.5 Technology and mMnagement of Boreholes in Kajiado District

An important aspect of boreholes is the way water is pumped. There are five possibilities: electric pumps, diesel pumps, solar panels, wind turbines, or manpower. In the past this choice was primarily limited to manpower (for shallow boreholes) or the diesel pump. In some cases a combination (e.g. solar panels and diesel pumps) is possible. The final decision is usually influenced by financial as well as technical factors, such as the depth of the borehole and the amount of water to be raised to the surface. Pumps operating on solar energy have been available since the mid 1970s. These systems are becoming cheaper but, because of the devaluation of most developing countries' currencies, they are benefiting less from the savings than the industrialized part of the world. The many hours of sunshine throughout the year make solar power, in principal, a very attractive source of energy. In Kajiado district, a number of boreholes have been equipped with solar panels due to the assistance of foreign donors. They mainly embrace the sustainable character of solar energy. Finally, a few boreholes in Kajiado

Cost component	Possible areas of saving	Comments
Mobilisation	▪ Packaging (letting contracts of multiple wells in similar geology to one contractor) and clustering (close proximity of wells in package). ▪ Use of lightweight equipment needing fewer support vehicles.	Since nothing can be done to reduce distances involved, the only strategies can be to aim for economy of scale, or use smaller, lighter equipment.
Drilling	▪ Use of lightweight equipment where possible (with lower depreciation costs). ▪ Adoption of well designs involving shallower depths and smaller diameters (so reducing energy costs and costs of drill fluids). ▪ Enhanced efficiency of "conventional" drilling operations.	The first two (which are inter-linked) are only possible where groundwater occurs at shallow depths, and where low well discharges are acceptable, enabling the use of small diameter pumps. Improved drilling speeds and efficiency of use of equipment are possible through best management practices, including incentives for drill crew.
Casing	▪ Use of plastic (rather than steel) casing and screen, where possible. ▪ Adoption of well designs involving shallower depths and smaller diameters (so reducing length and diameter of casings and screens, and smaller annular volumes for gravel packs). ▪ Enhanced efficiency of installation.	Not possible in situations where high yields are needed, or groundwater is deep. uPVC casings are not generally used in wells deeper than about 100m. Efficiency savings reduce installation times.
Development & Test Pumping	• Shorter test pumping periods for low-yielding wells.	Short-cuts should not be taken with development, since these would adversely affect long-term performance. There is an argument for carrying out less demanding yield/drawdown tests for hand-pump wells, but these should not be omitted altogether.

Figure 13.4: Approaches to cost savings in water well drilling (Source: Carter et al., 2006)

Period	Ngong Division	Magadi Division	Mashuru Division	Central Division	Loitokitok Division	Total
1927-30	11	-	2	-	1	14
1931-40	-	-	1	-	-	1
1941-50	7	2	8	19	3	42
1951-60	15	-	1	13	6	35
1961-70	2	-	7	18	6	33
1971-80	19	3	10	46	12	90
1981-90	96	1	3	74	26	200
1991-93	30	-	20	3	-	53
Per year	2,7	0,1	0,8	2,6	0,8	7,0
Total	180	6	52	173	54	468
%	39%	1%	11%	37%	12%	100%

Figure 13.5: Year of construction of boreholes, 1927-1993, per division in Kajiado District (Source: Mwangi, 1993)

pump water using wind energy. In contrast to solar energy where multinational companies are primarily involved, it is local industries and NGOs that are promoting the use and the improvement of this source of energy for collecting water. A major limitation is the below-average wind speed during the month when water is in the highest demand. The ideal wind speed should be above 2.5 metres per second and preferably it needs an average speed of 5-6 meters per second. An advantage of the windmill technique is that maintenance is limited, its lifespan is long and the chance of the mills being stolen is very small. A problem, however, is that information about wind speeds in Kajiado for different locations and seasons is not readily available.

13.5.1 Why Boreholes Fail in Kajiado District

The construction and maintenance of boreholes have at times encountered tremendous technical, physical as well as socio-economic problems. Diesel pumps have to be supplied with diesel and oil daily, oil and air filters need to be replaced after every 250 hours of operation and diesel filters only last about 1.000 hours. Due to the fine dust clouds, pumping houses need to be kept as clean as possible. All of this calls for a well-operated logistical set-up that allows for timely availability of new materials and funds to purchase and transport them. The latter is not easy considering the isolated areas the boreholes are located at. Sometimes, cheap (contaminated) diesel is bought which ruins the engines. Most of the solar-driven boreholes are no longer in operation. Sun panels are popular with thieves and therefore need to be monitored during the day and night. This is also necessary to avoid the damage of the panels; youngsters throwing stones are a constant problem. The fact that there are in principal no running costs makes it hard to convince users to set aside money to cater for regular maintenance and repairs. These have to be conducted by experts, who are often not available at short notice. As a result, repairs are time consuming. Moreover, it has become clear that enormous demands for water for animals cannot be delivered by solar-powered pumps in sufficient quantities and within a limited time period. This technical limitation increases the waiting time at the borehole in such a way that insufficient time is left to graze herds in faraway locations. Maasai pastoralists are therefore not keen to pay for the renewal or repair of lost or damaged solar panels.

13.5.2 Searching for Alternatives

During a borehole survey in Kajiado district by the present author, attention was paid to alternative water facilities. The pan, and particularly the shallow well, turned out to be of major importance for the rural population. These two facilities are among the most-used water sources. However, shallow wells are not included in the Kenya government's official water statistics. The boreholes are only able to provide two percent of the total local demand for water (Mwangi, 1993). Some of the problems identified during the field interviews affecting shallow wells in Kajiado district include: silting during the rainy season, potential collapse of the sand walls and water contamination from chemicals, animal urine and faeces during the rainy season. The local people also wash themselves and their clothes near the wells.

13.5.3 Shallow Wells: The Maasai's Answer to Water Problems in Kajiado District

The information in Box 1 below clearly illustrates how the Maasai communities of Kajiado district share the scarce water resource from shallow wells.

13.6 Use and Maintenance of Wells

Due to the seasonality and the irregularity of rainfall, livestock keepers use a traditional system for the management of their crucial natural resources: water and grass. Access to land and water is handled at the level of the so-called *olosho* (section). Maasai belonging to other sections are obliged to ask official permission before entering the territory of another section. Also at neighbourhood level families work together, for example, by closing certain pastures in the wet season to save them during times of drought. The selective use of water is also part of the management of the natural resources available. Unfortunately, this collaborative sharing of responsibilities and tasks is beginning to fall apart due to new land-tenure arrangements, the immigration of no-Maasai and the arrival of new activities that do not embrace traditional ways of livestock keeping.
Men and women have their own specific sets of tasks when getting water from shallow wells. The women collect water for domestic use and help the men by

Early in the morning, a number of Maasai herders meet with their herds near a well. The water is raised in buckets using the so-called human ladder. This could mean up to 6 or 7 people standing above each other in manufactured inroads in the wall of the shallow well. This way, the Maasai are able to bring huge amounts of water to the surface in a very short time. The buckets are emptied into a nearby trough where the thirsty animals are waiting eagerly. In small groups, the animals are led to the trough to drink. The herders ensure that each animal drinks enough water. After all the animals have had their turn, the herd is on the move to look for grass and graze and the next Maasai family will bring their animals down the well. The number of families using a single well depends on the season and its capacity, but numbers vary from 2 to 20. The Maasai, like most nomadic pastoralists, make use of dry river-bed during the dry season by scooping sand in search of water. In the past, water was lifted from these temporary wells making use of animal skins. The huge disadvantage of this type of well (*o-sinyai*) is that after the rainy season starts the sand will cover the well again, or at worst, make its future use impossible due to strong currents. In addition to the *o-sinyai* type, there are also wells dug in the river-bank either in sand or in stone. An important aspect is locating the right spot at which to dig a well and for this, expert knowledge is required. The presence of certain species of trees – *Oltepesi* (*Acacia Seyal*) and *Olerai* (*Acacia Tortilis*) – is a sign that water may well be found. An entrance route is then constructed to where a washing place is set up where the local women will wash their families' clothes. From this point, the herders will be able to go down with their animals to the trough and well to drink.

Figure 13.6: Sharing water resource from a shallow well by the Maasai communities

allowing livestock to descend towards the well in small groups. This guarantees that all the animals will drink and no accidents or damage will occur. The men are responsible for drawing the water, washing the animals and making them drink, de-silting of the well, controlling the surrounding pollution levels and repairing the well and the trough. This is an on-going process. Each user has to keep the well and its surroundings in good condition during and after the watering of the animals. In theory, only the more crucial maintenance tasks are left to the owner, but others will often assist as a sign of gratitude for being able to use the well. Sometimes a person is hired to guard the well and undertake these tasks.

13.7 Conclusion

This paper has stressed the importance of water for the Maasai economy, which explains the willingness of the Maasai now and in the past to develop sustainable water resources. These sources and the required equipment have over the years become less easy to obtain. This has been mainly due to an enormous growth in the demand for water by reason of the rising population and larger cattle herds, but even more so because of a greater interference of political and judicial processes, in the past as well as now. Attempts by colonial and post-colonial authorities and donors to solve the region's water problems were mainly found in the drilling of boreholes.

Technical, financial and organizational problems linked to boreholes have little contributed to a solution for the growing water problems in Kajiado district, especially in those regions where another option is available. This alternative - digging shallow wells in or next to dry river-beds - is partly to be found in the traditional Maasai strategy of gaining access to sufficient amounts of water both for humans and animals alike. Down to a certain depth, these water sources are a non-expensive and sustainable substitute for boreholes. Research has shown that this local method of water collection has always played a significant role in the management of natural resources by the Maasai, but that top-down implementation of modern technology both by the government and foreign donors has meant that planners have ignored it until recently. The donor community for a long time only valued modern, large scale and expensive techniques, considering local small-scale and cheap alternatives as inferior and less reliable. Finally, long-standing experience and interest from Kenyan water specialists and funds provided by a Dutch donor have raised the knowledge in donor and academic circles about shallow wells. Moreover, due to a parallel change in land rights in the Maasai area of Kajiado district - i.e. the sub-division of group ranches into individual plots - the construction of shallow wells has risen exponentially. Even more important is the fact that this growing interest happened at the same time as a serious alternative to boreholes emerged in certain areas, i.e. the linking of modern techniques, knowledge and problems. This has resulted in a merging of modern and traditional knowledge. This modern knowledge thus comes both from Western-trained technicians as well as from non-Maasai immigrants. The traditional knowledge likewise is a mixture of the wisdom of Maasai and Mbulu water specialist. Like the Maasai saying *Metolu lung' elukunya engeno*, - one single head does not have all the wisdom, more heads are better. This collaboration has resulted in an improved well that it is now very sustainable from a financial, technical as well as a management point of view. The passive adoption of Western techniques has stopped and has been replaced by one that builds upon the resources, means and ideas of the local people. From a role of supplying and donating resources, the donor has moved to a position of translator and facilitator. If the outside threats on the quantity and quality of water sources in Kajiado district are kept to a minimum, this cooperation will certainly last.

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14 Technologies of Water Storage in the Northeast of Brazil - Dr. José Wilmar Da Silveira Neto, Benjamin Eichert

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14.1 Abstract

The objective of the work is to present different methods of water storage in regions that are highly stressed by a high annual variation in precipitation. Such regions, as the semiarid northeast of Brazil, put a lot of efforts into the development of different methods. These methods regard the improvement of water availability for the people using it for agriculture as well as for domestic purposes. In contrast to the mega-projects on which the government mainly focuses, this paper tries to look at smaller-sized methods based on the family up to the community level. From the very beginning, these methods are related to a sustainable development of the region, focusing on economical and ecological aspects, as well as their possible realisation under given social circumstances.

14.2 Introduction

The collection of rainwater for the supply of humans and animals, as well as for agricultural use, is not a new idea and has been amply disseminated in the northeast of Brazil, principally by the initiative of Caritas Brazil and non-governmental organizations. Nevertheless, it is being largely ignored by Brazilian public planners and private initiative, since it is not considered attractive to the water supply mega-projects. This work aims at presenting some of the storage technologies most popularly used in the northeast of Brazil. These may contribute to the raising of income for family ranch-agriculture units of the semiarid area and for the diminishing of the prolonged dry seasons for the most vulnerable classes of the population. That is to say, these are technologies which contribute to the improvement of survival conditions for the population of the semiarid environment, and which are also appropriate to other regions of the globe which have the same conditions of hydro resource scarcity.

14.3 Methodology

The methodology used in this work is founded on a bibliographic survey of the principal technologies of hydro resources infrastructure disseminated in the northeast region of Brazil by the government and by non-governmental organizations. Furthermore, technologies that still exist by having been passed down from generation to generation through existing tradition and culture are approached. The methodology analyses the technologies which present themselves as viable for the present and promising for the future.

14.4 The General Climatic Characteristics of the Northeast of Brazil

- About 75% of the area lies in a semiarid climate.
- There are periodic droughts tidally connected to the El-Niño phenomena.
- Besides the natural conditions, the access to water had been used as a source of power for great land owners over the last centuries, through refusing the free access to water and concentrating the privilege of deep wells on the great land owners.
- In contradiction to what is commonly known about the northeast, there is some precipitation even in the dry season. This can be seen in the following table:

Area	mean annual precipitation (mm)	(%) earth surface
Arid	up to 250	25
Semiarid	250-500	30
Less humid	500-1000	20
Humid	1000 – 1500	11
Humid	1500 – 2000	9
Very humid	1500 – 2000	5

Figure 14.1: Northeast of Brazil: climatic classification and amount of precipitation. Source: Silva (1985)

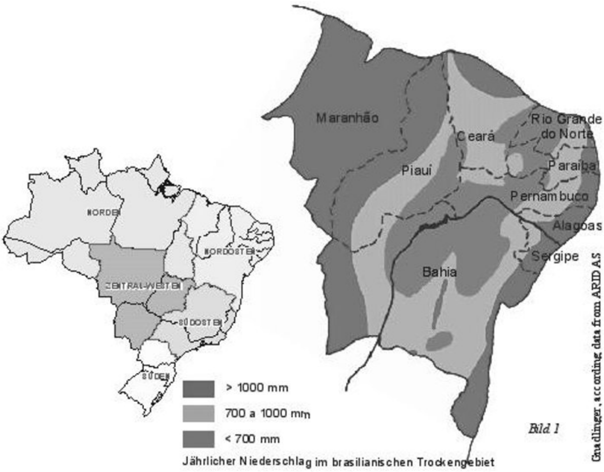

Figure 14.2: Annual precipitation in northeast region of Brazil

14.4.1 Aridas

- In 1972, a research of the drought polygon ("Polígono das Secas"), with an area of about 937.000km^2, was made by Rebouças and Marinho. Within this research a maximum precipitation of 700$Mrd.m^3$ was measured.

- About 91.8% (642.5$Mrd.m^3$) is lost due to evapotranspiration.

- Another 8% (56$Mrd.m^3$) is the annual average volume being stored in the area of research. The rest, with about 0.2% (1.5$Mrd.m^3$), flows to subsurface springs.

- During the time of research, about 35% (20$Mrd.m^3$) of the annual average volume of 56$Mrd.m^3$ had been flowing through rivers into the sea, but this amount did not distribute in a constant way. Only 275 of the existing dams included more than 55% of the volume.

14.5 Cisterns in Rural Areas

These water cisterns are tanks designed to collect rainfall from house roofs through a series of gutters channelling the water from the roof into the cistern. They have storage capacities of 10, 15, 16 or $20m^3$ litres - enough to supply a family with its drinking and cooking water for at least eight months of the dry season.
Until now, these are the various cistern types used to resolve the potable water problem in rural areas in northeast Brazil. The concrete plate cistern, made of cement plates (50 cm wide, 60 cm long and 3 cm thick), 14-gauge binding wire and being plastered on the in and outside, has been the most constructed cistern. As the adherence between the concrete plates sometimes is insufficient, tensions can cause cracks through which the water can leak.
For this reason, the wire mesh concrete cistern (using a cast during the first construction phase) will probably be the most used and appropriate type for cistern construction in this region in the future. This type of cistern hardly leaks and if so, it can be easily fixed. It is also useful for small and big cistern building programs.
The cisterns are built by the members of the community themselves who are being trained and given access to the materials they need. They enable people to remain on their land even during the worst months of the drought.

14.5.1 Water Demand

Listed in the following table you can see that, with a daily consumption of about 7 litres, 9 persons can be supplied with water out of a cistern with 15.000 litres.

14.5.2 Some Rules Regarding the Use of Water Taken from Cisterns

- The cisterns need to avoid exposure to light so as to prevent the development of water-living organisms such as algae.

- At least once a year, the rest of the water needs to be removed and the cisterns cleaned. After cleaning it has to be disinfected with a chlorine dilution.

	with assumed 14 liters/day			with assumed 7 liters/day		
ber of per	per month	in 6 months	in 8 months	per month	in 6 months	in 8 months
1	420	2520	3360	210	1260	1680
2	840	5040	6720	420	2520	3360
3	1260	7560	10080	630	3780	5040
4	1680	10080	13440	840	5040	6720
5	2100	12600	16800	1050	6300	8400
6	2520	15120	20160	1260	7560	10080
7	2940	17640	23520	1470	8820	11760
8	3360	20160	26880	1680	10080	13440
9	3780	22680	30240	1890	11340	15120
10	4200	25200	33600	2100	12600	16800

Figure 14.3: Water consumption of a household in litre

- The bucket used for delivering water out of the cisterns must not be used for other purposes and must not get in contact with the ground.
- Before consuming it is recommended to add a disinfectant, such as sodium bicarbonate, to the water.
- A filter system for the whole amount of water would need a high filter speed to use all the rainwater accumulating during a shower. Of course, high amounts of water and filter systems are a contradiction in itself. It would be easier to install a simple grit filter system under the top of the cistern that removes all the coarse-particle pollutants and lets even high amounts of water flow through quite fast. Often, however, the emerging costs are the limiting factor.
- Furthermore, it is not enough if the whole amount of water is filtered before being stored in the cistern. The danger of contamination has to be averted in the following eight months of the dry season, as well.

14.6 Storage Dams

These are the principal works carried out by the Brazilian Federal Government for living with the drought seasons. They may be defined as artificial reservoirs being capable of retaining the surplus of water produced by hydrographic river basins in the wet months and making them available in the dry months. The impact of these works was of such importance to the society that it came to be a part of the integral culture of living with the seasons of drought.

Figure 14.4: Storage Dam Marco Zero, Source: Araújo (2006)

For the solution of the problem of pollution and hydro-sedimentation, Araújo (2006) mentions the disciplined use of the earth in the dam's uprights and the construction of sedimentation dams. Those have the function of retaining the sediments and pollutants, thereby creating fertile sediments vital for agriculture and contributing to the ecological equilibrium. Together with the dams, the maintenance of native plants on the banks of the rivers and dams is suggested. These have roots that would help filtering the pollutants and sediments, thus contributing to the water quality in the rivers and dams. The installation of dams for water storage is possible, but often results in major water quality problems, mainly due to eutrophication and salinisation.

14.7 Life Saving Barriers

The so called “life-saving / supplemental irrigation impoundments” collect rainwater runoff from a big natural ground catchment area. Downstream from the impoundment, inhabitants plant annual crops like beans, corn or sorghum. If there is a drought spill during the rainy season, people can water the fields with water from the impoundment with the help of gravitation. If they do not need the water, they can then plant in the dry season again and use the water for irrigation of a second crop.

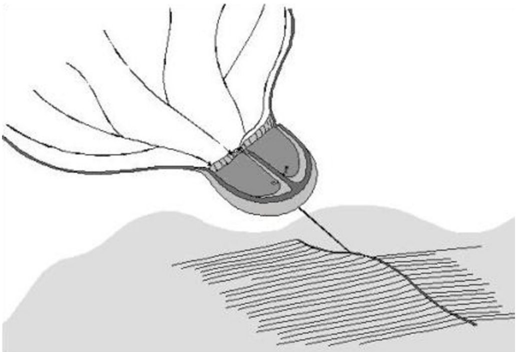

Figure 14.5: Supplemental irrigation impoundment (Porto, 1989)

14.8 Barrier Ditches

The barrier ditch developed out of a simple idea that seeks to maximize the conservation of water with the greatest depth and the minimum of superficial water reservoir. Firstly, the most appropriate area should be chosen - that is crystalline underground. Following this, the ditch is dug consisting essentially of two or more wells formed like rectangles, separated by dividing walls made of the same earth. The length of the barrier ditch varies between 4 and 5 metres, the width should be 3 metres, and the depth greater than 4 metres. These dimensions are

Figure 14.6: Supplemental irrigation impoundment (Porto, 1989)

fundamental for the reduction of water loss due to evaporation, which is accentuated by the heat and hot winds. The divided basins permit an alternate retention of the water, contributing to the diminution of evaporation. This is due to continual heating of the water close to the surface. The ditch may have a catchment area for harvesting the rain and needs to be enclosed to avoid animal access.

14.9 Sub-Surface Impoundments

Sub-surface impoundments or dams store surface rainwater runoff for a later usage: the barriers are dug below the ground surface in shallow soil towards the impervious crystalline subsoil. Then earth or rock filled dams are built with a PVC sheet on the upstream face, thereby avoiding seepage. On the watered upstream soil it is possible to plant crops or fruit trees. In addition to that, there is almost always an underground cistern to use the water for humans, animals or irrigation. Still in the first months of the dry season, it is possible to plant for a second time, and even in the driest years these impoundments always carry water.

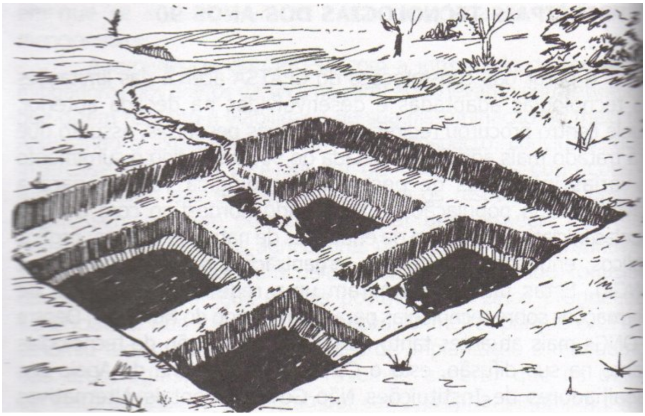

Figure 14.7: Barrier Ditch. Source: Duarte (2002)

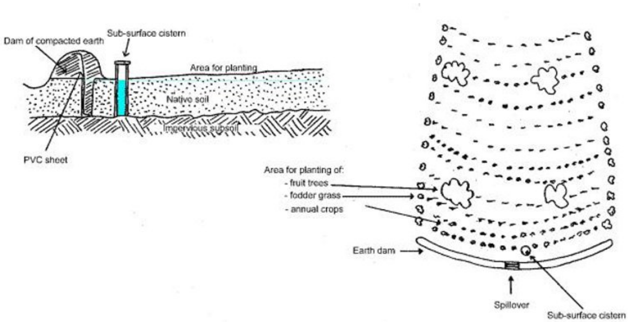

Figure 14.8:

14.10 In-situ Harvesting of Rainwater

In arid and semiarid regions, where precipitation is low or infrequent during the dry season, it is necessary to store the maximum amount of rainwater during the wet season for the usage at a later time, especially for agricultural and domestic water supply. One of the methods frequently used in rainwater harvesting is the storage of rainwater *in-situ*. Topographically low areas are ideal sites for in situ harvesting of rainfall. This technique has been used in the arid and semiarid regions of Brazil's northeast, primarily for irrigation purposes.

The *in-situ* technology consists of the creation of storage availabilities in areas where the water is going to be utilized. Topographic depressions represent ideal collection and storage areas. The *Guimarães Duque* method was developed in Brazil during the 1950s, and uses furrows and raised planting beds. On those, cross cuts to retain water are made using a reversible disk plough with at least three disks. The furrows are usually placed at the edge of the cultivation zone.

This technology increases the water supply for irrigation purposes in arid and semiarid regions. It promotes improved management practices in the cultivation of corn, cotton, sorghum, and many other crops. Furthermore, it provides additional water supply for livestock watering and domestic consumption. The *In-situ*technology is applicable to low topographic areas in arid or semiarid climates, requires minimal additional labour and offers flexibility of implementation. The furrows can be constructed before or after planting. Rainwater harvesting allows better utilization of rainwater for irrigation purposes, particularly in the case of inclined raised beds, and it is compatible with the best agricultural management practices, including crop rotation. It provides additional flexibility in soil utilization. Permeable *in-situ* rainwater harvesting areas can be used as a means of artificially recharging groundwater aquifers

Yet, In-situ rainwater harvesting has the following disadvantages: It cannot be implemented in areas where the slope of the land is greater than 5%. Also, it is difficult to implement in rocky soils and areas that are covered with stones and/or trees need to be cleared before implementation. It requires impermeable soils and low topographic relief in order to be effective and the effectiveness of the storage area can be limited by evaporation that tends to occur between rains. Moreover, the additional costs incurred in implementing this technology could be a factor for some farmers.

Figure 14.9: In-situ harvesting of rainwater Guimarães Duque

14.11 Irrigation Using Clay Pots

The irrigation method using clay pots consists of the application of either isolated pots or of pots being connected via pipes. The installation and acquaintance, as well as the maintenance of the system can be done by the farmer's family, but is only recommended for small areas up to 1 ha, since the non-enamelled clay pots do not irrigate homogeneously. This application is rather recommended for domestic vegetable gardens (10 to 20 units) and furthermore for the planting of fruit gardens within rural communities.

(L) The main line of water supply consists of two pots connected by pipes made of polyethylene. The pipes are connected with the supply reservoir (B), being attached to a sand filter (A). The pots of the mainline consist of a float system (P) to maintain the water level. (L1) represents the line of pots for the secondary water supply. This line is interconnected with L, the main line of water supply. (P) and (P1) are the clay pots with a capacity of 10 up to 12 litres.

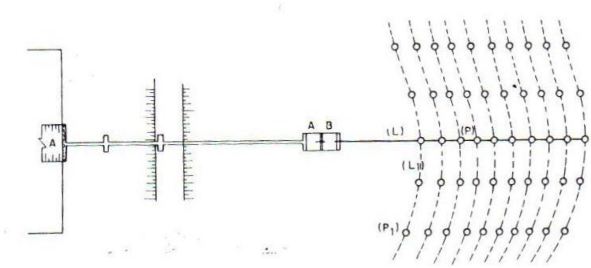

Figure 14.10: Drawing of the connected clay pots. Source: Silva (1982).

14.12 Irrigation Using Porous Capsules

The irrigation method using porous capsules is an improvement of the previous method that made use of clay pots. Although it demands more technological skills, the advantages are unchallengeable. The drain, for example, is constant and on a higher level. The porous capsule that is equipped with two connected beaks has a volume of 700ml, a mechanical resistibility of about $5kg/cm^2$ and a porosity of 21%. These attributes enable a guaranteed production on a high level.

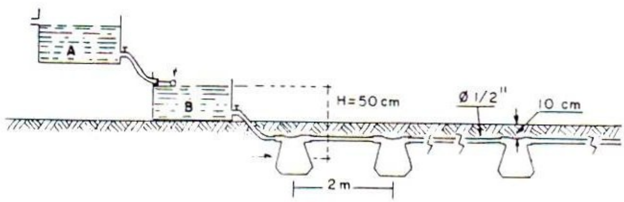

Figure 14.11: Construction of irrigation using porous capsules. Source: Silva (1981).

(A) The sand filter. (B) The reservoir supplying the system. It consists of a pot, which can be a homemade clay pot, with a storage capacity of 10-12l and a buoy marking the level between the reservoir's water surface and the height of

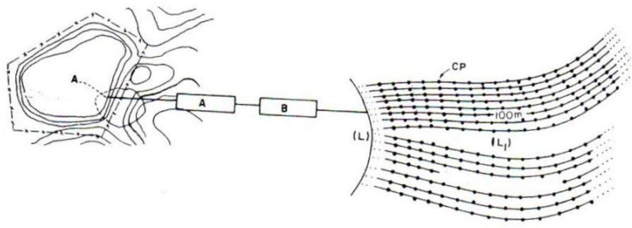

Figure 14.12: Construction of irrigation using porous capsules. Source: Silva (1981). 2

the porous capsules. (L) The main line of supply consisting of a pipeline made of polyethylene (1" diameter) that connects the porous capsules with the supply reservoir. (L1) The line of capsules consisting of a row of connected capsules either being installed in a high line or with small oscillations.
Characterisation: The irrigation method using clay pots and porous capsules has the general advantages of allowing that the raw material can be taken from the region and that the technologies are on a very low level. Therefore, these methods are accepted by small and medium farmers as they also only need a very small amount of water (less than 4-5% of the need of irrigation methods using sprinkling).

14.13 Successive Barriers

In order to save fertile soils from being eroded, stonewalls can be used. Characteristic for this method is that the agricultural fields are being surrounded by stonewalls and the gullies, which were formed by surface discharge, are filled. Moreover, this action involves small farmers collecting stones and constructing stonewalls. Thus, the loss of soil could be reduced, more water could be infiltrated and a fertile layer of sediment may develop throughout the years.

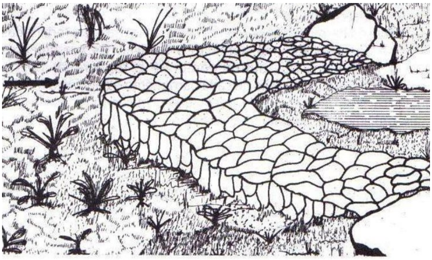

Figure 14.13: Construction of successive barriers Source: Paraiba (1994)

Figure 14.14: Construction of successive barriers Source: Paraiba (1994)

Successive barriers present themselves as being effective if the conditions of the hydrographic micro-basins are favourable as to the degree of inclination of the surface, the degree of inclination of the water course and of the area of the terraces formed by the barriers. The economic result of the crops cultivated on the terraces depends as much on the type of agriculture as on the area of the terraces. Other advantages, such as the reduction of erosion and saltiness, will have greater or lesser effect, depending on the other conditions already mentioned.

14.14 An Overview of the Presented Technologies

Description	**Water resources**	**Application**
drinking water for family	Cisterns	drinking water for cooking and washing
community water for washing, bathing and for animals	rain storage reservoirs, small dams, clay pots surrounding porous capsules, barrier ditches	bathing, washing, supply of animals and vegetable gardens
centralised between the villages	deep wells, channels, deep and wide dams	emergency water for drought years
water for agriculture	*In-situ* rain water harvesting, subsurface dams, successive barriers, rain storage reservoirs, Life saving Barriers	Infiltration, locally and temporally focused surplus irrigation

Figure 14.15: An overview of the technologies presented

14.15 Conclusion

The effective management of water resources demands an approach linking social and economic development with the protection of natural ecosystems. The technologies that were presented in this paper are adequate to such an approach but can only develop a sustainable character based on a participatory approach involving users, planners, and policy makers at all levels.
“Integrated water resources management is based on the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good.”(The World Bank, 1993).

14.16 References

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