Safe drinking water for Ta'izz, Yemen

IMPROVING INCORPORATION OF MICROBIOLOGICAL WATER QUALITY IN URBAN DRINKING WATER SUPPLY

Msc. thesis Civil Engineering & Management

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EXECUTIVE SUMMARY

The current goal of Vitens-Evides International (VEI) is to improve drinking water situations locally: "better drinking water for more people". This goal is achieved by establishing projects that aim for improvement of the business operation of local water supply companies. These projects aim at sustainable improvement of availability and quality of drinking water. The currently applied strategy of improving business operation of the local water company takes many years to become effective on the household level. Until then, aging of water between the point of supply from the piped network or private supplier and consumption is considerable. Contaminating hazards outside the piped supply network receive great opportunities to become effective and impose a great risk on the safety of drinking water. For this reason it is difficult to solve drinking water quality problems during the first years of a project. The currently applied project duration is mostly restricted to periods of 3 to 5 years. The relatively long period of the current strategy to become effective however requires longer project duration. To address this problem this thesis suggests VEI to embrace the long time period that is required for the current strategy to become effective. Consequently, the following two recommendations are made:

1. *Increase project duration to a strategic period of 5 – 10 years*

2. *Apply an additional strategy next to the current strategy that enables to address quality problems on the short term*

Increasing project duration improves effectiveness of the current strategy. Sustainable interventions are allowed sufficient time to become effective. To make VEI's presence effective also on the short term, a parallel track is recommended to be added to currently applied strategy. The possibility to implement interventions outside the business operation of the local company allows interventions that can solve problems with microbiological water quality in the short term until the more sustainable strategy pays of. This track necessitates embracing the local private and informal water supply sector. It increases VEI's influence on water quality at the point of consumption throughout the entire sector and increases the impact of its presence in a local sector. Largest potential for short-term benefits are found in the increase of the level of hygiene behaviour. The additional strategy track provides VEI with the opportunity to increase public health immediately at the start of a project, while in the mean time efforts can be made to secure sustainably safe water quality throughout the local supply sector for the long term. This approach necessitates a higher priority for water quality objectives in project proposals and more concretely formulated quality goals to achieve.

Compared to the current situation, the addition of the short-term track will increase the effectiveness of VEI's projects. Its presence in a local drinking water sector will not only yield sustainable access for more people to safe drinking water on the long term, but also addresses quality issues outside the piped supply system in the short term. In addition to these strategy recommendations, this thesis proposes to increase VEI's influence on the environment of local drinking water companies further. To improve grip on the institutional environment of a local drinking water company, the following recommendation is suggested:

3. *Focus new projects in regions where VEI is active already*

Focusing expansion of VEI's activities in areas where VEI already executes projects allows increased influence on the (national) institutional environment. This could provide faster and more appropriate reforms of institutions and legal boundary conditions that benefit business operation of a local water company.

During the research a case study has been performed for Ta'izz, Yemen. The currently applied project approach in Ta'izz focuses on the improvement of business operation of the Ta'izz Water and Sanitation Local Company (TWSLC). Currently executed activities in this project focus on the increase of business performance of TWSLC. To improve the incorporation of microbiological water quality as an explicit goal in current activities, the following recommendations are made:

- *Establishing a long-term vision and strategy to achieve microbiological safe water supply by the Quality Department*
- *Introduce a transparent rewarding system with more appropriate payment structures*
- *Establish an internal training program with priority for management skills*

The Quality Department of TWSLC needs to professionalize. It requires a long-term vision with clear goals and an according budget. The current rewarding system is suggested to become more transparent to increase motivation throughout the company. In addition intensified training efforts can increase the quality of current management staff to enhance overall performance. Furthermore, this thesis recommends that VEI adopts possibilities for improvements with short-term effects within their project description. In the Ta'izz water supply sector short-term benefits can be outside TWSLC, as well as within its business operation. It is recommended to implement the following interventions to gain short-term water quality improvements:

- *Rehabilitation and improvement of two automatic chlorination systems*
- *Replace and extend decentralized chlorination equipment at city wells*
- *Implement a hygiene awareness campaign*
- *Establish a program that allows independent continuous assessment of all providers in the Ta'izz water supply sector and awards quality labels*

Effects with short notice can be expected when adjustments in chlorination practices are executed. This requires minor effort and yield large results for microbiological water quality at the point where water is supplied from the piped network. Incorporation of the formerly suggested short-term track necessitates the ability and autonomy to perform activities beyond TWSLC's business operation. Households in Ta'izz are regularly faced with high storage times and largely rely on privately supplied water. The risk for contamination can be reduced by implementing a program that improves hygiene practices through the increase of the level of hygiene awareness. A suitable intervention in addition to such a program is provided by the implementation of a quality label with an accompanying continue assessment program. Until the local company is able to provide an adequate level of service, this program increases transparency in the private and informal sector and allow households to make well-informed choices when selecting secondary water sources for consumption.

The goal of this thesis is the suggestion of solutions for the improvement of incorporation of microbiological water quality in urban areas in developing countries. Especially the role that VEI can play in their implementation is considered. The main problems that are faced with incorporation of microbiological water quality in urban drinking water supply are identified to enable suggestions for improvement to be formulated. For this purpose the Sector Assessment Diagram (SAD) was designed. It includes 14 variables that determine microbiological water quality in a local water supply sector. The diagram is used in specific case studies to assess a water supply sector and identify crucial variables that influence water quality. During the research the SAD was applied in the case of Ta'izz, Yemen.

PREFACE

I am glad to present the product of my graduation at the University of Twente on which I spend the last year of my study Civil Engineering & Management. I would like to thank Vitens-Evides International B.V. for providing the opportunity to perform my research within their company. The confidence, time, and freedom I received from Jan Hoffer to formulate and execute my research was delightful. Although it appeared difficult to meet frequently I was very glad with the dexterous and motivating contribution of Siemen Veenstra. Especially the possibility he provided, in cooperation with Jan Hoogendoorn, to perform a case study in the city of Ta'izz in Yemen was very helpful. Due to the efforts of Jan and Heleen my stay in Bayt Sanibani has been an unforgettable experience, which I would like to thank them for. It has been a pleasure to sleep, eat and work at your residence. The Yemeni culture is one to never forget.

At the moment I proposed the subject of my research, it was difficult to find support for daily supervision of my work. However, in Denie Augustijn I found a very pleasant and skilful teacher who has made a lot of time for my questions and could always be approached when I lost myself again in a web of difficulties and possibilities. Together with Sirp de Boer he was able to direct my thoughts, methods and findings into this thesis. I would like to thank them both for the very pleasant atmosphere at our meetings and phone calls and the helpful attitude of both to keep me on the right track.

Next to the professionally involved people I would like to thank my dearest. Harm and Fennie, my parents, who made it possible to enroll my study in Enschede in the first place. They were always supportive, even though not al my choices and results were as they liked. They granted freedom to do what I wanted to do, while being there when I needed them. I cannot think of better parents to have. I'm glad you're still with me. Furthermore my roommate Bob van den Berg has been a source of inspiration at many moments. Of course these were not always relevant for my research. But his experience and the capacity to listen to my moaning when I wanted an ear to listen was a relief in the sometimes hectically period. He is one of the reasons why I feel at home in my new home town Utrecht. Thanks Bob.

ABSTRACT

Low microbiological quality of drinking water is a great risk for public health in urban areas in developing countries. Inadequate business operation of the local water company causes low reliability in quality and quantity, and a low household connection ratio. When performance is inadequate over a long period a situation can be expected in which households are reliable on secondary drinking water sources from a private market. Low business performance causes longer times between supply and consumption since fetching times increase and household storage becomes necessary. Contaminating hazards outside the piped supply system are provided more opportunities to deteriorate water quality. A low level of hygiene practices in these cases is decisive for microbiological water quality at the point of consumption.

The thesis aims at addressing issues in incorporation of microbiological water quality in the operation of urban drinking water supply chains in developing economies in general, and within projects of VEI in specific. To describe processes that influence microbiological water quality and structure observations from case studies, the Sector Assessment Diagram (SAD) is proposed. The SAD is a tool that supports the analysis of a drinking water supply sector by structuring observations and denominating determining variables that are causing water quality issues. It distinguishes the domains of business operation, governance, and hygiene practice. These three domains represent processes within the local drinking water company, the institutional environment in which the sector is located, and the remainder of the local water supply sector, respectively. The SAD identifies 14 variables that determine the level of microbiological water quality at the point of consumption. The variables provide a reference framework to design interventions that aim for improved incorporation of water quality throughout the water supply sector.

The SAD has been applied by studying the case of Ta'izz, Yemen. The results indicate that it is a helpful tool that is able to increase understanding about the situation in a local water supply sector. The SAD is not suitable to be used as an independent method to assess a local sector since it generates data that need interpretation and can only be used to support a parallel analysis by elucidating interacting processes in a local water supply sector. Based on its outcomes, interventions are suggested to improve the incorporation of microbiological water quality in VEI's project in Ta'izz. VEI's current strategy aims at improvement of business operation solely. This yields quality improvements only in the long term. The most important recommendation therefore concerns the application of a strategy that enables execution of interventions outside the business operation of the local water company. When this strategy can be performed next to VEI's current policy, interventions can be implemented that are able to increase microbiological water quality at the point of consumption in the short term as well. These interventions comprehend the increase of hygiene awareness and providing a system with quality labels that increases transparency about water quality throughout the entire water sector in Ta'izz.

This recommendation for the case of Ta'izz can be generalized towards general VEI policy principles. To become more effective it is necessary to increase influence in the sector where VEI is active. Improvements in business operation become effective only on the long term. Therefore it is recommended to increase project duration to a strategic period between 5 and 10 years. Increasing influence on the institutional environment is achieved by focusing new activities in areas where VEI is currently active already. Until long-term improvements are established in microbiological drinking water quality in a local supply sector VEI needs to be able to influence water quality at the short term as well. Therefore it is recommended to expand project description towards areas of the drinking water sector beyond the piped supply system. Moreover, water quality objectives are recommended to be more explicitly formulated and elaborated in more detail in project descriptions.

1 INTRODUCTION

1.1 CONTEXT AND MOTIVATION OF THE RESEARCH

Water is essential to sustain life. The quality of water used for consumption has a profound influence on public health. In particular the microbiological quality of water is important for preventing ill-health with short-term consequences. Poor microbiological quality is likely to lead to outbreaks of infectious water-related diseases with diarrhoea being the main symptom and is associated with the occurrence of serious epidemics. Based on different studies, Gadgil (1998) asserts that "the magnitudes of the mortality and morbidity from waterborne diarrhoeal diseases unquestionably make them the planet's biggest environmental health threat to populations". Approximately 1,1 billion people are living without access to 'improved' water sources (WHO/UNICEF, 2005). Those people are exposed to an increased risk of diseases. Poor water supply and sanitation are annually causing approximately 4 billion cases of diarrhoea and 2,2 million deaths (WSSCC, 2000), approximately accounting for 4.0% of all deaths (Prüss, 2002; Murray and Lopez, 1996). By including water supply, sanitation and hygiene in the Millennium Development Goals (MDGs), the world community has acknowledged the importance of the provision of safe drinking water for all (WHO, 2004).

Vitens-Evides International B.V. (VEI) is a firm founded by two Dutch enterprises engaged with drinking water supply in the Netherlands: Vitens and Evides. VEI was established to make a contribution in achieving the MDGs. Its purpose is to make available knowledge and experience for improvement of drinking water supply facilities in developing economies. The goal that has been formulated to be reached by 2010 is to provide improved facilities to 15 million people in developing economies. For this purpose the following four basic principles that shape their international activities are employed:

- A focus on urban drinking water supply
- Aiming at improvement of daily operation and its management
- Transferring knowledge and experience
- Achieving this, without making investments in infrastructure

Deficiencies in microbiological drinking water quality can greatly affect public health. Besides the social impacts this has for the local community, the image of both mother companies might be damaged as well. Although VEI is not responsible for the operation of the local supply system in most cases, Vitens and Evides are linking their names to them, causing additional concern for the quality of supplied drinking water. These reasons necessitate VEI to include microbiological water quality in their projects. However, despite its importance for public health and corporate value, it appeared that in practice the quality-focus is minimal. Even though theoretical knowledge about best practice is abundant and much research has been done, it seems to be very difficult to convert this knowledge into reliable urban piped water supply of good quality. UN-HABITAT (2003) mentions that a general explanation for the inadequacy of urban water and sanitation provision is nonexistent. These problems are reason for VEI to express the need for research to uncover the causes behind the underexposure of microbiological water quality and to provide advice about the incorporation of quality aspects in their projects. Therefore, this thesis identifies key-variables that are able to influence the microbiological quality of the water that is consumed by customers of a local drinking water company. Since VEI only operates in urban areas, the thesis is limited to urban situations. Moreover, this focus is justified by the expectation that African and Asian urban population will double between the year 2000 and 2025 (WSSCC, 2000), creating an explosive growth in demand for good quality water in urban areas.

1.2 GOAL AND RESEARCH QUESTION

The goal of this research has been formulated as follows:

Determining reasons for the failure to incorporate microbiological water quality into the operation of an urban drinking water supply sector in developing economies, and formulating interventions that can improve this situation

To achieve this goal, three central research questions are formulated:

1. *What are the main problems faced in incorporating microbiological water quality in the operation of local urban drinking water supply sectors in developing economies?*
2. *Which solutions can be formulated to improve incorporation of microbiological water quality?*
3. *What can VEI do to assist in the implementation of these solutions?*

To answer the first question, a model is proposed that describes the relations within an urban drinking water supply chain and identifies causes for microbiological contamination. Application of this model during an assessment of a local drinking water supply chain provides an answer to the first question. The results also indicate leads for answering the second question. In this thesis, the city of Ta'izz is used as a case study to test the application of the model. Based on their analysis, the needs for improvement are identified. Subsequently interventions are proposed that can be implemented by VEI to improve incorporation of microbiological quality in Ta'izz and in their projects in general.

Throughout the thesis a drinking water supply chain is considered that includes public taps, kiosks, vendors, and other secondary sources. Although this part of the water supply chain generally is not considered to be the responsibility of water supply companies, it is highly relevant for microbiological water quality at the point of consumption. This approach avoids a focuses on the piped supply system with household connections solely. Although these sources might not directly be related to activities under the responsibility of the local drinking water company, these elements largely determine the level of microbiological drinking water quality at the point of consumption (Gadgil, 1998). Therefore these processes are included in the water supply chain as well. A focus on household connections only can be useful for some purposes, but would in this case chiefly attract attention to areas that already have relatively reasonable drinking water facilities installed (Gadgil, 1998).

1.3 STRUCTURE OF THE REPORT

Chapter 2 describes the construction of an urban drinking water supply chain. It concludes with the identification of potential hazards for microbiological contamination throughout the chain. Chapter 3 elaborates a causal relation model that is being used to assess a local drinking water sector. It explains how that specific sector is constructed and identifies variables that determine microbiological quality of the water that is being consumed. In Chapter 4 the model is being used to assess the drinking water supply sector in the city of Ta'izz, Yemen. The conclusions include a score for all determining variables and an explanation of the local situation. Subsequently, the fifth chapter discusses how practices can be improved, related to the incorporation of microbiological water quality in the drinking water chain. It recommends interventions in Ta'izz specifically, as well as for general practices of VEI. In Chapter 6 the model that was constructed in the third chapter is evaluated. This chapter also includes suggestions for further research to improve drinking water chain assessments. The thesis ends with conclusions and recommendations in Chapter 7. Appendix I summarizes explanation of less commonly used concepts and the definition abbreviations.

2 HAZARDS FOR MICROBIOLOGICAL CONTAMINATION THROUGHOUT THE DRINKING WATER CHAIN

Water quality deterioration occurs in several different ways. Microbiological contamination is only one of them, but is considered the most common serious threat for public health. Other parameters that affect public health, such as chemical contamination, occur less frequent and normally do not have short-term consequences, are not infectious and therefore won't become epidemic. This research focuses on human-pathogenic micro-organisms that are transmitted through drinking water since they are most significant for microbiological contamination. The main micro-organisms involved include viruses, bacteria and protozoa (Gray, 1994; Lieverloo, 2002; Westrell, 2004). They are able to transmit diseases such as hepatitis, polio, cholera, dysentery, typhoid, etc. They are all transmitted through the faecal-oral route and are therefore directly or indirectly related to contamination of water resources by sewage or animal wastes (Gray, 1994). An infected person is likely to excrete a high number of pathogens for many days, which makes pathogenic contamination contagious. Although bacteria have shorter lifetimes, are better treated by disinfection and have a higher infection dose than protozoa and viruses, this group of pathogens is the cause of most of the reported outbreaks of water-related diseases, mostly related to inadequate sanitation. Improvements in microbiological water quality therefore should mainly concentrate on this type of pathogens. The drinking water supply system can be regarded as the total construct of the elements that are shown in Figure 1. The situation that this figure presents is typical for a well-developed system, where water is generally consumed directly after the point of supply. However, in most developing economies the point of supply does not coincide with the point of consumption. This increases time between supply and consumption increases the risk for contamination. Throughout this thesis the drinking water system will be referred to as "Drinking water chain", which includes the point of supply and consumption. Within the chain of Figure 1, several elements can be distinguished that determine the quality of the drinking water at the point of consumption.

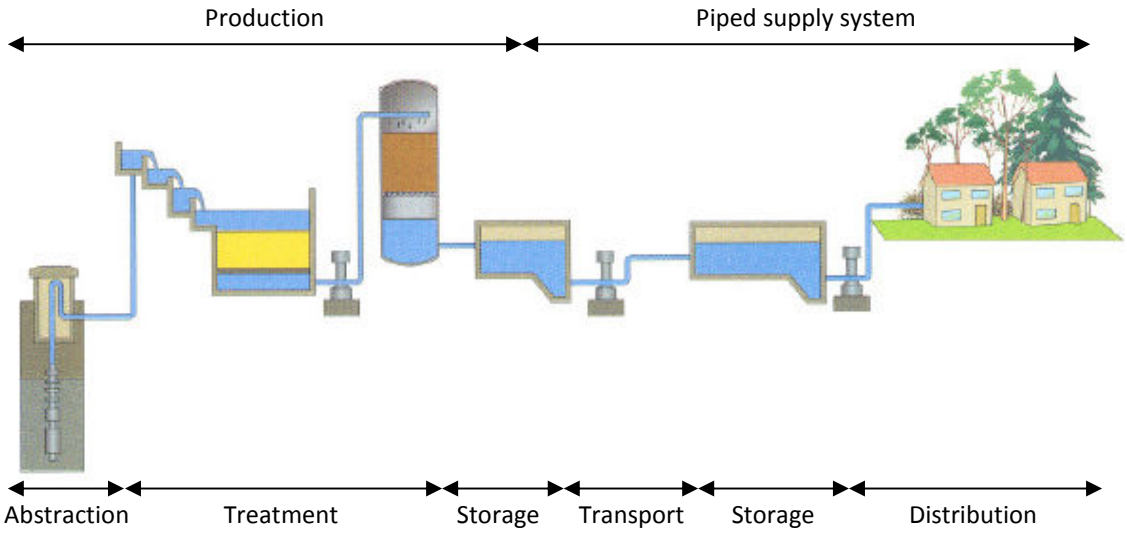

FIGURE 1: DRINKING WATER CHAIN (DE MOEL, 2005)

Based on Clark (2004), Davison (2005) and WHO (2004), the following physical barriers to contamination are identified as crucial for safe drinking water:

- Preventing pollution of raw water
- Selective raw water abstraction
- Treatment
- Controlled storage
- Protection during transport and distribution
- Safe storage within the house and treatment beyond the point of supply, at the point of consumption

Breaching one of these barriers will increase the risk that the supply system becomes microbiologically contaminated. The next subparagraphs will discuss each step of the drinking water chain. The listed barriers to contamination are discussed, providing an overview of the most important risks for the supply system to become microbiologically contaminated.

2.1 ABSTRACTION OF RAW WATER

Groundwater is usually more suitable as an abstraction source than surface water, since it's more likely to be free from suspended solids, bacteria and other pathogens (Gray, 1994). Pathogenic micro-organisms of faecal nature usually enter raw water through drain-off from (un)treated sewage and wash off from land surface, but a vast share cannot survive for long times outside the human or animal body and die off (de Moel, 2005). The pathogens that manage to survive outside the carrying body are a serious threat for microbiological water quality throughout the entire water supply chain. In most cases alternative raw water sources are not available in densely populated urban areas. Hence, improved raw water selection is not relevant for this research.

2.2 TREATMENT

An effective treatment process can remove pathogens that enter the supply system through raw water abstraction. The simplest and most important method, which is also common in developing economies, is chlorine disinfection (Gray, 1994). The Netherlands is one of the few countries where alternative methods have taken over this role. Although methods such as ozonization and UV-disinfection are more expensive and complicated, they have the main advantage over the use of chlorine that taste is not affected. To maintain quality integrity after the water has left the treatment facility, in many cases a disinfectant chlorine residual is applied that controls the growth of pathogenic micro-organisms in the distribution system. If a chlorine residual is present, additional reduction of pathogens is possible. This is necessary for contamination that might infiltrate the system beyond the treatment phase. In the Netherlands emphasis is laid on the curbing of "aftergrowth" by reducing the amount of biodegradable substances. Without these substances, micro-organisms are practically incapable of reproduction (de Moel, 2005). However in many situations, especially in less developed drinking water systems, the presence of a disinfectant residual is desirable. Long travel times and low flow rates result in loss of disinfectant residual and accumulation of sediments. Since residence time is considered a factor with a significant overall effect on quality (Trifunovic, 2006; Water Science and Technology Board, 2006), water quality can only be safe when the correct disinfectant dose is applied. This is unique for every situation because the appropriate dose depends on turbidity, pH, the appearance of some chemical elements, and fluctuation of microbiological quality of raw water. Problems in selecting the dose can be expected in environments with low access to information about real time quality parameters. Besides this, the operator has to take account of by-products, tastes and odours, and has to deal with the availability of equipment and materials (Ainsworth, 2004; Westrell, 2004). Especially in developing economies with insufficient infrastructure and facilities this may be a problem. Moreover, chlorine treatment lacks a visible effect. Neither users nor operators can visually perceive improvement in quality, which means that a contamination event cannot be observed easily. A correctly applied disinfection process, combined with adequate maintenance of a disinfectant residual throughout the transport and distribution network would enable a water company to supply relatively microbiologically safe water to its customers.

2.3 STORAGE

Storage of drinking water within the supply system is a generally applied for two different ends: removing pathogens, and buffering quantities between supply and demand. When not applied correctly, storage rather increases the risk of microbiological contamination by inflow of pathogens and other organisms. Storage times are often not very long, but the threat of contamination with pathogens is realistic, especially in cases where storage facilities are not covered (Wright, Gundry and Conroy, 2004).

2.4 TRANSPORT AND DISTRIBUTION

The transport and the piped distribution network are likely to face problems that are similar for both. Hazards to microbiological quality in these cases can be related to physical and hydraulic integrity.

2.4.1 PHYSICAL INTEGRITY

Physical integrity can be impaired by breaches in the pipework, mostly caused by physical and chemical deterioration of materials, absence or improper installation of critical components and use of contaminated components (Water Science and Technology Board, 2006). Such imperfections increase the risk of pathogen infiltration into the system. Deterioration of the pipe wall allows micro-organisms to settle more easily. In that case these organisms become more resistant to residual chlorination (Gray, 1994), which induces degradation of microbiological water quality at the point of supply.

2.4.2 HYDRAULIC INTEGRITY

For hydraulic integrity, a desirable water flow, pressure and residence time are necessary to maintain. Negative pressure events provide opportunities for groundwater to enter the system through pipeline leaks (LeChevallier, 2003; Trifunovic, 2006). Based on an assessment of potential health risks due to pressure transients, LeChevallier (2003) concluded that bacteria and other micro-organisms of faecal origin are present in the soil and water exterior to distribution pipes. Breaches in hydraulic integrity therefore are likely to increase the risk for microbiological contamination of water in the distribution system. A close distance between sewer and drinking water pipelines further increases this risk. In developing economies, pressure transients occur on a regular basis. Controlling water quality in intermittent supply systems is more difficult than in the case of continuous supply because of the occurrence of backflow, infiltration of contamination (Ainsworth, 2004), increased numbers of line breaks, occurrence of turbidity, additional storage and non-uniform chlorine residuals (Ayoub, 2006). Contrary to low pressure gradients, peaks in pressure and flow velocity in the pipe network can lead to detachment of biofilms (Ayoub, 2006; Coelho, 2003). If intended, this phenomenon can be used to "flush" the system. But when occurrence is unpredictable, it increases risks for microbiological water quality.

2.5 THE POINT OF SUPPLY

Practices that are applied at the point of supply differ considerably between developed and developing economies. In the Netherlands household connection coverage is almost 100%. Water is provided that is relatively constant of good quality and abundant in availability (when comparing an average Dutch daily consumption of over 125 litres per person (TNS-NIPO, 2005) with the defined minimum of 20 litres a day (WHO/UNICEF, 2005, 2006). In contrast, many urban households in developing economies are not connected to a reliable piped distribution system. They rely on communal or secondary sources, such as water vendors. The absence of reliable household connections severely increases the risk of microbiological contamination, since it elongates the period between source and point-of-use and increases the number of hazards for contamination.

2.5.1 SERVICE OPTIONS

The means through which consumers receive their water depends on factors such as their level of income, the legal status of their community, and the availability of potable water. Small-scale enterprises are present in large numbers within the water sector where service options are not satisfactory. This provides customers with the possibility to choose an appropriate service level for their needs and capacity to pay. Appendix II presents the most common service options from the highest to the lowest service level and the possibilities to operate them. In cases where a private market with small-scale water suppliers is present, operating options increase. The risk for contamination after the water has been supplied from the piped system differs considerably per service option and generally declines with the increase of level of service. Therefore, services that are provided by a water company or private enterprise perform a crucial role for the level of contamination in the water chain. A small market share for the local water company complicates central quality control and regulation.

2.5.2 CONTAMINATION BETWEEN THE POINT OF SUPPLY AND CONSUMPTION

Although the part of the drinking water chain beyond the point where water is supplied to the customers generally is not considered a responsibility of the supplying company, it is the most vulnerable part of the distribution network. Contamination occurs as a result of inadequate hygiene practice at the supply point, during transport between supply and the home, during in-home storage or at the point of consumption. Dutch legislation mentions that *"water supplying companies are obligated to supply reliable piped water to the consumers in its distribution area in adequate amounts and sufficient pressure as is of minimal interest for public health"* (VROM, 1960). The responsibility of Dutch water supply companies ends at the water meter or, if not present, at the point of entry of the concerning building. In many cases in developing economies however supply through household connections is limited. The route between supply and consumption in those cases is considerably longer. Households are barely supported to contest deterioration in this part of the drinking water chain (see also paragraph 0 for inappropriate institutional aspects in developing economies). Although interventions between supply and consumption have proved to be more effective (Clasen, 2007), current quality improvement investments are mainly being executed in the beginning of the water chain. Since bacteriological quality of drinking water significantly declines after it is collected by households (Wright, Gundry and Conroy, 2004), the effect of improvements early in the chain are likely to be neutralized by deterioration after the point of supply. In general, the poorest users have to rely on supply facilities that are most inadequate and consequently face longest periods between supply and consumption. To direct attention towards facilities and processes that are least adequate in providing safe water, interventions in the water supply chain would likely to be most effective when a focus is applied on the quality of supply services and processes that are applied and experienced by the poorest group of users, mainly being located beyond the point of supply.

2.6 CONCLUSION

The most important potential hazards that threaten the microbiological drinking water quality between the point of abstraction of raw water and the point of use are summarized in Table 1. Improvements in the drinking water supply chain close to the point of use have a low probability to face recontamination to reduce their effectiveness in the reduction of quality deterioration. Adjustments in the production phase are often compromised by re-contamination. Although they could be very effective, their influence is limited locally and their effect on public health minimal. More effective improvements are to be implemented close to the point of use. However, the part of the drinking water chain beyond the point of supply is excluded from responsibility of the local water company. Processes that are excluded include deterioration of water within households (due to deficiencies in fetching, storage, hygiene practice etc.) and the performance of small scale supply services. These exclusions complicate adequate quality control beyond the piped supply system. To achieve improvements at the place where they are likely to have most influence on public health, this research suggests including the part of the chain beyond the point of supply as a formal part of the distribution system. By acknowledging the important role of this part of the supply chain, interventions to improve microbiological quality are more likely to become successful.

TABLE 1: PHYSCIAL HAZARDS IN THE DRINKING WATER SUPPLY CHAIN

Phase	**Hazard to microbiological water quality**
Abstraction	Abstraction of contaminated raw water
Treatment	Ineffective or incomplete disinfection; Insufficient disinfectant residual maintenance
Storage	Inflow of pathogens due to physical imperfections in reservoirs
Transport & Distribution	Infiltration of pathogens due to physical imperfections; Fluctuation in hydraulic regimes that cause under-pressures nearby contamination; Pressure peaks leading to detachment of biofilms
Beyond point of supply	Inadequate end-of-use processes

3 VARIABLES THAT DETERMINE MICROBIOLOGICAL WATER QUALITY WITHIN THE URBAN DRINKING WATER SUPPLY CHAIN IN A DEVELOPING ECONOMY

The preceding chapter has introduced the most important physical hazards to microbiological water quality throughout the drinking water chain. To create understanding about the causes of microbiological quality deterioration, this chapter identifies variables that determine water quality from abstraction to consumption. They are called "determining variables". The model that is presented in Figure 2 represents a simplified presentation of the processes that influence microbiological water quality in urban drinking water supply.

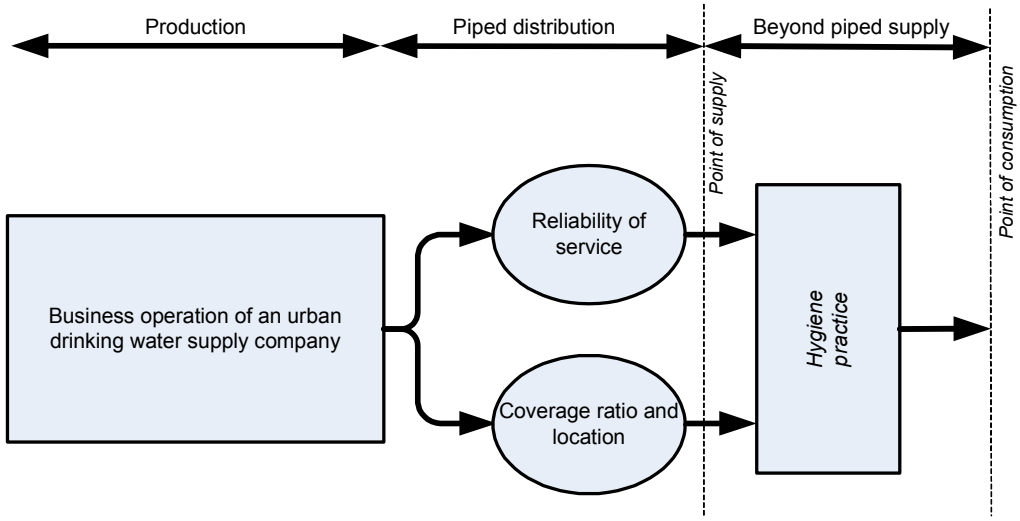

FIGURE 2: MODEL OF AN URBAN DRINKING WATER SUPPLY CHAIN

Throughout the chapter this model is used to explain how the identified variables determine drinking water quality. The addition of variables and more detailed processes to the model of Figure 2 during the chapter provide a tool that can be used when assessing a local drinking water sector: the Sector Assessment Diagram (SAD). The SAD provides increased understanding about relations within the drinking water chain that are responsible for microbiological water quality at the point of consumption. Figure 2 is build around the two most important domains for determining microbiological water quality of drinking water at the point of consumption: business operation and hygiene practice. The quality of business operation that is relevant for microbiological water quality is measured by two indicators that are represented as two circled process elements. The coverage ratio and location, and the level of service are used because they indicate the adequacy with which the local water supply company is operated. The level of service reflect the consumers' access to services in respect of reliability, availability, quality, quantity, cost and value for money (WHO, 2000) and the coverage ratio and location indicate which areas are omitted by piped supply. Both business outputs have considerable influence on the processes beyond the point of supply that determine microbiological quality at the point of consumption. This will be discussed further in paragraph 3.3. The arrows above the diagram (production, distribution) refer to Figure 1. They indicate where the specific processes have effect within the whole supply chain. This chapter is built up by discussing the two domains in the SAD separately, next to the environment in which a local water supply chain is located. Business operation is discussed in paragraph 3.1. and hygiene practices that influence water quality outside the piped supply system in paragraph 3.4. The former is engaged with processes that are related to the operation of a local water supply company. The latter identifies variables that originate from the time between supply and consumption. Environmental variables that are most influential in a developing context are identified in paragraph 3.2.

3.1 BUSINESS OPERATION OF URBAN WATER SUPPLY COMPANIES

The business operation of an urban drinking water company includes the area of the drinking water chain where water is produced, transported and distributed. For adequate operation an organization structure is

applied. Within this structure distinction can be made between operational, tactical and strategic levels of management. Daft (1999) suggests that distinction between these levels is a prerequisite for successful organization. Based on Cotton (2000) and WHO (1994), Table 2 describes the goals and time frames related to these three levels, typical for an urban water supply company.

TABLE 2: MANAGEMENT LEVELS FOR SUPPLY FACILITIES (COTTON, 2000; WHO 1994)

Level of planning	Goals	Time frame
Strategic	Provide (financial) resources to ensure continuous and satisfactory performance, including long-term decision-making concerning construction of new systems, capacity enlargement projects and major rehabilitation projects	2-5 years
Tactical	Ensure effective and efficient operation by choosing policy, such as planning and control of operation and (preventive) maintenance, quality control, administration of water resources and development of unique projects (such as water loss control and security improvements)	1-2 year
Operational	Formulate short-term (daily) objectives, targets and programs such as the calculation of resource allocation for operational units according to tactical input	Day to day

A strategic plan is "the blueprint" of the organization's future (Daft, 1999). It defines activities and resources on the long term and drafts lines along which tactical plans can be shaped, applying a timeframe of about 1 or 2, up to 5 to 10 years. A strategic goal could be: "acquire 80% market share by 2013". Tactical planning defines activities of major departments to implement and support strategic planning. They typically apply a shorter time frame of one year or so. Tactical goals that are most important for microbiological water quality are related to the performance of preventive maintenance activities and management of operational affairs. An example of a tactical goal could be: "increase the ratio of preventive maintenance activities to 50%, compared to reactive activities". Operational goals are characterized by precise and measurable (qualitative) formulation. Corresponding plans are developed at lower levels within the organization. They specify short-term actions and steps for supervisors and individual employees towards achievement of operational goals and support tactical plans. An operational goal could be: "keep the ongoing production of this well stable at 100 m^3/h".

In general, plans and goals intend to motivate employees by facilitating identification with the organization. They are to reduce uncertainty and clarify what the organization tries to accomplish. Plans let employees throughout the organization know what actions can be undertaken to achieve the goals. It provides a rationale for independent decision-making at lower levels and consequently prevents managers from thinking merely in day to day activities on an individual base. Hence, accurate goal-setting and planning increases the likelihood of decisions to be in alignment with outcomes that are desired by the organization's top management. The suitability of the applied organization structure largely determines boundary conditions for goal-setting and planning. An organization structure that is unsuitable for the local circumstances or is enforced inadequately therefore is able to affect the company's efficiency. Hence the first determining variable is identified as:

- ***Appropriateness of organization structure***

The effectiveness of a local drinking water company has been described by Cotton (2000) to require five key issues that have to be addressed by the organization. An appropriate organization structure therefore has to include the issues of Cotton (2000) that are summarized in Table 3.

TABLE 3: INSTITUTIONAL KEY-ISSUES TO ADDRESS (COTTON, 2000)

1	A clear understanding of roles and responsibilities
2	Knowledge of infrastructure asset base and its condition
3	The use of a system for forward planning of O&M
4	Sound financial management with adequate resources
5	Presence of a management information system to furnish information for planning

Throughout the following sections the business operation domain is constructed in further detail, answering to the key issues of Cotton (2000). Figure 3 provides a global overview of the business operation. It includes the three levels of management to increase understanding about processes within the business operation context. Together, they are responsible for the condition of transport, distribution and supply facilities. The quality of these facilities is an important determinator for the level of service that eventually is available at the point of supply from the piped network. The following three sections each discuss one domain.

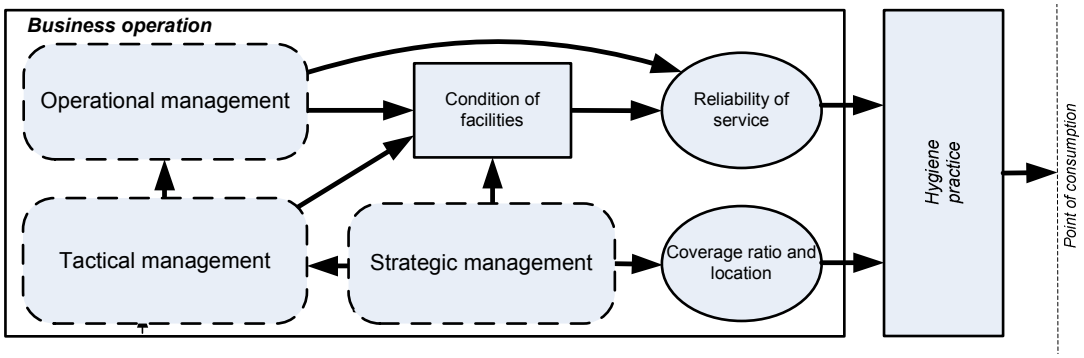

FIGURE 3: DOMAINS WITHIN BUSINESS OPERATION OF A WATER SUPPLY COMPANY

3.1.1 STRATEGIC MANAGEMENT

Sound strategic management enables adequate service at an affordable price, while sufficient revenues ensure adequate funding for investments, management, and operation and maintenance of the drinking water supply system (UN-Habitat, 2003). Although specific tasks that are necessary to achieve these goals are to be executed on the operational and tactical level, strategic planning determines an organization's financial balance. This management level establishes priorities that reflect in budgets and resource allocation. It provides a clear understanding of roles and responsibilities by enforcing an organization structure that identifies tasks adequately. Figure 4 displays relations of the strategic management level within the business operation domain.

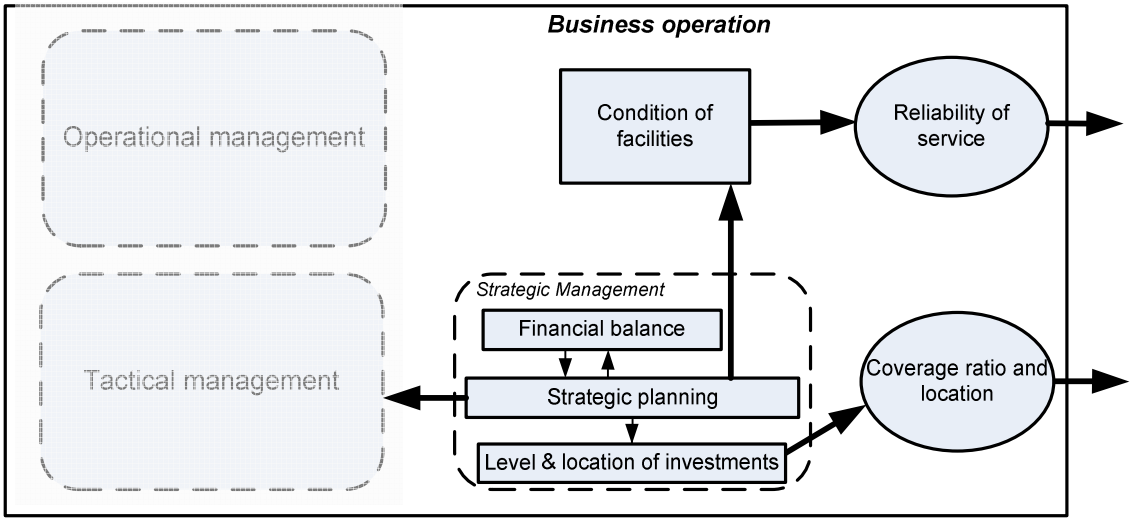

FIGURE 4: STRATEGICAL MANAGEMENT DOMAIN

The fact that Cotton (2000) mentions sound financial management with adequate resources as a key-issue is not surprising. Without sufficient budget, or inadequate priorities, essential parts within business operations are bound to fail. Strategic choices do not only reflect in large facility maintenance projects, but also in investments and upgrades of existing infrastructure. Hence the strategic planning directly determines the coverage ratio of different areas. An example of inadequate strategic planning that is mentioned to occur frequently is an uncontrolled financial balance (Cotton, 2000). At the start of the year, expected spending can hardly be estimated. Therefore, expenditures simply stop when money runs out during the financial year.

Lenton (2005) suggests that cost-reduction and improved revenue collection could make the water supply company less reliable on public support and could boost financial predictability.

3.1.2 TACTICAL MANAGEMENT

Adequate tactical business operation necessitates the availability of sufficient and reliable information. Cotton (2000) suggested that knowledge about infrastructure is indispensable. Especially the planning of preventive maintenance requires a reliable supply of knowledge and information. Absence or ineffectiveness of a Management Information System (MIS) frequently causes drinking water companies in developing economies to lack adequate preventive maintenance. Therefore the following determining variable is added:

- ***Appropriateness of the management information system***

A MIS can make available essential knowledge about company assets that are needed for effective and efficient asset management. It aims at gathering and processing information so that tendencies can be recognized within the data and predictions can be made that could support tactical and strategic management decisions. Within Figure 5 this variable is displayed to have a direct influence on the availability of information for tactical planning. A MIS requires the existence of reliable information through dependable sources (accurate collection, measurement, recording, storage and retrieval of data). Paragraph 2.2 mentioned for example the importance of the availability of real time quality parameters for selecting disinfection doses. Many systems in developing economies are incapable of providing microbiological quality data in short notice, or even at all. If data are retrieved, in many cases they are stored locally in varying formats that are difficult to compare.

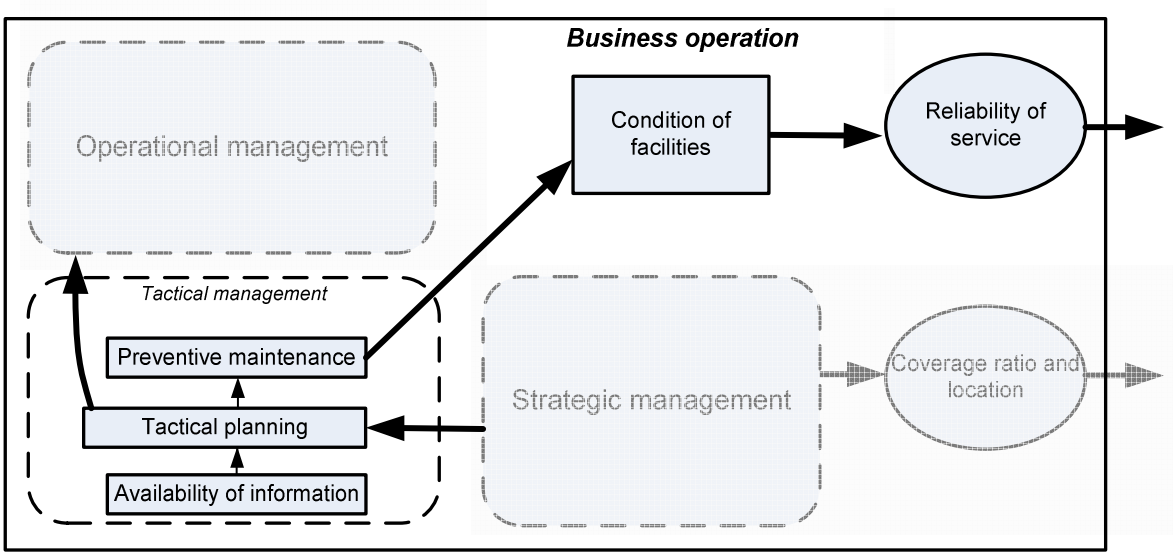

FIGURE 5: TACTICAL MANAGEMENT DOMAIN

Next to information availability, planning is of main importance for adequate long-term maintenance. Creation of an annual budget and planning of preventive maintenance is considered essential for the condition of facilities. Many organizations however approach preventive maintenance activities as an incidental project that is carried out once in a while, financed by external funding (Farley, 2003; Gadgil, 1998). Consequently, large maintenance tasks are only executed when additional funding becomes available. Low priorities for preventive maintenance lead to inappropriate budgets, resulting in accumulation of outstanding maintenance. High numbers of breakdowns can be expected and parts of the network become neglected. As a consequence of deteriorating condition of facilities, breaches are imposed in physical integrity (i.e. pipe work, storage facilities), as well as hydraulic integrity (pressure management etc.). An increased demand for corrective maintenance is the result. This affects the performance of, and budget for operational management. The relations of these aspects to the total construct of business operation are presented in Figure 5.

3.1.3 OPERATIONAL MANAGEMENT

Within the operational management domain, routine tasks and incidental activities with short-term effects are executed. Directives and guidelines for these tasks are provided by the tactical level of planning. Figure 6 displays the role of operational management within business operations. It can be seen that maintenance is also included on this level of planning. However, this only concerns failure-based, corrective maintenance activities that are necessary to repair incidental failures. The magnitude of this task depends on the adequacy with which tasks on the tactical level are executed. Being one of the five key-issues (Cotton, 2000), the quality of forward planning of operation and maintenance increases the reliability of operational planning. Failures of facilities are reduced in occurrence, resulting in an improved condition. The performance of staff on the operational level is crucial for the success of operational activities. Well-performing staff increases the level of services since activities are carried out more carefully. Since on-going maintenance on a day-to-day basis and the execution of other routine tasks are included on the operational level, more reliable operational planning reduces the necessity for corrective maintenance.

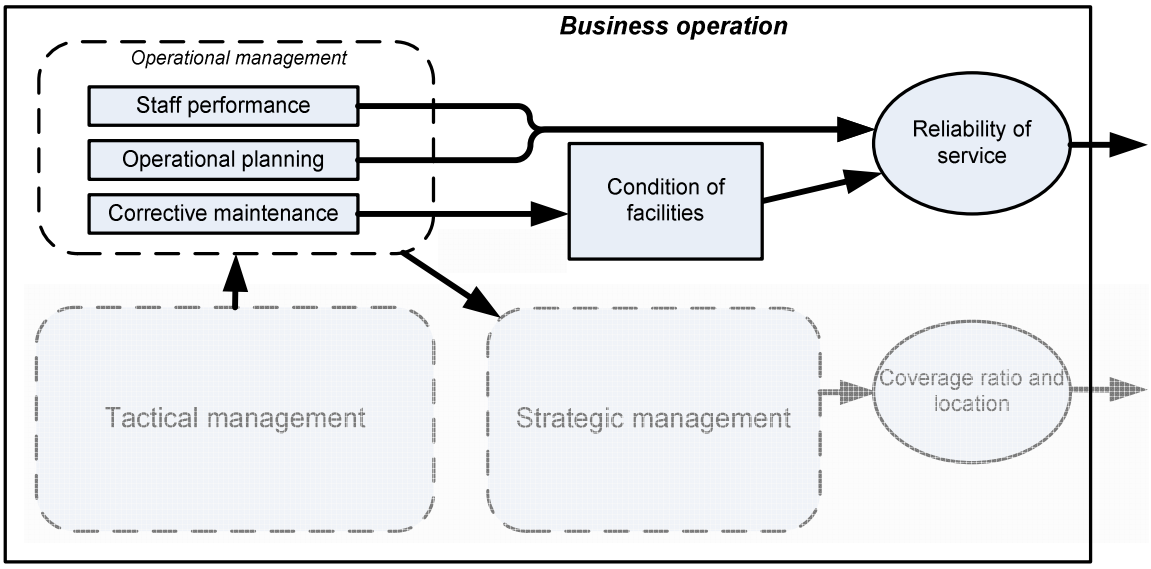

FIGURE 6: OPERATIONAL MANAGEMENT DOMAIN

3.2 ENVIRONMENTAL INFLUENCES IN A DEVELOPING CONTEXT

The effectiveness of an organization largely depends on the ability to adapt to its environment (Jaeger, 1990). This makes a water company dependable on the context it operates in. Knowledge about influencing factors therefore is crucial. This paragraph discusses aspects that are specifically relevant for drinking water companies in developing economies. Based on the models of El-Namaki (1979) and Austin (1990) three environments are distinguished: the socio-cultural, the institutional and the economic environment. Figure 7 presents the composition of this paragraph. For each environment is determined what its influence is on the drinking water chain, identifying determining variables. The effect on hygiene practice is discussed in paragraph 3.4.

3.2.1 SOCIO-CULTURAL ENVIRONMENT

Organizations have to function around social structures and within a set of implicit rules, determined by the culture that is typical for the particular area they are operating in. Culture in this sense is defined as "the collective mental programming that distinguishes one group or category of people from another" (Hofstede, 2007) or as "being an individual's theory of what his fellows know, believe and mean, his theory of the code being followed, the game being played" (Keesing, 1974). In general cultures between developing and developed countries vary heavily, although among developing countries differences of the same magnitude might be perceived. Within drinking water companies cultural influences reflect on the behaviour of employees throughout the organization, effecting their performance. The most important requirements for staff to perform adequately have been formulated by the WHO (Cotton, 2000) to be the provision of appropri-

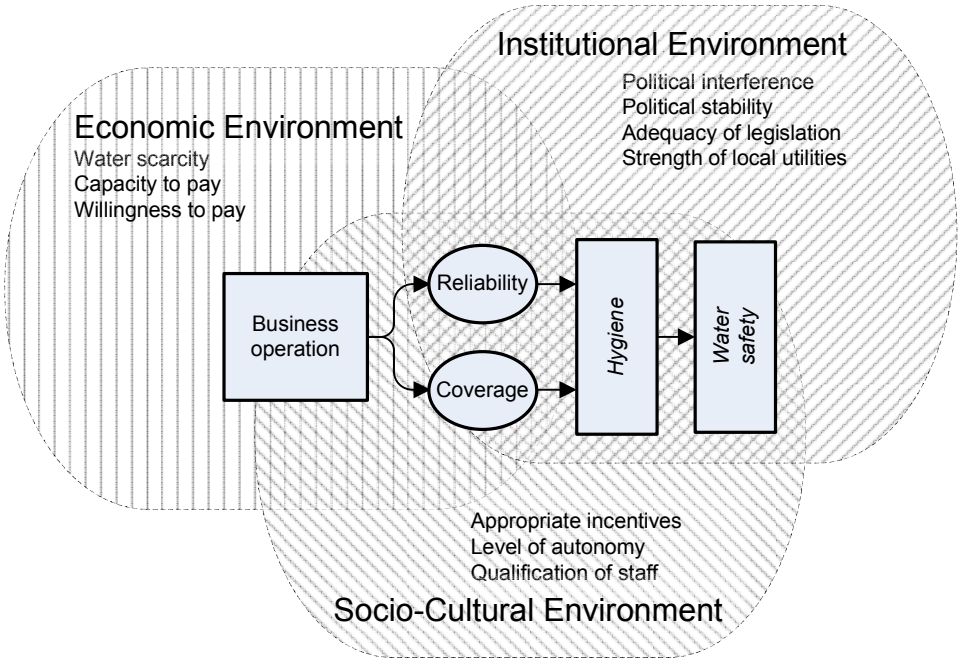

FIGURE 7: ENVIRONMENTAL ANALYSIS

ate incentives, the provision of sufficient autonomy for operational decision-making and execution of tasks, and suitability of personnel for the tasks they are assigned to. Although these three aspects might look pretty straightforward, the local socio-cultural environment determines which incentives are appropriate, what basic education looks like, and how employers and employees approach autonomy.

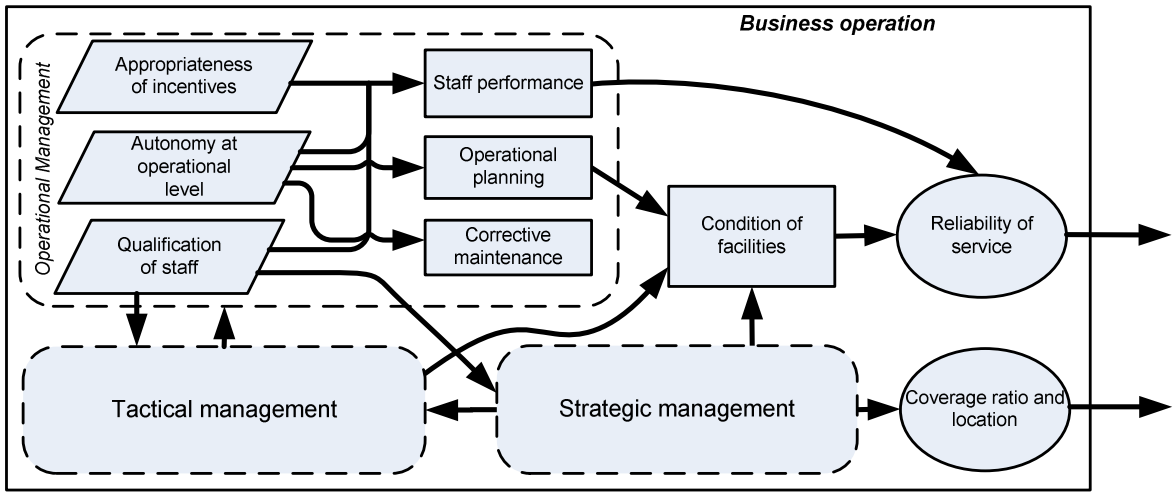

FIGURE 8: INFLUENCE OF THE SOCIO-CULTURAL ENVIRONMENT ON BUSINESS OPERATION

Based on the preceding section the following three determining variables are identified:

- ***Appropriateness of incentives***
- ***Autonomy at the operational level***
- ***Qualification of staff***

Although staff is active throughout the entire company, these variables are most dominating on the operational level, as is shown in Figure 8. *"Qualification of staff"* is also determinative for the tactical and strategic level of management since quality and education of managers highly determines appropriateness of policies and the quality of their enforcement. Moreover, managers on tactical and strategic levels are able to influence autonomy to a lower level and can accommodate more appropriate incentives.

APPROPRIATE INCENTIVES

Incentives are an indispensable tool for adequate employee performance. Appropriate incentives stimulate motivation and commitment among employees, which make them more loyal to the organization's goals and effective in their actions. Stimuli that trigger desirable behaviour depend on local socio-cultural standards. Table 4 displays a general overview of differences in socio-cultural behaviour between developed and developing economies, based on the theories of Hofstede (1991) and Jaeger (1990). It becomes apparent that informal rules of the cultural system along which personnel act, can differ greatly between cultures. Therefore, incentives that are appropriate in one culture might not necessarily be perceived as a stimulus in another culture. In many cultures increased autonomy at the operational level positively influences dedication to the job and enhances responsibility on lower levels, which improves the ability to react to sudden changes. However, high autonomy at lower levels in an environment with a high power distance is likely to affect business performance considerably. More universal appropriate incentives include respect and a sufficient level of income, which decreases the need for secondary income generation during working hours.

TABLE 4: DIFFERENCE IN CULTURAL DIMENSIONS BETWEEN A DEVELOPED AND A DEVELOPING CONTEXT

Dimension	Developed economies	Developing economies
Socio-cultural characteristics		
Power distance	Low	High
Collectivism/individualism	High individualism	High collectivism
Femininity/masculinity	Masculine	Feminine
Uncertainty avoidance	Low	High
Time units for action	Long-term	Short-term
Internal work characteristics		
Causality of outcomes	Internal	External
Creative potential	Unlimited	Limited
Abstractive/associative	High abstractive thinking	High associative thinking
Malleability	Future oriented	Past and present oriented
Task orientation	Proactive	Passive/reactive
Success orientation	Pragmatism	Moralism
People orientation	Collegial/participative	Authoritarian/paternalistic
Environment orientation	Context independent	Context dependent

QUALIFICATION OF STAFF

Employed staff needs to be suitable for the tasks they are supposed to execute. This involves adequate qualification and training to perform tasks sufficiently (WHO, 1976). A basic level of specific education is desirable for at least the lowest level of supervisors and managers. Besides this, also personal qualities are of importance to select suitable employees. Although labour availability is high in developing economies, trained workers generally are scarce. The young-age structure makes the surplus labour force inexperienced and immature. The WHO (1976) suggests that plant operators are required to have good management skills, to be familiar with hydraulic principles, be able to recognize hazards for public health and react with appropriate actions. A director is suggested to require appropriate education in engineering or science and to have experience in plant operation (WHO, 1976). A prerequisite for organization effectiveness and adequate business performance on the long term is sufficient qualification of higher management. Managers need to have sufficient skills and social support throughout the organization to be able to enforce their policies. Figure 8 shows these relations by causalities between "qualification of staff" and tactical and strategic planning.

LEVEL OF AUTONOMY TO EXECUTE TASKS

Within many organizations in developing economies, the level of autonomy to execute tasks that are necessary for adequate operation is very low. Managers that should be engaged with the strategic level are often occupied by arranging daily operational incidences. Operators are not allowed responsibility for the activities they have to perform. When they make short-term decisions that are not considered independent,

consequently, the operator will be corrected afterwards, resulting in a situation where every decision has to be approved by superior management before action is undertaken. This high level of power distance is likely to reflect to the workforce in high uncertainty avoidance, moderate risk taking, short-term focus and a low level of entrepreneurship. Eventually bottom-up initiatives will extinct, making lower levels completely dependent on top-down instructions. Operating staff becomes unable to influence circumstances and procedures they have observed to be ineffective. Besides diminishing dedication, the lack of autonomy disables quick responses on changing circumstances, such as sudden changes in raw water quality or the occurrence of a significant deterioration event within the system. The introduction of more adequate levels of autonomy has to start at highest levels of management. This allows penetration throughout the organization in due time. Although the level of autonomy that is provided within an organization also depends on the first identified determining variable "appropriateness of organization structure", it is considered to be an independent variable, since it reflects to what degree managers are able to deal with the consequences of such a structure.

3.2.2 INSTITUTIONAL ENVIRONMENT

The adequacy of the institutional environment running a water supply company is described by application of the concept of good governance. Governance describes the process of decision-making and the process by which decisions are implemented (or not). Hereby, public institutions conduct public affairs, manage public resources, and are engaged with realization of human rights. In case of good governance, governments essentially are free of corruption and abuse, and act with respect for the rule of law. Figure 9 summarizes the aspects that are considered to be included in the definition of Good Government (Commission, 2001; Graham, 2003; Hyden, 1998; Kaufmann, 2007; UN, 2007; UNDP, 1997).

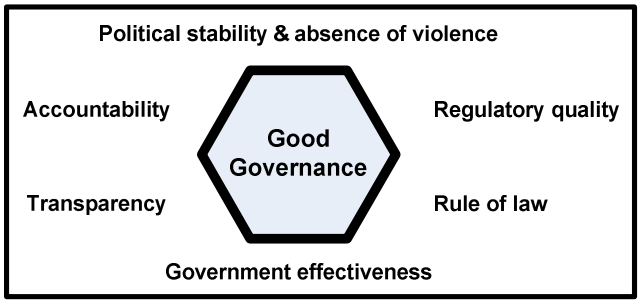

FIGURE 9: ELEMENTS OF GOOD GOVERNANCE

Transparency International (2007) identifies "good governance" as the antithesis to corruption. It provides a set of rules for the political system how to adopt decisions and solve conflicts between actors so as to take away breeding ground for corruptive practices. Corruption hurts the water sector by limited possibilities for expansion and improvement, and ineffective delivery of water supply services. Political actors with secondary agenda's may try to influence decisions negatively (Austin, 1990; Transparency International, 2006). Hence decision making is likely to suffer from manipulated allocation of financial means and is subject to extreme centralization. Customers are forced to pay bribes to get connected to water pipes or tankers and the cost of small-scale infrastructure is inflated. Other visible consequences of corruption include falsified meter-readings, procurement of poor facilities against high prices due to ill advice, and 'bought' directorships. The influence of governance penetrates the water company through the strategic level of management by influencing decisions for political reasons or creating boundary conditions such as fixed water tariffs. Governments determine long-term conditions for water companies to operate in. If they are committed to improve sustainable access to water supply services, authorities have to be prepared to make strong decisions regarding budget priorities, decentralization of power to local authorities, and the restructuring of incentives and accountability networks among the public private and civic sectors (Lenton, 2005). Since it includes all elements of the institutional environment, the environmental domain "Governance" is added as an independent domain that primarily interacts with the strategic level within the local water supply company (presented in Figure 10). In the remainder of the chapter more relationships from governance to process elements outside the business operation are revealed.

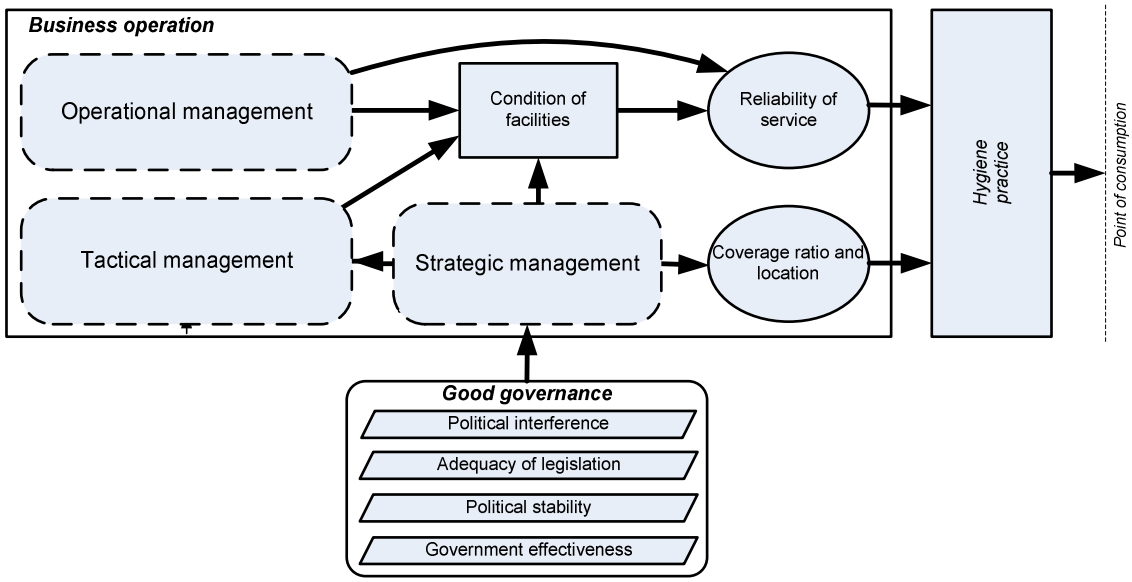

FIGURE 10: INFLUENCE OF THE INSTITUTIONAL ENVIRONMENT ON BUSINESS OPERATION

The aspects that were mentioned in Figure 9 can be grouped into three embracing terms that function as determining variables for microbiological water quality. The variables from the institutional environment are formulated as follows:

- ***Government effectiveness:*** *responsiveness, effectiveness, rule of law, accountability, transparency*
- ***Political stability:*** *transparency, absence of violence*
- ***Adequacy of legislation:*** *fair legal frameworks, regulatory quality*

Direct interference of authorities with the operation of an organization might severely damage its effectiveness. Such interventions often have political motives and frequently are inclined to achieve personal gains and affect business outputs. Policy preferences regarding tariffs directly influence the financial situation of the company, which impedes adequate business operation. Therefore an additional variable is identified as:

- ***Political interference***

The four sections on the next page discuss the determining variables from the institutional environment in more detail.

POLITICAL INTERFERENCE

Since water companies generally were, or are governed by local or central authorities, their functioning is subject to political influence. Currently applied strategic policies in private companies often relate to a heritage that is left behind by government bodies that formerly controlled the water supply sector. Exemplary for aggravating political interference are situations that VEI have come across in Mongolia and Ghana. In these cases, a newly installed minister or mayor appoints new persons at key positions within strategic management. Consequences include inadequate strategic planning and long-term stability. Moreover control of strategic decision-making becomes subject to motives that are rather political than professional (UN-HABITAT, 2003). Gadgil (1998) mentioned that many central government bodies prefer to spend (inter)national funding on extremely cost-inefficient and consumer-unresponsive water distribution systems that only improve service in already relatively well-facilitated areas, neglecting improvements for the majority of the population that is most in need. Besides these issues authorities that impose low fixed tariffs for water supply impede financial healthy business operation in some cases.

GOVERNMENT EFFECTIVENESS

Appropriate political and legal support is indispensable for a water company to adequately operate its business (UN-HABITAT, 2003). Effectiveness in this case mainly relates to responsiveness, accountability, and

transparency of the acting of authorities. Transparency in the drinking water sector could be greatly enhanced by application of more appropriate legal, financial and regulatory systems. UN-HABITAT (2003) suggests that a regulating body that is able to supervise the drinking water sector will further stimulate development of effectiveness in the drinking water sector since it ensures that providers are accountable to clients. This necessitates sufficient autonomy at the lowest appropriate level of governance (Lenton, 2005; UN-HABITAT, 2003). In most cases a process of decentralization of responsibilities is needed. This necessitates corresponding devolution of financial resources and authority, as well as the provision of technical and managerial support to build local capacity. UN-HABITAT (2003) suggests that the influence of this determining variable on the boundary conditions for local water companies is greatly determined by the autonomy that local authorities receive from central governmental bodies. Eventually they are an important determinator of local circumstances in which a local drinking water company has to function.

POLITICAL STABILITY

Compared to a developed environment, developing economies are more likely to experience high political instability (Hofstede, 1991). Consequently, the risk for social unrest is higher, which might provoke civic violence. In any case, predictability of government policies and actions diminishes and transparency declines. The environment is affected by decreased long-term predictability, complicating an organization's strategic planning. Opportunities for large-scale investments become merely irrelevant, since return on investments is less predictable. Sufficient political stability, combined with an effective government enables a strong, straightforward framework for the long term.

ADEQUACY OF LEGISLATION

The extent to which legislation is appropriate to the local circumstances is of considerable importance for a well-functioning drinking water supply sector. According to Lenton (2005) local authorities in particular seem to struggle with inadequate legal frameworks. Appropriate institutions are lacking at all levels, and currently applied institutional arrangements are in many cases insufficient. Inadequate legislation includes for example the inability to apply and enforce quality regulations for the private sector and to provide arrangements for informal settlements. Formal organizations in those cases are disabled to legally deploy activities there.

3.2.3 ECONOMIC ENVIRONMENT

From the economic environment three determining variables are identified that are discussed in this section and are displayed in Figure 11.

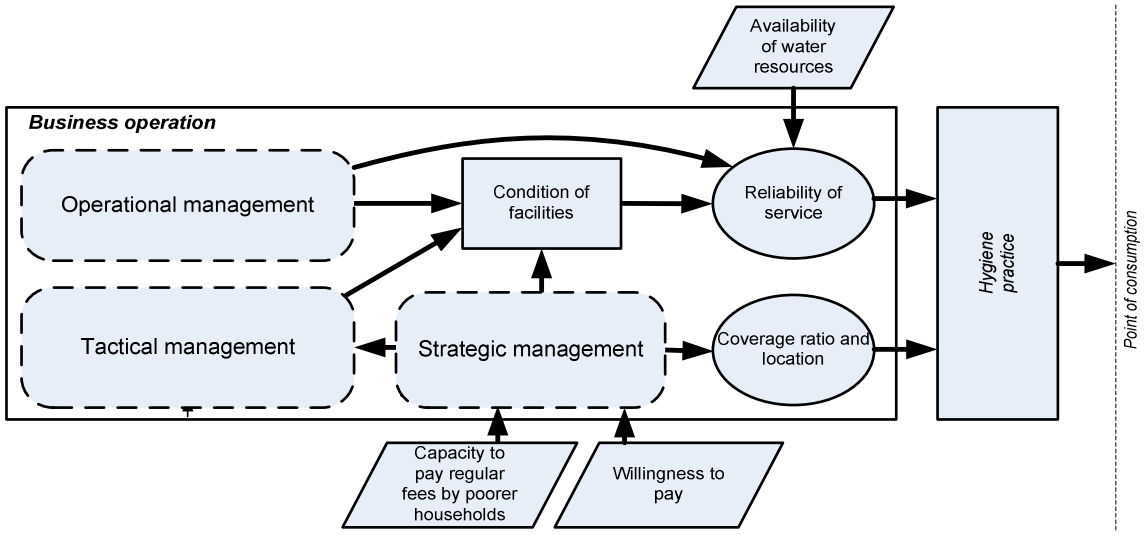

FIGURE 11: INFLUENCE OF THE ECONOMICAL ENVIRONMENT ON BUSINESS OPERATION

The financial balance is of main importance for strategic planning. This balance is partly depending on income from customers. Apart from imposed tariff restrictions, also the capacity and the willingness to pay by customers are determinative. This justifies the formulation of the following determining variables:

- ***Capacity to pay***
- ***Willingness to pay***

Capacity and the willingness to pay for improvements in the service of local drinking water companies can be decisive for strategic allocation of investments, directly influencing the coverage ratio and location. In cases where demand for secondary sources exists, the capacity to pay is likely to determine the medium through which the demand is satisfied. Therefore a causal relation between this variable and the use of secondary sources is included. Furthermore the availability of potable water emerges as an variable from the economic environment that has great effect on the level of service. If water resources are scare, supply services become less reliable. Therefore a third determining variable is included:

- ***Availability of water resources***

CAPACITY TO PAY

The capacity to pay for company supplied water by households is limited for low-income groups. Poorer households will access free sources where possible, even if these produce less reliable water quality (Kjellén, 2006). The major barrier for low income households to access utility-piped water is the cost of connection (fees and materials). Poor households are likely to experience difficulties with monthly payment since they often lack steady incomes (Kjellén, 2006). Although it is suggested by Clark (2004) that economic benefits of increased service levels indirectly safe money for low-income households by time-saving, the threshold is large. The capacity to pay of potential new customers is of strategic importance for the water supply company. Without the perspective of reliable income generation, a water company is likely to be unwilling to invest in new connections (Gadgil, 1998).

WILLINGNESS TO PAY

Although one might possess the capacity, if the willingness to pay is absent, the drinking water company is faced merely with the same consequences: areas where no or little payment for provided services might be expected. The willingness to pay for supply services highly depends on the current level of service and the coverage of the piped supply system. It is mainly based on trust in the company's services. In contrast to the capacity, the willingness to pay can be considered subject to change when the performance of the water company changes. If households are not willing to pay for currently supplied services, operational performance is threatened. When cases concentrate in a certain area, it becomes unattractive for further investments in drinking water networks and maintenance spending since no or little return on investment can be expected (Prasad, 2006). Besides experience with currently provided pipe supply services, reasons for a lack of willingness are multiple. A worrisome reason would be an inadequate level of awareness about the effect of water quality deterioration on public health. This is further discussed in paragraph 3.4 as "hygiene awareness". Other reasons include the presence of reliable secondary sources for affordable prices.

AVAILABILITY OF WATER RESOURCES

The shortage of fresh water that constrains provision of drinking water is frequently considered to be related to a lack of physical availability of raw water. However, UN-HABITAT (2003) mentions that many cities with abundant fresh water still face very inadequate water provision. Biswas (2006) has suggested that in such cases quality deterioration of potable water appears to be the main restricting factor. But reasons for water scarcity can be found in more areas. Sometimes physical availability may actually be a problem. In many cases however, scarcity originates from inefficient practices, over-use of local resources, or unsustainable economical choices for allocation of available water. In some cases for example industry or agricultural activities (irrigation) are able to pay more for raw water than households can or will. The availability of drinking water resources in those cases declines at the expense of economic activities.

3.3 PERFORMANCE OF BUSINESS OPERATION OF THE LOCAL WATER SUPPLY COMPANY

The first two paragraphs have described the role of business operation within the water supply chain and the influences that a developing environment exerts on it. The outcomes of business operation are determining what processes occur beyond the point of supply and how relevant the level of hygiene practice becomes at this point. This paragraph therefore discusses the influence of business performance on the lay-out of the local drinking water sector beyond the point of supply. The adequacy with which a local water supply company is operated that is relevant for the incorporation of microbiological water quality is reflected within Figure 12 by the following two parameters:

1. Level of service (quality, quantity and frequency)
2. Coverage ratio and location

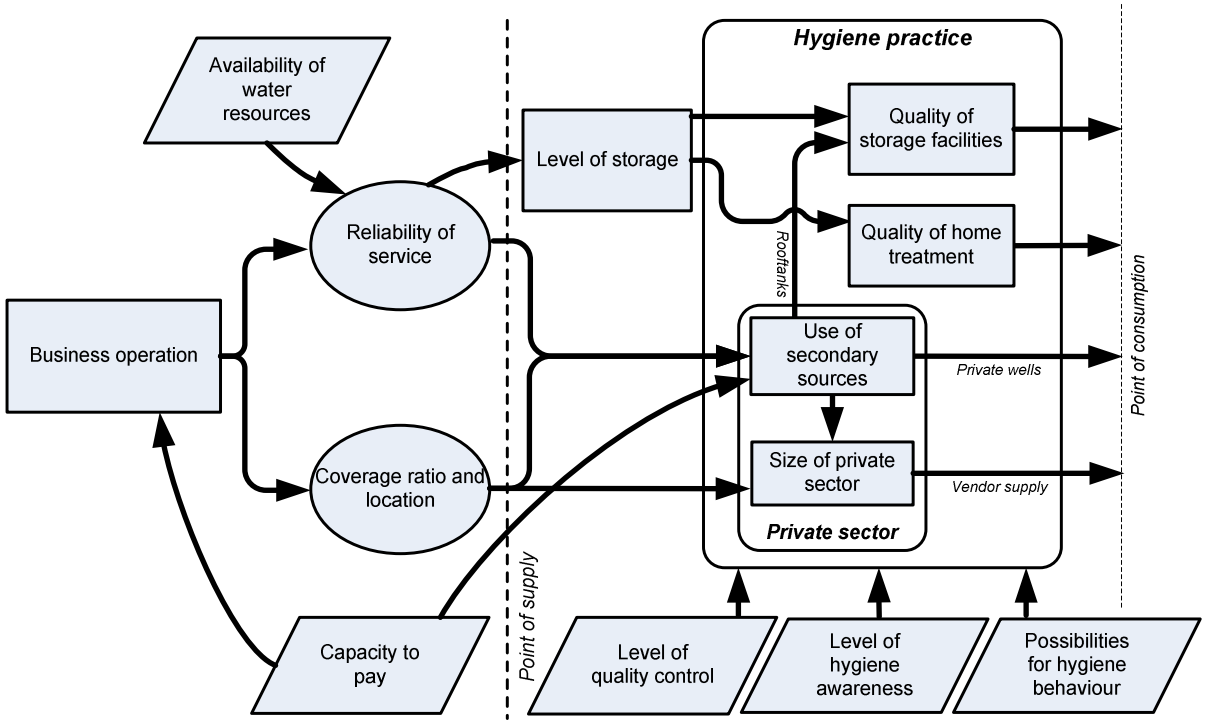

FIGURE 12: CONSEQUENCES OF THE PERFORMANCE OF BUSINESS OPERATION FOR THE WATER CHAIN BEYOND THE POINT OF SUPPLY

The water supply company is considered responsible for water quality up till the point of supply. After the water has been supplied, the drinking water company has no legal obligation to control water quality. However, the influence of the level and coverage of company supplied services reaches beyond their legal responsibility. The performance has a profound effect on the use and safety of other sources. Low levels of service and coverage necessitate longer storage and fetching times. This increases the period between supply and consumption that is exposed to contaminating hazards. Therefore low business performance increases the importance of hygiene practices to curb contamination between supply and consumption. A considerable share of urban households is not connected to the piped supply network of the local water company. They rely on other sources for (a part) of their daily needs. This area is discussed in more detail in paragraph 3.4.

3.3.1 LEVEL OF SERVICE

A service is considered reliable when quality and availability are predictable and adequate. An intermittent supply system faces restricted availability. Services are limited to a few hours per day or only a few days per week or month. Generally this originates from an increasing demand and inadequate management of supply facilities. It is used as a solution to supply more customers, although less frequently. In those cases parts of the network are exposed to low pressure gradients or reversed flow. The level of service is largely determined by

the condition of facilities such as pumps, pipes and treatment installations. Reliability is assessed by determining supply intervals and the variability within these intervals. The WHO has published guidelines (WHO, 2004) for chemical and microbiological quality that are used as performance indicator. Important consequences of unreliable supply services are an increase in home-storage and the use of secondary sources (Howard, 2005; UN-HABITAT, 2003). Coelho (2003) and Tokajian (2003) concluded that home-storage facilities face highest risks for microbiological contamination. A low service level therefore causes water quality to deterioration after the point of supply.

3.3.2 COVERAGE RATIO AND LOCATION

The coverage ratio of the water company's supply network originates from past-time strategic investment choices. The performance of coverage is indicated by the percentage of households that are able to receive piped services from the local water company. Choices are made whether or not to connect or improve supply services in certain areas based on expected return on investment, political interference, and imposed regulations. In general, poorest areas receive least sufficient, or no piped supply services. Since these areas are expected to entail high risks, improvements or expansion in more wealthy areas that are likely to yield higher returns on investment are considered more attractive. Consequently, households within insufficiently served areas develop a demand for secondary sources to ensure daily water consumption against affordable prices. This causes a niche market for small-scale enterprises to develop. These small suppliers often operate in an informal setting without formal papers, licenses, and permits (Howard, 2005; Kjellén, 2006; Conan, 2003). This complicates legal possibilities to involve small-scale enterprises to improve general service levels. Figure 13 displays the roles small-scale enterprises play in the drinking water sector. Typical examples of micro-enterprises that are run by individuals or families are street vendors and private wells (Zeffane, 1995). These small-scale enterprises are working independently with little capital resources and mainly serve lower-income groups, although high-income groups may use private services as a luxury good.

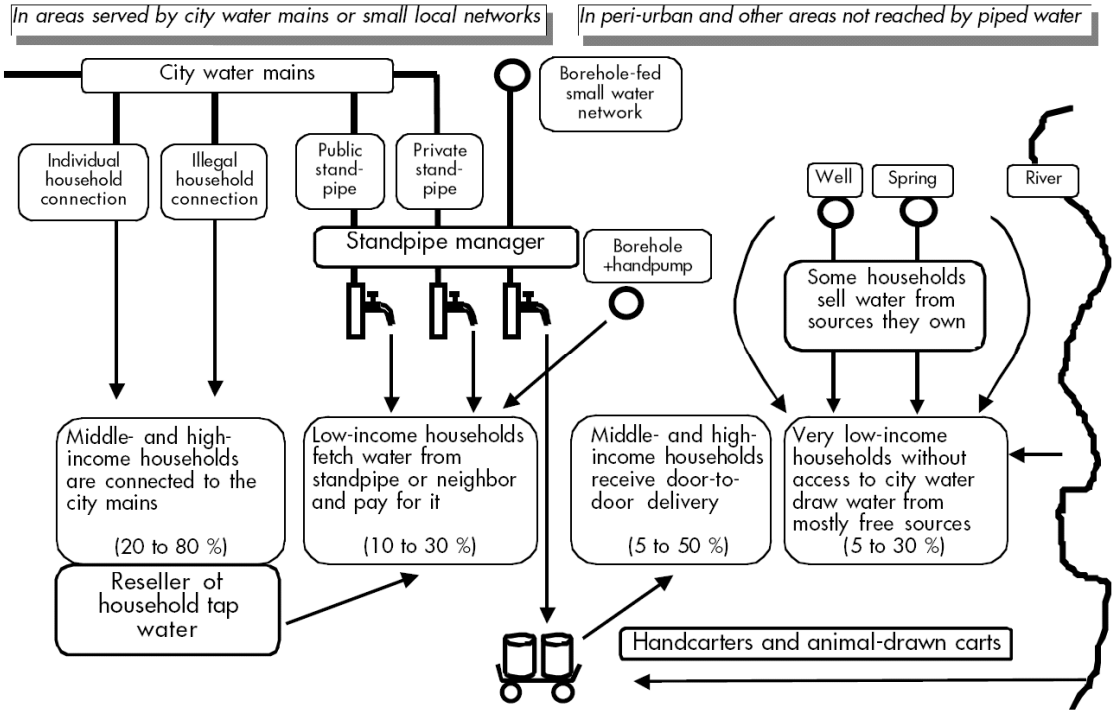

FIGURE 13: SCHEMATIC VIEW OF WATER SUPPLY AND DISTRIBUTION ROUTES (COLLIGNON, 2000)

3.3.3 ASSESSING PERFORMANCE OF BUSINESS OPERATION

The performance of business operation that exerts influence on processes within the water supply chain that are responsible for microbiological water quality can be determined by performance indicators. Based on the last two sections, these are overviewed in Table 5.

TABLE 5: PERFORMANCE INDICATORS FOR THE PERFORMANCE OF THE LOCAL WATER COMPANY'S BUSINESS OPERATION

Business output	Performance indicator
Level of service	Frequency with which water is supplied
	Predictability of supply intervals
	Chemical quality of supplied water, in relation to WHO guidelines
	Microbiological quality of supplied water, in relation to WHO guidelines
Coverage ratio	Percentage of households that is connected to the piped supply system

3.4 HYGIENE PRACTICE BETWEEN THE POINT OF SUPPLY AND CONSUMPTION

Figure 12 presented the implications that the performance of business operation has beyond the point of supply. From the point where water is supplied from the piped network, in less developed economies it is likely to be subject to several hazards of contamination. In fact, paragraph 2.6 suggested the part of the supply chain between supply and consumption to be the most relevant for determination of water quality at the point of consumption. Contamination beyond the piped supply network can occur at the supply point, during transport between supply and homes, during in-home storage or at the point of consumption. All these hazards are related to the level of hygiene that is practiced. Therefore, Figure 12 locates these aspects within the hygiene practice domain. Three variables are identified that determine the level of hygiene practice. They are listed below and are discussed in further detail in the following sections:

- ***Level of hygiene awareness***
- ***Possibilities for hygiene behaviour***
- ***Responsibility for quality control***

3.4.1 LEVEL OF HYGIENE AWARENESS

Recognition of the relation between illness cases and deterioration of drinking water is crucial for the level of hygiene that is practiced. However, a lack of knowledge about causal relations between hygiene and water quality are widely prevalent in developing countries. Quick (1997) for example demonstrated that only 30% of the respondents to his study in rural Bolivia associated dirty water with diarrhoea. Many regarded diarrhoea as a normal occurrence in childhood. Absence of sufficient awareness excludes the possibility to make choices that are necessary for improvement of hygiene practices.

3.4.2 POSSIBILITIES FOR HYGIENE BEHAVIOUR

Although one might have gained the awareness that hygiene behaviour is not sufficient, without the ability to improve practice it is impossible to improve the quality of hygiene practices. If for example households feel that filtration before consumption is necessary, they need the time and money to purchase equipment. An infrastructure to provide and maintain such equipment has to be present. In fact, this determining variable is considered to reflect the extent to which boundary conditions are present for improving hygiene practice.

3.4.3 RESPONSIBILITY FOR QUALITY CONTROL

Paragraph 2.6 suggested that the part of the water supply chain that lies beyond the point of supply lacks responsibility for water quality. The water supply company has no incentive to pay attention to quality control after they supplied the water to their customers. Without the presence of a strong quality controlling body that is able to appoint parties to be legally responsible, quality can simply not be controlled. The private sector, whether on-sellers or privately owned producers, are inclined to base the quality of their water supply on the demand of the market. Since the customers mainly assess the quality of their water on its taste, colour, and smell, microbiological quality is likely to be missed out. This problem is typical for developing economies since developed drinking water systems are able to supply continual good quality through a network with high household connection coverage. This avoids many hazards since the point of supply and consumption practically coincides. No such problem as post supply deterioration is relevant in those cases. For less developed systems, presence of clear responsibilities in whatever shape (guidelines, legislation etc) are

considered to improve the hygiene situation between supply and consumption considerably. Therefore, this element is identified as a determining variable.

3.5 CONCLUSION

Drinking water supply in developing countries experiences severe problems with reliability in terms of microbiological quality. The processes, variables and relations that were identified throughout the chapter are overviewed by the Sector Assessment Diagram (SAD) in Figure 14. Based on the findings in this chapter, three main areas of concern can be formulated that relate to the three domains in the water chain:

- Quality of business operation of a local water supply company that determines business performance
- The level of governance that is applied and acts upon the drinking water sector
- The level and quality of applied hygiene practice

The highest risk for microbiological contamination of drinking water within the water supply chain occurs outside the piped supply system. The time water is exposed to hazards beyond the point of supply determines the severity of the risk for contamination of good-quality drinking water. The length of the period between supply and consumption is largely determined by the performance of business operation. A high level of hygiene practices beyond the point of supply reduces possibilities for contaminating hazards to enter the water supply chain. The third area of concern represents influences from the institutional environment in which a specific water supply chain is located. It determines boundary conditions for a water sector to be able to supply safe water. The level of governance is entirely determined by the public sector.

Throughout this chapter, 15 determining variables have been identified. These are summarized in Table 6. Within Figure 14, the determining variables are represented by the wyber-shaped process elements. The list of variables can be used in Chapter 4 to assess a specific water supply chain on its ability to incorporate microbiological water quality. For this purpose Appendix III presents a scoring index on which the variables of Table 6 can score. This increases understanding about the current lay-out of a local water chain. The results provide a reference framework that enables improved insight in processes that can be influenced.

TABLE 6: DETERMINING VARIABLES FOR ADDRESSING ISSUES

Domain	**Determining variable**
Business operation	Appropriateness of organization structure
	Appropriateness of the management information system
	Appropriateness of incentives
	Level of autonomy at operation level
	Qualification of staff
	Capacity to pay
	Willingness to pay
	Availability of water resources
Governance	Political interference
	Government effectiveness
	Political stability
	Adequacy of legislation
Hygiene practice	Level of hygiene awareness
	Possibilities for hygiene behaviour
	Responsibility for quality control

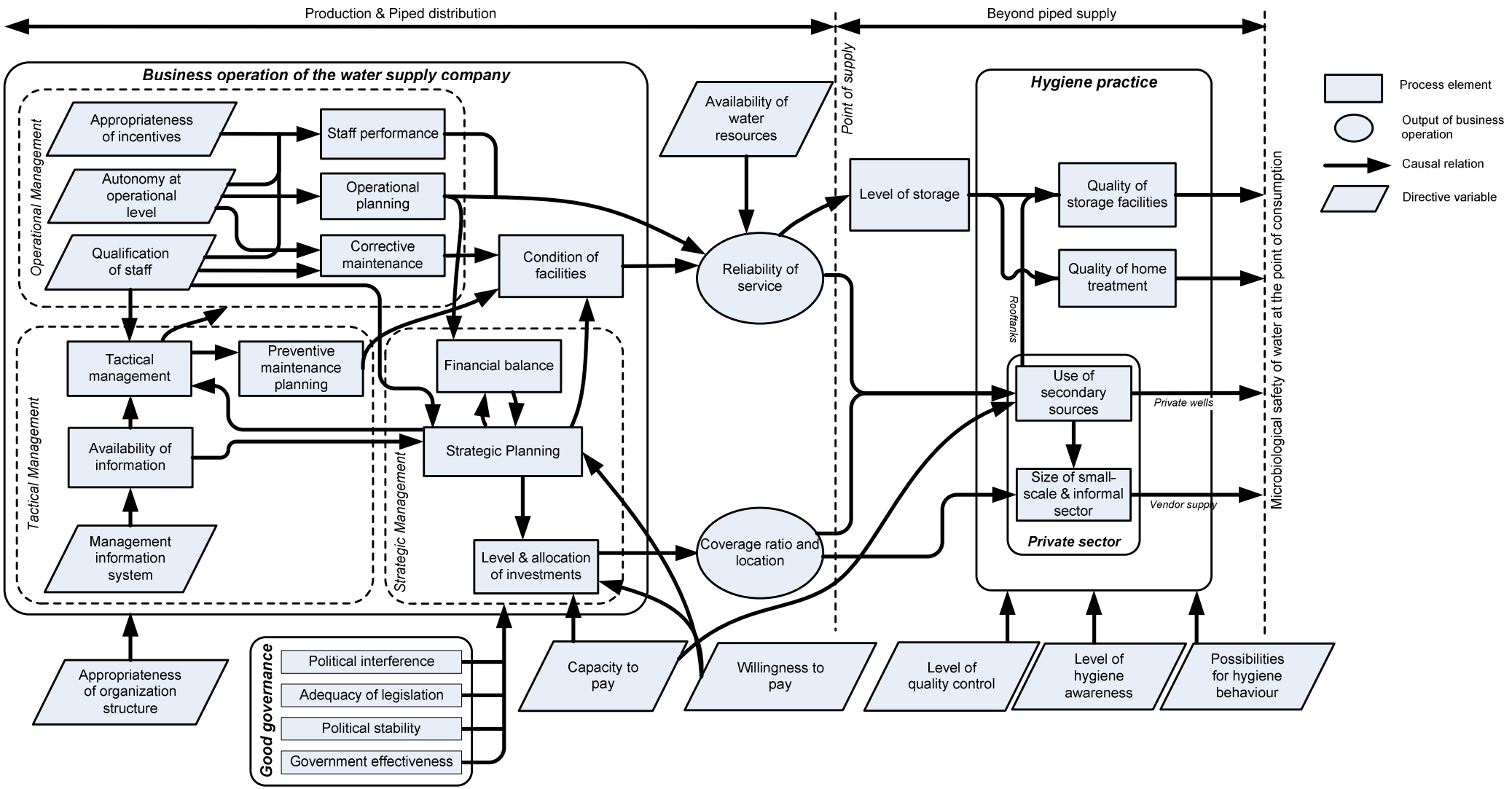

FIGURE 14: SECTOR ASSESSMENT DIAGRAM (SAD) FOR MICROBIOLOGICAL DRINKING WATER QUALITY IN URBAN DRINKING WATER SUPPLY

4 ASSESSING THE DRINKING WATER SECTOR IN TA'IZZ, YEMEN BY USING SECTOR ASSESSMENT DIAGRAM (SAD)

The water supply sector in Ta'izz, Yemen has been studied to verify the SAD that was proposed in Chapter 3. Special attention is given to the local water company: the Ta'izz Water & Sanitation Local Company (TWSLC). To be relevant for VEI, the selection of the case was restricted to locations where VEI performs activities. Microbiological water quality is a serious issue in Ta'izz. Business performance has not improved from the moment VEI started the project in 2006. Low priorities for water quality improvements within VEI's projects has been the most important motivation to formulate this research. The case of Ta'izz provides a typical situation for this problem. This chapter describes the observations that have been made during the field study in Ta'izz. Paragraph 4.1 presents the method that has been used to perform the field research. Paragraph 4.2 briefly outlines the local circumstances in which the drinking water chain of the case study is located. Paragraph 4.3 discusses the observations that have been made throughout the drinking water sector in Ta'izz and TWSLC in particular. Paragraph 4.4 applies the SAD to structure the observations.

4.1 OUTLINE OF THE FIELD RESEARCH

4.1.1 GOAL

The field study has two goals. It aims at determining the performance of the Ta'izz drinking water sector and identifying shortcomings of the model that was proposed in Chapter 3. Since the research object has been limited to one location and time was limited, the results are less complete than desirable for generalization. Since no other verification data are available, the results are being used to determine whether the model is sufficient in this particular case and to only indicate its applicability in other cases.

4.1.2 APPROACH

The Ta'izz drinking water sector is evaluated by application of a scoring index that is based on the variables that were summarized in Table 6. Applied indices can be found in Appendix III. It provides three possibilities to score, specified for each variable. The scores for the case of Ta'izz have been established based on:

- Interviews with employees of the local water company
- Question lists filled in by customers of the local company (see Appendix IV and 1.1.1.1Appendix V)
- Interviews with private producers and distribution shop-owners
- Personal observation during field visits

Evaluation of the model is done by reflecting on the application of the model in the case study. It identifies shortcomings in its completeness and determines the independency of the variables that were used.

4.2 LOCAL SITUATION

4.2.1 YEMEN

Yemen is the only democratic republic located on the Arabian Peninsula (see Figure 15). It is the poorest country in that area with a population of 22 million, mainly concentrated in the mountain chain that splits the country from north to south (CIA, 2007). Its climate is hot and humid on the coast and extraordinary hot, dry and harsh in the Eastern desert. The elevation of the mountains provides a more suitable climate for mankind and agriculture, with seasonal rain showers and more moderate temperatures. Figure 16 provides a map of Yemen with altitude profiles. During the autumn and winter, the

FIGURE 15: LOCATION OF YEMEN IN THE WORLD

country is faced with a long period of drought. The limited arable surface area of 2.9% restricts possibilities for agriculture. Moreover, to yield crop, agricultural areas need irrigation. With an estimated total of 5500 km^2 of irrigated land, the possibilities to feed the fast growing population (3.5% per year) are limited.

THE CITY OF TA'IZZ

The case study has been performed in the city of Ta'izz. With current estimations indicating a population size of 600.000 to 850.000, it is comparable to the two biggest cities of Yemen: Aden and the capital of Sana'a. Figure 16 displays their location in further detail. Lying at an elevation of about 1400 meters, Ta'izz is located in the mountain chain between the west coast and the eastern desert. It faces altitude differences of about 400 meters within city borders. Between 1948 and 1962, this city was the administrative capital of Yemen, being the most southerly area of the former North-Yemen. Currently, Ta'izz is the capital of the governorate of Ta'izz.

FIGURE 16: LOCATION OF TA'IZZ (CIA, 2007)

BRIEF HISTORY

North-Yemen became independent of the Ottoman Empire in 1918. The British, who had set up a protectorate area around the southern port of Aden in the 19th century, withdrew in 1967 from what became South-Yemen. Three years later, the southern government adopted a Marxist orientation. The massive exodus of hundreds of thousands of Yemenis from the south to the north contributed to two decades of hostility between the states. The two countries were formally unified as the Republic of Yemen in 1990. The situation has been stable the last 10 years or so. Nevertheless, friction between northern and southern groups remains tangible. Kidnappings of Yemeni officials and foreign tourists were carried out in the past by unsatisfied tribal groups pressing the government for increased financial support for their districts (Prados and Sharp, 2007).

DEVELOPMENT

With limited natural resources, an extraordinary illiteracy ratio, and high population growth, Yemen faces considerable development challenges. Differences in humanitarian development between countries is indicated by the Human Development Index (HDI) (UNDP, 2004, 2007), which applies a comparative measure of life expectancy, literacy, education, and standards of living for countries worldwide. On this index, Yemen is marked 153th out of 177 countries (UNDP, 2007). Therefore Yemen can be considered a country with low score for human development, comparable with countries like Uganda, Gambia and Senegal. Especially the contrast with its neighbour countries is sharp (Oman: 58th, Saudi Arabia: 61th).

ECONOMY

Oil production accounts for over 70% of government revenues; however, oil reserves are declining and may be depleted entirely in the next decade. Therefore Yemen is largely dependent on external aid from Persian Gulf

countries, Western donors, and international financial institutions. With a total Gross National Product (GNP) of USD 5 billion a year, Yemen ranks 105th out of 206 countries (World Bank, 2000).

INSTITUTIONAL FRAMEWORK

Yemen is a republic with an elected president, an elected House of Representatives, and an appointed Consultation Council. The president is head of state, and the prime minister is head of government. The constitution provides that the president be elected by popular vote from at least two candidates endorsed by Parliament. The prime minister subsequently is appointed by the president. The right to vote is universal over 18 years of age. The last election in 2006 was judged by international observers to be "relatively fair" (Prados and Sharp, 2007). Yemen's current legal system is based on Islamic law, Turkish law, English common law, and local tribal customary law. Since the country is an Islamic state, the Qur'an plays an important role. However, the constitution calls for an independent judiciary. Unlike other Islamic states, the mild stimulant qat is chewed by Yemenis of all strata of society. DORSCH/GITEC (2001) described that due to the unification many government departments were still in an initial stage of their development in 2001. The Ministry of Water and Environment was established in 2003. They formulated a strategic policy paper in which the national water sector strategy and investment program (NWSSIP) is presented for the period 2005-2009 (Ministry of Water and Environment, 2005). In essence it represents the view that the national urban drinking water sector has to be decentralized. The ministry aims at improved financial and regulatory performance and increased coverage levels. Strikingly water quality is not mentioned in the document at all.

PUBLIC HEALTH

Table 7 gives an indication of the health situation in Ta'izz. The number of illness cases with diarrhoeal symptoms is extraordinary. Although a direct relationship between water quality and diarrhoeal diseases is not present, Hutton and Haller (2004) concluded that drinking water and sanitation improvements yield great benefits, mainly by reducing the occurrence of diarrhoeal illness. Therefore the figures of Table 7 are useful to indicate that the magnitude of the water quality, sanitation and hygiene problems in Ta'izz are extensive. It should be noted that only *reported* illness cases are presented. Since poorer households may not have time or money available to see a doctor, the actual number may be even higher. For further background Appendix VI, Appendix VII, and Appendix VIII include information about the occurrence of childhood diarrhoea. Most striking conclusions from this information is that former North-Yemen experience a risk on diarrhoeal diseases that is three to four times as high as its Southern counterpart. Moreover, rural areas face a higher number of diarrhoeal cases, compared with urban areas. A low level of education seems to have a negative influence on the occurrence of childhood diarrhoea.

TABLE 7: PUBLIC HEALTH IN 2003 IN TA'IZZ (CSO, 2004)

Parameter	Data
Estimated total number of residents in Ta'izz	600.000 – 850.000
Total reported illness cases in Ta'izz	227.824
Of which malaria	23%
Of which diarrhoea	68%
Percentage of illness cases that involve N-Enteritis and Blood Enteritis in large high-altitude cities	75%

4.2.2 THE WATER SECTOR IN TA'IZZ

The market for drinking water in Ta'izz is dominated by two parties: *Ta'izz Water & Sanitation Local Company* (TWSLC) and the private market. The following sections describe the processes that are mainly relevant for TWSLC's activities. The phases that were overviewed by Table 1 in Chapter 2 are used for this. The private sector is discussed in the last section as processes beyond the point of supply from the piped network.

PERFORMANCE OF TWSLC

The performance of the business operation is determined by making use of the performance indicators that were provided by Table 5. They are used as a tool to compare the business performance of local drinking water companies at different locations. Data have been gathered to determine the score for the indicators (see Table 8). To provide a reference background within Yemen, data that was obtained during a two day visit to the local water company in Aden has been included.

TABLE 8: BUSINESS OUTPUT PARAMETERS FOR TA'IZZ AND ADEN

Business output	Performance indicator	Aden	Ta'izz
Level of service	Frequency with which water is supplied	Minimal 8-10h a day	One period of 3 days every month
	Predictability of supply intervals	Reliable predictability	Small fluctuations in regular intervals
	Chemical quality of supplied water, in relation to WHO guidelines	Appears to be sufficient	Insufficient
	Microbiological quality of supplied water, in relation to WHO guidelines	Chlorinated sufficiently	Largely uncontrolled
Coverage ratio	Percentage of households that is connected to the piped supply system	+/- 75%	+/- 50%

The company in Aden functions more adequate than TWSLC. The explanation why it differs from Ta'izz is hard to provide, especially since observation possibilities were little. It might be related to the quality of current management that has been in place for a long period. The different nationality before the unification of the Yemens could also be a cause. Aden has been under British influence for a long time, while Ta'izz has always been part of the former North-Yemen, influenced heavily by Arab and Ottoman rulers.

ABSTRACTION

TWSLC water production is solely based on ground water from a few well fields with a total of about 70 operational wells. The well fields can be categorized roughly into three different groups: city wells, wells near the city, and distant wells. The depth from which is abstracted varies per location, but can amount to several hundreds of meters. The best water is produced by the wells in distant locations. At some storage reservoirs, water from other wells with high contamination risks is mixed to reduce average risk. Within the city boundaries, there are several wells that are connected to a reservoir or to the network directly. Many of these wells produce microbiologically contaminated water. A number of wells that are located near the city boundaries are dug next to a wadi. Besides its main function of canalization of run-off water, the wadi is also used as an open sewer. Hence the wells nearby face a highly increased risk for microbiological contamination. Total production of TWSLC amounts about 16.000 m^3 per day, of which 40% can be marked as Unaccounted-for Water (UfW), leaving about 10.000 m^3 of water a day that is accounted for.

TREATMENT

TWSLC treats its raw water marginal. At some places irregular chlorination takes place. To avoid extremes in water quality, a part of the water from different sources is mixed. Consumption of water that is produced at the city wells exposes consumers to a high risk on consuming microbiologically contaminated water that is unreliably chlorinated since equipment is inadequate. Pressure in the network is too high for the current equipment to be able to add a chlorine dose. The other well fields generally receive treatment at storage reservoirs that are located in the city's periphery by chlorination. Although relatively new automatic chlorination systems have been installed at two important reservoirs, these systems are not functioning due to breakdown or erroneous connection. In these cases, chlorine doses that are added have been observed to be inaccurate since the system is replaced by an alternative, manually controlled installation that is fairly inaccurately adjustable.

TRANSPORT AND STORAGE

Water is transported from the city's periphery to smaller storage reservoirs in the city network and to a central reservoir at grounds of the head office. Most reservoirs have been replaced or will be replaced shortly by closed, concrete units that are constructed under supervision of the World Bank. The transport from distant well fields to the city reservoirs can take over 25 kilometers. However, there seems to be few problems with this transportation network. Although elevation differences produce a lot of potential energy, this is not being used optimal. From the city reservoirs, the water is distributed throughout the city network. Transport connections within the city boundaries are insufficient. In many cases, transport and distribution functions are mixed up, resulting in household connections that derive their water from transport mains. It has been observed that closing of a pressure zone is merely impossible since small inter-connections have proliferated.

DISTRIBUTION

The TWSLC distribution network is fed by two different sources: city reservoirs and direct supply from city wells. The quality of the former can be controlled relatively easy, while the latter cannot be observed by any means and therefore is uncontrollable in the current situation. The city is divided into different pressure zones which receive water periodically according to a previously defined schedule. Therefore the timing of supply periods is well predictable by customers. At the point of supply, mainly household connections are installed, although public taps are also to be found. The company has a few large clients, such as the hospital, the army, the presidential palace and the multinational Al Saeed Trading Company. Next to TWSLC provided piped water, the private sector distributes drinking water by the use of tanker trucks and shop-sale in bottles or jerry cans. From the questionnaire appeared that respondents indicated that they value privately supplied water quality higher than piped supply, even though this is based solely on taste and colour. Currently, a considerable part of the network is being replaced under supervision of the World Bank.

BEYOND THE POINT OF SUPPLY IN TA'IZZ

Since TWSLC provides unreliable services of low quality through their piped supply network, their water is less suitable for consumption. Households regard TWSLC's service to be of inferior quality and are highly displeased with its limited availability of one period of three days every month per household connection. But for some it is the only available source. Throughout the city, households use storage facilities to be able to deal with large periods of intermittence. Roof tanks, jerry cans and other smaller in-home tanks are popular for this purpose. The private sector in Ta'izz has responded to the inadequate business performance of TWSLC by offering higher quality water in small quantities for higher prices. The privately supplied water is used for consumption purposes only, in addition to TWSLC supply. It is distributed through an extensive network of private shops and vendors while chlorine or other disinfectants are not applied regularly. The 25 nanofiltration companies are estimated to produce 10% of the TWSLC services. Its price can be as high as 50 times the price of company supplied water.

4.2.3 THE ACTIVITIES OF VEI AND THE RESULTS OF ITS PRESENCE IN TA'IZZ

VEI has been invited by Dutch authorities to support TWSLC wit improving its business operation. VEI´s activities in Ta'izz concentrate at TWSLC by membership of its board of directors. This is achieved by means of a partnership. A project manager of VEI is accommodated in Ta'izz between 2006 and 2009. Specialists from the Netherlands support the project with short-term missions periodically. The project goal is to develop TWSLC towards a sustainable healthy company that is able to operate by self-generated financial resources. VEI designed a new organization structure at the start of the project. The results are defined to include:

- Strong reduction of energy use
- Improved management of drinking and waste water installations
- Reduce staff and training of personnel
- Development of a maintenance program
- Reduction of water losses due to leakage
- Substantial reduction of outstanding payments
- Identification of new water sources

The project started mid-2006 but has not yielded the intended results so far, although some improvements are notable. For example, the CEO has been appointed by an open application procedure and unreliable employees have been fired after an anti-corruption campaign. Moreover, programs have started to reduce outstanding debts, increase production, and provide management information. According to Kingdom and van Ginneken (2005) slow progression is perfectly normal when reforming a drinking water company.

4.3 OBSERVATIONS

The following sections discuss the most striking observations that have been made during the case study. Distinction is made between processes that are related to business operation of TWSLC and those that take place beyond the point where water is supplied from the piped system. Since few observations related to governance were made, this area will be omitted in this paragraph. The results are structured in the next paragraph (4.4) by application of the SAD. Further analysis is performed in Chapter 5.

4.3.1 BUSINESS OPERATION

Many departments within TWSLC are not able to perform as is desirable. The case study concentrated on the quality department. It appeared that a long-term vision with goals and milestones is completely absent. Moreover, despite the presence of a few highly motivated employees that manage the department, the ability to react to operational affairs is weak. Operational tasks are hindered by insufficient availability of materials and equipment, replacement of worn-out parts cannot proceed and imposed quality regulations are not being followed by TWSLC employees. The addition of chlorine is unreliable and in some cases even stopped. Activities are carried out without compliance with hygiene guidelines. The low level of support for expenses to water quality obliges the quality department to renounce activities that are considered to be vital for adequate quality control, such as the execution of microbiological sampling. Although some motivated staff members are present, throughout the company in general the level of motivation is low. A vast share of the employees works only a few hours a day and doesn't show personal responsibility for the tasks they are assigned to execute. Working days from 9.00h till 13.00h are no exemption. During the case study appointments and agreements have shown to be easily neglected. Failing performance is often blamed to external factors, showing a reluctance to commit to company goals. For example, over one third of the company owned cars are confiscated for private use by (former) employees. Besides poor work ethics, a share of the workforce is unqualified for the tasks they have to perform. The most obvious example is provided by the functioning of well-operators. Despite their low level of education, relatives or acquaintances of the land owner are employed by TWSLC to compensate for the use of his land. Some cases are known where these people turned down pumps or chlorination equipment since the noise they produced kept them awake. Other examples of low education levels that have been observed include inability to read maps and mechanics unaware of contamination risks from oil and sewer leakage near drinking water facilities.

4.3.2 BEYOND THE POINT OF SUPPLY FROM THE PIPED NETWORK

From the questionnaire became apparent that households use roof tanks or jerry cans with a capacity of 100 to over 400 liters, being sufficient for a maximum of one to three weeks. Since these households rely on TWSLC supply, they can be filled only monthly. The shortages are complemented by use of secondary sources that are obtained in the private sector or by rain water harvesting. Respondents tend to select their drinking water by its taste. Quality selection therefore is likely to become selection by taste solely. It appeared from an interview with a shop owner that his customers complained that their water tasted like chlorine. Now the shop owner has changed to a provider that only filters the water without application of a disinfectant residual, his customers are more satisfied with the taste. They seem not to be aware of increased risks for microbiologically contamination. Moreover, from the questionnaire appeared a tendency of TWSLC customers to use piped water only for household purposes and not for consumption. The private sector in Ta'izz has taken over the role of drinking water supplier. Water they supply is subject to at least three transfers during distribution from a private treatment installation to the point of consumption. First it is transported by tanker truck from the treatment location to the shop. The shop storage tank is filled every two days or so. The customers fetch their

water in recycled bottles or jerry cans. In some cases, this is transferred to a storage tank within the home. The storage time in-home varies from 0 to 3 days. Altogether it can be concluded that water is consumed one to five days after it has been treated. This period can increase to three or four weeks for piped water.

4.4 STRUCTURING OBSERVATIONS BY APPLICATION OF THE SAD

This paragraph relates the observations that were described in this chapter to causes in the drinking water chain. By using the Sector Assessment Diagram, it discusses how the water supply chain in Ta'izz performs. Therefore each determining variable of Table 6 is awarded a score that corresponds with the scoring index in Appendix III. The highest possible score is 2. This indicates that the variable is supporting the achievement of microbiological quality at the point of consumption very well. The lowest possible score is 0, indicating that the variable is has negative influence on water quality. If a determining variable is considered to have some negative influence with limited implications, a moderate score is awarded: 1.

4.4.1 BUSINESS OPERATION

APPROPRIATENESS OF ORGANIZATION STRUCTURE: LOW (SCORE: 0)

The currently applied organization structure induces centralization of responsibilities that should be located within operational. Staff members that should be engaged with tactical and strategic decisions are occupied with reactive decisions for operational tasks. Consequently, sound tactical planning and formulation of visions and related goals are largely absent within TWSLC-departments. Furthermore, the current structure does not allow sufficient communication vertically as well as horizontally through the company.

PRESENCE OF A MANAGEMENT INFORMATION SYSTEM: LOW (SCORE: 0)

Strategic and tactical managers are not able to adjust activities appropriately despite the many data collected. The absence of a MIS within TWSLC causes information to be processed in different systems, of which many are not digital and lack uniformity. Consequently, knowledge about operating processes that is available is mainly implicit and therefore restricted to personal knowledge of individuals throughout the company. The impossibility of strategic and tactical managers to overview desired information partly explains why they tend to show direct involvement in operational decisions. Absence of an adequate MIS withholds TWSLC possibilities to recognize and predict trends and performance, impeding opportunities for pro-active behaviour. Moreover, adjustments to react adequately on changing circumstances cannot be implemented.

APPROPRIATENESS OF INCENTIVES: LOW (SCORE: 0)

Inappropriateness of incentives can be considered to be an important instigator of observed work ethics that lead to inadequate company performance. Employees receive insufficient incentives to trigger them to increase performance, especially payments are poor. A long period of inadequate human resource management may have created the current company culture in which many employees do not show any involvement in the company's performance. Incentives to motivate employees that have been observed to lack, at least at some places within the TWSLC include:

- Insufficient salary payment
  - Arrears in payment
  - Low level of basic payment
- Lack of authority:
  - Inability to mobilize sufficient manpower for intended amount of work
  - Employees in subordinated positions ignore the manager's authority
- Lack of autonomy:
  - Inability to allocate finances for operations autonomously through a pre-determined budget

Besides these lacking incentives, outstanding results are not being rewarded. In fact some employees that do not show up still receive their salary. Demotivated employees lose their urge to excel and their inspiration easily vanishes. Although exemptions have been observed within TWSLC, generally little motivation is visible.

AUTONOMY AT OPERATIONAL LEVEL: LOW (SCORE: 0)

The current functioning of the quality department can be explained by the low level of autonomy that is awarded by TWSLC's management. Even small scale decisions require approval, becoming apparent in the absence of an operational budget. Throughout the company, strategic management tends to interfere with operational activities, which results in an inefficient organization with reduced flexibility, initiative, and motivation. Within TWSLC, insufficient levels of autonomy are highly related to the quality of management and an inappropriate organization structure. Employees cannot make small-scale decisions independently on the operational level since delegation of responsibility is insufficient.

QUALIFICATION OF STAFF: MEDIUM (SCORE: 1)

Within TWSLC the qualification of staff can be considered an important variable for the low business performance. Especially the lack of management skills makes an important share of the employees on tactical and strategic positions unqualified for their function. Their influence throughout the business operation domain is considerable and therefore can be considered to affect business performance largely. Unqualified staff at the operational level hinders adequate business operation in some cases. In spite of sufficient qualification of a share of the staff, it can be concluded that employees in general have inadequate education and skills to perform tasks they are responsible for.

CAPACITY TO PAY: MEDIUM (SCORE: 1)

A structural insufficient capacity to pay for daily water needs by a certain share of the local population can explain the government's demand for the fixed price levels. The size of the private market in Ta'izz however indicates that a considerable share of households have sufficient capacity to pay. Customers pay up to 50 times as much for privately supplied water as for TWSLC services. Moreover the respondents of the questionnaire indicated that they are able to pay for additional services that are far more expensive.

WILLINGNESS TO PAY: MEDIUM (SCORE: 1)

Inability of TWSLC to deliver good-quality drinking water has caused customers to lose faith in piped supply. They embraced the private sector, which can be partly attributed to a high willingness to pay for improved services. The respondents' reactions from the questionnaire indicate that quality is the most valuable aspect when selecting the drinking water sources. Although households have shown to be highly willing to pay for improved services it is questionable whether TWSLC could benefit from it since confidence in TWSLC services has declined. Therefore this variable is not awarded full score.

AVAILABILITY OF WATER RESOURCES: MEDIUM (SCORE: 1)

During the case study, a lack of sufficient water resources was frequently referred to when disappointing business performance had to be explained. Seasonal water shortages are a normal occurrence in Ta'izz, but general shortages seem to have different origins. A fast growing urban population and applied patterns for water use are more likely to be the cause. Especially the application of irrigation for the cultivation of water intensive crops diminishes availability of water for household use, creating economic water scarcity. The cultivation of the natural stimulant qat, which is chewed by over 70% of the Yemen's population, is rapidly depleting Yemen's water resources (Prados and Sharp, 2007). The current price that is paid by the agricultural sector competes with the price paid by drinking water producers. In addition, inadequate business operation causes inability to employ available water resources. Wells are out of service or are run in ineffectively, UfW percentages are skyrocketing and the potential water source from rain water harvesting is not utilized. Since precipitation tends to accumulate in a few short periods a year, rain water runs off to lower areas with only a small amount available to recharge local aquifers. Altogether it can be concluded that the availability of water at some well fields in certain periods restricts production possibilities to a certain extent. Nevertheless, the large production potential that currently is being omitted seems to be of considerable higher importance.

4.4.2 GOVERNANCE

The restricted availability of time during the case study has necessitated a focus on business operation and

hygiene practices rather than governance. Little data have been found that provide sufficient information about performance of the governance domain. Nonetheless, the following sections describe which score seems to be most appropriate.

POLITICAL INTERFERENCE: MEDIUM (SCORE: 1)

Political influence within the strategic management of TWSLC is apparent. The minister for water and environment is member of the board of directors. He is able to discharge and install the CEO. Recently, the CEO has been replaced by the minister. From this event can be concluded that political interference is occurring within TWSLC. Political actions that have been observed don't seem to aim at personal enrichment, but are coordinated with VEI and solely intend improvements in TWSLC's business performance. The Ministry of Water & Environment aims at decentralization of urban water companies and an increase of their autonomy (Ministry of Water and Environment, 2005).

GOVERNMENT EFFECTIVENESS: MEDIUM (SCORE: 1)

The evident inability of government bodies to enforce legislation that is related to water quality indicates government ineffectiveness. Responsibilities are widespread throughout different authorities and layers of governments, as is displayed by Appendix IX. Tasks and responsibilities overlap, inducing lack of transparency and ineffectiveness. The report of DORSCH/GITEC (2001) mentioned that contradicting interests have caused delays and occasionally hindered vital decision-making in the Ta'izz region. Supervising authorities have not been capable to formulate, let alone enforce quality control impeding corrective interventions from controlling bodies. Although WHO guidelines are defined for Yemen and are mandatory to be applied, they are not enforced. Nevertheless small-scale achievements are visible, such as the conviction of a few employees by a central anti-corruption authority. This indicates the rising of a more effective government that is able to curb corruption. However, strong governmental bodies that are able to control the sector adequately and are able to enforce legislation are still a mirage.

POLITICAL STABILITY: MEDIUM (SCORE: 1)

Political stability in the past explains the moderate level of current institutional development in Yemen. It takes time to establish policies, guidelines and legislation for specific subjects such as water supply. It can be concluded that former political friction has left is marks on the current functioning of the water sector. The current Ministry of Water and Environment for example has only been established in 2003.

ADEQUACY OF LEGISLATION: MEDIUM (SCORE: 1)

The observed lack of quality control in the Ta'izz water sector can largely be related to slow institutional transition after the unification in the early 90's. Legislation and policies are not in all cases clear and straightforward. The weakness of the regulatory framework impedes enforcement of policies and guidelines. In general legislative matters seem to restrict TWSLC in its current process of improving its financial situation. National government imposes a fixed tariff system that allows water companies to yield insufficient income.

4.4.3 HYGIENE PRACTICE

Hygiene practices play an important role for determination of microbiological water quality at the point of consumption. The low business performance of TWSLC has provided a situation with relatively long periods between supply and consumption. Consequently, contaminating hazards outside the piped supply system are provided with great opportunity to affect drinking water quality. The demand for secondary sources originates from dissatisfaction of customers about the following three aspects of TWSLC's services:

- Intermittence of supply through the piped supply system with insufficient frequency
- Relatively low level of connection to the piped supply system
- Insufficient piped water quality, not living up to user's demands

LEVEL OF HYGIENE AWARENESS: MEDIUM (SCORE: 1)

The fact that households prefer taste over microbiological safety is likely to originate from a low level of hygiene awareness and knowledge. If one is not aware of the fact that chlorine tastes indicate increased microbiological safety, one will assess the water as polluted, based on its odd taste. However, microbiological contamination often is not given away by tastes. None of the respondents indicate that they make use of public or company information to inform themselves about the quality of available water sources. However, when asked which aspects are likely to be the cause of the diarrhoeal diseases they suffer, water and food are frequently mentioned as the perpetrators. A basic level of hygiene awareness therefore seems to be present.

POSSIBILITIES FOR HYGIENE BEHAVIOUR: HIGH (SCORE: 2)

The adequacy of hygiene practice in Ta'izz seems not to be restricted by the possibilities that are provided. Cooking gear is abundantly available, as are chemicals to disinfect. Furthermore the market for storage facilities has mushroomed, providing a broad selection of tools for hygienic storage. The purchase of such equipment and materials however require sufficient capacity to pay. Most respondents indicated that they do not feel any need to apply additional treatment. Only one response was related to insufficiency of time or money. Possibilities to improve hygiene behaviour therefore seem to be no restricting factor for achievement of adequate hygiene practice.

RESPONSIBILITY FOR QUALITY CONTROL: LOW (SCORE: 0)

From interviews with privately operated small-scale water producers appeared that a quality control mechanism is absent. Nevertheless, high levels of competition have settled the private water market to an equilibrium with steady prices and competition on service and quality. Therefore, the market is forced to react on the demand of its customers, inducing a situation in which service and quality receive thorough attention. However, consumer's knowledge is not sufficiently developed to let the private sector compete on microbiological quality parameters. In contrast, the public sector aims to achieve WHO guidelines for water quality, but TWSLC is not able to perform accordingly.

4.4.4 PERFORMANCE OF THE DETERMINING VARIABLES IN THE TA'IZZ WATER SECTOR

Table 9 summarizes the performance of the Ta'izz water sector along the variables that were discussed in this paragraph. It can be concluded that "Possibilities for hygiene behaviour" is the only variable that does not restrict adequate attention to microbiological water safety. The variables with the lowest scores affect the business operation domain. The level of governance in general can be considered intermediate. Especially for a developing country, this is a relatively good score. TWSLC's operation seems to suffer from governmental behaviour. Interference by the ministry is not aggravating per se, but fixed prices that are imposed impede increased revenue generation. Low level of government effectiveness affects the ability to enforce central quality control. However, the performance of the level of hygiene practice seems to be moderate in the Ta'izz region. The level of competition within the private sector has enabled a market where small scale enterprises compete on service level and quality performance. Possibilities for hygiene behaviour are plenty and hygiene awareness seems to be developed to at least a basic level.

Low scores for variables within the business operation domain can be related largely to specific inadequacies of staff qualification. In particular the qualification of staff for management positions is inadequate. Since managers within TWSLC largely determine attitudes and performance on lower levels, unsuitability for their job affect staff performance and the quality of aspects such as operation and maintenance considerably. The inappropriate organization structure might also party be related to low capacity of current and former management to design and enforce an appropriate structure. In addition, managers seem to be unable to delegate responsibilities to the level where it is most appropriate.

TABLE 9: PERFOMANCE OF THE TA'IZZ WATER SECTOR

Process domain	Determining variable	Score
Business operation	Appropriateness of organization structure	0
	Appropriateness of the management information systems	0
	Appropriateness of incentives	0
	Level of autonomy at operation level	0
	Qualification of staff	1
	Capacity to pay	1
	Willingness to pay	1
	Availability of water resources	1
Governance	Political interference	1
	Government effectiveness	1
	Political stability	1
	Adequacy of legislation	1
Hygiene practice	Level of hygiene awareness	1
	Possibilities for hygiene behaviour	2
	Level of quality control beyond the point of supply	0

5 IMPROVING PRACTICE

This chapter answers the research questions for the case of Ta'izz, Yemen. It discusses which improvements are necessary to increase incorporation of microbiological water quality in the drinking water supply sector in Ta'izz. Subsequently the current activities of VEI are compared to the needs that are identified. Recommendations are made about interventions that are necessary to improve microbiological water quality in Ta'izz on the long as well as on the short term.

5.1 ASSESSING THE DRINKING WATER SUPPLY SECTOR

5.1.1 IDENTIFYING PROBLEMS

Based on the findings in Chapter 4, the first research question can be answered for the case of Ta'izz:

"What are the main problems faced in incorporating microbiological water quality in the operation of local urban drinking water supply sectors in developing economies?"

Currently, hazards outside the piped supply network determine quality of water at the point of consumption. Aging of water between the point of supply from the piped network or private supplier and consumption is considerable. Two solutions are available that can reduce the impact of the hazards for microbiological contamination: reducing the period between supply and consumption, and improving hygiene practices between supply and consumption. The first method can only be achieved on the long term by improving business performance of TWSLC. This reduces the use of secondary sources, increases the number of household connections and reduces storage times, which is considered necessary to achieve sustainable safe water. The second method is able to yield results in the short-term by improving knowledge about hygiene practices. However, its application is less likely to be sustainable.

Chapter 4 awarded scores to the determining variables of the SAD for the water supply chain in Ta'izz. The largest problems that impede sustainable improvement of business performance are summarized in Table 10. The right-hand column attaches the variables that are necessary to influence when problems are to be solved.

TABLE 10: PROBLEMS IN THE BUSINESS OPERATION OF TWSLC

Operational problems within TWSLC	Determining variables
Little attention for long-term goals	Inappropriate organization structure
	Managers are not suitable for their jobs
Low performance of operational staff	Inappropriate organization structure
	Inadequate motivating incentives
	Low level of autonomy at the operational level
Lack of operational information for informed choices Inability to increase financial position	Absence of a MIS
	Political Interference
	Adequacy of legislation

These problems are mainly caused by the absence of boundary conditions that are necessary for adequate staff performance on operational, as well as management levels. As paragraph 4.4.4 suggested, an important part of these phenomena can be related to the qualification of managers that occupy key-positions within TWSLC. They are unable to delegate responsibilities and prefer dealing short-term matters instead of enforcing long-term goals. This practice increases the risk of TWSLC becoming subject to day-to-day worries instead of achieving strategic goals. In addition, the current situation impedes adequate management due to a lack of operational information since the absence of a MIS disables the possibility to make informed choices. The worrisome financial situation of TWSLC limited availability of budgets for quality improvement. Improvement of this position is impeded by fixed tariffs and limited possibilities to force households to pay their bills, imposed by national governments.

Since the situation in Ta'izz induces that the low level of hygiene practices currently determines water quality at the point of consumption, VEI's currently applied policy is unable to solve the problems in the short term. It focuses on improving business operation and therefore aims at quality improvements for the long term.

5.1.2 FORMULATING SOLUTIONS FOR IMPROVED INCORPORATION OF MICROBIOLOGICAL WATER QUALITY

Based on former conclusions, the second and third part of the research question can be answered:

"*Which solutions can be formulated to improve incorporation of microbiological water quality?"*

"What can VEI do to assist in the implementation of these solutions?"

Since the case study concerns a specific region where VEI is involved, answers for the two questions coincide. Solutions that are formulated in this case are implicitly to be implemented in cooperation with VEI.

Solutions to improve the incorporation of water quality in the water supply sector in Ta'izz can be formulated on two levels. The first level comprises sustainable long-term improvements that require adequate business performance of TWSLC. The currently applied policy of VEI is fairly adequate for this purpose. What lacks is the second level: solving quality issues in the short-term. Currently executed projects by VEI hardly yield quality results in the short term. Currently hygiene practices are decisive for quality at the point of supply. To address problems until long-term improvements become effective interventions need to be implemented that are able to reduce hazards of contamination in the existing situation in the short term. This mainly concerns processes that are included in the domain of hygiene practice. The following sections overview solutions that can be implemented by VEI to relief quality problems in the case of Ta'izz.

LONG-TERM, SUSTAINABLE SOLUTIONS

The currently applied strategy of VEI to improve business performance will have great effect for the incorporation of microbiological water quality in the Ta'izz water sector in the long term. To support current activities and to suggest improvements, Table 11 summarizes the most important improvements that are necessary to achieve sustainable good quality water supply for Ta'izz.

TABLE 11: IMPROVEMENTS TO INCORPORATE MICROBIOLOGICAL WATER QUALITY IN THE LONG TERM

Adjusting the organizational structure to improve strategic and tactical management possibilities and increase staff performance
Improving qualification of managers for their tasks to increase enforcement of long-term strategies and increase staff performance
Providing sufficient incentives to increase staff performance
Increasing autonomy at the operational level to increase staff performance
Implementing an effective MIS to enable informed decision-making

SHORT-TERM SOLUTIONS WITH IMMEDIATE EFFECT

To cover the period until long-term interventions have effect, solutions are necessary that allow immediate increases in drinking water safety in the current situation. This means that interventions are needed that have effect on the private sector and hygiene practices that are applied in general. For this reason Table 12 summarizes determining variables that have to be influenced to improve hygiene practices beyond the point of supply.

TABLE 12: IMPROVEMENTS TO INCORPORATE MICROBIOLOGICAL WATER QUALITY IN THE SHORT TERM

Increasing hygiene awareness
Improving or introducing home treatment
Introducing quality control

5.2 ACTIVITIES OF VEI IN TA'IZZ

This paragraph provides specific recommendations for VEI to improve incorporation of microbiological water quality in its project in Ta'izz. First, current activities are summarized and compared with the identified needs for improvement that appeared form the case study. Based on this conclusion recommendations are formulated.

5.2.1 CURRENT ACTIVITIES

VEI started the project in Ta'izz in March 2006 after a period of exploration and project definition. The goal at that moment was identified as *"Providing better quality water supply and sanitation services to more people in order to increase the number of households that have access to reliable drinking water supply and acceptable sanitation facilities".* VEI intends to achieve this goal by increasing the autonomy of TWSLC through improved business operation and stronger financial autonomy. At the start of the project desired results were identified to achieve this. They are summarized in Table 13.

TABLE 13: DESIRED RESULTS OF THE VEI PROGRAM IN TA'IZZ, YEMEN

Reduction of water losses
Development of a maintenance program
Staff training and capacity building
Improving customer service, billing and collection
Supporting implementation of investment program

Table 14 summarizes the interventions that were observed in the case study to be implemented to achieve these results. However these interventions are not all (yet) effective. Although a new organization structure has been implemented on behalf of VEI, it has not been accepted company-wide and enforcement is lacking strength. Training of employees is incidental and on the job training has not been executed for the present. The implementation of the establishment of a MIS and the strengthening of the GIS department has been started recently. Results however look promising. Large efforts are still needed to improve the transparency of the financial structure of TWSLC since current results are minimal.

TABLE 14: IMPLEMENTED INTERVENTIONS IN THE BUSINESS OPERATION OF TWSLC

Implementation of a new organization structure
Replacement of low performing managers
Improving asset-knowledge by strengthening GIS-application
Improving financial transparency
Establishing a management information system

5.2.2 IDENTIFICATION OF DEFICIENCIES IN ADDRESSING QUALITY PROBLEMS

LONG-TERM

The current project of VEI already covers the most important improvements that were identified in Table 11. A MIS is being implemented, restructuring of the organization has started, and more suitable managers have been appointed to key-positions. Moreover, VEI is involved in the intervention of the anti-corruption authority to provide evidence against corrupt staff and increase transparency. Nevertheless some improvements can be made. Although the qualification of managers has increased by substitutions there is a large potential that has not been used for current managers to increase their skills. Appropriateness of incentives for personnel at lower levels can be increased further, although the current intervention to increase financial transparency is likely to improve boundary conditions to tackle this problem more adequately. The reluctance to reward outstanding performance with increased responsibility and adequate financial compensation can partly be overcome by formerly suggested improvement of management practices.

SHORT-TERM

When short-term improvements in microbiological water quality at the point of consumption are regarded, VEI has not included any of the identified improvements into their project in Ta'izz. The currently implemented interventions are solely intended to improve the business operation of TWSLC and therefore only yield long-term effects on microbiological water quality at the point of consumption.

5.3 RECOMMENDATIONS FOR IMPROVING INCORPORATION OF MICROBIOLOGIAL WATER QUALITY IN THE TA'IZZ' WATER SECTOR

5.3.1 LONG-TERM

Suggested long-term improvements are overviewed in Table 15 and are elaborated in the following sections.

TABLE 15: RECOMMENDED INTERVENTIONS WITH LONG-TERM EFFECT

Establish a long-term vision and strategy for the Quality Department to achieve safer water supply service
Introduce a transparent rewarding system with more appropriate payment structures
Establish an internal training program with priority for management skills

ORGANIZATION STRUCTURE

The currently applied organization structure for TWSLC is not sufficient. For example planning of activities in the Quality Department appeared to be highly inadequate. A long-term vision and a year-to year plan about maintenance, need for investments and operational goals are absent. To improve the functioning of this department, the project proposal *"Professionalization of the quality department"* has been formulated (Koop, 2007a). Implementation of this intervention leads to a long-term vision with milestones that identify sub-goals to achieve the supply of safe water. It mainly focuses on improved execution of management tasks that are related to planning on the longer term and enforcement of hygiene guidelines and regulations. In addition it proposes an autonomous budget for operational expenses.

STAFF PERFORMANCE

Improved HRM policies increase staff performance by application of more appropriate incentives and arranging possibilities for training to increase qualification of staff. In addition to the ongoing improvement of financial transparency it is recommended to introduce a transparent rewarding system with more appropriate payment structures. Outstanding performance needs to be rewarded to provide more motivating incentives. The recommendation to offer internal training programs would be most effectively executed when priority is given to management skills. But other subjects, such as English language, basic mathematical skills, and specific job training could be included in the long term. Managers can be made familiar with more adequate organization structures and experience how to use management tools. They can learn to apply long-term visions with milestones to achieve sub-goals in shorter time periods, such as the use of year planning with according delegated budgets. Further training is necessary to improve delegation of responsibilities to increase autonomy at the operational level. Moreover, executing a management training program group-wise induces better commitment to company goals and increase cooperation within TWSLC, indirectly improving staff performance. The current implementation of a MIS and improved organization structure will eventually improve boundary conditions for adequate management. With better functioning tools, sufficiently skilled managers are able to increase their effectiveness and enhance staff performance.

5.3.2 SHORT-TERM

Effects of current interventions to improve business performance have not been able to increase microbiological water quality at the point of consumption so far. It may be expected that this will take a long time period to have effect (Kingdom and van Ginneken, 2005). Until the long-term strategy has effect, it is recommended to implement less sustainable interventions that have effect on the short term. Therefore it is recommended to implement the interventions that are summarized in Table 16.

TABLE 16: RECOMMENDED INTERVENTIONS WITH SHORT-TERM EFFECT

Rehabilitate and improve two automatic chlorination systems
Replace and extend decentralized chlorination equipment at city wells
Implement a hygiene awareness campaign
Establish a program that awards quality labels and increases transparency about quality differences

IMPROVING CHLORINATION

Current chlorinating installations within TWSLC's network are unreliable. The proposal "*Improving chlorination processes throughout the network*" (Koop, 2007b) recommends two interventions that are relatively easy to implement and yield considerable short-term quality improvement. It proposes the rehabilitation and improvement of two automatic chlorination systems. Furthermore it is recommended to replace and extend decentralized chlorination equipment at city wells. The part of the network that is not suitable for central chlorination need reliable local chlorination facilities. The application of a chlorination residual throughout the TWSLC network improves microbiological water quality at the point of supply considerably.

HYGIENE AWARENESS

Increasing the level of hygiene awareness could optimize processes within the hygiene practice domain. Therefore it is recommended to implement a hygiene awareness campaign. Important elements that are necessary to be effective include knowledge about:

- Consequences of drinking water quality for health
- Means to recognize contaminated raw water
- Influence of hygiene practices on drinking water quality
- Influence of household storage on drinking water quality
- Indication of differences in quality between sources
- Possibilities to improve hygiene within the households

Since female members of households are responsible for the provision of daily drinking water, awareness-raising will be most effective when focused on women. Successful experiences with education-related interventions are known from a demand-driven Indian program that was able to raise awareness about the benefits of sanitation by providing information, education and communication (Department of Drinking Water Supply, 2004). A similar approach could be adopted in Ta'izz. The highly Islamic nature of the local society causes practically all Yemini to visit mosques regularly. It is common practice to wash hands, feet and face before praying, five times a day. This provides some kind of religion-determined hygiene ritual. The prominent position in the local society provides an opportunity to involve mosques in informing the population about hygiene practice and the consequences of consuming deteriorated water.

QUALITY CONTROL

It is recommended to establish a program that allows independent ongoing assessment of all providers in the Ta'izz water supply sector. If a provider is able to live up to defined standards, it receives certification. Awarded certificates can be used throughout the private distribution network by shops that get water from private water companies. In combination with a media campaign, certification provides consumers a tool with which they are able to make informed choices about the selection of water for consumption. For example a comparative list can be published every month or so, indicating the quality of private enterprises. When the system appears to be effective it can be expanded to other cities throughout Yemen. To be successful the following aspects have to be taken care of:

- Independency and reliability of the certification authority
- Cooperation with national and local authorities
- Strong enforcement of regulations to ensure the certification is only used when officially registered
- Frequent check-ups of certified companies to assure reliability of the certification

Regulations that can be enforced for certification could include for example basic parameters such as salinity and pH or guidelines for chlorine residual. Besides this, microbiological parameters are very important to be included, but their assessment requires a more advanced, well-equipped testing infrastructure. The transparency of the Ta'izz water supply sector with well-organized private enterprises is a suitable environment to implement this intervention. It would be most convenient to start certification at the best performing private suppliers. From there certification system can percolate the entire sector. In order to provide accessibility to enterprises that are not able to live up to the highest standards a system is proposed in which distinction can be made between a defined set of quality levels. It is recommended to involve institutions such as KEMA, KIWA or ISO to establish the program.

5.4 RECOMMENDATIONS FOR VEI ACTIVITIES IN GENERAL

Table 17 summarizes the recommendations to improve the incorporation of microbiological quality in VEI projects in general. These recommendations are discussed in more detail in the following sections.

TABLE 17: RECOMMENDATIONS TO IMPROVE INCORPORATION OF MICROBIOLOGICAL WATER QUALITY IN VEI'S PROJECTS IN GENERAL

Policy Principles	Expand projects towards areas of the drinking water sector beyond the operation of the local water company
Project duration	Establish only projects with a strategic project period of between 5 and 10 years
Project definition	Add a water quality goal to project descriptions
	Focus new activities in countries where VEI currently is active

5.4.1 POLICY PRINCIPLES

The policy principles that are currently applied by VEI that were summarized in paragraph 1.1 are based on a strategy that exclusively aims at improving business operation of local urban drinking water companies. Many urban dwellers in developing economies however rely on secondary sources from the private market or fetch their own water from common sources since they are unable to purchase piped water or the quality of piped services is not suitable for consumption. Because improving business operation is a timely process (Kingdom and van Ginneken, 2005), VEI's current policy is only suitable to addresses quality problems in the long term. Until sustainable interventions have effect on the water quality at the point of consumption, households remain dependent on their current (unreliable) resources. To be able to influence this situation it is recommended to adopt the possibility to expand projects towards areas of the water supply sector outside the business operation of the local water company. This increases the effect of the presence of VEI on the quality of locally consumed water in shorter notice. Interventions beyond the point of supply are likely to sort effect in shorter time. They intend to optimize the current situation without willing to change the present processes and relations. Since these interventions do not provide a sustainable safe situation, they are to be executed next to the currently applied long-term strategy.

5.4.2 PROJECT DURATION

The long-term project objectives that are applied by VEI generally are not realistic to be achieved within the current project duration. Sustainable changes in the business operation of drinking water companies take a considerable period to become effective. Therefore it is recommended to establish only projects with a time frame that is suitable to the nature of the objectives. To continue current policies, this implicates a strategic project period of between 5 and 10 years.

5.4.3 PROJECT DEFINITION

The current projects that are executed by VEI do not always explicitly identify quality performance goals. Without realistic and explicit performance objectives it is likely that quality focus diminishes. Depending on the local situation, it is recommended to add a water quality goal to the project description. For example "improving public health through the decrease of contamination risks of waterborne diseases" could be adequate in many situations. To incorporate such a goal it is recommended to expand the focus of the

preliminary executed assessment from business operation towards the entire local sector. This could include for example the role and functioning of private enterprises and hygiene behaviour within households. The presented SAD in Figure 14 can provide foothold for this. The extended focus opens up possibilities to improve water quality at short notice. Moreover, desired partnerships can be identified with actors that are able to influence essential processes locally.

VEI's influence on regional or national issues is limited when it's only active locally within a country. Especially changes in the institutional environment are difficult to achieve. In many cases national authorities are required to obtain desired changes in the local supply sector. To be able to deal with this, it is recommended that VEI focuses its activities to a limited number of countries to become an important player in the national water sector. Where possible future expansion of VEI's activities is concentrated in areas where currently projects are executed. In those cases governments can be influenced more to reckon with VEI's advice and demands. The most important benefit would be the acquiring of sufficient autonomy to enable adequate actions to increase business performance. For example governments can adjust their demand for fixed tariffs in certain cases. Eventually the reach of VEI's influence beyond the business operation of a local company towards its environment strengthens. Consequently, effectiveness of actions increase and the chance to achieve desired project results increases.

6 EVALUATING THE SECTOR ASSESSMENT DIAGRAM (SAD)

This chapter discusses experiences that have been provided by application of the SAD in the case study of the Ta'izz water supply sector. Conclusions are drawn about its applicability and completeness. Paragraph 6.4 concludes with suggestions for further research to improve the model further.

6.1 USING THE SAD

6.1.1 COMPLETENESS OF THE MODEL

During the case study the SAD was used to structure and analyze problems and bottlenecks. For this case the business operation and hygiene practice domains were able to describe and explain the phenomena that were encountered adequately. The governance domain was not considered extensively. Consequently, its completeness cannot be assessed.

6.1.2 RIGHTNESS AND INDEPENDENCY OF DETERMINING VARIABLES

Although the model seems to be fairly complete, this does not indicate that determining variables are independent and are not correlated. Correlation between the variables however cannot be determined based on one case study. Therefore the following sections discuss this issue qualitatively.

BUSINESS OPERATION

Throughout this thesis it appeared that "Qualification of staff" is related with many processes within the entire business operation domain. Employee performance on all levels is highly dependable on this variable. Moreover, some other variables are likely to experience influence by "Qualification of staff". Its current notation suggests differently. Therefore it is placed outside the domain and is considered to act in the same manner as "Appropriateness of organization structure". Correlation is expected between certain variables. "Autonomy at the operational level" for example partly depends on the type of organizational structure and managerial quality of certain employees. An appropriate and adequately enforced structure stimulates autonomy at appropriate levels. Although qualified staff is desirable, it cannot be considered a necessity for an appropriate organization structure or for adequate levels of autonomy. Furthermore, "Adequacy of the MIS" may partly depend on the organizational structure that is applied. Although an appropriate organization structure is likely to yield an adequately functioning MIS, the presence of such a structure is not a prerequisite.

HYGIENE PRACTICE

In contrast with business operation, the hygiene practice domain is not naturally defined. Business operation comprehends all processes the local water supply company is responsible for. The hygiene practice domain is considered to include all processes between the point of supply and consumption, including secondary source supply. This group of processes lacks joint characteristics, except for the fact that they all are located outside the piped supply system. Since their influence on water quality is determined by the role hygiene plays in each specific case, its name is considered to cover its functionality. However it does not make explicit that the domain includes all processes outside the piped supply system. This can be improved. In addition, two independency issues can be identified for the directing variables that act upon this domain. "Possibilities for hygiene behaviour" is heavily related to "Capacity to pay". However, households that are able to pay for sufficient hygiene boundary conditions still require availability of equipment and materials (such as filters, boiling equipment, soap etc). Since availability is not depending on an individual's capacity to pay, the variable "Possibilities for hygiene behaviour" cannot be replaced completely by "Capacity to pay". Instead, a causal relation between "Capacity to pay" and "Possibilities for hygiene behaviour" is added to the SAD. Besides this, it has been observed that a lack of quality control from a central body is entirely dependant on low effectiveness of involved governments. This justifies the addition of a causal relation from "Government effectiveness" directly to the hygiene practice domain. The causality arrow in the model is given the annotation "Level of quality control and enforcement" and replaces the variable "Level of quality control".

GOVERNANCE

The determining variables within the governance domain are likely to show some correlation. For example "Government effectiveness" and "Adequacy of legislation" show some relation, while they are both influenced by "Political stability".

6.1.3 GENERALIZATION DIFFICULTIES

The results that were provided by the case study in Ta'izz, Yemen are difficult to generalize for some aspects. Yemen is an Islamic country where practically all male Yemenis visit a mosque regularly. Only a small share of the developing countries has such a strong Islamic focus that controls its society. Hence some behavioural aspects are difficult to generalize. Furthermore, the large elevation differences within the Ta'izz city borders are fairly unique and cause very specific demands on infrastructure. It complicates generalization of the technical part of operational activities. Next to this, generalization of production deficiencies is hindered by the precipitation pattern. It does not provide a typical situation for a developing context with inadequate drinking water supply. Moreover, water for consumption purposes is mainly provided by the private sector in Ta'izz. Although this is not unique for developing countries, the level of organization and the high quality compared to public supply might not be found in every case. The relatively transparent and extensive market for secondary sources of good quality cause problems in generalization of matters that are related to hygiene practice and the position of the local water company compared to the entire water market.

6.2 APPLICABILITY

The case study demonstrated that an assessment of a drinking water sector with application of the SAD provides an indication about the situation in a local urban water supply chain. The variables are used to structure observations of processes and phenomena to provide a snapshot of the local water supply sector. Their application improves basic understanding about processes that determine microbiological quality at the point of consumption. It yields leads for the design and implementation of effective interventions. Drawbacks of SAD include absence of straightforward data that is unambiguous and easy to interpret. The specific scores that are generated for the determining variables do not indicate the level of influence of each individual variable for water quality which hinders practicality in the interpretation of its results. This limits applicability of the SAD to a tool that can be used during an assessment only, rather than a method on its own. A possibility to prioritize bottlenecks among the determining variables would increase applicability. In addition the possibility to identify performance indicator for the level of hygiene practice increases understanding about the local situation. However, the SAD in its current existence can be used by VEI to support their local drinking water sector analysis before committing to a project. It could increase predictability of the implication of suggested interventions and strategy for microbiological water quality at the point of consumption. Moreover, the SAD can support identification of boundary conditions that are necessary for incorporation of water quality on specific locations or within specific projects.

6.3 IMPROVEMENTS TO THE SAD

The changes that are suggested throughout this chapter are summarized in Table 18 and processed with red colour in Figure 17.

TABLE 18: PROPOSED CHANGES TO THE SAD

Move the variable "Quality of staff" outside the business operation domain
Replace the variable "level of quality control" by a causal relation between the variable "Government effectiveness" and the Hygiene practice domain
Adding a causal relation between "Capacity to pay" and "Possibilities for hygiene behaviour"

From the fewness of additions and changes to the model can be concluded that the proposed model was fairly complete and correct to overview the situation in Ta'izz. In this case the verification of the model can be considered successful for the domains of business operation and hygiene practice. However, is recommended

that the SAD is also applied by another individual. This reduces the influence of the biased view of the constructer of the model.

6.4 FURTHER RESEARCH

Recommendations for further research that are discussed in the following sections are overviewed in Table 19.

TABLE 19: RECOMMENDATONS FOR FURTHER RESEARCH

Explore possibilities to extend the SAD towards a method that can be applied independently to assess a local water supply sector
Design a hygiene performance indicator
Repeat the validation process by another person to exclude the SAD-constructor's bias
Determine correlation between the variables in the SAD by performing more case studies
Determine relations from the institutional environment in more detail
Determine the relevance of recommendations for the case of Ta'izz for other projects
Identify interventions that are easy to implement and directly increase microbiological water quality at the point of consumption

6.4.1 APPLICABILITY OF THE MODEL

In its current being, the SAD is not able to uncover long-term dependencies. It basically provides a snapshot of the current situation, which does not directly yield information about the causes behind the development of that specific situation. The SAD provides a few leads on which identification of areas for interventions can be based. The applicability of the model can be enhanced greatly by further research for possibilities to extend the model towards a method that can be applied independently to assess a local water supply sector instead of being a tool only. This necessitates the ability to describe the weight of the variables for influencing microbiological water quality in the local chain. Moreover, it needs to be able to distinguish short-term and long-term mechanisms. To improve easy understanding of its results it is recommended to design a hygiene performance indicator which reflects the hygiene situation of a local water supply sector, preferably at different locations.

The current model has been verified in only one case study by the constructor of the model, which includes a bias in the analysis. Applicability of the SAD would be greatly improved when it is verified with execution of additional case studies. Preferably these are executed by one or more persons that were not involved in the construction of the model.

6.4.2 CORRELATION BETWEEN VARIABLES SUGGESTED BY THE MODEL

To be able to apply the model more accurately, the correlation between the variables need further research. Several internal dependencies may be possible. It would be desirable for a good functioning of the model that the variables are independent. Ideally, this is done by an extensive field study that considers several different situations in a wide array of countries.

6.4.3 GOVERNANCE

This thesis was not able to determine and verify the influence of the institutional environment on the capacity of the drinking water supply chain to improve microbiological water quality sufficiently. Therefore further research is necessary to determine relations from the governance domain throughout the water supply chain in more detail.

6.4.4 IMPROVING QUALITY

The thesis has suggested interventions to improve quality incorporation for the case of Ta'izz. Further research can be done to determine whether these recommendations can be applied in other projects of VEI. In addition further research is suggested to identify uniformly applicable interventions that are able to increase water quality at the point of consumption in the short-term and are easy to implement.

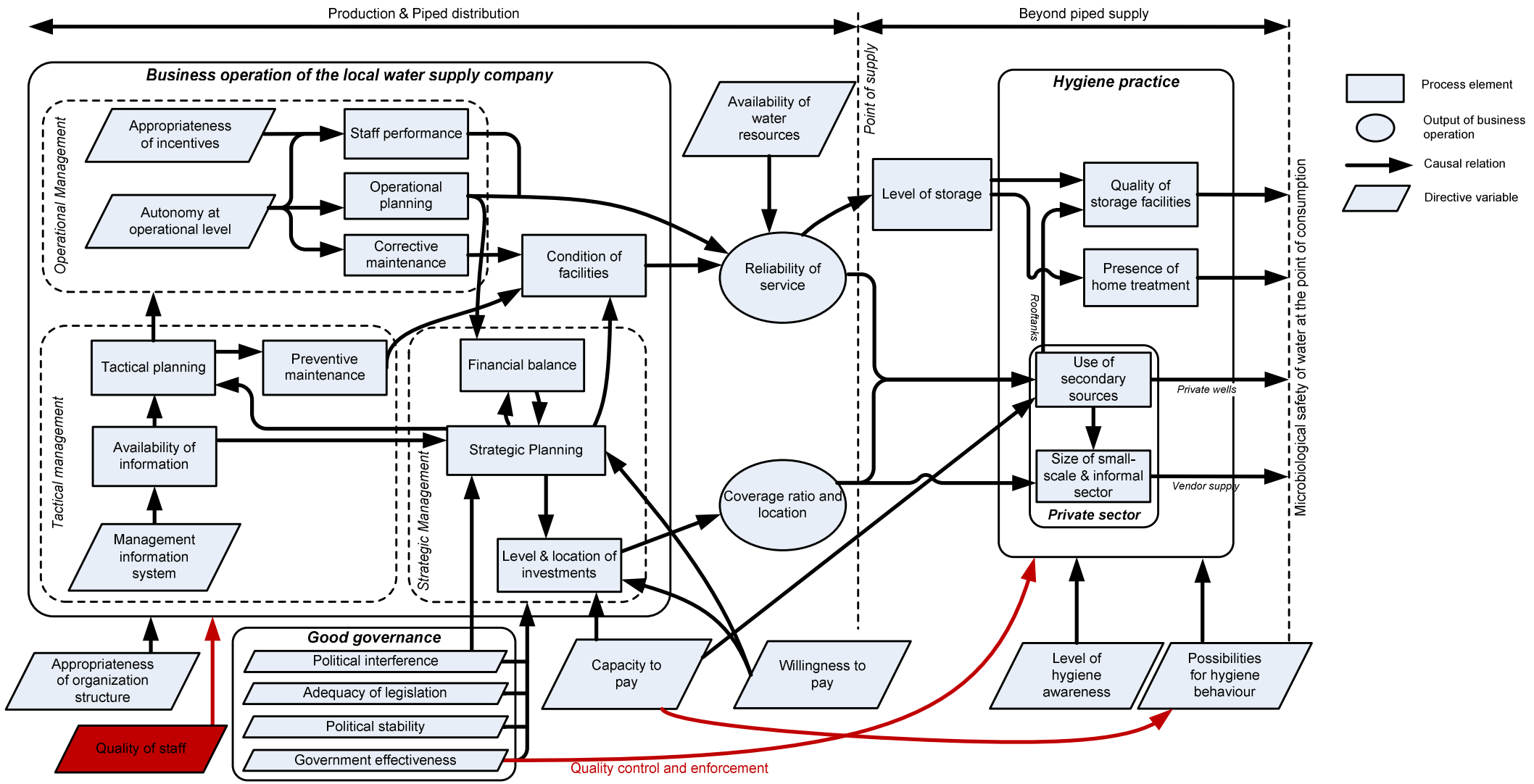

FIGURE 17: IMPROVED SECTOR ASSESSMENT DIAGRAM (SAD) FOR MICROBIOLOGICAL DRINKING WATER QUALITY IN URBAN DRINKING WATER SUPPLY

7 CONCLUSIONS & RECOMMENDATIONS

7.1 CONCLUSIONS

The goal of this thesis is to determine why it appears to be so hard to get microbiological water quality incorporated in the operation of an urban drinking water supply chain in developing economies and to formulate interventions to improve this situation. During the research, close attention has been paid to the role Vitens-Evides International (VEI) plays in achieving improved incorporation of water quality. The first research question to achieve the goal was formulated as follows:

What are the main problems faced in incorporating microbiological water quality in the operation of local urban drinking water supply sectors in developing economies?

To answer this question, the Sector Assessment Diagram (SAD) has been formulated (Figure 17). It provides 14 determining variables to structure observations that are made during the assessment of a local drinking water supply sector. Application of the SAD provides an indication of possible bottlenecks in a local water supply chain. The research question asks for a more general answer than can be provided by the performed research. The research question asks for a more general answer than is provided by the detail level of the performed research. Nevertheless, a number of conclusions can be drawn from the findings.

First of all, physical contaminating events that cause microbiological degradation of water quality can occur at two places in the water supply chain. The first place is within the local drinking water company. This means that contaminating hazards occur between the point of abstraction of raw water and the point of supply of drinking water from the piped network. The second opportunity for microbiological contamination hazards is located outside the piped network, beyond the point of supply. In many developing economies the latter category determines the level of water quality at the moment of consumption since periods between supply and consumption are often considerable. Aging water is exposed longer to potential hazards, providing more opportunity to deteriorate. Especially insufficient application of hygiene practices between supply and consumption impose great risks on public health. The long periods between supply and consumption are caused by inadequate availability of safe drinking water sources. Service levels are low, with intermediate supply of too little, low quality water with an insufficient coverage ratio. This necessitates the application of home-storage facilities or purchase of water from secondary, private, and sometimes informal sources. It is concluded that for most developing economies the inability to reduce time between the point of supply and consumption and the inability to apply adequate hygiene practices are the most important cause for insufficient incorporation of microbiological water quality. In areas where household connection ratios are relatively high, the use of secondary sources low and the application of household storage is unnecessary, quality of company supplied water becomes determinative for water quality at the point of consumption. Insufficient incorporation of water quality issues in those cases are related to the local company's operational performance. Piped network is maintained inadequately or treatment methods are insufficient.

The research included a case study of the drinking water sector in Ta'izz, Yemen. The results of this study support the answer to the second research question:

Which solutions exist to improve this situation?

Application of the SAD model during the case study provided leads for the design of interventions. It can be concluded that two solution paths are available that can reduce the impact of the hazards for microbiological contamination: reducing the length of water aging between supply and consumption, and improving hygiene practices between supply and consumption. Currently applied policies by VEI utilize only the first solution path. Microbiological water quality issues are only addressed as an implicit goal on the long term by increasing business performance of the local water company. In the long term this yields benefits for water quality throughout the entire local sector since time between supply and consumption is reduced considerably.

Consequently, the need for storage and secondary sources declines. The quality of company-supplied water in that case becomes more relevant for safety of water at the point of consumption than the level of hygiene practices between supply and consumption. Adequate business performance of the local supply company eventually addresses the quality problems in the sector. However, this takes a long period to become effective. Therefore application of the second solution-path becomes attractive. Improvement of hygiene practices between supply and consumption are likely to solve largest quality problems in the short-term. Interventions that originate from this strategy take away or reduce the influence of contaminating hazards beyond the piped network. These hazards mainly occur within the domain of hygiene practice. Therefore it can be concluded that short-term interventions prerequisite interaction with determining variables that have influence on the level of hygiene practice.

7.2 RECOMMENDATIONS

This paragraph is engaged with recommendations for VEI to improve incorporation of microbiological water quality in their projects. This provides an answer to the third and last research question:

What can VEI do to assist in their implementation?

The recommendations that are formulated aim at three different areas. In the first place suggestions are made to improve the current policy and strategy of VEI in general to allow better incorporation of water quality in their activities. Secondly recommendations are provided to achieve that objective for the case of Ta'izz specifically. Conclusively recommendations are made for further research to be executed.

7.2.1 IMPROVING INCORPORATION OF MICROBIOLOGICAL WATER QUALITY IN VEI'S POLICY

Currently VEI's policy aims at improving business operation of local drinking water supply companies. This goal eventually improves the incorporation of microbiological water quality in a local urban water supply sector in a sustainable manner. However, improvements in the business operation of a local company take a long period to become effective. Since VEI's project strategy does not explicitly include short-term incorporation of microbiological water quality, households in areas where VEI is active are likely to keep facing the same quality issues during the first years of VEI's presence. Table 20 provides recommendations how this situation can be tackled. In essence it is concluded that VEI changes the way it executes projects. Formulation of water quality goals in project proposals are not sufficiently explicit and detailed elaboration is often missing. The duration of VEI's projects is short, compared to the time it takes to achieve intended objectives of its current strategy. To become more suitable to the nature of the applied strategy of improving business operation it is recommended to increase project duration to a strategic level of 5 to 10 years and to formulate more specific water quality objectives that are elaborated in detail in project proposals.

Next to the currently applied strategy to improve business operation, it is recommended to apply a strategy that allows interventions beyond the local water company's activities. This provides possibilities to implement measures that are able to influence microbiological water quality at the point of consumption on the short term. Application of this short-term strategy increases the effectiveness of VEI's presence in a local water supply sector considerably. Application of this strategy also addresses the need for immediate action to reduce urgent quality deficiencies in the short term in addition to the sustainable benefits on the long term.

TABLE 20: RECOMMENDATIONS TO IMPROVE INCORPORATION OF MICROBIOLOGICAL WATER QUALITY IN VEI'S PROJECTS

Improvements to optimize the current strategy
Establish only projects with a strategic project period of between 5 and 10 years
Focus new activities in countries where VEI currently is active
Improvements to incorporate short-term effects on microbiological water quality
Expand projects towards areas of the drinking water sector beyond operation of the local water company
Add a water quality goal to project descriptions

7.2.2 RECOMMENDATIONS TO INCORPORATE WATER QUALITY IN TA'IZZ

In general VEI is on track to improve the situation in the long-term by increasing business performance. What is worrisome is the absence of short-term improvement of microbiological water quality at the point of consumption. To overcome this problem interventions are recommended that are grouped under the denominator "short-term". All recommendations for the case of Ta'izz are summarized in Table 21.

TABLE 21: RECOMMENDATIONS TO IMPROVE INCORPORATION OF MICROBIOLOGICAL WATER QUALITY IN VEI'S PROJECTS

Long-term improvements
Establishing a long-term vision and strategy to achieve microbiological safe water supply by the Quality Department
Introduce a transparent rewarding system with more appropriate payment structures
Establish an internal training program with priority for management skills
Short-term improvements
Rehabilitation and improvement of two automatic chlorination systems
Replace and extend decentralized chlorination equipment at city wells
Implement a hygiene awareness campaign
Establish a program that allows independent continuous assessment of all providers in the Ta'izz water supply sector and awards quality labels

7.2.3 FURTHER RESEARCH

The recommendations for further research focus on improvement of the SAD. When executed the applicability and reliability of the model increases. The recommendations are summarized in Table 22.

TABLE 22: RECOMMENDATIONS FOR FURTHER RESEARCH

Explore possibilities to extend the SAD towards a method that can be applied independently to assess a local water supply sector
Design a hygiene performance indicator
Repeat the validation process by another person to exclude the SAD-constructor's bias
Determine correlation between the variables in the SAD by performing more case studies
Determine relations from the institutional environment in more detail
Determine the relevance of recommendations for the case of Ta'izz for other projects
Identify interventions that are easy to implement and directly increase microbiological water quality at the point of consumption

7.3 REFLECTIONS

The WHO has produced many publications describing guidelines for the drinking water supply sector to provide safe water to its customers (water quality parameters, coverage ratios etc). They focus on ideal situations and preferred performance of these sectors locally. This thesis focuses rather on an analysis of the processes that are responsible for the situation as a sector is encountered. Why are processes performed as they are, and why is it so difficult to incorporate water quality as an important objective in drinking water supply? This approach provides an addition to currently available literature since it aims for practicality. The model that has been constructed can be used by drinking water companies world wide that are experiencing difficulty in incorporating microbiological water quality in their projects in urban developing areas.

In this research the construction of the SAD was seminal to gain understanding about the relations as they can be found in many urban water supply sectors in developing economies. It is likely that without the model the results that are presented in this thesis would not have been as straightforward as they are. In fact, I was not surprised by any of the observations that were made throughout the case study; while I actually was surprised about the fact that I did not encounter any surprises. Before verification of the model had started I would have thought that it would show several shortcomings since the model entirely originates from literature sources, beforehand the verification I expected the model to be shortcoming for practical application. However, it

provided a very convenient reference framework which enabled explanation of the observations that were made. Results that were encountered could be related to the processes behind them that are less visible in first instance.

The interviewed people in Ta'izz are most likely to be a member of the more wealthy part of the local population. This shortcoming could have biased the findings on certain elements, because this group is likely to possess a higher capacity to pay then many other households. The current results indicate that the demand for secondary sources automatically transforms to use of these sources. However, if a group could have been included that has a low capacity, the results could have been significantly different. Moreover, the influence of language difficulties can be large since specific terms had to be used to obtain information

Altogether the research was able to achieve the goal that was formulated at the start of the research. Reasons why it is hard to incorporate microbiological water quality in urban water supply in developing economies have been determined. It was concluded that the current policy of VEI is largely adequate to solve this problem, however only in the long term. The recommendations that were provided are likely to be adequate to improve the current situation. However, this research has only focused on the role of VEI. It would be a great achievement if actions and interventions for other actors within local supply chains can be identified as well.

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APPENDICES

Appendix I ABBREVIATIONS AND GLOSSARY

bicameral legislature	In government, bicameralism (bi + Latin camera, chamber) is the practice of having two legislative or parliamentary chambers. Thus, a bicameral parliament or bicameral legislature is a legislature which consists of two chambers or houses. Bicameralism is an essential and defining feature of the classical notion of mixed government. Bicameral legislatures tend to require a concurrent majority to pass legislation. (Wikipedia, 2007)
HDI	Human Development Index
hydraulic integrity	The level of risk a piped supply system faces, regarding maintenance of correct pressures and hydraulic regimes to prevent infiltration of contamination due to under-pressure or backflow
ISO	International Standardization Institute
local water company	The company that provides water supply, mainly through their piped network, often being (formerly) government run
maintenance	Activities aimed at keeping existing capital assets in serviceable condition, e.g. by repairing water distribution pipes, pumps and public taps
MDGs	Millennium Development Goals
nanofiltration	A method to filter particles and substances from raw water by pumping water through fibers, based on the difference in molecular structure between different materials
NWSSIP	National Water Sector Strategy & Investment Program (Ministry of Water and Environment, 2005)
operation	The procedures and activities involved in the actual delivery of services, e.g. abstraction, treatment, pumping, transmission and distribution of drinking-water
physical integrity	The level of reliability of infrastructure regarding physical defects such as actual leakages
point of consumption	The point where the drinking water is consumed by household members
point of supply	The point where water is supplied by the local drinking water company from their piped network
potable water	Water that is considered safe to drink
residence time	The time between entry and exit of the drinking water supply system
small scale enterprises	Small companies that operate on the local private market, often being run by a family or household
TWSLC	Ta'izz Water & Sanitation Local Company

UfW	Unaccounted-for Water: the percentage of water that is produced by the local water company but cannot be accounted due to physical or administrative losses
wadi	River valley in dry areas that receives little water during the year, but is used to transport large run-off quantities in wet periods
waterborne diseases	Diseases that are caused by pathogenic microorganisms that are directly transmitted when contaminated drinking water is consumed (WHO, 2004)
WHO	World Health Organization

Appendix II OPERATION OF URBAN WATER SUPPLY

SERVICE OPTIONS FOR URBAN WATER SUPPLY (COATES, 2005)

Service options
Individual house connections with various pressure regimes and frequency of water supply. Water is usually obtained from a tap in the house.
Individual yard connections at various pressure regimes and frequency of supply, where water is obtained from a tap outside the house. The house may not have internal plumbing.
Shared (yard) connections at various pressure regimes and frequency of supply (with a few households sharing one connection).
Stand posts: communal/public points where many people collect water. Stand posts are usually without an attendant and water is provided for free.
Water kiosks: communal/public water points, technically similar to 'stand posts' where people buy water from a person who sells it from the kiosk. A utility, private operator or community group may manage the water kiosk and sell water at a predetermined price per container.
Supply by vendors using various modes of transport such as bicycles, hand carts, animal-pulled carts and motorized delivery vehicles (trucks) to deliver water to consumers.
Supply by water tankers by the utility or a private provider (especially in cases of water shortages).

POSSIBILITIES TO OPERATE AN URBAN WATER SUPPLY IN A DEVELOPING ENVIRONMENT (COATES, 2005)

Operating options
Utility managed (e.g. contracted tap attendants, kiosk operators)
Shared management (e.g. community committees or community-contracted tap attendants manage water points and charge individual users at the point of collection; the revenue is used to pay the public service provider for the bulk supply)
On-selling (e.g. household connection where the house owner pays the utility water bills but takes revenue from sales of water to neighbours)
Privately managed kiosks (e.g. small water enterprises).
Community management (e.g. hand pumps).

Appendix III SCORING INDEX FOR DETERMINING VARIABLES

	Score		
Determining variable	**0**	**1**	**2**
Appropriateness of organization structure	Highly inappropriate or no organization structure	Sub-optimal structure that impairs performance	Organization structure is fairly optimal
Appropriateness of the management information system	Not present	Present, but doesn't work sufficiently	Present and working sufficiently
Appropriateness of incentives	No motivation visible	Personnel shows moderate motivation	Personnel shows high motivation
Level of autonomy at operation level	All actions need authorization	Operating staff are allowed to make small decisions	Authorization present to execute operational tasks independently
Qualification of staff	No or inadequate education and skills for performing responsible tasks	Basic education with sufficient skills for performing responsible tasks only	Sufficient education and skills for outstanding performance on responsible tasks
Capacity to pay	No capacity to pay	Limited capacity to pay	Unrestricting capacity to pay
Willingness to pay	No willingness	Willingness to pay a limited extra amount	Strong willingness to pay for improvements
Availability of water resources	Availability of water is restricting production	Locally, water is scarce and production is lightly affected by its availability	More water is available (sustainable) than can be exploited
Political interference	Strongly influencing strategic planning	Limited influence on strategic planning	Negligible influence on strategic planning
Government effectiveness	Authorities are unable to perform actions effectively	In some cases, authorities are able to enforce legislation with effective actions, but continuance is still absent	Authorities perform actions to control situations adequately and enforce legislation
Political stability	Unstable institutional environment with frequently changing legislation	Fluctuations in political attitude that influence the water sector to some extent	Consistent political attitude with reliable legislation
Adequacy of legislation	Legislation hinders execution of activities and investments	Legislation is not adequate, but does not hinder execution of activities and investments	Legislation supports performance of activities and investments
Level of hygiene awareness	No awareness about the consequences of hygiene behaviour perceivable	Basic understanding of the relation between hygiene and illness	Full understanding of the consequences of the level of hygiene applied
Possibilities for hygiene behaviour	No possibilities to improve hygiene	Limited possibilities for hygiene improvement present	Unlimited possibilities to improve hygiene
Level of quality control beyond the supply point	No control on quality is applied	At certain places, quality is controlled	A quality control program is in place

Appendix IV QUESTION LIST HYGIENE AND HEALTH

Demographic						
1a	How do you live?	alone	with wive	with wive and children	with parents	with family
1b	How many persons live in your household?	1-2	3-4	5-6	7-8	> 8
1c	Of which are children under 16 years of age:	0	1	2	3	> 3
Basic hygiene						
2	I wash myself:	< 1 time a month	monthly	weekly	daily	
2a	I am satisfied with this frequency	yes	no			
3a	Do you wash your hands on certain moments?	yes	no			
3c	How often in total?	more than 5x a day	1-5x a day	daily	different:	
4a	Is soap available within your household?	yes	no			
4b	Do you use it?	never	sometimes	always	for washing only	
5	Is there anything you want to change within your household?	no	yes, namely:			
Water use						
1a	Do you receive water from the Ta'izz water company?	daily	weekly	monthly	less	
1b	I use it for:	everything	drinking	cooking	washing	other
1c	How would you describe the quality of this water?	good	reasonable	bad	unusable	
1d	This is based on:	colour	taste	smell	public information	different:
2a	Which aspects are important for selecting your water source?	price	quality	reliability of availability	different:	
3a	Do you have sufficient water available in your home?	yes	no			
3b	Where do you get your water, when you need more?	private well	neighbour	water vendor	private enterprise	different:
2a	How would you describe the quality of this water?	good	reasonable	bad	unusable	
2b	This is based on:	colour	taste	smell	public information	different:
4a	Do you use a storage facility in your home?	yes	no			
4b	How do you store your water?	rooftank	smaller vessel	jerry cans	bucket	different:
4c	How many days does your storage last at maximum?	< 1 week	1-2 weeks	2-3 Weeks	> 3 weeks	
4d	Can you estimate how many litres the capacity is?					
5a	Do you feel it is necessary to treat your water before use?	yes	no			
5b	Do you treat your water before use?	yes	no			
5c	Why (not)?					
5d	Which method do you use?	cooking	filtering	chlorine	different:	
Health						
1a	How many times do you suffer from diarrhoea?	weekly	monthly	< once a month	never	
1b	How many times does your wife suffer from diarrhoea?	weekly	monthly	< once a month	never	
1c	How many times do your children suffer from diarrhoea?	weekly	monthly	< once a month	never	
1d	How many days does it last in general?	less than 5	5-6	7-8	9-10	
2	Which aspects do you think are the cause?	air	food	water	none	different:

Appendix V SCORES FOR QUESTION LIST HYGIENE AND HEALTH

Demographic		**no answer**							
1a	How do you live?	0%	wive and children	83%	with parents	8%	with family	8%	
1b	How many persons live in your household?	0%	3-4	25%	5-6	50%	7-8	25%	> 8	8%
1c	Of which are children under 16 years of age:	0%	0	17%	2	8%	3	42%	> 3	25%
Basic hygiene									
2	I wash myself:	0%	weekly	25%	daily	25%	more than once a day	50%	
2a	I am satisfied with this frequency	0%	yes	83%	no	17%			
3a	Do you wash your hands on certain moments?	0%	yes	58%	no	42%			
3c	How often in total?	0%	more than 5x a day	75%	1-5x a day	17%	daily	8%	different:	
4a	Is soap available within your household?	0%	yes	83%	no	17%			
4b	Do you use it?	0%	never	0%	sometimes	50%	always	17%	for washing only	33%
5	Is there anything you want to change within your household?	0%	no	58%	Yes	42%			
Water use									
1a	Do you receive water from the Ta'izz water company?	0%	daily	0%	weekly	8%	monthly	92%	
1b	I use it for:	0%	drinking	0%	cooking	8%	washing	67%	other	42%
1c	How would you describe the quality of this water?	0%	good	0%	reasonable	17%	bad	75%	unusable	8%
1d	This is based on:	0%	colour	8%	taste	92%	smell	17%	other	8%
2a	Which aspects are important for selecting your water source?	0%	price	25%	quality	58%	reliability of availability	17%		
3a	Do you have sufficient water available in your home?	0%	yes	17%	no	83%				
3b	Where do you get your water, when you need more?	0%	private well	50%	neighbour	8%	water vendor	42%		
2a	How would you describe the quality of this water?	0%	good	17%	reasonable	0%	bad	67%	unusable	17%
2b	This is based on:	0%	colour	25%	taste	75%	smell	25%	public information	17%
4a	Do you use a storage facility in your home?	0%	yes	100%	no	0%				
4b	How do you store your water?	0%	rooftank	83%	smaller vessel	8%	jerry cans	17%		
4c	How many days does your storage last at maximum?	0%	< 1 week	8%	1-2 weeks	50%	2-3 weeks	17%	> 4 weeks	25%
4d	Can you estimate how many liters the capacity is?	17%	< 200	25%	200-400	25%	> 400	33%		
5a	Do you feel it is necessary to treat your water before use?	8%	yes	50%	no	42%				
5b	Do you treat your water before use?	17%	yes	0%	no	83%				
5c	Why (not)?	33%	no care	33%	no time	8%	to expensive	8%	no tools available	17%
5d	Which method do you use?	67%	cooking	25%	chlorine	8%				
Health									
1a	How many times do you suffer from diarrhoea?	0%	weekly	8%	monthly	8%	< monthly	58%	never	25%
1b	How many times does your wife suffer from diarrhoea?	25%	weekly	8%	monthly	17%	< monthly	42%	never	8%
1c	How many times do your children suffer from diarrhoea?	17%	weekly	33%	monthly	17%	< monthly	8%	never	25%
1d	How many days does it last in general?	58%	less than 5 days	8%	5-10 days	17%	> 10 days	17%		
2	Which aspects do you think are the cause?	0%	air	0%	food	33%	water	50%	don't know	17%

Appendix VI OCCURRENCE OF CHILDHOOD DIARRHOEA DURING THE CENSUS OF 1991 IN YEMEN (DHS, 1994)

Number of children	Having diarhoea during investigation		Background of characteristics
	during the last 24 hours	during the last two weeks	
			age of child by months
718	17,3	30,1	< 6
802	21,1	42,3	6-11
1256	21,9	44	12-23
1429	19,2	37,3	24-35
1321	12,6	28,2	36-47
1188	11,3	25,1	48-59
3427	18	35,3	male
3288	16	33,5	female
1113	12,2	26,3	urban
5602	18	36	rural
5793	19	38	North-Yemen
922	4,5	12,1	South-Yemen
			education of the mother:
5939	17,8	35,9	illiteracy
306	11,3	23	lowest level of education
211	8,2	17,4	basic level of education
58	9,6	18,8	reading and writing
202	13,7	29	not specified
6715	17	34,4	total

Appendix VII SIDE EFFECTS OF CHILDHOOD DIARRHOEA DURING THE CENSUS OF 1991 IN YEMEN (DHS, 1994)

Number of children	Side effects suffered from diarrhoeal disseases				Background of characteristics
	vomitting	fever	dehydration	blood/slime	
					age of child by months
216	54,4	67,9	28,7	11,3	< 6
340	61,6	79,7	41,3	19	6-11
553	56,1	77,5	36,2	20,7	12-23
532	47,1	73,7	34,4	26,3	24-35
372	52,5	74,7	36,3	24,9	36-47
298	50,1	77	41,9	30,7	48-59
1210	53,2	74,9	35,8	23,8	male
1101	53,2	76,2	37,4	21,8	female
293	41,2	61,1	25,3	16,4	urban
2018	55	77,6	38,2	23,8	rural
2200	54,2	77	37,5	23,4	North-Yemen
111	33,4	47	17,8	11,8	South-Yemen
					education of the mother:
2134	54,2	76,2	37,2	23,7	illiteracy
70	44,6	61,7	20,8	11,3	lowest level of education
37	25,3	46,3	13,8	5,7	basic level of education
11	*	*	*	*	reading and writing
59	52,5	86,2	50,1	21,3	not specified
2311	53,2	75,5	36,6	22,8	total

Appendix VIII SEVERITY OF CHILDHOOD DIARRHOEA DURING THE 1991 CENSUS IN YEMEN (DNS, 1994)

Total %	Severity of diarhoeal dissease				Background of characteristics
	not mentioned	unknown	Strong	little	
					age of child by months
100	1,6	0,8	44,6	53	< 6
100	1,7	1,1	52,5	44,7	6-11
100	0,7	0,8	51,5	47	12-23
100	1,2	1,4	51,3	46	24-35
100	2,1	0,6	49,3	47,9	36-47
100	2,4	1,7	53,1	42,8	48-59
100	1,5	1,3	49,4	47,8	male
100	1,5	0,8	52,4	45,3	female
100	0,7	1	41,1	57,2	urban
100	1,6	1,1	52,3	45,1	rural
100	1,4	0,9	51,8	45,9	North-Yemen
100	2,5	5	31,4	61,1	South-Yemen
					education of the mother:
100	1,5	1,1	51,8	45,7	illiteracy
100	1,7	0,9	36,2	61,2	lowest level of education
100	0	2,1	22	75,9	basic level of education
100	*	*	*	*	reading and writing
100	4,1	1,6	55,2	39,1	not specified
100	1,5	1,1	50,8	46,6	total

Appendix IX PUBLIC AUTHORITIES ENGAGED WITH RESPONSIBILITIES REGARDING WATER SUPPLY (DORSCH/GITEC, 2001)

Institution	Tasks
Ministry of Agriculture and Irrigation	Irrigation project development and management; agricultural extension
Ministry of Public Health	Health care provision, disease prevention and management
Ministry of Electricity and Water	Regulatory authority for public electricity corporation and NWSA
NWSA	Development and operation of water supply and sewerage systems in urban areas
NWRA	National water resources investigation, development and monitoring
Dept. of Environmental Health	Monitoring of water quality and other public health matters in respect to the existing public health legislation