Provision of Safe Drinking Water for All

Water Safety Plans for Rural Water Supply
A resource manual
Safe Drinking Water for All Programme

Water Safety Plans for Community Water Supply
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The provision of safe drinking water is a major challenge. The Pakistan Council of Research in Water Resources (PCRWR) is undertaking a country-wide comprehensive assessment of drinking water systems: the results indicate that coverage of drinking water systems is in many districts low to medium, that non-functionality of drinking water systems is high and that the water quality of the functioning drinking water systems is all but satisfactory.

The challenge of providing safe drinking water is not limited to the performance of the drinking water supply systems. It is also a matter of the quality of the source and the safe handling of water at consumers level. Excessive use of groundwater for instance has seriously affected the quality of groundwater and has increased the incidence of water-borne diseases. PCRWR undertook a countrywide program of water quality monitoring from 2001-2006. Under this program a monitoring network was established from where water samples were collected and analyzed once every year for aesthetic, chemical and bacteriological parameters. The results indicate serious contamination in many cities. Four major water quality tribulations found in the drinking water were bacteriological (68%), arsenic (24%), nitrate (13%) and fluoride (5%). These contaminations have serious impacts on the consumers.

Based on the recommendations of the PCRWR, the Government of Pakistan has initiated a project "Provision of Safe Drinking Water for All". Training of professionals engaged in the provision of water to the community is the most important component of this programme. To cater the needs of the programme, the PCRWR in collaboration with UNICEF, METAMETA developed this manual to be used for both trainers and trainees. I commend the efforts of the PCRWR staff, UNICEF and METAMETA for preparing this excellent manual and hope that it will help planners, policy makers and executors to provide safe drinking water to the community – by guiding the development of water safety plans for the different drinking water systems. I wish a success to the MetaMeta team in achieving the uphill task to imparting training in the vital field of water supply.

Sabih-ur-Rahman
Chairman PCRWR
1. Introduction

Safe drinking water supply is an issue of great importance in Pakistan – socially and economically. The Strategic Environmental Assessment for Pakistan estimates the loss to the economy because of bad quality drinking water to be a staggering PKR 112 Billion (Euro 1 Billion) due to high mortality and morbidity and the loss of productivity (World Bank, 2007). Pakistan is making efforts to achieve the Millennium Development Goals (MDGs), but actual coverage of people with access to improved water supply systems is considerably less than MDG statistics suggest. This is due in the first place to non connection to improved drinking water systems: this ranges between 10-90% per district. The second issue is the high non-functionality of piped drinking water systems in rural areas and small towns, estimated by PCRWR at 34% in Punjab, 60% in Sindh, 20% in NWFP and 44% in Balochistan (see also annex 1 for an overview per district). For the country as a whole non-functionality of drinking water systems stands at 37%. This is higher than many countries in Africa and not at all in line with Pakistan’s economic status. The situation is even more dramatic because many handpump operated deepwells are also not operational and few of the functioning systems provide water that is safe for human consumption.

To change this situation major efforts will be needed including:
- Improvements in sector organization and enabling environment
- Strengthening of management and maintenance of systems
- Better cost recovery
- Better understanding of the risk involved in poor water quality
- Rehabilitation of deteriorated systems
- Capacity building at all levels
- Increase of investments

Figure 1.1  Urgent action is needed as many water supply systems are not functioning
The government of Pakistan has initiated different activities to help change the situation. One of these initiatives is the project ‘Provision of Safe Drinking for All’ which is implemented by the Pakistan Council for Research on Water Resources (PCRWR) since 2006. This project includes a training component for professional staff working in the water sector. To strengthen the capacity building effort in this project a request from PCRWR to Nuffic was granted for the establishment of a tailor made training programme to help improve the quality of this nation-wide training. For the implementation of this programme a team of MetaMeta has been selected. This team developed and tested the programme and materials in consultation with PCRWR and UNICEF.

The main orientation of the developed training programme is to help communities to get access to safe drinking water. This is urgently needed as the incidence of water borne diseases is very high in Pakistan and the extensive survey carried out by PCRWR shows that very few water supply systems provide safe water supply. Hence a lot of effort is required in which sector staff has to help communities to better understand the situation and improve the water supply conditions.

The training programme embraces the concept of water safety plans as an appropriate response to combining the work that PCRWR is doing in further developing the surveys in piped water supply systems with an approach to help communities to find practical solutions to prevailing water quality problems. The extensive surveys carried out by PCRWR so far show that hardly any action is taken at community level to help communities understand the problem of water quality and possible options for water supply improvement from source to consumption - including measures such as household water treatment. The emphasis is on ensuring that people get access to safe drinking water from available piped water supply systems or other alternative sources. The programme embraces practical measures to improve the situation looking both at short term (often more household focused) and long term (more water source and system based) solutions. The programme was developed partly on the basis of existing training materials related to water supply in rural communities and small towns.

Two main target groups for capacity building were identified:

- Senior/ middle-level managers, in particular sector staff of Local Government and other support organizations. This includes Nazim, naib Nazim, Tehsil Municipal Officer (TMO), Tehsil Officer Infrastructure, Executive Engineers/ SDOs of the Public Health Engineering Departments (PHED), representatives of CC-B (Citizen Committee-Board), Tehsil Nazims.
- Technicians level with direct links with the Village Development Association and water operators. This includes sub engineers at TMA and District level as well as Community Development Officers (CDO) of PHED. The objective of this training is to prepare these staff in developing water safety plans.

This resource manual was developed as background reading for both courses. The manual and the references to further reading are also of relevance to a broader group of sector professionals who want to better understand prevailing problems and potential solutions in the sector.

It is important to underscore that training is not a panacea but only one aspect that needs to be improved. Participants in the first training workshops confirmed that communities face different problems in sustaining their systems. Village Development Associations or Water Management Committees are supposed to take care of the day-to-day management of the systems, but receive little support and are generally ill-equipped to handle the sometimes complex systems. As a result system fall-out is high and there is little attention for hygiene and sanitation aspects or source protection – both being very important for sustained performance. Some of these systems need
Indeed considerable financial resources to be improved, but in other cases in fact low cost solutions can be found to quickly ensure access to potable water.

Community Water Safety Plans (CWSPs) are at the heart of this manual and training programme. A CWSP is an effective means of consistently ensuring the safety of the different water supply systems in a community. It involves a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from source to consumer, based on the existing consumption patterns and water sources.

Good and safe water supply, proper sanitary facilities and safe hygiene behaviour are crucial for the health and well being of mankind. Unfortunately according to the World Health Organization (WHO) over 85 million people in Pakistan (37% of the population) do not have access to safe drinking water. Other sources give even higher percentages and taking into account that many water supply systems are not functioning as shown in the nation wide survey of PCRWR the number is considerably higher.

Water borne and water related diseases are taking a considerable toll in Pakistan. Some 20 to 40% of the hospital beds are occupied by patients suffering from water related diseases (UNICEF 2004). Diseases such as cholera, typhoid, dysentery, hepatitis, giardiasis, cryptosporidiosis and guinea worm infection are about 80% of all diseases and cause 33% of deaths (Tahir et al, 1994). Dawn April (2004) suggests that in Pakistan 30-40% of all reported diseases and deaths occur because of the use of poor quality water and every fifth citizen suffers from illness and diseases caused by polluted water. Presently 7 million cases of Hepatitis B and C have been registered in Pakistan.

This grim reality makes it very urgent to develop CWSPs with clear actions to improve the water supply systems. In many cases immediate actions may particularly relate to simple and concrete actions which users can undertake themselves to get access to safe water and to practical improvements which operators and the community can make in their water supply systems, where needed with external support.
2. Water supply and water resource protection

This chapter discusses a number of key concepts related to sustainable community water supply. It includes a conceptual framework, key themes and indicators, and an overview of the actors involved with emphasis on the community dimension and gender perspectives. It includes a review of the roles of different actors and explores the need for an enabling environment to make community water supply a feasible and sustainable option. Main sources used for this section include Galvis (1999) and Visscher (2006).

2.1 Searching for Sustainable Solutions

The main trust of the concept of Sustainable Development is that activities by the present generation should neither compromise the resources, nor the environmental conditions of future generations. Others give a somewhat different interpretation by stating that a development programme is sustainable when it can provide an appropriate level of benefits over an extensive period of time after the financial, administrative or technical support of an external agency has ended (OECD/DAC, 1988, cited by MDF, 1992). Warner (1990) presents the same concept, orienting it more to the community level by stating that ‘the success or sustainability of a project is achieved when it meets its objectives and is maintained by its users over a significant period of time’.

A more comprehensive definition of sustainable water supply and sanitation systems is presented by Visscher et al. (1997):

A water supply or sanitation system is sustainable when it
- provides an efficient and reliable service at a level which is desired;
- can be financed or co-financed by the users with limited but feasible external support and technical assistance;
- is being used in an efficient way, without negatively affecting the environment.

Sustainability is an enormous problem
In drinking water supply, sustainability is an enormous problem and an all too often ignored issue. Non-functionality in drinking water supply is high in many countries. The assessment of PCRWR shows that 37% of 4879 systems assessed in 58 districts were non-functional (see annex 1 for a breakdown per district).

1 According to the 1987 report of the World Commission for Environment and Development
Several other case studies indicate that this performance is comparable with countries in Africa, whose economic status is considerably less, however:

- In two districts in Ethiopia (Alaba and Mirab Abaya) non-functionality was measured at 44% of the system. A main reason was the lack of technical capacity to repair deep borewell systems in time.
- Some 35% of all drinking water systems in Mozambique in 2001 are non-functional. After more intense surveillance this figure reduced to 30% in 2005.
- In Collines Province in Benin 33% of all rural drinking water systems had a pump breakdown for at least two months a year – with major issues being the difficulty of getting spare parts (86%), the lack of arrangements of the water committee (59%) and the unavailability of local mechanics (23%).
- In Uganda non-functionality was 30% in 2003. With investments in the supply chain of spare parts and investment in the local capacities (training of mechanics and training of new and old water user committees) this was reduced to 17% in 2006.

Sustainability however goes beyond the long term functioning of drinking water systems. The definitions of the DAC and of Warner are too narrow, because they do not make a clear reference to the environment, which is becoming more and more the bottleneck in many water supply and sanitation systems. A system may be maintained for many years, producing benefits for the present generation, but the management of the water resources in the area may undermine the long term sustainability. There may be serious pressures on water resources – pollution of surface and groundwater, overuse of groundwater and disturbance of recharge zones. All these jeopardize the long-term functionality of drinking water services.

It is, moreover, very important to keep in mind that people do not necessarily depend on improved water supply systems, but often largely rely on individual or collective wells and ponds. The functioning of these wells and ponds similarly is very much subject to the sustainable use of the water resources in the area and the management of the environment in general.

Case studies from PCRWR underline the threats to water resources and their impact on the drinking water supply. Between 10 to 20% of the system failure is caused by the drying up of the source. Water quality at the source is a major problem (Table 2.1), often because of microbiological contamination but in several cases also because of excess chemicals such as Fluoride, Arsenic and Nitrates. The worst case is Badin – where water supply is dependent on the canal system (semi-perennial channels only!) – with canals also used at liberty to discharge effluents by municipalities, industries and local users alike. At the same time more than half of the drinking water systems is not functioning – and the effective coverage of the population is 110,000 out of 1,420,000 amounting to a humanitarian tragedy. These data clearly show that addressing non-functionality and water quality are critical issues to tackle as quickly as possible as many people are at risk.

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2 It is remarkable that these data come from case studies as there is little systematic surveillance and monitoring of rural drinking water systems upon completion – even though it would be relatively simple to keep constant vigilance on the performance. Official statistics in general do not capture functionality and non-functionality and appear to overestimate access to effective improved drinking water supply systems.
2. Water supply and water resource protection

### Table 2.1 Overview of water quality and water availability problems

<table>
<thead>
<tr>
<th>District</th>
<th>Unfit for drinking unless treated</th>
<th>Non functioning because water source dried up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rawalpindi</td>
<td>72%</td>
<td>14%</td>
</tr>
<tr>
<td>Haripur</td>
<td>54%</td>
<td>10%</td>
</tr>
<tr>
<td>Badin</td>
<td>100%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Source: PCRWR, 2008

2.2 Sustainable Water Supply and Sanitation Services

The definition of sustainability implies a match between the political, socio-economic, legal and institutional frameworks in which the systems need to operate. It involves three strategic inter-linking dimensions as indicated in Figure 2.1 (Galvis et al, 1994).

**The community and the local institutions.** This dimension concerns different groups of people with some common but often also some conflicting interests and ideas and different socio-economic and cultural backgrounds. The water supply system may be one such common interest, but at the same time can be a major source of conflict. The identity of the people in the communities is shaped by their history and their socio-economic and environmental conditions. Viewing their parents and grand parents drinking (polluted) water from a river or pond may encourage them to do the same. It is also important to realise that a community is not homogeneous. It is made up of different people with different interest and some of them, often the economically better off, may be better informed and may know more of the world. They may also have certain interests in keeping the status quo and therefore may not be willing to solve certain problems. Women may have interests different from those of men and may not have been heard in the past, or their position may make it difficult to achieve changes on their own.

The community dimension includes the roles of men and women, the poor and the rich as well as issues such as the capacity and willingness to pay for the required service level, possibilities of national or international institutions to finance or co-finance the initial investment and the management capacity at local level. It also includes the possible existence of resources and of institutions that can provide support and assistance. This may concern issues such as technology development, water surveillance and control, environmental, conflict management, hygiene promotion and environmental education. The importance of the community dimension is growing in the context of the trend towards decentralization that puts management more and more in the hands of community or district based organizations sometimes also including private sector organizations. Projects that enhance the management capacity and the self-esteem of communities and make sure that jointly, solutions are adopted that take into account the local conditions and culture and particularly the prevailing sanitary problems, stand a better chance to develop sustainable systems.

**The environment**, the boundary that shapes the community and dictates the risks it faces and the local resources it can draw from to meet its needs. What are the water sources community members can access; what is their behaviour over the year; what is their level of pollution; what are the sanitation practices of the community, do they pollute their own or their neighbours water sources; what are the land and water use patterns. The possible effect a water supply system may have on the environment, for example, by taking away water from nature or by producing wastewater and chemical sludge, also needs to be reviewed. A main issue is to get good insight in
the level of contamination of the water supply and the sanitary risks involved. The interface between the environment and the community represents the risk the community has to overcome in relation to, for example, its water supply. The risk-analysis helps to establish for example if the water source is polluted and if this can be prevented or if the water needs to be treated, but also if community members treat the water with care to avoid pollution etc. This analysis thus may help to prioritize actions to reduce the risks.

The technology, reflected in the knowledge, the culture, the infrastructure and the tools actors can use to reduce the environmental risks the community is facing.

The interface between environment and technology represents actions that can be taken to reduce the contamination in the water sources or reduce or eliminate them by treatment preferably applying a multi-barrier concept in which different barriers are being included to reduce the risk of contamination. This may be technical interventions, but also may have to do with changing behaviour to reduce the risks. Better management of catchment areas may for example reduce the contamination hazard, but promoting hand washing may also be a key issue to reduce water related diseases in a community. It encompasses discussions with the community concerning the best possible water sources (rain water, surface water or ground water) possibly combining them to ensure an effective use. The interface between technology and community deals with the type of solutions the community desires and is willing and able to manage and sustain. Not every solution is feasible however as solutions need to be in line with the technical, socio-economical and environmental conditions and capacities of the community. The activities related to risk reduction can only be sustainable if the community adopts the solution and gains ownership of it by making it their own.

![Figure 2.1 Conceptual framework underpinning the search for sustainability](image)

Solutions that match the three interfaces and the overall political, legal and institutional framework are most promising in terms of sustainability. This requires joint problem solving with the different actors involved and a clear role of the community and the local level in decision making. The conceptual framework presented in Figure 2.1 is a simplification of the elements involved in the process and serves to illustrate the diversity of the variables. The complexity of reaching
sustainable solutions is often underestimated because of lack of dialogue, poor access to information, lack of interdisciplinary in the approach and inadequate research and development activities. Although science may not be able to provide immediate solutions in a specific project environment, it does provide the tools and techniques to initiate the search for them and ensure quality results. The resulting benefits of such research activities, if properly shared with sector agencies and communities, often outweigh by far the investment required to undertake them.

Development programmes in the Sector thus need to enhance the research and development capacity of the institutions involved, and strengthen the network of organizations in search of sustainable solutions. Some of the answers may already exist in the communities or local institutions. This calls for good communication between the actors involved and stimulation of their creativity and initiative. Technologies that are traditionally used in a region often are an important part of the solution, calling for a participatory review of local experience. If ‘new’ technology has to be introduced, testing is needed to allow for the necessary adaptation to the local conditions and to ensure that adequate operation and maintenance can be taken care of, before promoting large scale application. This also includes a review and adaptation of training materials for the different levels of education involved in the use of the technology.

Just focusing on water supply is not sufficient to reach an adequate health impact and truly contribute to development (Esrey, 1990). It is essential to combine water sector interventions with activities to improve basic sanitation, hygiene behaviour and environmental education.

2.3 Sustainability Aspects

Advance in construction and the depletion of budgets are important monitoring indicators, but do not say much about the sustainability of project’s achievements. It should be recognised that good water supply and sanitation services are a pre-condition for better public health, a higher productivity and a better quality of life (WASH, 1990). To ensure that the systems contribute to these objectives, they need to function properly and be efficiently used. These two themes, functioning, and use, are the basis for the minimum evaluation procedures WHO already presented in 1983.

From a sustainability perspective the emphasis has to move away from construction targets and focus on other indicators that better show the medium and long term outcomes of projects. Three main groups of indicators have been identified that are presented under the following headings:

- the quality and level of service, clearly related to the functioning of the system
- the efficient use of water, related to the way the community is using the resource
- the management of the service.

Together they comprise the main aspects to use in the evaluation of water supply systems (Visscher et al, 1996; IRC, 1991). Having clear indicators facilitates decision making with the community and the funding agencies concerning the service level that a new system needs to provide to the users. For each theme, specific indicators are required to quantify the benefits a system is expected to provide and establish the implied management and support requirements.
Box 1  Key themes to explore in sustainable water supply

- **Coverage** - who has access and are benefits and burdens equally shared
- **Quantity** - sufficient to reduce health risk and to meet prevailing or improved water culture
- **Continuity** - to facilitate access at required time and place
- **Quality** - needed to obtain health benefits
- **Cost** - can users afford the water supply service
- **Capacity to manage** - is management practice adequate and receiving sufficient external support
- **Culture** - is water use practice efficient and contributing to good hygiene

### 2.3.1 The Quality and the Level of Service

To establish the quality and level of service of water supply systems, the following criteria and basic indicators can be used (adapted from Lloyd et al., 1987):

**Coverage** refers to the access that people in the community have to water supply systems. For many people, it seems to be the most important indicator, but, the conclusions from the Water Decade show that to obtain health and social benefits it is not enough to focus on coverage alone. Access to good quality water should be fairly distributed to the greatest number of users possible. This may, for example, require special design measures in mountainous areas to ensure that both people living on higher and lower grounds receive sufficient water. Also, if water availability is a problem, users from high and low income zones should receive identical quantities. If sufficient water is available, people who want to have more water can obtain this extra service, but at a higher price.

Coverage can be expressed as the percentage of households in a locality that are connected to a water supply system or that have fair access to potable water, thus also including households with access to other protected water sources. Coverage is also a management indicator, as its change over time can indicate if the community water agency has been able to maintain or increase the existing number of connections without affecting the service supply.

**Continuity** in service provision is needed in order to avoid risk of recontamination of water in the distribution network or in storage tanks in the households or the risk that people revert to polluted sources if protected wells run dry. This has implications for water source selection but also for the design of treatment systems and distribution systems. It is important to guarantee, for example, that the service continues under if normal operation and maintenance tasks are carried out. In localities where water cannot be supplied continuously, the risk of recontamination in the distribution network should be investigated very carefully and prevented by making proper designs and identify protection actions with the community. In the case of intermittent water supply distribution hours need to be specified in consultation with the users to avoid unnecessary waiting times.

The continuity of the service can be reviewed by considering the hours of supply per day, the variation in supply over the year and by area, and the number of service suspensions lasting, for instance, longer than half a day per month. The latter can be related, for example, to intermittent electricity supply or lack of fuel in pumped systems, or with water source problems in the dry
season, erosion problems or flooding. Continuity needs also to be reviewed within the community and particularly those living on higher ground may have more service interruptions as a result of design deficiencies, operational problems or high water wastage of their neighbours or in the system.

**Quantity** is an important factor for health improvement. Enough water should be provided for drinking, cooking, food preparation and good personal and household hygiene. Bringing water close to the user reduces the time and efforts involved in water collection, a benefit which is particularly important for women and children. Also the inclusion of other demands, such as watering cattle and small scale irrigation, requires a full discussion with the community that includes an analysis of the environmental and socio-economic consequences. If the community is prepared to finance other types of use, and if the source and the existing sanitation conditions permit it, further demands can be considered at cost, provided the community understands the negative impact of excessive demands and water wastage. Making provision for such additional uses, although more expensive as it requires a larger system, may be very important to gain full acceptance by, and continuous support from the users. In fact multiple water use may raise their income just a little which may allow them to pay the water bill. Existing standards used for system designs assign global norms to water consumption. These may not be in line with the demands and capacities of the users and may not cater for multiple water use. Therefore it is essential to discuss the implications with the community and if needed to deviate from the existing norms.

An initial estimate of the quantity of water that is being supplied in a system can be defined from the daily production measured in the storage tank, and the number of users that it supplies. This value is greater than the per capita consumption, as it includes visible and invisible losses that occur within the system. The quantity supplied can only be analysed in detail if the reading of meters that register consumption is carried out. An alternative to estimate water consumption is to carry out a survey by installing a few water meters in randomly selected households, provided water quality permits the use of meters. Another option is to carry out a users survey asking about daily water consumption. This may not produce fully accurate results, however, as users may not inform properly about water use for activities such as irrigation or watering cattle.

Another key point for a sustainable service relates to the capacity of the water source. The supply volume should preferably be considerably less than the capacity of the source during the critical dry period. The greater the difference the better, particularly if the source is also used for other purposes, such as irrigation.

**Quality**, key factor for public health, for the acceptance by the users and for operation and maintenance of the water supply system. Water quality will be discussed in more detail in one of the other resource notes. Here we just reiterate that the combination of systematic observations in sanitary inspections combined with water quality analysis provides the basis for identifying the risks and for prioritizing remedial action.

**Cost** of systems will be largely determined by the water quality risk associated with the source, and the geomorphologic and geographical conditions. Sometimes a combination of water sources may be feasible to reduce the cost. In Zaragoza, in the Pacific Coast of Colombia a piped water supply was provided to the lower part of the community whereas the higher part was served with rainwater harvesting systems to avoid costly pumping.

The implemented technology should, if possible, be in harmony with the socio-economic conditions and above all with the willingness of the users of the system to pay. As a minimum the tariff
2. Water supply and water resource protection

should cover aspects such as operation and maintenance, and, if agreed upon between the financing body and the users, recovery of the initial investment. Furthermore, if possible, it should be able to cover unforeseen costs and future expansions. At the international level, it is considered that monthly tariffs should preferably not exceed 3 to 5 percent of the average monthly income of the user (UNDP, 1990). This indication may help to establish national and regional guidelines for tariff setting and recuperation of investment cost. As an indicator of the willingness to pay, the percentage of the users that have not paid the tariff in the last two to four months can be utilized.

2.3.2 Efficient water use

The attitudes of different stakeholders towards the environment in general, and especially to the water resources, are essential aspects to review with them. The conservation of water resources and the efficient use of the water supply system are important issues to review. In the Andean region, water consumption in different communities varies from 20 to 1000 l/d. These communities have different ‘water cultures’, the forms in which they see and use their water resource. This is often related to history and local conditions. Understanding the beliefs and local customs related to the utilization, protection, and care of the water supply sources is an important basis to help facilitate a reflection process in the communities.

Figure 2.2 Saving water campaign to influence community to be more careful with water

Through this process understanding of the importance of better source protection and efficient water use can grow, and can serve as a basis for changing attitudes and practices. This may include different approaches to, for example, watering animals, small plot irrigation and quicker repair of taps and leakage’s.

It should be realized that a lot of the high ‘consumption’ levels stems from poor design of distribution networks allowing for excessive pressures leading to high use. Also water is wasted because of taps that are left open, toilets that keep running and high leakage in the distribution network.

The indicators that can be used to evaluate the efficient use of water include:

- the volume of water used per consumer;
- the percentage of people that use water from other sources with a high sanitary risk for human consumption;
- the percentage of households with taps and flush toilets that are leaking;
- the extent of unplanned and uncoordinated use for irrigation and watering of animals;
2. Water supply and water resource protection

- the number of users that boil the water even although it complies with the national norms for water quality.

2.3.3 The administration

To ensure that the level of service is sustained over time, it is necessary that the management capacity at the local level matches the operation and maintenance requirements of the system, requiring only a minimum of support from government or external institutions. The administrative entity should have knowledge of the staff and material required to maintain its system in optimal condition. It requires a good accounting system (register of income and expenditure), access to technical services and adequate communication channels to share information with the community and supporting agencies. It is important that the community trusts the administration and the supporting agencies in technical, managerial and financial matters. This may require special efforts to gradually build this trust. The administration should be accountable and open, particularly concerning expenditures and contracts with third parties, having, for example, clear criteria for contract procedures.

The support institutions have to provide assistance while ensuring that they do not take over the role and function of the local or municipal administration. It is also important not to combine the support activities and the control function in the same support institution.

The capacity to manage the system can be analysed by making use of some indirect indicators such as:

- relevant years of experience of staff and the training received;
- effective participation of men and women and their roles in decision making in the administrative body;
- the number of meetings between the members of the administration and the community or their representatives (or communities in the case of one administration for different systems);
- the type and frequency of supervision that is carried out on the work of the operators;
- the number and type of problems resolved with the users;
- the existence of a monitoring system for system performance and user payments.

The management can also be reviewed using more direct indicators such as the number of inspection visits made, the compliance with the existing regulations such as water quality norms, availability of financial accounts, high degree of punctuality in payments, opportune calling upon external institutions and active search for training opportunities and advice.

2.4 The community dimension

Communities play an essential role in the search for sustainable solutions. Continuous use and good management of the systems can be achieved more easily when the opportunity is given to the community to express their needs and their points of view, and to actively participate in the planning and execution of the project (Van Wijk, 1986). This implies that Governments need to stimulate and facilitate communities in problem solving and to mobilise communities to seek out their new future (IRC, 1995).

This requires that representatives of all the sectors of the population (man and women, different ethnic and religious groups, with different levels of income), would be informed and consulted, to
enable them to participate in decision making, from the beginning of interventions, on aspects such as:

- the conservation and protection of natural resources and particularly water resources. In fact community members are the first to be affected from poor protection, often are doing the damage themselves and as they may live close are also best placed to monitor the watershed;
- the benefits of the continuous supply and efficient use of good quality water;
- the rights and responsibilities of the development actors (community, government, financing organizations, technical agencies etc.) in the formulation and implementation of projects;
- the technical implications (particularly related to operation and maintenance) and financial consequences (tariff) of selection of water sources, service levels and the location of the different components of the technology option that they select;
- the roles of planners, designers, constructing firms, supervisors, civic monitoring committee during the development and construction of the water supply system.

2.4.1 Community participation

In the early 80ies community participation in water supply projects became an issue, but there was considerable confusion about what this really implied. The definition ranged from the provision of free community labour inputs in government projects on the one extreme, to autonomous self-reliant development on the other. Governments embraced the concept of community participation as the increasing number of small systems they had to service proved too difficult to keep functioning. It was thought that with community participation a stronger feeling of ownership would arise and communities would be more careful with ‘their’ systems and more willing to maintain them. Despite the efforts to involve the community in construction and handing over systems to communities, performance remained problematic, as the approach still was the participation of users in agency projects.

Yet many governments were convinced that centralised systems cannot deliver the required services and so they initiated a strong push towards decentralization in the early nineties. Often however they did not transfer decision making (and resources) to lower levels or provided adequate training, thus making the chances of success very slim. In this period a change in thinking also arose shifting from community participation to community management, in which communities were encouraged to take full responsibility for their water supply systems.

2.4.2 Community management

It is suggested that community management is an approach that seeks to make the best use of resources available within the community with support from government agencies. It puts people in charge of their own water systems in flexible partnership with supporting agencies. In this, communities take on more tasks and responsibilities, relieving agencies of routine management and maintenance duties. This releases agency resources which then can be used to reach more people. Successful community management is claimed to build community confidence and to stimulate wider development efforts. It is also stressed that there is still a lot to learn (Evans and Appleton, 1993). Much of this learning is at agency and institutional level as they often still hold the strings of the purse and so can dictate the developments.

Increasingly governments and institutions are trying to adopt a more integrated and demand responsive approach. This is stimulated by the growing pressure to focus on sustainable
functioning and effective use of water supply and sanitation systems. Another reason why
government agencies are searching for alternatives and are amenable to participatory approaches
is that over the past two decades "blue print" development strategies have been shown to be
ineffective in meeting the basic needs of large numbers of marginalized, vulnerable people
(Thompson, 1995). Despite this interest it is surprising to see that agencies do not really have
internal mechanisms to learn from their experience with communities, to learn how to work with
them and to share this among their staff.

Not only does the agency staff need to learn to work with communities and to overcome the top-
down approach from the past, but the communities also need to come to grips with working with
the agency staff in a horizontal relationship. In the future the push for change however will be
more radical with increasing decentralization and with communities who are to pay a larger share
of the cost. Then the paradigm shift of communities participating in agency projects to one of the
agencies participating in community projects will become even more important.

Community management does not imply that the communities must take care of everything or pay
the full costs. They operate in partnership with the agencies and possibly the private sector thus
enabling different distributions of responsibilities. The function and task to be performed by the
organization acting on behalf of the community can thus vary considerably (Lammerink et al.,
1995).

In essence the question of community management of water supply systems boils down to: Who
manages (decides) what, with what tools and with whose support so that the community as a
whole benefits from improved services. It is often overlooked that new water supply systems have
to compete with existing sources. Only if a better level of service can be provided in terms of
coverage, quantity, continuity, quality and cost sustained system performance and effective use
may be achieved (Visscher ed., 1997). This implies that an adequate insight is needed for the key
actors both on the community and agency side of the existing situation, the perceptions of the
problem, the desires and the realistic options for improvement.

To successfully implement community water supply at large scale it is necessary to move away
from the short term project approach to construct systems to an approach that aims at long term
service provision and to strengthen the institutional framework to provide adequate back up to
local service providers. A lot needs to be done in the years after construction. People who leave
their positions must be replaced, water committees must be audited, conflicts resolved, major
repairs carried out, systems expanded and one day replaced. (Schouten and Moriarty, 2004).

This supportive environment unfortunately has been singularly missing in many countries, Pakistan
being a prime example. Rural water supply systems at one stage were managed by the Public
Health Engineering Department – but then transferred to the Teshil Administration the idea being
that they would be community-managed. The medium-term support to local community groups
was in most cases very small and it is no surprise that the experiment in many cases failed.
Committee members and local operators were replaced but there was no system to replace and
renew. The local organizations being weak default on electricity bills was common and basic
repairs got even less attention – the result was that systems either failed or that communities had
to be bailed out by government or NGOs. Constant interaction and clear support appears to be a
much better option.
2.5 Actor analysis and gender

Community water supply in the developing world is a "soft system", as defined by Checkland (1989), in that it is characterized by a highly complex network of interrelations involving many actors. Water and food are vital for life, but whereas the provision of food is mostly an individual decision, water supply is usually the result of a larger decision-making process, often in the hands of governments, controlled by bureaucratic systems and engineers, and requiring collective action. The providers have a monopoly that brings power, particularly in the urban sector, but also in rural areas (Swijngedouw, 1993). The end users, the ultimate beneficiaries, are not taking the decisions to construct a water supply system. Yet, perhaps unknowingly, they do have influence as they can and do frustrate some of the solutions being established without their participation in decision making. Non-use of new water systems or of imposed sanitary installations like latrines need not stem from technical flaws, but rather from the fact that the intended beneficiaries perceive their benefits as negligible (Vaa, 1990).

An operational and sustainable water supply system results from the interaction of some or many different actors, who intervene directly or indirectly in its performance (Figure 2.3).

Figure 2.3 A general interaction model for a functioning water supply system

The figure indicates the interactions that take place within the community and the support actors outside the community. This may involve a large number of actors as shown in the figure or fewer as is the case in many rural water supply systems in Pakistan (see section 3.6) where the main actors are the PHED, the Teshil government, the Village Development Association (VDA), the operators, private sector and the users.

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3 The main resources used for this section are Facilitating Community Water Supply, from technology transfer to multi stakeholder learning by J.T. Visscher (2006).
2. Water supply and water resource protection

2.5.1 The actors at community level

The users
This is a diverse set of actors – men, women and children – who may, knowingly or unknowingly, strongly interfere with the water system. Their interference can involve a range of activities that are usually not addressed in a comprehensive way. They can, for instance, leave their tap open and so consume more water than the average consumption level that has been used to design the system. If the system is not designed for this higher consumption, other users in higher parts of the distribution system may experience low water pressure or not receive water at all. Some users may not pay for the water, and for the poorest of the poor this may be the only option they have. Subsidizing part of the population is feasible, but should be agreed upon in advance to establish the proper tariff. People may also put pressure on the operator to add connections or make illegal connections themselves. Also they may ask for more water and in extreme cases the operator has been known to by-pass the treatment system and supply untreated water to the community.

Political cycles often have harmful effects on the sustainability of water systems. A change in political leadership in a community implies in a fair number of countries that the earlier administration is abandoned in favour of new political appointees. This may result also in replacement of the (paid) operator of the water system by a new (often untrained) one.

The water committee
Many hand-pump schemes and piped water systems are managed by water committees or similar types of community-based organizations (CBOs) such as the VDA. Whereas these committees may have received some kind of training, this often does not include management tasks. The CBOs, or water committees, may have very different origins, but often they are established by project implementing organizations. They may be elected or may just be formed by individuals willing to take part in them. The composition of these committees can be very different and may sometimes be reasonably representative, but most of the time interest groups play an important role.

Gender balance is often not well addressed in these committees. This is unfortunate, because having better representation of women in the committee has shown to have a positive effect on the sustained performance of water supply systems (Wijk, 2001).

The CBO is the link to outside organizations. In theory this creates a broad network, but in practice the interaction is very limited. So the bottom line is that community members participating in the CBO, with little or no experience or training in the management of a water supply system, are responsible for it and have to orient the operator in his/her job.

The operator
Water system operators are crucial to sustain the systems, but their role is under-rated in the sector and under-represented in decision making. It is interesting to note that community members value academic knowledge and look up to engineers and other government staff, but, in common with most engineers, they often look down on operators. They do not realize that the operator actually is the most important person as he or she (although female operators are very rare) is safeguarding the lives of his/her fellow community members on a daily basis. Even a perfectly designed water treatment plant is useless if the operator does not look after it properly. System design therefore needs to facilitate the operator’s task as much as possible. In some
schemes, the job of the operator or caretaker is rather broad and includes not only the operation and maintenance of the system but also tap repair, relations with users and collection of funds.

2.5.2 The external actors

A range of external actors may intervene in community water supply, particularly in the design and construction stage. This includes government staff, NGOs and private sector organizations. Government staff often sets the rules, establishes the control institutions, channels funding and tends to be involved in construction. This has changed somewhat as a result of structural adjustment, but they still have an important impact as they make the rules, often together with, or oriented by, staff from development banks (World Bank, Asian Development Bank, etc.) or donor agencies. Many of them have a technical background and come from urban areas. Because of their training and their background, they apply an urban perspective to the local setting to establish what they perceive to be the problem and the solution. They often share a ‘culture’, a set of common values, with other agency staff and higher-level politicians and administrators. “The key element of this culture is generalizing about consumers, intended beneficiaries, in a way that makes them objects of intervention instead of partners in development. Poor people in remote communities are seen not only as lacking material goods and adequate institutions, but fundamentally lacking insight about what is best for them and how to go about achieving it. Their belief systems are seen as unscientific and anti-modern, their values and practices are exotic and constitute barriers to rational problem-solving. To change this way of thinking would imply no less than a professional revolution, where reliance on knowledge acquired in schools and universities would be replaced by a willingness to "learn from below" and by seeing people’s perceptions, values and practices as resources rather than barriers (Chambers, 1985).

With its changing role, central government in many countries has passed responsibility for water supply to local government, whilst keeping responsibility for supervision through regulatory bodies and water quality monitoring. This change brings the responsibility closer to the community, but the available capacity of local government – often small municipalities – is limited and they do not have the human or financial resources to seek adequate advice.

Another important group of agency staff are health promoters and community-development workers, who often form the link between the agency and the community. Many of these staff members are used to bring messages to the community. With diminishing inputs from the government, their role is changing more to monitoring and their other tasks are taken over by staff from NGOs.

NGOs are a mixed group of organizations, often having a "social" mission to assist the poorer sections of society in their struggle for life. Most national NGOs are small and cover a limited geographical area. A variety of NGOs also exist at international level. Many are rather small, but some, such as CARE International, Plan International and Action Aid, are organizations with large networks and operate in many different countries. NGOs often have a closer link with communities than government agencies; they are present for longer-term activities and are more inclined to apply participatory methods. Many still have a tendency to provide the communities with solutions, albeit sometimes with perceptions that are closer to community reality. Staff members of these organizations are usually more dedicated, not least because they often get somewhat better and more regular pay than government staff.

The private sector is a relatively new player in community water supply (except for local water vendors, who often sell water of dubious quality to consumers and local contractors). Private firms
have a long track record in urban water supply, but are less attracted to rural water supply because of the smaller rate of return. Exceptions are the construction of water systems and particularly the selling of ‘package plants’.

2.5.3 Roles change over time

There is a big range of situations in developing countries, each characterized by different levels of interaction among the key actors involved. Figure 2.4 presents a schematic model of the key actor groups involved in different stages of a community water supply system. The roles and realities will not only be different in different countries and even within countries, but also will differ over time. So the levels of involvement marked in Figure 2.4 are only illustrative.

The figure helps us to appreciate the changes and is a good indication of the need to analyze the real situation and to recollect that the process of providing safe water supply does not stop when the system is constructed. Over time, the number of people that depend on the system will change and the quality of some of its parts will deteriorate – as may also happen with the water source. Also, progressive improvements in the technology supported by economic development change quality and quantity criteria and may require adjustments in the systems. It follows that one intervention often will not suffice to build and sustain a system. Therefore it is good value for money to invest in capacity building in a community.

In many countries we see that the role of the external agencies strongly diminishes when construction is over. CBOs and the communities are pretty much left to themselves. “Some communities may alone bear the full responsibility for managing their water supplies, many will not. Community management can not mean that, following the installation of a system, the outside agency drives off in the sunset and everyone lives happily ever after. Indeed, a comprehensive and effective framework for institutional support is needed if we want to keep the systems working after ‘handing over’. The efforts and capacities of communities are crucial, but they must be supplemented with the efforts and capacities of governments, support agencies, NGOs and the private sector. Together, they can create a rural water supply service in which each stakeholder takes its share of responsibility in an institutional framework that addresses all the functions needed to provide water to rural people, including policy making, regulation, legislation, taxation and price policy, planning and construction, technical support, operation and maintenance” (Schouten et al., 2003).
Figure 2.4 An example of possible distribution of inputs between different actors
2.5.4 Who takes the decisions?

Many different groups all may influence decision making. The most important are:

- Policy makers at national level setting the boundaries for sector interventions, often together with staff from donor agencies and/or development banks;
- Agency staff and especially engineers who may be quite conservative and sometimes favour certain approaches because of educational background or political links;
- Community representatives (mayors, women groups, political rivals etc.) and
- Users

In large development projects, decisions are usually made by the funding agency in collaboration with central or regional authorities. Often these projects rely heavily on external consultancy firms and even suppliers of technology. They may be guided in their decisions by a framework of longer-term sector plans and decide on the service level, the choice of technology and methodology, the financial support and the required inputs from the community. Thus, in this type of project most decisions are still made for the users. Wijk (2001) indicates that this situation is changing in different projects in that more time is taken for the planning of projects and preparation is now more participatory, flexible and gender and poverty-sensitive. Yet she also indicates that this is only a partial change, with many of the characteristics of agency projects remaining unchanged.

With more funding being channelled through local government, decision-making processes change. Local governments may still have to live by the rules set by their national governments or by funding organizations, but they have more freedom when it comes, for example, to technology selection. This may seem positive, as they are closer to the community, but often there are political strings attached that may colour their decision making. Or they may be influenced, for example, by private-sector actors who want to sell package plants that do not necessarily solve the local problem.

In the case of NGO projects, the community appears to have a larger influence in decision making, but this too depends very much on the NGO and the perception of its staff. Some have the same characteristics as government staff and hence leave less room for community involvement. Also it may be relatively easy to manipulate decision making, as not all members of the community may have equal access to the necessary information to make informed decisions.

What is clear at the end of the line is that the user has ‘veto power’ over use. Users ultimately decide whether they will use a new system (provided that they have an alternative water source). Because of the trend to ask users to pay for the water, the users acquire a larger say. When they are paying, it is easier for them to claim their ‘right’ to be involved in decision making. On the other hand, as mentioned earlier, payment is not a panacea, and exceptions may have to be made for the poorest sections in the community. This can best be done in consultation with the community, as the local population often is well aware of the people involved and their needs.

2.5.5 Gender and equity aspects

It is increasingly recognized that gender sensitive approaches are crucial for the sustainability and use of water supply and sanitation services. Here we just will highlight a few issues that among others are being based on the work of the Gender and Water Alliance (http://www.genderandwater.org/).
Gender refers to the roles and responsibilities of both men and women in a society or culture. These roles are not determined biologically, but socio-economically and culturally, and therefore gender dynamics change over time. A gender approach to WASH analyses the roles and responsibilities of women and men and involves them in designing and planning WASH and in implementing and managing services. This has been demonstrated to improve effectiveness. A gender approach identifies ways to support men and women both by recognising traditional tasks and by supporting changing roles to enhance strategic programmes. Nevertheless, often special measures are needed to support women as they have benefited much less from development activities than men.

You can do a lot by being aware of the issues, having knowledge about gender and gender relations, having a positive attitude to reducing gender inequalities and being creative in seeking low-cost, culturally acceptable solutions to problems. This requires however that you introduce gender analysis by disaggregating data by sex.

Equity: The poorest 10 to 30% of the population systematically miss out on the benefits of water and sanitation programmes. Some groups are especially disadvantaged because they are marginalised within society. There are also critical situations, such as war, conflict, refugee camps and natural disasters when the poorest are most at risk of losing basic services. Approaches that address the needs of the poorest, such as socio-economic mapping and participatory monitoring, are important steps towards equity.

Without specific gender approaches, and policies and strategies for reaching the poorest in society, these actors including local governance cannot succeed in meeting need and scaling up services. Without achieving these water and sanitation goals then many other goals, including poverty reduction, income generation, reduction in childhood diseases, and increases in education are put at risk. Gender and equity approaches are therefore at the core of successful local governance. Information can be spread to women and men along channels and in forms that are adjusted to their different situations and interests. Meetings can be held at times and locations that are convenient to women and men, adjusting these to meet the needs especially of poor women and men.

Figure 2.5: Ring used by women in mountain areas of AJK to carry water on the head
Discussing problems and possible solutions with groups helps. Often, people are so used to their situations that they are not aware of gender inequalities until someone else helps bring them out. Practical measures can be taken that require awareness and good communication and planning skills, rather than a lot of extra time, money and human resources.

Active participation of women in discussions and decisions may require special efforts including specifically encouraging their participation in meetings, helping them to speak in public or by finding a person who can speak for them or having meetings separate from men etc.. Both men and women can make informed choices about local technology and design, location, financing and implementation, including making choices about cross-subsidies and about the scale of work needed for maintenance, hygiene tasks and quality control. Making informed choices means knowing about responsibilities, rights, authority and tasks, and about the amount of work, knowledge, skills, training and compensation involved.

In Pakistan interesting experiences are developing with the involvement of women in water projects. In the ADB supported project in 335 villages initiated in 2002 in Punjab a community-based, demand-driven approach was used in which local people were involved in planning and overseeing the construction of the systems, and were responsible for all the operation and maintenance costs (Samson, 2002). Female promoters were used to create community-based organizations among women to help design and carry out the project. Without sacrificing traditional values, the community motivators regularly met with women—separately from men—in community centres to discuss the project. The women exchanged views and adopted ways of promoting health and hygiene.

The women were also actively involved in monitoring the project implementation and in tariff collection. “They kept watch and told the contractor when they believed the construction materials were of inferior quality. At times, monthly tariff collections from households have exceeded requirements. The money was used to provide scholarships, books, and street lighting; finance small industries; and help orphans. Savings were also recently used to buy 12 sewing machines for women.

2.6 Community Management and Enabling Environment

Community management is not a very clear concept as it has different connotations in the literature. Despite or perhaps because of the unclear definition, community management of water supply and sanitation systems is increasingly seen as a fundamental option for sustainable development. Community management of services, backed by measures to strengthen local institutions in implementing and sustaining water and sanitation programmes, was one of the guiding principles adopted in the New Delhi Consultation in 1990 and reconfirmed in Agenda 21 (Evans and Appleton, 1993).

Community management puts people in charge of their own water systems in flexible partnership with supporting agencies. In this, communities take on more tasks and responsibilities, relieving agencies of routine management and maintenance duties. This releases agency resources which then can be used to reach more people. Yet it does not imply that the communities must take care of everything or pay the full costs. They operate in partnership with the agencies and possibly the

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4 The main resources used for this note are Putting Community Management in Place by Visscher J.T. and Lammerink, M.P., 1998, Delft, IRC and Scaling up Community Management, Schouten, T. 2006. London, WEDC
private sector thus enabling different distributions of responsibilities. The function and task to be performed by the organization acting on behalf of the community can thus vary considerably (Lammerink et al., 1995), but often involve the same basic requirements (Table 2.2).

### 2.6.1 Communities managing their water supply

Projects can change the attitudes of people, when they start with developing respect for each other among the actors involved and stimulate information sharing without qualifying it. Here initial responsibility is with the external agency staff who often still need to learn to respect the local culture and beliefs. But even in the communities self-respect may be low. Starting a project with a historical review by the community themselves of their water supply situation and the rites and myths involved has proven to be a good tool to get this going in the Transcol project in Colombia (Visscher et al., 1997). An interesting result was that after two project years a local farmer indicated that he learned from this project that 'everyone is the teacher of everybody and everybody learns from everyone'.

<table>
<thead>
<tr>
<th>Table 2.2</th>
<th>Basic requirements for community management</th>
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<tbody>
<tr>
<td>• Enabling environment which guarantees that communities can establish legal enterprises to manage their system and can decide for example on tariffs</td>
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<tr>
<td>• Choosing technology based on maintenance and management requirements both at local level and in terms of possible back-up by private sector or government.</td>
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<tr>
<td>• Ensuring a level of service that responds to a realistic demand of the community</td>
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<tr>
<td>• Partnership attitude between agencies and communities in which perceptions of problems and solutions can be discussed on the basis of equity and respect, valuing both academic and community knowledge in the same way</td>
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<tr>
<td>• Transparent decision making ensuring that informed choices can be made</td>
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<tr>
<td>• Proper management arrangements including practical management tools</td>
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<tr>
<td>• Impartial institution that has the power of authority and the skills to mediate between the (community) water enterprise and the users in case of important differences of opinion</td>
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<tr>
<td>• Accepting a learning period in which training and learning go hand in hand until water enterprises and the communities they serve can cope by themselves with limited institutional back-up support.</td>
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Based on Visscher ed., 1997 and Brikké et al., 1997

Informed decision making is another tool to change attitudes. As it is clear for everyone what choices there are and what choice eventually has been made the power of the decision makers changes from hidden agendas to public accountability. It also dramatically cuts opportunities for malpractice and corruption and may lead to easy acceptance of the consequences.

### 'Informed decision making' helps to change attitudes

In one of the Transcol communities the tariff was raised tenfold by the water committee to enable the introduction of water treatment without any protest. In a community meeting a metaphor of a bus company was used for the water supply system. People being accustomed to paying for the bus could clarify the reasons for this. Then a similar reasoning was presented for the tariff related to the water system in which the different cost items were explained and discussed. After the discussion it was very clear what the tariff needed to be and what possible cost savings could be introduced.
2.6.2 Scaling up community management: objectives and challenges

Scaling up community management aims to strengthen community management, not to do away with it. Its two objectives are:

- Ensuring that community managed water services are sustainable and that adequate institutional support and policy arrangements are put in place to support community management indefinitely.
- Expanding coverage from the current “islands of success” to larger areas, reaching entire populations.

Adaptations to Current Practice

“Scaling up” aims to build upon the successes of community management but advocates adaptations and additions to the model. The most important adaptations are the following.

- Look beyond the two to three year life cycle of a water implementation project. A lot needs to be done in the years after construction in terms of management, training, repairs and system expansion.
- Adopt a service delivery approach which takes into account the whole life cycle of a water service: from design and construction to eventual replacement and everything that needs to be done in between to keep the water flowing from the taps.
- Strengthen the institutions and capacities at the intermediate (decentralised) level (districts, departments or provinces) to help them plan service delivery and support community institutions, while also involving local NGOs and private entrepreneurs.
- Harmonize effective service delivery approaches, systems and tools instead of every agency using its own approach and materials.
- Ensure that community based organizations are legally recognised or formally integrated in national institutional frameworks for water service delivery. (Davis and Iyer 2002; Lockwood 2002; Thematic Group 2005)

Uganda a district support programme to scale up community management

Responsibility for the delivery of basic services in Uganda lies at the District and Town Council levels. WaterAid developed a District Support Programme with the participation of local governments, beneficiaries and all the implementing agencies in the districts. ‘Memorandums of Understanding’ were signed making the District Governments the leading partners in the programme. WaterAid assigned staff to facilitate the work with local government to improve the planning process and increase their effectiveness in co-ordinating and monitoring implementing agencies on the ground. Mr Kato Salongo, the director of Kyakulumbye Development Foundation (KDF), a community based organisation, confirms the benefits of the programme. He says “now in the new approach, the district officials respond to our requests and we are even invited to their planning meetings. They support us in base line surveys and understand why we need more than six months for community mobilisation. The officers concerned regularly visit our projects and they give us technical support. Now I feel KDF is contributing at the district level.” (WaterAid Uganda 2001).
Aquacol: support organised through an association of community-based organizations

Decentralisation in Colombia has caused the disappearance of national agencies from the rural water scene. Municipalities fail to establish support to community managed systems and they lack financial resources. 27 community-based water supply organisations in south-western Colombia serving 75,000 people, decided to create an association to:

- improve the quality of their water supply and sanitation services;
- generate "economies of scale" for training, spare part acquisition, project development etc.
- have a better access to funding;
- act as a communication bridge between communities and local, departmental and national institutions;
- influence national policies for water and sanitation
The Challenges of Scaling Up

**Scaling up takes time** to build the necessary institutional support mechanisms, to strengthen policy and legislation to foster a service delivery model based on community management, to coordinate, plan and act together, and to change mindsets.

**Scaling up aims at sustainability and coverage at the same time** as it is unacceptable to delay the extension of coverage because actions that make community water services more sustainable (building community institutions and capacities) take more time.

**Scaling up requires commitment** as lessons learned so far relates more to projects level interventions. Putting in place the capacities and systems at intermediate level to support communities will be a major effort for all stakeholders.

**Scaling up requires harmonisation and standardisation** of approaches, technology and planning in particular at the operational intermediate level are needed to make rural water services sustainable and to extend coverage more quickly. Only by breaking through the current practice of “every agency is doing its own thing” and replacing it by joint action scaling up can be achieved. (Thematic Group 2005; Davis and Iyer 2002)

### 2.6.3 The enabling environment

The local management of a water supply system cannot succeed without an enabling environment which includes the necessary support services and a well established policy and regulatory environment (Figure 2.6). Yet important limitations exist today in this environment to ensure adequate performance of water supply systems (Table 2.3).

![Figure 2.6 Management and support levels](image)
2. Water supply and water resource protection

Table 2.3  Difficulties resulting from an insufficient supportive enabling environment

<table>
<thead>
<tr>
<th>Problems at system level</th>
<th>Problems at policy level</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Failure to generate sufficient tariff income</td>
<td>• Political interference in planning and resource allocation</td>
</tr>
<tr>
<td>• Failure to account transparently for funds</td>
<td>• Poor system design and poor quality of construction and implementation</td>
</tr>
<tr>
<td>• Lack of preventive maintenance</td>
<td>• Lack of supportive policies and legislation</td>
</tr>
<tr>
<td>• Lack of capacity (technical, managerial, financial etc)</td>
<td>• Absence of legal status</td>
</tr>
<tr>
<td>• Lack of community cohesion</td>
<td>• No support for repairs extension/upgrading</td>
</tr>
<tr>
<td>• Political or social conflicts</td>
<td>• No support for conflict management</td>
</tr>
</tbody>
</table>

External support is needed to sustain the functioning of the water supply systems (Visscher, 2006), as several tasks are beyond the capacity of local service providers including:

- Quality control of construction, in which the community can play a key role as they are locally present, but they need guidance and advice.
- Spare part supply, as lack of spare parts is a huge problem in many systems.
- Training (operators + committee). Training is often done at the project level and mostly in the construction phase, refresher courses are virtually absent and when an operator or water committee member is being replaced, at best he or she learns the job from the predecessor, inheriting the mistakes that have developed over the years.
- Technical assistance, for larger problems such as borehole repair which may be complex and costly and require sophisticated equipment.
- Water quality surveillance, can partly be done at system level, with simple means and sanitary surveys, but support may be needed if for example water quality changes.
- Financing of important repairs and extension of the system may require funding beyond the capacity of the local provider and community in the form of loans and/or grants.
- Sanitation and hygiene promotion are important to better control water related disease. The community may need support to help convince others to change their behaviour.
- Conflict mediation is a growing need as conflicts over (scarce) water resources and water supply services are growing.

The policy and regulatory environment has to ensure that the local service provider can provide a good service to the community as a whole and has access to adequate support. This particularly requires:

- A water resources policy that ensures access to drinking water supply and regulates access to water for other purposes including productive use.
- An adequate water supply and sanitation policy that is pro-poor and gender sensitive to ensure that all community members have the possibility to get fair access to improved water supply and sanitation services, without negative effects on the environment.
- A legal and regulatory framework which establish the status and role of all actors.
- An orientation to, and resources for, coordination and joint learning as still many hurdles have to be overcome.
3. Water resources and water supply in Pakistan

Pakistan is a federation of four provinces (Punjab, Sindh, North West Frontier Province (NWFP) and Balochistan) and three federally administered territories (the Northern and Tribal Areas, the Islamabad Capital Territory and the State of Azad Jammu and Kashmir).

3.1 Ground water and surface water resources in Pakistan

3.1.1 Groundwater sources
The total abstraction of groundwater in Pakistan is estimated at 50 BCM out of a potential of 63 BCM (Kahlown and Majeed 2004). Most water is used for agriculture, but some 70% of the population uses groundwater for domestic use (both shallow and deep groundwater). Many industries also use the relatively clean groundwater.

Groundwater is largely unmanaged and hardly monitored despite the serious threats to livelihoods which include declining groundwater tables, saline water ingression, aquifer pollution particularly in urban areas, increasing sodification, and raising arsenic and fluoride levels. Overuse of groundwater is dramatic for example in some areas of Balochistan where orchards are being dismantled, where people migrate and where water supplies dry up. In the large alluvial aquifer systems of the Indus water shortage is less acute, but in some areas groundwater use is larger than recharge. Intrusion of saline groundwater is also growing and in many areas water tables are falling.

The rapid rise in groundwater use took place when cheap locally manufactured diesel pump sets for agriculture came on the market in the second part of the eighties and the number of private tube wells started to rise dramatically (Figure 3.1).
In 1960 groundwater accounted for only 8% of the farm gate water supplies in Punjab. At present this has gone up to 60%. Balochistan is also facing the same problem and as a result ground water tables are falling. The most recent estimate puts the number of tube wells in Pakistan at some 630,000 (Qureshi, Shah and Akhtar 2003). The majority of these wells are in Punjab. In comparison to its population and groundwater potential the number of tube wells in Balochistan is very high.

Table 3.1  Tube wells per province and type of prime mover

<table>
<thead>
<tr>
<th>Province</th>
<th>Total</th>
<th>Diesel</th>
<th>Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punjab</td>
<td>566,446</td>
<td>501,092</td>
<td>65,354</td>
</tr>
<tr>
<td>Sindh</td>
<td>28,079</td>
<td>25,086</td>
<td>2,993</td>
</tr>
<tr>
<td>NWFP</td>
<td>11,077</td>
<td>5,539</td>
<td>5,538</td>
</tr>
<tr>
<td>Balochistan</td>
<td>24,000</td>
<td>13,871</td>
<td>10,129</td>
</tr>
<tr>
<td>Total</td>
<td>629,602</td>
<td>545,588</td>
<td>84,014</td>
</tr>
</tbody>
</table>


**Groundwater quality**

The quality of groundwater is a major concern. In many urban areas and around rural industries groundwater is polluted by sewerage effluents, oil residuals, chromium or other contaminants. This holds true for the major cities, such as Karachi and Lahore, where a large number of households still depends on individual wells for water supply (Rahman 1996, Mashhadi and Anwar 2000). Other problems relate to the presence of fluoride and arsenic particularly for example in areas of Sindh and Punjab (Map 3.1 and 3.2). The most widespread problem however is bacteriological contamination, both in urban (Table 3.2) and rural areas, leading to a high child mortality (128/1000).
Table 3.2 Water quality survey in 23 cities

<table>
<thead>
<tr>
<th>Type of contamination</th>
<th>Number of cities with problems (N=23)</th>
<th>Average % of contaminated samples</th>
<th>Range among cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coliforms</td>
<td>23 (all)</td>
<td>68%</td>
<td>40 - 100%</td>
</tr>
<tr>
<td>Excess Nitrate</td>
<td>15</td>
<td>19%</td>
<td>7 - 50%</td>
</tr>
<tr>
<td>Excess Arsenic</td>
<td>8</td>
<td>63%</td>
<td>15 - 100%</td>
</tr>
<tr>
<td>Excess Fluoride</td>
<td>7</td>
<td>12%</td>
<td>4 - 22%</td>
</tr>
</tbody>
</table>

Based on Kahlown et al (2006)

3.1.2 Surface water sources

Surface water is used for drinking water in areas where groundwater is not suitable for drinking purposes. In a part of the Indus Irrigation Basin in Bahawalnagar District of the Southern Punjab, villages depend on irrigation water since groundwater is brackish. Water is provided through watercourses to open reservoirs in villages (Van der Hoek et al., 2001).

The increase in the demand of surface water is mainly caused by the increase of irrigation practices in the agricultural sector. In the Indus Basin for example, the cropping intensity increased from 50-70% to an average of 120% per year (Ahmad, 2005).

Competition arose between the four provinces for surface water. Therefore in 1992, the Indus River System Authority (IRSA) was founded. The IRSA implemented the Water Appointment Accord allocating water to provinces. However, conflicts still exist in periods of high demand especially between Sindh and the Punjab.
Surface water quality
Surface water is contaminated in most parts of Pakistan. This concerns bacteriological contamination from discharge of waste water and solid waste from human settlements as well as from industry. The tanneries industry, the paper industry and the sugar industry are very important contributors to surface water contamination.

3.2 Legislation and regulation
Over the years a number of laws and acts have been issued to support the management of water (see table 3.2), but the common feature is that they have not been implemented on the ground.

The lack of decisiveness in legal arrangements is mirrored by the absence of focus in institutional arrangements and emphasis for example seems more on new groundwater development and not on water management and control of water logging and salinity. This is reflected for example in the fact that no Water Quality Act is available to help protect ground and surface water sources. Already in 1958 the Pakistan Water and Power Development Authority (WAPDA) was founded to coordinate the development of Water and Power Schemes, which previously was done by Provincial Electricity and Irrigation Departments.

In 1997 Provincial Irrigation and Drainage Authorities were established (under the different Provincial Irrigation and Drainage Authorities Acts) to develop and manage both surface and groundwater. These Authorities are however in various stages of formation The Authorities are also involved in the establishment of Farmers Organizations (FOs) for participatory irrigation management. This task may be stretched to include the local management of water resources. Water quality – including groundwater management – is part of the mandate of the provincial Environmental Protection Departments/Agencies. Because of resource constraints this task in practice is very narrowly interpreted to control industrial wastes.

Several other provincial departments are involved in groundwater use, in particular the Public Health Engineering Department and the Agriculture Departments (tube well census). Under the decentralization the Local Government Bodies have become involved in developing groundwater for domestic and industrial needs. While all these organizations have a partial mandate in groundwater development and monitoring, groundwater management and regulation is not undertaken by any one of these.
Table 3.2 Legislation and rules concerning water in Pakistan

<table>
<thead>
<tr>
<th>Legislation / regulation</th>
<th>Content</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punjab Soil Reclamation Act</td>
<td>Basis for the Soil Reclamation Board to control water logging and salinity through development and operation of drainage tube wells. At one stage in 1965 licensing rules were framed, yet they were never enacted.</td>
<td>1952</td>
</tr>
<tr>
<td>Pakistan Water and Power Development Authority Act</td>
<td>Legal basis for establishment of the Water and Power Development Authority (WAPDA) which also is to issue area-specific rules on groundwater use.</td>
<td>1958</td>
</tr>
<tr>
<td>Groundwater Rights Administration Ordinance</td>
<td>Legislation to control groundwater mining. A procedure was spelled out to issue permits for the development of new karezes, dug wells and tube wells.</td>
<td>1978</td>
</tr>
<tr>
<td>Accord on apportionment of surface water among provinces</td>
<td>The Federal Government and the Provinces allocated surface water shares of the provinces.</td>
<td>1991</td>
</tr>
<tr>
<td>Pakistan National Conservation Strategy</td>
<td>Formulated in 1992 as medium-term strategy (fifteen years) – currently discussion on follow up</td>
<td>1992</td>
</tr>
<tr>
<td>Environmental Protection Agency Act</td>
<td>This act provides the first beginnings of groundwater quality management. It establishes the Environmental Protection Councils at federal and provincial level that are charged with setting standards on groundwater quality.</td>
<td>1996</td>
</tr>
<tr>
<td>Provincial Irrigation and Drainage Authority Acts</td>
<td>Basis for establishing Provincial Irrigation and Drainage Authorities; includes responsibilities for irrigation and drainage operations and cost recovery. The new authorities are to ensure that groundwater monitoring is undertaken.</td>
<td>1997</td>
</tr>
<tr>
<td>National Drinking Water Policy</td>
<td>The overall goal is to ensure safe drinking water to the entire population at an affordable cost and to ensure reduction in mortality caused by water borne diseases by 2020. The main objective is to make a clearer segregation between the functions of service provision and regulation (Ministry of Environment, 2007).</td>
<td>2007</td>
</tr>
<tr>
<td>Safe Drinking Water Act</td>
<td>This will be enacted to cover technical and supply standards, and legislation approved to ensure compliance with the Pakistan Drinking Water Quality Standards (Ministry of Environment, 2007).</td>
<td>2007</td>
</tr>
</tbody>
</table>

At federal level the Ministry of Water Resources serves as umbrella institution. The Ministry is involved in reviewing and approving projects. At this level the Water Resources Research Institute and the Pakistan Council of Water Resources Research (PCRWR) is involved in research on water resources. This organization has for instance carried out a Groundwater Quality Monitoring Study.

Environmental management was put on the agenda in Pakistan with the formulation of the National Conservation Strategy in 1992. The NCS was a mid-term strategy meant to last fifteen years.
Following the NCS several things happened on the institutional front, such as the enactment of the Pakistan Environmental Protection Act (1997), the establishment of the Pakistan Environmental Protection Council (PEPC), the establishment of federal and provincial Environmental Protection Agencies and the initiation of Provincial Conservation Strategies.
All Provinces have an Environmental Protection Agency and at federal level there is a Ministry of Environment. Their functions are largely confined to regulation. As a result the PEPAs and the Ministry of Environment tend to be isolated and not popular. The Ministry of Environment is mainly involved in making policies (revised National Quality Standards, National Environmental Policy, National Sanitation Policy), yet as all the subjects are the responsibilities of the provincial administration or the district administration, there is a gap between policymaking and policy implementation. The need to broaden the environmental efforts and integrate environment in other fields is reflected in the Mid Term Review of the NCS that recommended that NCS-2 should become a Sustainable Development Policy. The formulation of this is currently in the making, but in the meantime not much is taking place in terms of integrating environmental issues in main development activities.

### 3.3 Current situation in different provinces

The figure below shows the unequal regional availability of water regarding precipitation. Precipitation is not the only determining factor; in Pakistan it is important whether or not a region is located in the Indus Basin.

![Figure 3.2](image)

**Figure 3.2** Annual precipitation per province (mm) *Source:* Siegmann and Shezad, 2005.

**Groundwater declining**

Figure 3.3 is an example from Chaj Doab, Punjab, where water tables dropped 3 meters over the period 1998-2001. Because of the intense use of groundwater in the irrigation commands, the area that is water logged and has water tables of less than 1.5 meter is reduced drastically and is confined to a number of highly saline areas only in Punjab.

Table 3.3 gives an overview of groundwater table depths in Sindh Province and Punjab Province. The selected areas are SCARP (Salinity Control And Reclamation Program) areas.

In Sindh, salinity and water logging persist in most parts, even in some fresh groundwater areas. In 1999, 38.5% of the irrigated area was water logged (table 3.3) causing a range of problems –
lower farm yield, but also impediments to rural sanitation facilities and a large prevalence of human and animal diseases. The problems appear to be most persistent in the areas, served by non-perennial canals. These canals receive copious supplies in the kharif season, causing the water table to rise significantly, but to fall again in the winter season, when the canals are not functioning. This annual cycle of rise and fall of water table has brought the salts to the upper soil strata (Mukarram 1994). Also in areas with saline groundwater there is often no storage in top layers left for relatively better quality seepage water from canals that can be used for local water supply (even though it is nowhere near water quality standards). The problems in the perennial channels in Sindh are different from the non-perennial channels. In the perennial channels water duties are generally lower. Here salinity is concentrated on areas with deficient surface water supplies, where there is not enough water for leaching accumulated salts. This often concerns the tail reaches of the channels.

![Water Table Decline in SGW Zone of Chaj Daob](chart)

**Figure 3.3** Water table decline in different saline groundwater zones (SZ) of Chaj Doab

**Table 3.3** Groundwater table depth in selected SCARP areas of Punjab and Sindh (1999)

<table>
<thead>
<tr>
<th>Water Table Depth (in Meters)</th>
<th>Punjab</th>
<th>Sindh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1.5</td>
<td>0.62</td>
<td>2.21</td>
</tr>
<tr>
<td>1.5 to 3.0</td>
<td>1.89</td>
<td>2.87</td>
</tr>
<tr>
<td>3.0 to 4.5</td>
<td>2.92</td>
<td>0.35</td>
</tr>
<tr>
<td>4.5 to 6.0</td>
<td>1.47</td>
<td>0.17</td>
</tr>
<tr>
<td>More than 6.0</td>
<td>3.06</td>
<td>0.14</td>
</tr>
<tr>
<td>Total Area covered</td>
<td>9.96</td>
<td>5.74</td>
</tr>
</tbody>
</table>

**Source:** SMO

3.4 Water supply and sanitation in Pakistan

Pakistan is the sixth largest country in the world by population. In 2005, it had a population of some 154 million, with a density of more than 190 persons per km². By 2025, the population will rise to around 229 million. According to WHO and UNICEF (2006) 96% of the urban population has access to improved water supply systems including 49% with house connections. For the rural

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5 Improved water supply include house connections, taps outside the house, motor pumps, hand pumps, protected dug wells, protected springs, and rainwater harvesting tanks.
population this is 89% including 15% with house connections. The other people take water directly from streams and ponds.

Having access to improved water sources however does not imply access to safe drinking water because the quality of water sources has been altered by the impacts of the various human, industrial and agricultural activities. This may explain that the World Health Organization (WHO) estimates that more than 85 million people do not have access to safe drinking water in Pakistan, whereas other sources give other data which is possible because precise data particularly on the number of water supply systems that are not functioning and the scale of contamination are not available. Contaminants such as microorganisms, chemicals, toxic substances, industrial wastes or waste water in higher concentrations make water unfit for drinking. Such contaminants cause acute or chronic health effects such as circulatory system problems, skin diseases, kidney damage, bone damage, gastrointestinal stress, blue baby syndrome, increased risk of cancer and nervous system disorders etc. Presently 7 million cases of Hepatitis B and C have been registered in Pakistan.

UNICEF has reported that in Pakistan 20 to 40% of the beds in the hospitals are occupied by patients suffering from water related diseases (UNICEF 2004). Diseases such as cholera, typhoid, dysentery, hepatitis, giardiasis, cryptosporidiosis and guinea worm infection are about 80% of all diseases and cause 33% of deaths (Tahir et al, 1994). Dawn April (2004) suggests that in Pakistan 30-40% of all reported diseases and deaths occur because of the use of poor quality water and every fifth citizen suffers from illness and diseases caused by polluted water.

**Water sources face considerable problems**

Of the total annual water resources available to Pakistan, approximately 6% is used by the domestic and industrial sector and 94% is used for irrigation purposes. The per capita water availability has dropped from 5600 cubic meter in 1952 to 1200 cubic meter in 2003 and will decrease to less than 1000 cubic meter by year by 2012.

The quality of ground water and surface water is low and is further deteriorating because of unchecked disposal of untreated municipal and industrial wastewater and excessive use of fertilisers and insecticides. Another important problem is that a considerable part of the ground water is brackish.

Surface water from most of Pakistanis rivers is also polluted. The Kabul River at Nowshera for example has high coliform content, suspended solids, high Biological Oxygen Demand (BOD) and low Dissolved Oxygen (DO).

**Sanitation**

According to WHO-UNICEF (2006) sanitation coverage in urban areas was 92% including 40% with sewer connections (most without treatment). For rural areas the coverage was 41% including 6% with sewer connections.

Solid and liquid excreta are the major source of water pollution in the country and the cause of widespread waterborne diseases. Ill health in turn is a major cause for the poor remaining stuck in poverty. The lack of safe and clean sanitary facilities imposes constraints on the mobility of women and thus contributes to their disempowerment. In cities and towns, public toilets are rare and most are in a state of filthy neglect. Few offices and schools have clean well-maintained toilets. Public transportation does not cater to any such facility for its women passengers. Nor do recreational
settings provide for such a facility. Women are most inconvenienced by the lack of sanitation facilities (Sacosan, 2003).

The sanitation conference SACOSAN-2, held in Islamabad from 20 to 21 September 2006, was organized by the Ministry of Environment. The conference focused on activities currently being undertaken in the sanitation sector by key international funding institutions and the status of the sector. Key sector constraints highlighted were:

- Sanitation and hygiene offer little hope of short term cost recovery.
- Much of the investment needed by the poor is small-scale and at household level.
- The traditional dominance of water supply over sanitation in the sector needs correcting.
- There is limited client institutional capacity to program and manage large-scale sanitation and hygiene projects.

One of the recommendations made was for improved monitoring, evaluation, and accountability in sanitation and hygiene projects to achieve a greater focus on the unserved and a clearer understanding of costs.

Solid waste is also frequently discarded into the open drains or nullahs in urban areas, blocking sewerage systems and polluting local water courses and aquifers. Solid waste disposal must be considered whenever storm water drainage and sewerage projects are being planned and designed. Water pollution has become the major environmental problem in Pakistan, with less than 1% of municipal and industrial wastewater treated before disposal (Bridges, 2007).

**Low awareness of water related health risks**

In many locations in Pakistan people drink contaminated water and in rural areas it is common to find that people even use turbid canal water for drinking. This seems to indicate that awareness of the seriousness of the situation is not really felt among the population.

Some of the survey reports (PCRWR, 2006, 2007) mention that also at institutional level this awareness is not very present. They suggest that: the PHED and the local governments, which are the main agencies responsible for domestic water supply in the country, do not seem to be conscious about the quality of water they are supplying to the consumers and take supply of water only as the area of their responsibility. Any attempt to check the quality of water is made only when problems arises.

The same is the situation with the water supply schemes being operated by Users Committees and other private agencies in the rural areas. Housing Societies in the urban areas are also not conscious about this problem and leave it to the individual consumers to arrange for domestic filtration of water or use of bottled water which is easily available in the cities. WASAs, which are responsible for domestic water supply to ten major cities of the country, are more mindful of the quality of water, but all of them do not have proper facilities for this purpose. While some of the WASAs have developed their own laboratories and have appointed qualified staff for water sampling and testing, others are still lagging behind.

**Cultural diversity across rural landscapes**

Villages in the densely settled irrigated tracts, remote uplands, and water scarce rangelands of Pakistan have distinct cultural practices and related sanitation issues. The field-based knowledge of sanitation practitioners is helpful in understanding the variations that result from cultural practices, as summarised below.
The people of Hunza, Nagar and Baltistan (in the Northern Areas) give importance to human excreta and animal dung as a source of fertilizer. A local form of latrine is common in these areas. It is a raised platform type with ground level storage that is vacated when full. Dried excreta and dung are mixed with straw to form manure.

But across the Shandur Pass, open defecation is common in the equally mountainous Chitral district.

Women in Azad Jammu and Kashmir have to fetch water from distances of 2-3 kilometres, yet people generally prefer pour-flush latrines.

Where water is scarce, such as in Balochistan and Tharparkar (Sindh), the dry-pit latrine is the only feasible option.

In rural Punjab, women generally go out to the fields for defecation at night. In many areas of the NWFP, even this is not permitted. A small pan is used for defecation. Children pick up and dump the night soil outside the compound.

A national survey by Gallup/BRB of the knowledge levels, attitudes towards and practices for sanitation and hygiene revealed that the majority of Pakistanis do not have a clear understanding of the relationship between unsafe excreta disposal and diarrhoea. There was not much difference in the frequency of diarrhoeal episodes between households having latrines and those without latrines, indicating that latrines alone do not have an impact unless the behavioural patterns associated with sound hygiene practices are also ensured. There is also a misconception about the costs of latrines (as contrasted with the money spent on medicines in case of resultant illnesses). The majority of respondents felt that latrine construction was expensive (about twice the actual cost) and they were unable to afford it. Social status is the major reason for construction of latrines by the respondents, and privacy is perceived to be the major advantage (Sacosan, 2003).

Key challenges to be faced
Bridges (2007) suggests that the main issues and key challenges can be summarized as follows:
- Inadequate coordination between water user organizations.
- No inter-ministerial or inter-provincial body for water sector planning.
- Increase autonomy of water and sanitation agencies.
- Financially unsustainable - tariffs should at least meet O&M costs.
- Limited private sector participation or investment - need to increase this.
- Connect the urban poor (no connection fee or subsidized fee).
- The practice of open defecation must cease.
- Irrigation sector inefficient - overuse causes waterlogging and salinity.
- Low service levels and coverage.
- Deteriorating water quality - raw sewage must be treated.

Pakistan currently only spends 0.25% of GDP on water supply and sanitation. It needs to increase water sector investments to at least 1% of GDP and also must focus on tariff reform, increased wastewater treatment capacity, greater water conservation, and effective implementation of the National Water Policy.

Provision of safe drinking water project
Realizing the importance of uncontaminated and safe water for drinking purposes, Government of Pakistan launched a project by the name of “Provision of Safe Drinking Water Project” under the Khushal Pakistan Program. Pakistan Council of Research in Water Resources (PCRWR) of Ministry of Science & Technology is the executing agency of the project. The aim of the project is to ensure the provision of safe drinking water to the urban and rural communities of the country by monitoring the water quality, identification of problems with water supply schemes and their
sources through comprehensive technical assessment surveys, installation of demonstration filtration plants, training the technical staff of water supply agencies in operation, maintenance and monitoring of water supply schemes and creating awareness about the importance of safe drinking water in the staff of water supply agencies and among the general public of the country.

The Project will help to set up essential infrastructure, to build capacity of the staff, to identify problems of already completed water supply schemes and thus will work as a vehicle to promote a working relationship between the Federal Government and District Governments and will provide back up support for provision of safe drinking water. The project also includes a Technical Assessment Survey of Water Supply Schemes to assess the status of all existing water supply schemes in Pakistan.

**Point water treatment by filtration systems**
An important element adopted by the government of Pakistan is the provision of small water filtration systems (ultra filtration (section 5.5) combined with UV disinfection (section 5.4)) at strategic locations mostly in different locations in towns. This concept in itself is very valuable as it accepts that it will not be feasible to guarantee the water quality in most piped water supply systems which often operate intermittent and therewith may allow for intrusion of pollution even if adequate treatment would be provided before putting the water into the supply system. Hence small treatment systems are provided with public taps where people can come and collect water, often during certain times of the day. The implementation of the approach however has several flaws. Already a number of the systems ceased to function within a year because of inadequate maintenance. Part of the problem is that the water is free of charge and therewith no resources are being generated to maintain the system. Free water in fact reduces the value of clean water. It is the wrong message and it leaves the users without power. They need to be grateful if the system works. Changing the concept is therefore important. By introducing payment the users will have more leverage and if operators would be (partly) depending on the users’ payment (water kiosk concept) they would have a direct interest to keep the system working.

**3.6 Organizational and legal framework**
The Ministry of Water and Power through its Department (WAPDA) is responsible for water resources development and management. Urban water supplies are the responsibility of public sector water boards or water and sanitation agencies (WASAs) controlled by municipality, local government, or city council. There is a policy vision for the sector (Box 1), but there is no independent water regulator. The Ministry of Health plays an important role in setting water quality standards and in monitoring and control of drinking water quality in urban and rural areas (Bridges 2007).

Prior to the formation of Local Governments in Pakistan in the year 2000, the responsibility of providing water and sanitation facilities to the people was with the provincial Public PHED. These departments were managed by qualified engineers in the field of water supply and sanitary engineering/ environmental engineering. The engineers were assisted by sub-engineers and other technicians etc. The staff of PHED was spread throughout the province and planning, design, construction as well as the operation and maintenance (O&M) of water supply schemes was the responsibility of these departments. A vast majority of the water supply schemes have been constructed by PHED, but according to Bridges (2007) they followed a top-down approach, often producing schemes that are costly and technically difficult for local communities to maintain. Water supply and sanitation in the big cities are now looked after by Water and Sanitation Agencies (WASAs) which are headed by Managing Directors or General Managers. Most of the
WASAs have a considerable number of technical and managerial staff. Generally speaking, WASAs have considerable number of engineers and technicians including water quality experts and water quality technicians.

**Box 1. National water policy vision**

The National Water Policy vision is that Pakistan should have adequate water available, through proper conservation and development. Water supplies should be of good quality, equitably distributed and meet the needs of all users through an efficient management, institutional and legal system that would ensure sustainable utilization of the water resources and support economic and social development with due consideration to the environment, quality of life, economic value of resources, ability to pay and participation of all stakeholders.

The Water Sector Strategy provides a roadmap for the sector planning, development and management up to 2025. The National Water Policy prioritizes water rights, commits to clean potable water to all by 2025, promotes public-private partnerships, targets full financial sustainability in urban water supply, and with poorer communities subsidized through the tariff and charges at affordable rates. The National Drinking Water Policy and National Sanitation Policy detail strategies. The Government has begun an ambitious reform program (Bridges 2007).

Under the Local Government Ordinance 2001, Pakistan has embarked upon the creation of a new system of local government. A range of federal, provincial, and local services and resources have been rationalized. Three tiers of local government have been established: District, Tehsil and Union. Municipal functions including water and sanitation have been devolved to the newly created Tehsils, with the status of a corporate body. The earlier urban and rural local councils have been merged under the Tehsil, which has helped remove the urban-rural administrative divide in the provision of services and amenities. The staff of the departments previously responsible for water supply and sanitation, such as Public Health Engineering Department (PHED), Local Government and Rural Development (LGRD), Physical Planning and Housing (PP&H), and Urban Local Councils (ULC) have been transferred to the new Tehsil Municipal Administration (TMA).

The transfer of capital, human, and financial resources is planned to accompany the devolution of responsibilities. As expected, challenges have emerged during the transition phase of this complex reform. (Sacosan, 2003)

**Post-devolution structure of PHED in provinces**

The devolution of municipal services to the TMA level was intended to break the long chain of hierarchical approvals related to the administrative and technical aspects of the water supply and sanitation schemes. The LGO 2001 envisages that provincial department responsible for municipal level service delivery (LGRD, PHED, PP&H) would eventually be abolished, with the human and financial resources, assets and liabilities transferred to the Tehsil level. It is envisaged that the TMAs would be able to independently conceive, plan, design, implement, manage and operate municipal services. Technical staff drawn from the defunct departments would help elected representatives identify and implement feasible schemes. This has not happened to date.
Swayed by political compulsions, the devolution of PHED has followed different trajectories in the provinces. In Balochistan, the PHED remains fully functional. Parallel structures have emerged at provincial, district and tehsil levels, without formal linkages with each other. In NWFP, three departments were consolidated at the apex level, but subsequently, the provincial government has established six circles headed by the Superintending Engineer of the Works and Services Department, with a jurisdiction over 4-5 districts each. Sindh has kept a technical tier for meeting technical support functions. After an initial effective implementation of the LGO, Punjab has started re-centralising local government powers by establishing four regional offices. The half-hearted and incomplete devolution is resulting in duplication of municipal services in some cases. Their adverse fallout in development schemes is evident. Clear vision and direction is required to avoid a lasting decline in capacities to provide water supply and sanitation services.
Village and small town water supply
Whereas in some cases the PHED still plays a role in general it appears that the water supply schemes of small towns and villages are looked after by Local Government organizations (District governments and Tehsil administrations). Some of the small schemes have been transferred by Tehsil Administration to Users Committees (UCs). Schemes with the UCs are looked after by the Chairman of the Users Committee or Village Development Association or somebody designated by the Committee, who is usually a non-technical person but manages the system and takes decisions about collection of funds and operation and maintenance of the scheme facilities. He is usually assisted by an operator and a guard. The operator usually has education up to primary level. Some of the schemes have operators who have matriculation or higher qualification. Otherwise all the operators are totally illiterate but have experience of operating the motor and pump etc. In few cases more than one person looks after the scheme.

As for water supply schemes in small cities and rural areas, the staff dealing with WSS in the District and Tehsil offices is generally limited. Usually there is one Executive Engineer for the district which deals with the whole infrastructure of roads, buildings, water supply, sewerage etc. However there is one Sub-Divisional Officer (SDO) under him who deals with water supply schemes on a full time basis. However if no other person is available in the Tehsil office to look after roads and buildings etc. he has to perform that duty also. Usually there is nobody in the District and Tehsil office to look after the water quality aspects.

3.7 Rural water supply systems
Different water supply systems exist in rural areas and small towns in Pakistan (Box 2.).

<table>
<thead>
<tr>
<th>Box 2. Types of rural water supply systems in Pakistan*</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Gravity piped water supply systems, some with treatment</td>
</tr>
<tr>
<td>▪ Pumped piped water systems drawing water from ground water or surface water sources (canals, ponds), some with treatment</td>
</tr>
<tr>
<td>▪ Handpump on deep wells and on shallow wells. Many of these handpumps are locally produced and installed by local private sector. They tend to be cheap and of simple design but lack in durability</td>
</tr>
<tr>
<td>▪ Dug wells, sometime protected</td>
</tr>
<tr>
<td>▪ Springs with and without distribution network</td>
</tr>
<tr>
<td>▪ Open ponds, rivers and irrigation channels with and without distribution network</td>
</tr>
<tr>
<td>▪ Supply by tankers or local vendors</td>
</tr>
</tbody>
</table>

*In many communities more than one system exists

Bridges (2007) indicates that water supply systems are characterized by limited hours of supply, low pressure, intermittent water supply, high levels of non-revenue, and pollution of the treated water through contaminated groundwater infiltrating through leaky pipes whenever the distribution network is not pressurized. In the first half of 2006, major outbreaks of waterborne disease epidemics swept Faisalabad, Karachi, Lahore and Peshawar as a result of sewage and industrial waste leaking into drinking water through damaged pipes.

The assessments made by PCRWR show that also the rural and small town water supply systems face important problems in terms of water quality, water quantity and continuity (Table 3.7). Their assessments of piped water supplies confirm that the situation is critical. A large number of the water supply systems has serious problems, are not delivering 'safe water' to the consumers or
not providing water at all. The survey shows an array of difficulties including lack of awareness of water quality, water conflicts and other social, technical, managerial, and water quality problems faced by water supply schemes. Other reports show that the situation with for example hand pump supplies is equally critical.

### Table 3.7 Summary of survey results in 58 districts based on PCRWR (2008, updated)

<table>
<thead>
<tr>
<th>Total systems</th>
<th>Non Functional</th>
<th>Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td>4879</td>
<td>1825 (37%)</td>
<td>3054 (63%)</td>
</tr>
</tbody>
</table>

#### Best districts
- Gilgit
- Haripur
- Bahawalpur
- Abotabad
- Lower Dir

#### Worst districts
- Nankana Sahib
- Thandu Mohammed Khan
- Naushahro Feroze
- Matiari
- Khairpur

Interestingly it was found in several cases that differences exist in the registration of water supply systems in the Public Health Engineering Department and Tehsil Administration. Another important finding was also that in many cases no data on water supply schemes were available from the construction or operating agencies of the schemes. Particularly data on design and layout of the schemes could not be obtained from any sources. Data therefore had to be constructed with the help from Users Committees or O&M personnel and are not very accurate. The fact that many schemes do not provide good quality water however is a reliable finding as water sampling and analysis were done by qualified staff in qualified laboratories and results.

**Sustainability is not at all guaranteed**

It can be derived from the survey reports that many of the rural and small town water supply systems are not sustainable. The technical design has considerable limitations and does not match the local conditions. The management of the systems has a lot of limitations, repairs are not carried out in a proper way and financially most systems expenditures are higher than the income, with deficiencies being met by either people for the local community which are better off or by local government. The main problems can be summarised as follows:

- **Major technical deficiencies** in piped water supply systems including frequent problems of pipe leakage and damage due to the uneven topography of the area sometimes resulting in intrusion of pollution in the distribution network.

- **Water Quality and Treatment is not guaranteed**: Most water sources are open, including even boreholes, with no protection against faecal contamination. Often therefore microbiologically contaminated water is supplied to consumers resulting in frequent occurrence of water-related diseases such as diarrhoea and dysentery. In some cases also
chemical pollution such as Fluoride is present as well as high quantities of pesticides and herbicides. In some systems, disinfection of the water is occasionally being carried out in the overhead water tank by adding bleaching powder. This however is not done on a permanent basis and therefore has little effect.

- **Management and Technical Capacity is insufficient**: The management committee of the scheme is often technically and managerially unskilled. Also the operator may have limited skills with limited responsive actions to resolve problems.

- **Routine maintenance is not practiced**, resulting in important damages that gradually make systems even more unsustainable and costly. Pumps burn because of poor electric protection. Equipment corrodes because of lack of care etc.

- **Revenues not sufficient to cope with operation and maintenance and inadequate community organization.** In many systems there is imbalance between earnings and expenditures. The present monthly revenues are insufficient to carry out the routine maintenance and repairs. The revenue is needed to meet the requirements of operation and maintenance. The functioning of the local village association is in many cases insufficient to ensure the sustainability of the system. The local associations are also often hardly supported and trained.

- **Theft of transformers.** Most systems in Pakistan run on electricity and theft of transformers is a particularly vexing problem in some cases – the problem of course is not the transformer itself but the collusion and lack of local vigilance that allows such vital crime to happen.

- **Resource is drying up.** Either springs, wells or rivers, canals are loosing discharge or are unreliable sources of water supply. A particular problem is the drinking water systems supplied from irrigation canals: water is often contaminated and unreliable, especially in the so-called non perennial canals. In perennial canals the water systems may be closed for extended periods for cleaning – causing drinking water supply to suffer. Scheduling is not common in these cases.

In table 3.8 to 3.10 below the performance of three districts in Pakistan is given: Badin (low performer), Haripur (high performer) and Rawalpindi (average performer) – as well as the reasons for non functionality. These differ from district to district. A general feature is that there are often relatively simple basic reasons behind the non functioning. In Badin community fund collection is a major problem. In Haripur this is resolved as the local government takes all effort to keep the systems running and plug financial short falls: as a result – because the service is relatively good – the users contribution is relatively good. In Badin on the other hand the situation is more of ‘collapse and discouragement’.
Table 3.8a: Non functionality and functionality of drinking water schemes in Badin District

<table>
<thead>
<tr>
<th>Name of Tehsil</th>
<th>Water Supply Schemes</th>
<th>No. of Water Supply Schemes</th>
<th>Functiona l</th>
<th>Non-Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Survey ed</td>
<td>Populatio n Served (000)</td>
<td>No.</td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Badin</td>
<td>20</td>
<td>20</td>
<td>37.5</td>
<td>9</td>
</tr>
<tr>
<td>Matli</td>
<td>23</td>
<td>23</td>
<td>21</td>
<td>8</td>
</tr>
<tr>
<td>Talhar</td>
<td>10</td>
<td>10</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>Tando Bago</td>
<td>16</td>
<td>16</td>
<td>35.75</td>
<td>10</td>
</tr>
<tr>
<td>Shaheed Fazal Rahu</td>
<td>10</td>
<td>10</td>
<td>12.5</td>
<td>2</td>
</tr>
<tr>
<td><strong>District Total</strong></td>
<td><strong>79</strong></td>
<td><strong>79</strong></td>
<td><strong>122.75</strong></td>
<td><strong>34</strong></td>
</tr>
</tbody>
</table>

Table 3.8 b: Reason for non functionality in Badin

<table>
<thead>
<tr>
<th>Reasons for Non-Functioning</th>
<th>Number of Non-Functional Schemes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Badin</td>
</tr>
<tr>
<td>Repair of Pump/ Motor/ Trans/Distribution etc.</td>
<td>7</td>
</tr>
<tr>
<td>Low Pressure in System</td>
<td>-</td>
</tr>
<tr>
<td>Source Dried-Up</td>
<td>1</td>
</tr>
<tr>
<td>Non-Completion of Scheme Infrastructure</td>
<td>-</td>
</tr>
<tr>
<td>Theft of Transformer</td>
<td>-</td>
</tr>
<tr>
<td>Community Dispute/ Collection of O&amp;M Funds</td>
<td>3</td>
</tr>
<tr>
<td><strong>District Total</strong></td>
<td><strong>10</strong></td>
</tr>
</tbody>
</table>
Table 3.9a: Non functionality and functionality of drinking water schemes in Haripur District

<table>
<thead>
<tr>
<th>S#.</th>
<th>Tehsil/District</th>
<th>No. of WSS Surveyed</th>
<th>Functional</th>
<th>Non-Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>1.</td>
<td>Haripur</td>
<td>90</td>
<td>85</td>
<td>93</td>
</tr>
<tr>
<td>2.</td>
<td>Ghazi</td>
<td>11</td>
<td>06</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>101</td>
<td>91</td>
<td>90%</td>
</tr>
</tbody>
</table>

Table 3.9b: Reasons for non functionality in Haripur District

<table>
<thead>
<tr>
<th>S#.</th>
<th>Reasons for Non-Functioning</th>
<th>Number of Non - Functional Schemes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Haripur</td>
<td>Ghazi</td>
</tr>
<tr>
<td>1.</td>
<td>Repair of Pump/ Motor/ Trans/Distribution etc.</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Low Pressure in System</td>
<td>0</td>
</tr>
<tr>
<td>3.</td>
<td>Source Dried-Up</td>
<td>1</td>
</tr>
<tr>
<td>4.</td>
<td>Non-Completion of Scheme Infrastructure</td>
<td>0</td>
</tr>
<tr>
<td>5.</td>
<td>Theft of Transformer</td>
<td>0</td>
</tr>
<tr>
<td>6.</td>
<td>Community Dispute/ Collection of O&amp;M Funds</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>5</td>
</tr>
</tbody>
</table>
### Table 3.10a: Non functionality and functionality of drinking water schemes in Rawalpindi District

<table>
<thead>
<tr>
<th>Name of Tehsil</th>
<th>Water Supply Schemes</th>
<th>No. of Water Supply Schemes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Surveyed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxila</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Rawalpindi</td>
<td>112</td>
<td>112</td>
</tr>
<tr>
<td>Gujar Khan</td>
<td>73</td>
<td>73</td>
</tr>
<tr>
<td>Kallar Syedan</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Kahuta</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Kotli Sattian</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Murree</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>District Total</td>
<td>385</td>
<td>385</td>
</tr>
</tbody>
</table>

### Table 3.10 b: Reasons for non functionality in Rawalpindi District

<table>
<thead>
<tr>
<th>Reasons for Non-Functioning</th>
<th>No. of Non - Functional (Temporarily Closed) Schemes/District</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TAX</td>
</tr>
<tr>
<td>Repair of Pump/ Motor</td>
<td>3</td>
</tr>
<tr>
<td>Breakage in Trans/Distribution</td>
<td></td>
</tr>
<tr>
<td>Low Pressure in System</td>
<td>0</td>
</tr>
<tr>
<td>Source Dried-Up</td>
<td>0</td>
</tr>
<tr>
<td>Non-Completion of Scheme Infrastructure</td>
<td>1</td>
</tr>
<tr>
<td>Theft of Transformer</td>
<td>2</td>
</tr>
<tr>
<td>Community Dispute/ Collection of O&amp;M Funds</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Some of the WSS are closed because of more than one reason. As such the total is greater than the number of closure schemes.
4. Water quality and treatment

4.1 Types of water supply systems

In rural areas and small towns in Pakistan different water supply systems can be found (see section 3.7). It is important to realize that in many communities more than one system exists and sometimes people have a choice to select the system they like best. Considerable experience exists of people returning to their traditional water sources because they did not get the service they wanted from an improved system, were not willing to pay the price or were in fact forced to go back because the improved system broke down. In many communities it is also common that different sources are used in parallel, often because of convenience but also because of lack of financial resources.

The different water supply systems indicated in section 3.7 all may be able to deliver good quality water but equally may contribute to spreading of disease. It is not the technology in itself but the appropriate use of the technology that makes the difference. Such use implies that the technology is in harmony with the local culture, that it matches the technical and financial capacity of the community and that it is in line with the available natural resources. It truly has to match the main principles that need to be satisfied in a good water supply system (Box 1).

If the technology and the water supply system do not meet the community demand it will be abandoned quickly, thus leading to a loss of investment and efforts. Every technology that is being installed in conditions different from where it was developed needs to be tested, evaluated and, if required, adapted, to ensure its compatibility with the new situation in which it will be used. Its cost needs to be in harmony with the benefits as perceived by the user communities and had to match their willingness to pay. It is essential to consider the technology (the hardware), as well as its requirements for operation, maintenance and management, the type of staff needed and the training they require, and finally its environmental impact. This facilitates its assimilation by the community and enhances the possibility of guaranteeing its adequate operation and maintenance. When the technology promotes the autonomy of the community with respect to external resources and assistance, particularly in operation and maintenance, the chances of sustainability are increased.

If a technology is already in place and is posing problems the first option is to explore if these problems can be solved by:

- Building the capacity of community members
- Improving the back-up support including availability of spare parts
- Improving the link with the users to reduce tampering with the technology
- Adjustment of the technology to better suit the local conditions.

It is however also important to review if this type of problem solving will be more suitable and less costly than replacing the technology with a system that is more suitable for the local situation.
Box 1: Requirements of WSS service provision

- **Coverage** that permits equal distribution of benefits.
- **Quantity** sufficient to satisfy the community demand within reason and ensure health benefits.
- **Continuity** offering access to service at the required time and location.
- **Quality** needed to obtain health benefits.
- **Cost**, not only in line with the communities' willingness to pay, but also matching a rational and efficient use of resources, with special care for the environment.
- **Management Capacity** of the community, enabling it to participate in the whole project including problem identification, planning, implementation, operation, maintenance, management, surveillance, control and evaluation.
- **Culture**, recognizing that development refers to persons, not things and that the possibilities to improve the quality of life depend on the real potential of the community to satisfy its needs using the knowledge and experience of the founders.

### 4.2 Water treatment

Water can be contaminated by different agents:

- **Pathogens** – disease-causing organisms that include bacteria, amoebas and viruses, as well as the eggs and larvae of parasitic worms.
- **Harmful chemicals** from human activities (industrial wastes, pesticides, fertilizers).
- **Chemicals and minerals** from the natural environment, such as arsenic, common salt and fluorides. Some non-harmful contaminants may influence the taste, smell, colour or temperature of water, and make it unacceptable to the community.

Water from surface sources often contains microbial contamination, whereas groundwater is normally safer in this respect, but even (shallow) groundwater can be contaminated because of harmful human activities or because of the natural conditions (fluoride, arsenic etc.). Rainwater captured by a rooftop harvesting system is relatively safe in terms of microbial contamination, provided that the first run-off is allowed to flow to waste when the rainy season starts.

There are few chemical components that produce an acute health risk for the users, except for situations where accidents occur in industry or through the spraying of pesticides and herbicides. In such cases risks are still small because the contaminated water is often rejected by the consumers. Chemical pollution may, however, imply a chronic health risk associated with long periods of exposure. Its control is therefore important, but of a secondary order in water supply systems that are subject to severe bacteriological contamination.

The user may not be very much aware of bacterial or chemical contamination, accepting the water mainly through its appearance. Issues such as turbidity, colour, taste and smell can make users turn to other water sources possible more contaminated with ‘invisible’ micro-organisms and involving a high health risk. Thus these organoleptic aspects need to be taken into account in community water supply.

With increasing life expectancy, enhanced institutional capacities and improved economic conditions, water treatment will progressively combine technologies to reduce both the acute
health risks, often of micro-biological nature and the chronic health risks usually of physical-chemical origin (Figure 4.1)

![Image of Figure 4.1: Conceptual relation between socio-economic level and water treatment objectives (adapted from Reid, 1982).]

Improving the water quality in itself will have limited effect as many water related diseases are being transferred through other faecal-oral routes (Figure 4.2) and therefore it is essential to combine water treatment with activities related to basic sanitation and hygiene promotion.

![Image of Figure 4.2: Routes of fecal disease transmission and protective barriers]

**Figure 4.1** Conceptual relation between socio-economic level and water treatment objectives (adapted from Reid, 1982).

**Figure 4.2** Routes of fecal disease transmission and protective barriers
The real risk of a water resource cannot be established by taking a few water samples. It is essential to combine water quality testing with a sanitary survey to explore all possible risks that are involved. A sanitary inspection consists of a systematic review of the water catchment area, the water source and the water supply system, preferably by experienced sector staff, together with community members and staff from the local organization responsible for the management of the system. The inspection aims at identifying all possible sanitary risks in the catchment area and the water supply system (intake, transmission main, treatment system, water storage, distribution network and water use) that may put the users at risk (Lloyd and Helmer, 1991; WHO 1997 and 2004).

4.2.1 Priority setting in water quality improvement

The establishment of the risk level in a sanitary inspection as well as the interpretation of the results of the water quality analysis requires experience and insight in the local situation. In the sanitary inspection the risk is identified on the basis of an inspection sheet that categorises the problems that are being identified. Depending on the complexity of the water supply systems one overall format (checklist) can be established, or the different system components can be reviewed separately by having separate formats for the catchment area, the intake and transmission main, the treatment system and the distribution system. The risk level is established by listing the ten to 20 main possible sanitary risks such as open field defecation in the catchment area or surface water infiltration in the transmission main or storage tank. If such risk is available a positive score is given and all positive scores are added up. A high final score implies a high sanitary risk.

For similar conditions in terms of geography, type of systems, type of vegetation the form can be standardized, thus reducing the cost of specialist inputs and making comparison possible. Lloyd and Helmer (1991) and the WHO (1997), give a number of valuable examples of sanitary surveys and the forms they applied. These forms may provide a good basis that needs to be adjusted to the specific conditions of the area under review.

Also the bacteriological water quality can be classified which for example is important to establish the possible level of treatment needed for a given water source. If a larger number of systems needs to be compared the classification of risks makes it possible to establish priorities. Table 4.1 provides two cases of risk classification used in different settings. If after some time a series of corrective actions have been taken or better technologies are coming available in the area under review, the classification may be adjusted, giving that the intention is to interfere primarily in systems classified in the higher risk categories.

<table>
<thead>
<tr>
<th>Table 4.1</th>
<th>Two examples of risk classification based on contamination levels of faecal coliforms (Lloyd y Helmer, 1991)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level</td>
<td>Study area in Indonesia</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1 - 10</td>
</tr>
<tr>
<td>C</td>
<td>11 - 100</td>
</tr>
<tr>
<td>D</td>
<td>101 - 1000</td>
</tr>
<tr>
<td>E</td>
<td>&gt; 1000</td>
</tr>
</tbody>
</table>
The results of the water quality analysis and the sanitary inspections carried out for different systems in a region can be brought together in one model as proposed by Lloyd and Helmer (1991). This model will help to define where priority improvements need to be made in the existing water supply systems to particularly reduce the risk associated with micro-biological contamination. In this model both systems with a high sanitary risk identified with the sanitary inspection and systems facing a high micro-biological contamination need urgent improvements. For systems where both risk levels coincide, the decision is easy. However also for systems that only have a high score in one of the two risk levels, still improvements are a priority. The discrepancy between the two may be due to for example undetected sources of contamination in the sanitary inspection, cross connections or undetected infiltration of polluted water in the distribution network that may cause a high level of faecal coliforms. Also the water quality analysis, being based on spot samples may not always reflect the true level of contamination. Still in these cases data have to be checked carefully to avoid undue investments as a result of inadequate interpretation of results. For example, in a catchment area that is well protected, has an undamaged flora and very little human activity, one would expect low risk levels and low treatment cost. If in these conditions micro-biological contamination is detected, it is important to double check if sampling and testing has been carried out correctly.
It is possible to relocate the position of a specific water supply system in the model by, for example, changing the water source, modifying patterns of open field defecation and cattle breeding, thus placing less emphasis on water treatment requirements. This makes it possible to adopt less complicated water treatment methods that can be more easily managed and maintained by the community.

### 4.3 Main water treatment concepts

Applying different barriers is important to reduce the risk of micro-biological contamination and prevent the transmission of water-borne disease. This includes selection and protection of the best available water source, water treatment to remove or inactivate disease causing micro-organisms, proper water storage and promotion of safe water practices of the users (Okun, 1991; Geldreich and Craun, 1996).

The protection of watersheds in Europe and the USA is set by advanced regulations that are being developed further. The protection of watersheds in developing countries is still in its initial stage, with insufficient legislation, lack of monitoring tools and a lack of trained personnel to oversee the process. This aspect needs greater attention, particularly in the rural areas where tighter collaboration can occur between the communities and the entities of the water sector. It can be necessary, for example, to regulate the cutting of trees in remote areas, which can often only be achieved through “social” control by the community that live in the zone. Furthermore, it is possible that it may be necessary to restrict the use of pesticides in some watersheds, which then presents the problem of compensation to the farmers of the watershed, in regions where the market economy has hardly begun.

Reduction of waste water discharge particularly if including human and animal excreta can very much contribute to lowering the sanitary risks. For dispersed populations and small hamlets on site...
treatment is a feasible option. For larger settlements collection and subsequent of-site treatment seems the best possibility. The level of treatment should be such that the remaining contamination can be removed by the natural purification effect in the receiving water bodies.

4.3.1 Basic water treatment concepts

Water treatment may be one of the barriers to ensure that water produced from surface water sources complies with the WHO water quality guidelines (WHO, 1997 and 2004). The level of treatment should maintain harmony with aspects such as: the type of risk existing in the supply source, the socio-economic conditions in the community and the environmental management in the supply watershed. Some key concepts and characteristics can be identified that very much contribute to making water treatment reliable and efficient (Figure 4.4).

![Figure 4.4 Combination of multi-barrier concept, the integrated treatment concept and safety disinfection](image)

**Multi-stage treatment.** This concept has a long history and has evolved gradually when interest in water quality improvement increased (Craun et al., 1988). According to this concept, there should be more than one stage of treatment to produce water suitable for human consumption. Together, these stages progressively remove the raw water contaminants and consistently produce water fit for drinking. Ideally, water of low sanitary risk should be obtained before the final stage of treatment which then represents a security barrier (Galvis, 1999).

**Integrated treatment.** In the application of the multi-barrier concept, it is important to understand that not all the barriers have the same removal efficiency for the different types of contamination. Therefore, the concept of integrated treatment is applied that considers the possibilities and limitations of each stage or barrier for the removal of different types of contaminants. The removal should be quantified and balanced in such a way that all the contaminants can be removed effectively and in a cost efficient manner. In general it is convenient to first separate the heaviest and larger material and gradually proceed by separating or inactivating the smaller material represented by particles that include colloidal solids or micro-organisms.

**Terminal disinfection.** The last stage is usually disinfection and in order for it to be effective, the previous barriers or stages need to remove virtually all the pathogenic micro-organisms and substances that can interfere with the disinfection process. This needs to be achieved in such a way that under all circumstances the capacity of the disinfectant is sufficient to ensure a safe
water supply. Adequate treatment implies that only a small and rather constant dose of disinfectant is needed, thus making this last stage more easy and reliable to operate. This and adequate strategies for the transfer of disinfection technologies are needed to overcome the vulnerability of the present situation were many disinfection systems applied in community water supply systems are not functioning adequately.

Table 4.2 presents an example of the application of the water treatment concepts described to reach an end product that meets the WHO criteria, adopting processes that do not require dosing of coagulants.

<table>
<thead>
<tr>
<th>Treatment step</th>
<th>Turbidity (NTU)</th>
<th>Faecal Coliforms (FCU/100 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Removal (%)</td>
<td>Average Load</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Removal (%)</td>
</tr>
<tr>
<td>Screening</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Gravel filtration</td>
<td>80</td>
<td>30</td>
</tr>
<tr>
<td>SSF</td>
<td>&gt;90</td>
<td>6</td>
</tr>
<tr>
<td>Disinfection</td>
<td>NA</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Quality in distribution</td>
<td>&lt;1</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>

* Removal (%) is the required removal efficiency in each treatment stage to reach the treatment objectives.
* ** NA, not applicable. This implies that the treatment process does not remove turbidity or micro-organisms.

Source: Lloyd et al, 1991

**Disinfection as the only process?**

In many countries water treatment still has a lot of limitations and in some cases disinfection may be the only process that is included. This however is still very risky and in that respect is it interesting to look at the very stringent conditions used in the USA, if disinfection of surface water is the only treatment step. Pontius (1990) presents that this is only acceptable under the following eight conditions:

1. the level of faecal contamination has to be less than 20 FCU/100 ml in 90 percent of the samples;
2. the turbidity has to be below 5 NTU. Sometimes higher values are accepted provided they occur less than twice per year;
3. the disinfection has to be operated in such a way that it inactivates 99.9 percent of the quists of *Guadria Lamblia* and 99.99 percent of viruses. This is controlled by prescribing minimum residual chlorine levels and contact times before the water reaches the first consumers measured at the peak consumption hour;
4. a sustained control programme for the catchment area needs to be developed;
5. sanitary inspections are needed every year with participation of the health authorities or their delegates;
6. outbreaks of water borne diseases should be eliminated;
7. compliance with the procedures concerning indicators for contamination with fecal coliforms;
8. compliance with the procedures concerning the maximum level of trihalomethanes.

These conditions are very strict and can only be adhered to in few countries of the world. In most developing countries they definitely cannot be met thus underscoring the need to adopt the concepts of water source protection, multi-barrier and integrated treatment leaving terminal disinfection as the last safety barrier.

**Disinfection by-products**

The understanding that chlorine reacting with organic matter can cause disinfection by-products that may represent a chronic health risk, raised concern about its application to avoid the transmission of cholera (Salazar, et al, 1993). However it has been established that the health risk associated with these by-products is very small compared with the risk related to inadequate disinfection. In reality, the chronic risk must not be ignored, but the acute risk of micro-biological character is much more important. This is especially the case of systems drawing water from sources that are high in micro-biological contamination. Not applying chlorine in these conditions has serious implications for public health and a negative socio-economic effect on the communities. This is the situation in many developing countries with a poor sanitary situation and a low level of socio-economic development (Craun et al., 1994). In the search for possible alternatives for chlorine, it should be carefully explored if they are equally effective and easy to dose and supply. The selection of good quality water resources and if required proper treatment, including filtration will reduce the required chlorine dose, and the possible formation of by-products making the disinfection more efficient. The incidence of water borne diseases in the USA has been eight times more in communities using surface water sources without filtration than in those using filtration (Craun et al, 1994).

### 4.3.2 Reduction of water pollution from waste water discharge

Waste water and on-site sanitation systems may be an important source of pollution for drinking water. A colour code has been developed to characterize the different types of water and waste water. The code includes the colours: blue, yellow, brown, black. Two other categories have been added without colour waste water from industry and from agriculture (Table 4). Waste water that reaches water courses may be a very important source of pollution depending on its origin and the level of treatment. The discharge may be at one location (point discharge) or it may reach the water course in a diffuse manner (e.g. drainage water from agriculture land). The risk involved also depends on the composition if the waste water, the level of dilution and the distance between the point of discharge and the location of the water intake. Waste water main contain many contaminants including bacteria, viruses, helminths (worms and eggs), organic material and nutrients (P, K, N) but sometimes also medicines and other chemicals. Waste water discharge may affect the recipient water body. For example organic matter requires oxygen for its decomposition which in extreme cases can lead to the complete depletion of the oxygen level of the recipient river or lake causing the disruption of aquatic life. Nutrients may stimulate the algae growth and may cause the eutrophication of water bodies. Industrial waste water contains acids, heavy metals and others. Agricultural run-off can bring DDT and other pesticide residuals. The different types of sanitation systems bring different effects and risks in terms of direct exposure and contamination of surface water bodies, shallow groundwater and soils (Table 4.3).
In many areas storm water from rain showers and sewerage are collected in a combined sewerage system which involves high peak flows, and considerable dilution of the black water making treatment more complex, and peak flows may lead to overflows causing direct contamination of the environment. In other cases separate sewerage systems are used, with the advantage that the black water system collects smaller quantities with a more regular and concentrated flow which favours treatment.

Waste can also be seen as a resource and be converted into valuable products. In fact there are concerns in Europe that waste water is treated to the extent that it has become too poor in nutrient to sustain downstream aquatic life. Converting waste works best if the waste is not too much mixed. In several countries efforts are at work to make business out of waste reuse. One example is the Safi Sana concept, that is underway in Ghana. Under Safi Sana old sanitation blocks and water kiosks are restored and new ones are built. A standard unit consists of 20 showers, 20 toilets and a water kiosk. Through this concept 1,200 people will be reached per unit. To make the project sustainable slum dwellers have to make a small contribution for management and maintenance when using the facilities. The management and maintenance will be done by local (private) parties, which will be supported by a larger mother company. The second novelty is the effort to interest local entrepreneurs in the reuse of the human excreta and grey water. Reuse could concern bio-fuel, fertilizer or mineral extraction. Another example is the conversion of waste in animal feed in ponds and small wetlands, among others through the growth of duckweed or water hyacinth. This fast biomass converters can also develop into a pest. The cultivation of duckweeds in ponds fed with manure, both human and livestock, is traditionally practiced in China. The duckweed provides the green fodder to herbivorous grass carp fingerlings. As the fingerlings grow larger they can consume grass directly.
Table 4.3 Effects and risks of different excreta disposal methods

<table>
<thead>
<tr>
<th>Disposal method</th>
<th>Effect</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open field defecation uncontrolled disposal of faeces of adults (flying toilets) and children</td>
<td>• Contamination spreads over soil, drains into surface sources and into ground water</td>
<td>Ingestion of bacteria and viruses through direct contact with soil and surface water or transmission via insects; Shallow ground water may not be safe to drink. Risk is lower in dry climates and in areas with low population density</td>
</tr>
<tr>
<td>Pit latrine, poor flush latrine</td>
<td>• Contamination of ground water from seepage</td>
<td>Relatively low risk unless shallow groundwater wells are nearby. Nitrate contamination may build up over years in areas with high population density. Flooding may cause a higher risk as pit content may wash out</td>
</tr>
<tr>
<td>Ecological sanitation</td>
<td>• Contamination of environment if emptying is poorly managed</td>
<td>Very low risk unless fresh excreta are removed and disposed of. Nitrate build up is virtually no risk if urine is diverted and being used as fertilizer. Flooding less likely to cause problems as structure is closed and above ground</td>
</tr>
<tr>
<td>Septic tank</td>
<td>• Contamination of ground water from seepage</td>
<td>Relatively low risk unless shallow groundwater wells are nearby. Flooding may cause a higher risk as tank content may wash out</td>
</tr>
<tr>
<td>Sewer systems</td>
<td>• Contamination of ground water from seepage along the pipes</td>
<td>Risk of contamination from seepage may be low unless water supply pipes are close by. Risk of discharge will depend on the level of treatment and the subsequent use of the receiving water body or the direct re-use in agriculture. Some risk also exist in discharge of accumulated waste from treatment processes. Flooding may involve a considerable but often localized risk.</td>
</tr>
</tbody>
</table>


Much of the interest in duckweed based systems has come from the potential of duckweed as high-protein animal feed for fish or for livestock. The protein content of duckweed is 25-45% on a dry matter basis and growth rates of 10 to 40 ton of dry matter can be achieved per year. Duckweed grows in shallow water and the shade and can be harvested easily. The drawback is that growth is affected by temperature extremes and by high light intensity. Duckweed is sometimes susceptible to infestation and is generally difficult to dry.
4.3.3 Wetlands to reduce pollution

In many cases wetlands may have a positive effect on water quality (Table 4.4). This includes reduction of nutrient loads (nitrate, phosphor), removal of heavy metals and reduction of turbidity levels. A review of some sixty wetlands showed that in 80% levels of phosphorus and nitrogen were reduced. In the other 20% however these levels increased which may contribute to eutrophication of downstream waters. Reduction in bacterial levels can be considerable. Research in the Nakuvungo swamp near Kampala (Uganda) showed that the Ecoli level was reduced by 91%, thus greatly improving the water quality, but additional treatment is needed to use it for example for drinking water. Also some hazardous substances such as fluoride, DDT, and pharmaceutical residues may be retained and accumulate in the wetland. The accumulated substances than can enter into the food chain for example through fish caught in these environments. Hence some caution is needed which calls for close monitoring when introducing wetlands.

<table>
<thead>
<tr>
<th>Table 4.4 Functions of wetlands in waste water treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapping sediment</td>
</tr>
<tr>
<td>Reduce turbidity</td>
</tr>
<tr>
<td>Restrict passage of toxics and heavy metals</td>
</tr>
<tr>
<td>Decreasing BOD (biological oxygen demand)</td>
</tr>
<tr>
<td>Decreasing nitrate levels</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Decreasing phosphate levels</td>
</tr>
</tbody>
</table>

An attractive aspect of wetlands is that if properly managed they may positively contribute to the livelihood of people using them for productive purposes and to the local economy. They can become part of closing the sanitation nutrient cycle with waste giving rise to income opportunities. The most impressive example are the Kolkata Eastern Wetlands in India, covering an area of 12500 ha and providing a livelihood to fishermen and farmers – besides serving to clean most waste water produced by Kolkata (Box 5).
Box 5: East Calcutta Wetlands

Close to one of the world’s biggest cities in India, the East Calcutta Wetlands are located between the River Hugli and the Kulti Gong. The wetland is used intensively: for the treatment of waste water from Calcutta, but also to sustain fishery and agriculture as well as residential areas.

Over time the way wetlands has undergone several changes, caused by man as well as by nature. Originally, the East Calcutta Wetlands were saline marshes, but over the last century the area has changed into a non saline waste-recycling region. City sewage was introduced deliberately in the area and has been the basis of the sustenance of the wetlands. The reason to channel the Calcutta waste flows to the area was that at the time the tidal flow was reduced, threatening the livelihood of thousands of fisherman and their families. Over time the flora and fauna in the area changed from saline to non saline adapted species. The dynamic change continues and in the last decades parts of the ecosystem have been lost permanently due to increasing urbanization and others, in principle temporarily due to pollution.

As early as 1929 a start was made with integrating wastewater in economic activities. In that year a leading local fish producer experimented with the process of farming fish in sewage-fed ponds. The experiments turned out successful and till today this technique is practised. Organic loading rate of the fish ponds varies between 20 to 70 kgs per hectare per day (in the form of BOD). Especially species like Rohu, Catla, Mrigal, and exotic ones like Silver Carp, Grass Carp, Common Carp, Walking Catfish and Tilapia do well in the sewage-fed ponds. It is estimated that the livelihood of over 8,500 persons is sustained by the fishponds. In addition in other parts of the wetlands agriculture is the main activity: both effluent-irrigated paddy cultivation and vegetable farming on garbage substrate.

An estimated 750 million litres of sewage and wastewater and more than 2500 metric tons of garbage are produced daily by the city. The wastewater is lead through underground canals to the eastern limit of the city, where it is pumped into open canals. It is here that the responsibility for the wastewater shifts from the Kolkata Municipal Corporation to the fishery owners. The latter take care that the wastewater makes it way into the fisheries of the East Calcutta Wetlands. The cumulative efficiency in reducing the BOD of the wastewater is above 80 percent and that in reducing coliform bacteria is 99 % on an average. The solar radiation is high and is adequate for photosynthesis to take place. In fact, the sewage-fed fishery ponds act as solar reactors. This solar energy is tapped by a dense plankton population, which, in turn, is consumed by fish. While the plankton plays a highly significant role in degrading the organic matter in the wastewater, handling plankton overgrowth does become a problem in terms of pond management. It is at this critical phase of the ecological process that the fish play an important role by grazing on the plankton. The two-fold role played by the fish is crucial: they maintain a balance of the plankton population in the pond and convert the available nutrients in the wastewater into readily consumable form for the humans.

Besides domestic wastewater the East Calcutta Wetlands also receive wastewater from nearby industries, and this is released to the fish ponds as well. Not all the industries pre-treat the wastewater As a result heavy metal deposits have been found in fish and vegetables grown in the area. However, several studies suggest that the metal accumulation in fish from the wastewater fed ponds is at par with freshwater fed fish ponds in the area. The fish ponds also serve to trap sediments in the water, which are removed manually by fishermen. The latter reduces the public cost for desilting of the outfall canals.
The water treatment function of wetlands

This section presents the main processes that are present in water treatment in wetlands.

Sedimentation and settling

Most types of wetlands are good sediments traps. Many wetlands include parts with dense vegetation. These field-forest edges slow down the flow of the surface water, depositing much of the coarser sediment. As the water moves further through the wetland, the texture of the deposited sediments becomes finer and finer. In the process the turbidity of water is reduced and the water that is released from the wetland is relatively clear.

Bacterial action

Nitrate-nitrogen is removed through a biological process known as denitrification. In denitrification, soil bacteria convert nitrate-nitrogen to nitrogen gas, which eventually returns to the atmosphere. This process is most active in the upper part of the wetlands. The location of the wetland (or wet soils) is more important for water treatment than the degree of wetness or size of the wet area. Soils immediately adjacent to streams, which are wet because they receive surface or subsurface flows from higher elevations, are the most effective at removing nitrate- nitrogen from agricultural and other runoff waters.

Vegetation processes (plants, micro-organisms, macro-algae)

Wetlands vegetation plays an important role in water treatment. Plants are especially effective in the retention of nitrogen and phosphorous. This prevents eutrophication which may lead to oxygen depletion and for instance fish kills. The uptake of nitrogen by plants in wetlands is not constant over the year: it takes place during the growing season. Nitrogen removal is further accelerated by microbial action – the working of bacteria and micro-organism around the roots of the plants in particular. Also heavy metals are removed from the water by plant uptake.

Soil processes

Compared to adjacent (for instance uplands areas) wetland soils have a high organic content. This binds and stores nutrients and contaminants (see box). Phosphorus too is processed by the soils of the wetlands. However, unlike nitrogen phosphorus cannot be lost from wetlands through metabolic processes and accumulates over time. The composition of the soil determines the amount of phosphorous uptake, but remarkable here is that if the soil has low phosphorus loadings it tends to release rather than retain the element. Therefore wetlands sometimes usually function as a sink, but sometimes as a source of phosphor too.
Plankton and photosynthesis
Many nutrients are converted into plankton by photosynthesis. The importance of the plankton community in wastewater treatment has been underestimated for a long time, simply because of it tends to accumulate and thereafter release the nutrients again. But by introducing highly productive fisheries the nutrients are being removed.

Conversion by algae
In coastal wetlands it is not so much the plant vegetation that can bring down nutrient loads, but the growth of algae and sea weed. These algae can also be used productively and thus imply income generating opportunities including: oil extraction, food or biomass production and support fisheries.

Box 6: Wetland soils
There are generally three layers of soil in wetlands. The top layer is an oxidized or aerobic surface layer where oxygen is always present. The second layer is alternately oxidized and deleted. In the last zone no free oxygen is ever present. The thickness of these layers can vary diurnally. The process of decomposition proceeds at different rates depending on the amount of oxygen present. Many wetlands plants have a unique capacity to transport oxygen into the root zone and create oxidized rhizosphere. The aerobic rhizosphere of wetland plants support nitrification, while the adjacent anaerobic zone supports denitrification. The sediments that enter the wetland can accumulate in the sub-soil and remain there or be transformed by ongoing chemical and biological processes.

Factors affecting effectiveness of water treatment by natural wetlands
Several factors affect the treatment processes in of wetlands.

- **The type of wetland.** Swamps and marshlands have a better overall retention of ammonium-N. Depending on their morphology water movement is slower. Riparian wetlands on the other hand are more effective in reducing the TP loading and reduced TN. The capacity for nutrient removal may be less in coastal wetlands, and estuaries sensitive to eutrophication or near coral reefs.

- **Temperature.** At lower temperature levels the nitrification process slows down.

- **Carbon availability.** Sufficient carbon needs to be available to allow the uptake of P and N.

- **Age.** With aging the phosphor fixation in wetlands decreases.

- **Type of vegetation.** Reeds and sedges are known to be extremely effective. Fast growing species also remove more nutrients, but their decomposition may release the nutrients back.

- **Oxygen levels** in the sediments are important as is the presence of cyanobacteria that fix N.

- **Hydraulic factors.** The performance of the wetland depends on the duration, the volume and the pollution level of the inflow and the fluctuation in water levels.
Ways to enhance the effectiveness in water treatment in wetlands
There are a number of ways to enhance the effectiveness of natural wetlands to improve water quality, leading to what has been called modified or adjusted wetlands.

- **Pre-treatment.** Is an important option to improve water quality before it reaches the wetland to avoid overloading. It adds however to the cost which may be difficult to manage.

- **Changing wetland vegetation.** Vegetation is a major factor in the effectiveness of wetlands in water treatment. This effectiveness can be improved by rehabilitating the original vegetation or by planting species that are known to be very effective. In addition floating island can be introduced or duckweed – to accelerate the treatment process.

- **Promoting surrounding vegetation.** As part of the Project for Improvement of Water Governance in the Volta Basin trees were planted along the river banks of the Volta River – thus converting the river bank from agricultural use (causing erosion and pollution) to high value horticulture use and creating a buffer zone in the process.

- **Inflow control or pulsing.** Evidence suggests that the longer the period between the inflow of waste water and excreta and the harvest of plants or fish, the larger the removal of nutrients and pathogen reduction. Low level charging or intermittent charging gives better results. Pulsing is a way of jumpstarting the removal processes. Varying water tables is alternative.

- **Hydraulic manipulation.** There are a number of interventions in hydraulics that will increase the treatment capacity of wetlands. The construction of small dams and man-made rapids will increase the turbulence of the water and will increase oxygen levels. Allowing rivers to overflow and expand wetland areas will prolong retention and increase aeration.

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**Box 7 Floating islands, Ujjain, Madhya Pradesh (India)**

Artificial floating islands can contribute to the on-site water treatment services of freshwater bodies – including lakes, reservoirs and rivers. Artificial floating islands have been used to clean up pollution in the Shipa River near Ujjain in Madhya Pradesh (India) since 2005. The pilot system was set up at a cost of USD 15000. An island of 200 square meters was constructed at the place where a drain carrying the effluent from Indore City joins the river. The island consists of reed grass, placed on small platform units made of bamboo, ropes and wires. The reed grass absorbs nutrients in the water, whereas the roots add oxygen. This increases the dissolved oxygen level in the water, enhancing the self purifying capacity of the river. The reed root-coir matrix has several additional functions – it traps suspended particulate matter in the water and micro-organisms and micro-macro invertebrates that feed on the reeds get attached to it. The microbes remove particulate matter and clean impurities. Over times as the entire system grows it provides shelter for micro and macro organism, which consume the organic matter trapped in the root system. In Shipra the fishing population is already benefiting from the floating islands. Below the floating island at least 40% of pollutants such nitrates ammonia, TKN, Org-C, BOD, COD and solids are reduced. The floating islands also reduce bank erosion and improve the aesthetics of the area.

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6 Centre for Science and Environment (2008), Do-it-yourself: recycle and reuse wastewater. New Delhi: CSE.
5. Water treatment technologies

This section presents a number of water treatment technologies that are or can be used in water supply systems in rural communities and small towns in Pakistan. These include:

- Slow sand filtration and Multi Stage Filtration
- Rapid sand filtration
- Ultra filtration
- Defluoridation
- Arsenic removal
- Disinfection (UV, chlorination)

The section provides a brief description of these technologies and their main treatment mechanisms. The operational requirements and complexity of these technologies is different but all cannot just be operated by local operators. Back-up support is needed as well as spare parts and sometimes chemicals. Often also a combination of the technologies is needed to make sure that the treatment objectives are met and good quality water is being supplied.

It is important to realize that incorporating treatment adds considerably to the complexity and the cost of a water supply system. This cost will be in vain if subsequently the water is being re-contaminated in the water distribution system or between collection and use. Hence a broader approach is needed to ensure the sustainable performance of the system and safe use of the water which requires a close link with the consumers.

5.1 Slow Sand Filtration (SSF)

SSF is a treatment process in which water is passed at a low flow velocity through a layer of sand. During its passage, the water quality improves considerably by reduction of bacteria, viruses and cysts, removal of suspended and colloidal material and changes in its chemical composition. The process was first applied around 1800 in England. The effectiveness of SSF treatment was clearly established in 1892 in Germany. An outbreak of cholera in the city of Hamburg, which did not have a water treatment plant, resulted in 7,582 deaths (1.3 percent of the population), whereas in the adjacent city of Altona, taking water from the same river but treating it by SSF, only 328 persons (0.2 percent of the population) died (Huisman, 1982).

The SSF unit basically consists of a box containing a layer of supernatant water on a filter bed of fine sand with an effective diameter of 0.15 to 0.30 mm and a depth of 0.5 to 1.0 m (Figure 5.1). The sand sits on a gravel bed that functions as a support medium and a transition stage to the drainage system. The operation is controlled by a set of regulation and control valves. The

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7 The main sources used for this section are: Visscher, 2006 and Galvis et al, 1998.
filtration rate to ensure a good operation of the SSF usually is in the range of 0.1 to 0.3 metres per hour (m/h)\(^8\).

![Figure 5.1 Schematic drawing of an SSF system](image)

**The removal mechanisms**
The water treatment in an SSF unit is the result of a complex combination of biological and physical mechanisms and chemical processes. The biological processes include: predation, natural death or inactivation, and metabolic breakdown. Physical mechanisms associated with particles removal include: surface straining, interception, transport, and attachment and detachment mechanisms. Other mechanisms that play a role include sedimentation, diffusion and chemical oxidation.

Because of the removal process which mostly takes place at the surface, the filter gradually clogs and needs to be cleaned by draining off the water and scraping a few centimetres of the sand. This process needs to be repeated every few weeks or month depending on the local conditions.

**Efficiency and limitations**
SSF is a very effective treatment that can be easily operated by local operators with limited level of training. If properly operated the SSF produces an effluent low in turbidity, free of impurities and, even more important, virtually free of bacteria, entero-viruses and protozoa.

The first SSF gave very good results as they were treating water with relative low turbidity and as a result even today cities such as Amsterdam use SSF as one of the treatment processes. When SSF were introduced in Asia, Africa and Latin America the situation changed considerably as tropical rivers often have considerable turbidity loads. This hampered the performance of SSF in even today many systems can be found that are not operating. World wide experience shows indeed that SSF is not a panacea because:

- The level of contamination of the raw water source may exceed the treatment capacity of the SSF. High turbidity levels (over 20 to 50 NTU) are the most common problem mentioned in SSF treatment. Other quality problems may include excess iron and manganese or algae, all basically contributing to a quick clogging of the filters.
- Several conditions may reduce or inhibit the treatment process. These include low temperature, low nutrient content and low dissolved oxygen which all negatively affect the microbiological process.

\(^{8}\)The filtration rate is the total volume of water that enters the filter in m\(^3\) per hour divided by the surface area of the sand in m\(^2\). The unit for the rate is thus m\(^3\)/m\(^2\)/h, but this is often simplified to m/h.
5. Water treatment technologies

- Inadequate operation and maintenance processes such as overloading or interrupting the flow and disrupting the “Schmutzdecke” may affect the treatment process.

5.2 Multi-stage Filtration (MSF)

MSF emerged from research to overcome the limitation of SSF to treat water that is high in turbidity. This is a very serious constraint in many tropical rivers, which are characterized by heavy peaks in the level of suspended solids.

MSF is a combination of coarse gravel pre-filtration often comprising a dynamic gravel filter, an upflow gravel filter and SSF (Figure 5.2.). This combination allows the treatment of water with considerable levels of contamination well above the levels that can be treated by SSF alone. MSF retains the advantages of SSF in that it is a robust and reliable treatment method that can be maintained by operators with low levels of formal education. It has the advantage over SSF that it is less labour-intensive, as the scraping frequency of the SSF units is lower. It is much better suited than chemical water treatment to conditions in rural communities and small and medium-size municipalities in the South, as well as in more remote areas in the industrialized countries (Galvis et al., 1998). MSF technology can be preceded by other treatment processes such as simple sedimentation, sand traps and screens. Wherever possible, terminal disinfection needs to be included as a safe barrier after the MSF.

![Figure 5.2 Components of a multi stage filtration (MSF) plant](image)

The dynamic gravel filter (DyGF) is in essence a shallow downflow gravel filter functioning as the first treatment step. It has a surface layer of fine gravel on top of a layer of courser gravel and the drainage system. An overflow weir is situated a few centimetres above the top of the gravel layer. The fine gravel layer will quickly clog if high peaks of suspended solids reach the unit. It will then act as an automatic switch or valve that reduces the flow quickly or interrupts it altogether. A drainage system is included. Cleaning the DyGF is a simple task that involves raking the surface area and draining the unit by opening a valve. This is much simpler and far less laborious than cleaning a SSF.

The next stage can be an upflow, downflow or horizontal-flow gravel filter. A comparative study of these three options showed that the option of Upflow Gravel Filter was to be preferred technically.

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9 The main sources used for this section are: Visscher, 2006 and Galvis et al, 1998.
5. Water treatment technologies

and economically over the other two options, although these also have good removal efficiencies. Two types of UGF exist: upflow gravel filtration in layers (UGFL), a system comprising different layers of gravel on top of each other, diminishing in gravel size in the direction of the flow) and upflow gravel filtration in series (UGFS) – two or three units after each other with the first comprising the coarsest gravel and the last the finest (Figure 5.3). In most systems, filtration rates between 0.3 and 0.6 m/h are applied. A drainage system placed on the bottom of the structure serves to distribute the flow during the filtration period or to drain the gravel layers during periods of cleaning, discharging the water through the drainage system.

![Upflow Gravel Filter in Altit Hunza, Pakistan](image)

**Figure 5.3**  Upflow Gravel Filter in Altit Hunza, Pakistan

### 5.3 Rapid sand filtration

Rapid sand filtration (RSF) is quite different from SSF as it uses a much coarser sand with an effective grain size in the range 0.4-1.2 mm, and the filtration rate is much higher, generally between 5 and 15 m3/m2.h (120-360 m3/m2.day) (Table 6.1). The pores of the filter bed are relatively large and the impurities contained in the raw water penetrate deep into the filter bed. RSF has therefore a much larger capacity to store deposited impurities and even very turbid river water. The deep penetration of impurities makes it necessary to clean the filter by backwashing. This involves passing water at high velocity from the bottom through the filter bed, whereby it expands and is scoured. The backwash water carries away the deposited material that was clogging the filter. Backwashing can be done quickly in less than half an hour and as frequently as required. Yet the water for backwashing has to come from the filtered water production, which implies that frequent backwashing reduces the net output of the filtration process. If the filtration run falls below six hours, other steps are needed such as pre-treatment for example in the form of roughing filtration to reduce the sediment load.

**Applications of rapid filtration**

According to di Bernardo in Smet and van Wijk (2000) different applications of RFS can be distinguished in the treatment of water for drinking water supplies. RSF is used for:
- the removal of iron and manganese from groundwater, frequently adding aeration as a pre-treatment to form insoluble compounds of iron and manganese.
- Treating water with a low turbidity, as frequently found in lakes and sometimes in rivers. The limitation is that the filtered water may still contain pathogenic micro-organisms, thus disinfection is needed.
- Treating river water with high turbidity. In this case it may be used as a pre-treatment prior to SSF or it may be applied for treating water that has been clarified by coagulation, flocculation and sedimentation. Also in this case final disinfection is needed. The use of chemicals such as iron sulphate to destabilize the suspended solids and encourage the formation of flocs that can be removed by filtration and the pumps required for backwashing makes RSF hardly appropriate for use in rural areas of countries with a less developed infrastructure.

**Pressure filters**

Pressure filters are functioning in the same way as RSF but the filter bed and filter bottom are enclosed in a watertight steel pressure vessel. The driving force for the filtration process here is the water pressure applied on the filter bed. Pressure filters are commercially available as complete units. They are easy to install, but more difficult to operate and maintain, particularly as it is not readily possible to inspect the condition of the media. Hence they are even less suited than conventional RSFs in rural areas of countries with a less developed infrastructure.

<table>
<thead>
<tr>
<th>Item</th>
<th>SSF</th>
<th>RSF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction</strong></td>
<td>Simple construction often with local materials;</td>
<td>More complex construction that includes pumping equipment; also available as complete package plant</td>
</tr>
<tr>
<td><strong>Surface area of filters</strong></td>
<td>Larger surface area is needed</td>
<td>Surface area is smaller</td>
</tr>
<tr>
<td><strong>Flow velocity</strong></td>
<td>0.1-0.15 m/h</td>
<td>&gt; 5 m/h</td>
</tr>
<tr>
<td><strong>Sand</strong></td>
<td>Large volume of relatively fine sand is required that is often locally available</td>
<td>Smaller volume of sand is required, but has to match more stringent specifications</td>
</tr>
<tr>
<td><strong>Sand (grain size)</strong></td>
<td>0.15–0.3 mm</td>
<td>0.4–1.0 mm</td>
</tr>
<tr>
<td><strong>Treatment efficiency</strong></td>
<td>In general higher treatment efficiency and particularly effective in removing bacteria and organic matter</td>
<td>In general lower treatment efficiency</td>
</tr>
<tr>
<td><strong>Backwashing</strong></td>
<td>Not required, the filters are scraped manually</td>
<td>Required which almost always involves water pumping</td>
</tr>
<tr>
<td><strong>Chemicals</strong></td>
<td>No chemicals required except for safety disinfection</td>
<td>Required for chemical coagulation as well as for safety disinfection</td>
</tr>
<tr>
<td><strong>Labour requirements</strong></td>
<td>Low level of trained operators, but they need to understand the biological treatment process</td>
<td>More training is needed to ensure proper dosing of chemicals and handling of equipment.</td>
</tr>
<tr>
<td><strong>Vulnerability of system</strong></td>
<td>The overall system is robust and requires limited maintenance except for a number of valves</td>
<td>The system is more vulnerable as it includes more mechanical equipment and requires pumping</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td>Labour intensive and only able</td>
<td>Able to cope with high turbidity due to</td>
</tr>
</tbody>
</table>
5.4 Disinfection

Water treatment processes reduce the bacterial content of water but with the exception of SSF and MSF treating water with low or moderate level of pollution these processes cannot assure that the water they produce is bacteriological safe. Final disinfection, the destruction or inactivation of harmful micro-organisms present in the water, will be needed. Disinfection is the last barrier in water treatment but when no other treatment methods are available, it may be used as a single barrier against bacterial contamination.

Different forms of disinfection exist including:
- Physical disinfection by boiling or applying solar disinfection
- Ultraviolet radiation
- Chemical disinfection with chlorine, iodine, ozone, silver etc.

In this manual we will provide some further information on just a few of these methods and particularly those that are more common in rural water supply. The section on further reading provides different documents that also give more information on the other methods.

### 5.4.1 Physical disinfection

Two physical disinfection methods used at family level are boiling of the water and solar disinfection. Boiling of water is a very effective method as it destroys pathogenic micro-organism including cysts and ova. The downside is that it may be costly because of firewood requirement and people may reject the taste. Particularly in emergency situations it may be a very good temporary solution.

Solar disinfection (SODIS) uses pasteurization to destroy pathogens that may be present in the water. The principle is that destruction takes place if water warms up above say 45°C, but the higher the temperature the faster the process. The promotion of SODIS is growing in the world as it can be applied very easily. Often plastic bottles are used that are exposed to sunlight for more than six hours either on the roof or on a special black painted frame (Figure 5.3.). The black paint adds to increasing the temperature thus making the process more effective. In many remote areas SODIS may indeed be the most feasible option even though its effectiveness cannot always be secured as it depends on different factors including hours of sunlight, clouding, temperature etc. Further information can be found at [www.sodis.ch](http://www.sodis.ch).
5.4.2 Ultraviolet radiation

Ultraviolet radiation is increasingly used in small community water supply systems because of its reliability and declining costs.

In the process short wave UV radiation from a UV lamp strikes the water flow at close distance. The UV waves disrupt the genetic material (DNA) of micro-organisms and viruses, killing them in a very short time. This process is very effective in the wave range that is provided by these lamps, but the effectiveness also depends on the intensity of the waves and the type of micro-organisms. In clear water the intensity will be higher as it will not contain too many UV-absorbing elements like turbidity, organic matter, iron and/or manganese etc. that can shield the micro-organisms from the lethal rays. To have an effective process in which the rays reach the whole water body, water depth should not be more than 75 mm. The effective contact time is vital for the destruction of the micro-organisms but is difficult to determine. Normal exposures are in the order of 10-20 seconds.

The method has considerable advantages. It is simple to operate and maintain, does not require chemicals, leaves no bad taste or odour in the water and carries no risk of overdose. It effectively destroys bacteria and viruses. It does however not leave residue that may provide some protection to the water during transport and can be used for monitoring purposes. Also it may require pre-treatment to ensure that the water is sufficiently clear. Another important issue to verify is if the UV lamp is an original product because fake products may be sold in local markets. If you purchase lamps from the original producer this should not be a problem. But if you are not sure, you can do a small test with polluted water and submit the result to a laboratory.

5.4.3 Chemical disinfection

Chemical disinfection has a long history as in ancient times water was stored in silver pots which protected the water. This bactericidal effect of silver is used as an inside coating in some candle filters. The filtered water passes through this coating which destroys the micro-organisms.

Chlorination is the most widely used method for disinfection in water supply systems. It is also used at household level, mainly in the form of tablets. In water supply systems two types of systems are most commonly used. Dosing a solution of hypochlorite or using chlorine gas. The
latter may be cheaper, but does require more precautions and training. Hence for smaller supplies dosing of a solution of hypochlorite is the most feasible option.

The disinfection occurs when the chlorine compounds come into contact with the harmful microorganisms. Chlorine is particularly effective when it is present in the form of HOCl which requires a pH below 8. It is necessary that sufficient contact time is provided to ensure that the germicidal effect takes place. A minimum of 30 minutes is usually recommended.

Chlorination is far more effective in clear water as the chlorine compounds may react with organic particles and bacteria may even be protected against the effect of chlorine by higher turbidity levels. It is recommended that the turbidity of the water is below 5 NTU but ideally below 1 NTU and that some 0.5 mg/l of Chlorine is present after the prescribed contact time. This residue protects to some extent the water in the distribution against recontamination. The related advantage is that the water quality can be monitored as residual chlorine is easy to measure. When put into supply the chlorine will react with organic material and other impurities in the distribution network and gradually the residue level will drop. In large systems it may therefore be necessary to provide additional chlorine dosing points at strategic locations to avoid complete depletion of the residual chlorine.

Different test kits are available to test the level of residual chlorine. These are readily available in most countries and are easy to use.

**Application of chlorination** can be done at different levels. This includes:

- **Household level** application which often concerns dosing of sodium hypochlorite in tablet, powder or liquid form. It may be even locally produced by electrolytic cells using a solution of common salt (NaCl).
- **Disinfection of dug wells and small reservoirs** which may be difficult because it is impossible to get a good constant dosing device. Systems that are used include porous pot chlorinators and Chinese plastic bags. The systems may give a false expectation of safety. If it concerns (open) wells that are subject to continuous pollution it may be better to adopt household level chlorination.
- **Disinfection of protected wells and bore wells** is needed after construction and after repairs. This requires a high chlorine concentration of 50-100 mg/l with a contact time of preferably 12 but at least six hours.
- **Disinfection of water supply systems** requires a dosing of chlorine that matches the chlorine demand. As generally production is kept as continuous as possible, constant dosing may be a good option. Different devices are being used including a constant head device which includes a small reservoir with a float valve or a floating tube device.

### 5.5 Ultra filtration (UF)

Ultrafiltration (UF) is the process in which water (or other liquids) passes a semi permeable membrane under a relatively low hydrostatic pressure usually of some 3.5 atmosphere. The principle of micro filtration and ultra filtration is physical separation. The extent to which dissolved solids, turbidity and micro-organisms are removed is determined by the size of the pores in the membranes. Substances that are larger than the pores in the membranes are fully removed. Substances that are smaller than the pores of the membranes are partially removed, depending on the formation of a refuse layer on the membrane.
UF is not fundamentally different from microfiltration except in terms of the size of the molecules it retains. In UF membranes are being used with pore sizes in the range of 0.001 to 0.1 micron. Typically, UF will remove high molecular-weight substances, colloidal materials, and organic and inorganic polymeric molecules, including the partial removal of organic colour and microorganisms. Low molecular-weight organics and ions such as sodium, calcium, magnesium chloride, and sulphate are not removed. The also implies that the water produced in UF needs to be disinfected, which usually is done by UV disinfection.

Figure 5.4 Ultra filtration system used in Pakistan (2008)
5. Water treatment technologies

UF produces between 2-8 m3/day per m2 membrane at an operating pressure of about 3.5 atmospheres. To remove the refuse layer on the membrane the flow can be reversed (backwash). Literature indicates that UF provides a simple and effective means for the production of potable water for small communities. On the other hand it needs to be recognised that cost involved are still considerable, as membranes need to be replaced and water pressure needs to be created. Furthermore operation and maintenance may still give problems as experience in Pakistan shows for example that dozens of UF plants are out of order in Sjalkot and Dashka only two years after they have been installed (Dawn features 03-06-2008 http://www.dawn.com/2008/06/03/fea.htm).

5.6 Arsenic removal

Until recently arsenic was not an element for routine measurement in groundwater but the recent discovery of widespread arsenic contamination in Bangladesh and India is making it necessary to explore the presence of this toxic component in drinking water. In 1993 WHO lowered its guideline value for arsenic in drinking water from 50 to 10 µg/l, but many countries, including Bangladesh and India, still have 50 µg/l as their standard.

The symptoms of arsenic-related diseases start with the darkening of the skin, the appearance of black spots and the hardening of palms and soles of feet. In the second stage, white spots appear on the skin and painful cracks appear in the palms of hands and soles of feet. The third stage is damage of internal organs like lungs, kidney, liver, bladder, etc, and in extreme cases gangrene and cancer.

Field test kits are available that can detect arsenic contamination down to 50 µg/l with an acceptable accuracy. New kits are claiming to detect down to 10 µg/l, but these have not been extensively tested as yet.

If the Arsenic concentration is above the limit, treatment will be necessary or alternative water sources need to be used. In Bangladesh for example handpumps are painted red when the arsenic concentration is found to be above the allowable limit, indicating that it is not suitable for drinking and cooking.

Removal methods

Detailed description of common methods for removing arsenic from drinking water is given by Petrusevski et al. (2007). These methods are based on the following processes:

- Precipitation processes, including coagulation/filtration, direct filtration, coagulation assisted microfiltration, enhanced coagulation, lime softening, and enhanced lime softening
- Adsorptive processes, including adsorption onto activated alumina, activated carbon and iron/manganese oxide based or coated filter media
- Ion exchange processes, specifically anion exchange
- Membrane processes, including nano-filtration, reverse osmosis and electrodialysis.

Several of these methods are available for applications at different scales including at household level. For community scale, iron and alum coagulation and Iron coated sand (IBS/IOCS) adsorption are low cost methods. A promising emerging technique is Enhanced Coagulation (EC). With this technique a very efficient removal of As(III) and As(V) is possible to below the recommended WHO-value of 10 µg/l. The liquid BAT co-agulant of PCRWR is an example of this. With EC also the removal of fluoride, humic substances and other harmful or toxic matters is realised (metal hydroxides). For groundwater with high iron content, also conventional iron removal techniques,
like aeration and filtration, can be used to remove arsenic at low costs. However the efficiency of these techniques for As-removal is not very high.

In situations where high arsenic removal efficiency is necessary, the household methods can achieve an arsenic concentration reduction to well below 50 µg/l. This concentration is still applied as a drinking water standard in many developing countries. It must be stressed that these household methods were tested under field conditions in rural Bangladesh with no or limited monitoring involved. Under optimal conditions and with the required monitoring, a reduction of the arsenic concentration to below the WHO guideline value of 10 µg/l can be achieved by using advanced methods like membrane processes and adsorption. Most of the methods do not remove arsenite (arsenic III) as efficient as arsenate (arsenic V). Therefore an oxidation of arsenite to arsenate is recommended. For brackish water membrane processes like reverse osmosis and electrodialysis reversal are available. The emerging techniques Memstill® and the Water Pyramid®/Solar Dew are also suitable. Again, enhanced coagulation is a very promising technique for this application.

5.7 Fluoride removal

The Fluoride content of natural waters varies. Surface water seldom exceeds a level of 0.3 mg/l but groundwater may have much higher concentrations and may cause a chronic disease known as fluorosis. Dental fluorosis or mottled enamel may occur at a dose of somewhat above 1 mg/l and the crippling skeleton fluorosis at a level above 3 mg/l. Hence if levels exceed the limits the water needs to be treated.

As indicated in Smet and van Wijk (ed), (2002) different methods are used for defluoridation which can be grouped into five categories:

- **Addition of chemicals** such as alum and a small amount of lime which will lead to coagulation of the fluoride which then can be removed by settling and filtration. This so called Nalgonda technique is successfully used at household and treatment plant level.

- **Contact Precipitation**, a technique in which fluoride is removed from water through the addition of calcium and phosphate compounds. The presence of a saturated bone charcoal medium acts as a catalyst for the precipitation of fluoride either as CaF2, and/or fluorapatite.

- **Adsorption/ion-exchange method** in which water is passed through a bed containing material that retains fluoride either by physical, chemical or ion exchange mechanisms. The adsorbing material gets saturated after a period of operation and requires regeneration. A wide range of materials has been tried for fluoride uptake. Among these materials, bone char, activated alumina and calcined clays have been successfully used in the field; Adsorption is also used for household treatment where for example Activated Alumina (AA) such as alumina oxide is put in candle filters. After some time the material has to be replaced as it gradually loses its capacity to remove the fluoride.

- **Reverse osmosis** is basically large scale process in which the fluoride is retained by a membrane, through which the water is applied under high pressure.

- **Evaporation** is an option in which the fluoride is retained in the water and does not enter into the vapour.

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10 UNESCO-IHE reports that with the IHE-family filter also arsenic concentrations to below the WHO standard of 10 µg/l can be reached (Petrusevski et al., 2007)
Defluoridation as a treatment technique is adding a burden for the users if they have to do it at household level. Still this may be more practical in terms of the volumes that need to be treated. If treated as a component in a water supply scheme, a high quantity of water needs to be treated which involves higher costs and the production of a considerable amount of sludge that needs to be disposed of. At household level only the part used for drinking water needs to be treated.

The Nalgonda process, Bone charcoal and Calcined clay are relatively low costs methods for domestic use. On a community scale, the Nalgonda process is also a low cost option. If a high fluoride removal is necessary then activated alumina and reverse osmosis are preferred methods. For brackish water only reverse osmosis and evaporation can be used.

Yet in all cases the preferred option is to first look at other alternatives such as the use of alternative sources or the mixing of water with higher fluoride content with water with low fluoride content. It may also be an option to look for a special source for drinking water alone. The main reason to adopt safe sourcing is any fluoride treatment method is complex to operate and sustain.

5.8 Household water treatment

According to WHO (2008) a variety of candidate technologies for treatment of household water have been described and many are widely used in different parts of the world. The physical methods, include boiling, heating (fuel and solar), settling, filtering, exposing to the UV radiation in sunlight, and UV disinfection with lamps. The chemical methods include coagulation-flocculation and precipitation, adsorption, ion exchange and chemical disinfection with germicidal agents (primarily chlorine).

Some water treatment and storage systems use chemicals and other media and materials that can not be easily obtained locally at reasonable cost and require relatively complex and expensive systems and procedures to treat the water. Such systems may be too inaccessible, complex and expensive to employ for treatment and storage of household water in some places and settings.

The efficacy of some treatment methods to physically remove particles (turbidity) and microbes or to inactivate microbes in household water has been documented, primarily for indicator bacteria. Some treatment methods, such as boiling, solar disinfection, UV disinfection with lamps, chlorination and the combined treatments of chemical coagulation-filtration and chlorination have been evaluated for reductions of bacteria, viruses and in some cases protozoa. However, the ability of some of these methods to remove or inactivate a wide range of known waterborne pathogens has been inadequately investigated and documented.

The most promising and accessible of the technologies for household water treatment are filtration with ceramic filters, chlorination with storage in an improved vessel, solar disinfection in clear bottles by the combined action of UV radiation and heat, thermal disinfection (pasteurization) in opaque vessels with sunlight from solar cookers or reflectors and combination systems employing chemical coagulation-flocculation, sedimentation, filtration and chlorination. All of these systems have been shown to dramatically improve the microbiological quality of water. Further development, refinement, implementation, evaluation and comparison of household water treatment and safe storage technologies is both justified and encouraged.

We may expand this section with some practical examples (Chlorination Solar Disinfection and perhaps also include defluoridation and arsenic removal see 6.4 and 6.7)
6. Operation and maintenance

Operation and maintenance of water supply systems of small communities is still being neglected in many countries. Different estimates show that depending on local conditions between 10 and 60 percent of existing water supply systems are not operational. This implies an enormous loss of effort and resources and a continuation of the suffering of many people.

These grim figures show that operation and maintenance needs to be much higher on the agenda of all organizations involved in the sector. Water supply systems can only be sustained if they are properly operated and maintained. A good design and sound construction can facilitate operation and maintenance, but cannot take over the crucial role of the system operator. The operators are the key to adequate system performance and not only should receive training and understand the importance of their role, but they need a stimulating and respectful work environment and sufficient back-up support for activities that are beyond their capacity. Operation and maintenance is not just a technical issue. It also encompasses social, gender, economic, institutional, political, managerial and environmental aspects.

The resources and facilities which the operator and the community will require to operate and maintain the system need to be always on the agenda, during the stages of planning, design, and construction of the system. Subsequently a clear schedule is required for the water operator to manage the system, which also outlines the required support from other community members and external institutions. The operation and maintenance scheme has to include all important tasks and their frequency of application. This includes ‘technical’ tasks in the water supply system, such as the maintenance of the water intake and the distribution network but also needs to include the broader tasks such as tariff collection, bookkeeping and reporting.

An important complication is that in many countries roles are changing. National governments gradually change their role from provider to facilitator also under pressure of the high cost involved. They devolve tasks to local governments and communities, but often without providing sufficient resources and support to ensure that local actors together with the private sector can deal with the problems at hand. In many situations a much better structured effort is needed that clarifies the roles and realities, the cost involved and the way in which the organizational and financial implications will be met.

The problems in rural water supply in Pakistan are diverse and include poor quality of design and construction and lack of funding. Inadequate operation and maintenance, and poor quality of repairs are however very prominent problems as well. Most schemes have been established by the PHED and are thereafter handed over to the communities. Village Development Association or Water Management Committees are supposed to take care of the day-to-day management of the systems, but receive little support and are generally ill-equipped to handle the sometimes complex systems (Figure 6.1).
An added complication is that they receive little support from the Teshil Administration as rural water supply receives low priority and capacity and guidance is lacking to provide adequate backstopping. As a result system fall-out is high and there is little attention for hygiene and sanitation aspects or source protection, issues that are equally essential to sustained performance. As a result the performance of the water supply and sanitation sectors is far below what could be reasonably expected of a country of the development status of Pakistan.

Whereas it was the intention to shift construction responsibility to Teshil level and efforts were made in some provinces, these were not very successful which may not come as a surprise as little support and resource seem to have been provided to properly arrange the transfer. In general a vacuum prevails and there is little attention to ensure the functioning of drinking water systems. Irrespective whether construction will remain with PHED or not, it seems clear that O&M will remain an issue of the Village Development Associations (VDA) and Teshil government.

**Figure 6.1** Most common approach in RWS system development

### 6.1 What is Operation and Maintenance?

Operation and maintenance are at the heart of the long term sustainable performance of water supply systems. Both need to be done properly and on a regular basis to ensure an adequate rate of return on the investment in water supply systems.

**Operation** refers to the everyday running and handling of a water supply. This involves several activities including:

- Major operations required to convey safe drinking water to the users, e.g. starting and stopping a motorized pump, the supply of fuel and the control of valves.
- The correct handling of facilities by users to ensure long component life, e.g. the handling of a rope and bucket at a well, handpump use, and the use of public taps.

The proper operation of a supply results in its optimum use and contributes to a reduction in breakdowns and maintenance needs.

**Maintenance** refers to the activities required to sustain the water supply in a proper working condition. Maintenance can be divided into:

- **Preventive maintenance** - regular inspection, servicing and cleaning to preserve assets and minimize breakdowns.
- **Corrective maintenance** - minor and larger repairs including replacement of broken and worn out parts to maintain the system in good working conditions.
- **Crisis maintenance or break down maintenance** - unplanned responses to emergency breakdowns and user complaints to restore a failed supply.

Maintenance costs money and a policy of crisis maintenance alone may appear cheap in the short term. However, continuing crisis maintenance leads to frequent breakdowns, an unreliable supply, poor service levels, and a lack of user confidence. Reliance on crisis maintenance may ultimately lead to complete system failure.

**Rehabilitation** entails the correction of major defects and the replacement of equipment to enable a facility to function as originally intended. Rehabilitation becomes necessary when it is no longer technically feasible or economically viable to maintain a facility in good working condition.

### 6.2 Maintenance and sustainability

When building a new water supply or when introducing improvements in an existing system (at technical, management or control level) the most crucial question to ask is: Are we helping to develop a system or situation that will be sustained in the future?

Figure 6.2 shows what can happen in the course of the intervention. In the planning and design phase usually there is no increment in the benefits that are being obtained, although in some cases it may well be that some little advice can already help to improve things. In the construction or rehabilitation phase benefits already may increase because community members learning about the system may start changing habits etc. When completed however the real challenge begins. Will it be possible for the local operator and the community to sustain or even improve the service and the situation or will the benefits gradually cease to exist.

![Figure 6.2 Are we ensuring sustainable system performance](image-url)

**Figure 6.2** Are we ensuring sustainable system performance
6.3 Key elements of an operation and maintenance system

A number of important elements need to be in place to facilitate adequate operation and maintenance. These include:

- A proper legal framework
- A leading organization which if needed can call upon other actors if problems cannot be solved at the local level
- A clear definition of roles and responsibilities to be able to hold people accountable
- Staff with the necessary skills and knowledge and a positive work attitude
- Clear operational routines
- An adequate monitoring schedule which specifies the range within performance is adequate and what to do and who to contact if performance falls outside the range
- A clear maintenance schedule for all routine and less routine activities
- A very simple reporting system to keep track of performance (perhaps only asking to report abnormalities
- Adequate tools and spare parts to do the job
- An agreement with an external organization for back-up support
- Financial resources to sustain the system
- Good rapport with the users including a complaint system

The fact that in many cases the elements indicated above are not in place is shown by the constraints that are mentioned in Davis and Brikke (1995) shown in Box 1.
Box 1. Main constraints for adequate operation and maintenance

- The low profile and hence low priority given to O&M by policy makers, which makes that the necessary policies, legal frameworks and a well defined division of responsibilities to support O&M in the sector, are not in place.
- Even though centralized government departments are often unable to respond efficiently to the maintenance of scattered rural supplies, they only partly hand over their role to local government, autonomous agencies, private sector and communities.
- Political interference makes sustainability that much more difficult to achieve. The political decision to provide free water means users do not contribute funds for the upkeep of supplies. Political influences can determine technologies (e.g. tied to aid) or result in sub-standard systems. Such influences can be reduced by devolving management responsibilities away from government.
- A focus on capital construction and expansion by governments and external support agencies neglecting the maintenance of existing and future supplies.
- Overlapping responsibilities of staff and departments can divert skills, funds and equipment away from O&M. This often happens when operational staff is redeployed to construction work as a new project is started. New projects benefit while existing projects are neglected.
- Inappropriate design and technology choice creates unnecessary operation and maintenance difficulties and increases costs. Initial design must consider long term O&M. Poor design is often compounded by inadequate supervision of construction.
- A lack of community involvement in project development can lead to inappropriate designs. Poor user understanding of how to correctly operate systems can result in the misuse and damage of facilities.
- Some communities are disadvantaged by their remoteness or difficult access. This adds to the cost and problems of maintenance and requires special attention.
- There are often inadequate data for planning and establishing the cost of O&M.
- The state of national and regional economies can have a crippling effect on O&M as high inflation and fluctuating exchange rates can significantly increase O&M costs. Fuel prices for example may have a major impact on pumping and transportation cost.
- Water supply facilities are often poorly managed. Some of the management constraints, such as unskilled staff, may be a result of under-funding but are often also due to poor management. O&M responsibilities are rarely delegated to individuals and this can result in a lack of sense of responsibility for the proper use and upkeep of facilities.
- Management supervision of operation and maintenance may be virtually absent in many cases.
- A lack of training and understanding of maintenance procedures leads to poor performance of O&M staff (operators, mechanics, caretakers, etc.).
- Insufficient and inefficient use of funds for O&M restricts the availability of spare parts, tools and the recruitment and training of competent staff.
- A lack of accountability in many water supply systems and maintenance departments leads to inefficient use of maintenance funds.

(Adapted from Davis and Brikke, 1995)
6.4 Organization of O&M

To be able to support the improvement of operation and maintenance of water supply schemes, first it is necessary to explore which are the actors involved, what are their current roles and are their better alternatives. The number of actors may be quite diverse and may include:

- Operators and mechanics
- The water committee or a similar water service provider
- The community - users (women, men; young and old), user groups, community leaders, and village councils.
- The government and public authorities - local, district, regional and national officials
- A government agency or support agencies - managers, maintenance teams, inspectors, trainers, and social, financial and health extension workers
- Private sector - local entrepreneurs, local artisans, shopkeepers, wholesalers, manufacturers of equipment and spare parts, bankers, consultants, contractors
- Non-governmental organizations - local, national and international NGOs
- External support agencies multilateral and bilateral aid agencies, development banks.

It is crucial to clarify the roles and to ensure that a simple organizational model is achieved with short and direct reporting lines and responsibilities to ensure transparency and accountability.

6.5 Examples of maintenance requirements

This section describes routine maintenance and monitoring schedules for two types of water supply systems that exist in rural and small towns in Pakistan. It is based on the principle that it is essential that staff involved knows very well what to look at, what to do and who to report to. These two schedules can serve as the model for maintenance schedules for specific water supply systems. The development of such a schedule can be included in the actions that need to be undertaken as described in the water safety plan.
6. Operation and maintenance

6.5.1 Hand pumps

### Routine maintenance of a handpump system

<table>
<thead>
<tr>
<th>Routine</th>
<th>Explanation</th>
<th>When</th>
<th>Who</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean pump environment</td>
<td>Dirt and debris deteriorate the work environment and may create puddles. It also reduces the feeling that water needs to be safe.</td>
<td>When needed</td>
<td>Users and operator</td>
</tr>
<tr>
<td>Grease pump</td>
<td>Well greased pumps live longer; Tighten nuts and bolts when needed</td>
<td>Weekly</td>
<td>Operator</td>
</tr>
<tr>
<td>Repair cracks in apron</td>
<td>Repair cracks in the apron and ensure that pump is tightly well fitted on apron</td>
<td>When needed</td>
<td>Operator</td>
</tr>
<tr>
<td>Check pump performance</td>
<td>Check flow reduction by measuring time to fill as bucket (reduced flow sign of plunger seal problems); Check number of strokes before water appears (sign of foot valve problem)</td>
<td>Weekly</td>
<td>Operator or users</td>
</tr>
<tr>
<td>Change foot valve and plunger seals</td>
<td>For optimal performance these valves need replacement (every 4 to 12 months depending on use).</td>
<td>When needed</td>
<td>Operator or mechanic</td>
</tr>
<tr>
<td>Order spare parts</td>
<td>Keep the required stock of spare parts. Also check existing spare parts for deterioration</td>
<td>When needed</td>
<td>Operator or Mechanic</td>
</tr>
<tr>
<td>Collect fees</td>
<td>To keep the system running fees will be needed for spare-parts, mechanic etc.</td>
<td>Monthly or as agreed</td>
<td>Operator or other person</td>
</tr>
</tbody>
</table>

### Routine monitoring by operator

<table>
<thead>
<tr>
<th>Item</th>
<th>Desired situation</th>
<th>When</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check flow</td>
<td>Bucket of water (10 litres) obtained in less than X strokes at regular pumping frequency (40 strokes/minute)</td>
<td>Weekly</td>
<td>Register if production drops below X initiate repair procedure</td>
</tr>
<tr>
<td>Check back-flow</td>
<td>Pump delivers water after less than three strokes</td>
<td>Weekly</td>
<td>Register if more strokes are needed initiate repair procedure</td>
</tr>
<tr>
<td>Check overall environment</td>
<td>Clean environment without dirt and puddles and well fenced</td>
<td>weekly</td>
<td>Register; stimulate users to keep environment clean</td>
</tr>
<tr>
<td>Check overall pump</td>
<td>Pump in good working condition</td>
<td>weekly</td>
<td>Register and take action in case of problems</td>
</tr>
<tr>
<td>Reporting</td>
<td>Operator reports to water committee about general performance and abnormalities</td>
<td>Monthly</td>
<td>Bring register and suggest and discuss actions that are needed</td>
</tr>
</tbody>
</table>
### 6.5.2 Piped supply

<table>
<thead>
<tr>
<th>Routine maintenance of a groundwater based piped water supply</th>
<th>Routine</th>
<th>Explanation</th>
<th>When</th>
<th>Who</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean pump environment</td>
<td></td>
<td>Dirt and debris deteriorate the work environment and may create puddles. It also reduces the feeling that water needs to be safe.</td>
<td>When needed</td>
<td>Users and operator</td>
</tr>
<tr>
<td>Grease pump</td>
<td></td>
<td>Well greased pumps live longer; Tighten nuts and bolts when needed</td>
<td>Weekly</td>
<td>Operator</td>
</tr>
<tr>
<td>Repair cracks in apron</td>
<td></td>
<td>Repair cracks in the apron and ensure that pump is tightly well fitted on apron</td>
<td>When needed</td>
<td>Operator</td>
</tr>
<tr>
<td>Check pump performance</td>
<td></td>
<td>Check and register flow rate (bulk water meter) and be alert on possible reduction over time; Check an register the electricity consumption and the number of pumping hours</td>
<td>Daily</td>
<td>Operator</td>
</tr>
<tr>
<td>Check water table</td>
<td></td>
<td>Check the level of the water table when pump is not working</td>
<td>Monthly</td>
<td>Operator</td>
</tr>
<tr>
<td>Change moving parts in pump when needed</td>
<td></td>
<td>For optimal performance moving parts need to be in good condition. Hence they need to be replaced when pump performance drops, unless this is caused by a fall of the water table.</td>
<td>When needed</td>
<td>Operator or mechanic</td>
</tr>
<tr>
<td>Order spare parts</td>
<td></td>
<td>Keep the required stock of spare parts. Also check existing spare parts for deterioration</td>
<td>When needed</td>
<td>Operator or Mechanic</td>
</tr>
<tr>
<td>Check overhead storage tank</td>
<td></td>
<td>Check overhead tank for leakages and leaking valves</td>
<td>Weekly</td>
<td>Operator</td>
</tr>
<tr>
<td>Clean overhead tank</td>
<td></td>
<td>Clean tank by flushing</td>
<td>At least yearly</td>
<td>Operator</td>
</tr>
<tr>
<td>Check distribution network</td>
<td></td>
<td>Make a physical inspection of the distribution network and measure the water pressure on strategic locations</td>
<td>Every three months</td>
<td>Operator or mechanic</td>
</tr>
<tr>
<td>Repair leakages</td>
<td></td>
<td>If problems are identified initiate repairs as soon as possible</td>
<td>When needed</td>
<td>Mechanic / Plumber</td>
</tr>
<tr>
<td>Collect fees</td>
<td></td>
<td>To keep the system running fees will be needed for spare-parts, mechanic etc.</td>
<td>Monthly or as agreed</td>
<td>Operator or other person</td>
</tr>
</tbody>
</table>
### Routine monitoring by operator with supervision of water committee

<table>
<thead>
<tr>
<th>Item</th>
<th>Desired situation</th>
<th>When</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check flow</td>
<td>Daily production should be between ... and ...</td>
<td>Weekly</td>
<td>Register if production drops below X initiate repair procedure</td>
</tr>
<tr>
<td>Check electricity consumption</td>
<td>Consumption should be below .. per m³</td>
<td>Weekly</td>
<td>Register if consumption increases above ....</td>
</tr>
<tr>
<td>Check overall environment</td>
<td>Clean environment without dirt and puddles and well fenced</td>
<td>Weekly</td>
<td>Register; keep environment clean</td>
</tr>
<tr>
<td>Check overall pump</td>
<td>Pump in good working condition</td>
<td>Weekly</td>
<td>Register and take action in case of problems</td>
</tr>
<tr>
<td>Reporting</td>
<td>Operator reports to water committee about general performance and abnormalities</td>
<td>Monthly</td>
<td>Bring register and suggest and discuss actions that are needed</td>
</tr>
</tbody>
</table>

### 6.6 Sustained finance

To ensure sustained performance of water supply systems resources have to be available to ensure adequate management and maintenance. Increasingly users are being requested to pay for the water supply service. This is the most sustainable way of obtaining financial resources as long as a good service is being provided. The difficulty is that not all households are in the same economic condition and for some the tariff may be too high, and so special measures may be needed for the weakest sections in society.

Women and households headed by women are frequently the most chronically poor within rural communities. Women have lower social status than men and consequently less access to schooling and training, particularly in childcare and health practices. Yet women play significant roles in rural economic activities. While the number of men migrating from rural areas in search of employment has increased over the last decades, the number of households headed by women has risen substantially. Women struggle to cope as the burden of work, at home and in the fields, falls on their shoulders. Malnutrition is a frequent problem in these households (IFAD 2007).

Giving poor households access to sustainable water supply and sanitation services can make an important contribution to reducing poverty as it has a direct impact on the incidence of disease and indirectly on several other indicators that are part of the millennium development goals, including education and malnutrition. Unfortunately water and sanitation is given a low priority in the Poverty Reduction Strategy (PRSP) process in most countries. Even where water has been prioritised, government budget allocations have been insufficient. Lack of coherent policy planning and financing frameworks, and lack of systems for accountability and transparency at a government and sectoral level hinders market-based sources of finance. The good news is that

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A key resource used for this section is the WASHIRIKA package for capacity building in support of better local governance and WASH service provision of the IRC (www.irc.nl).
there is a considerable rate of return on investment. Hutton et al (2006) estimate a return of 2.8 on investment in water supply and 6 in sanitation for Sub-Saharan Africa.

But this only becomes reality if a good financing system is in place that will ensure sustained service delivery.

**6.6.1 Cost recovery in Water Supply and Sanitation**

Few countries have realistic policies, operational strategies or plans for cost recovery and financing for sustainable water supply services, particularly for the poor (Figure 6.3). In fact most of the strategies for cost recovery are short sighted and address only part of the issue of sustainability, resulting in system degradation. Typically approaches are focused on recovering operation and maintenance cost from the consumers, but this is not sufficient to ensure sustained performance of water supply and sanitation facilities.

![Figure 6.3 Are realistic policies for cost recovery in place?](image)

What is needed is the matching of all costs related to providing a sustainable service, with all the available sources of funding (Figure 6.4). These funding sources may lie entirely with the users, but may also include external funding from governments or donors. Unless all the costs (technical, human resource, institutional) related to providing and maintaining a service are identified and covered, a system cannot be considered sustainable.

In rural and low-income urban areas user based cost recovery strategies become crucial as communities are progressively made responsible or co-responsible for the financial management of their system. Making communities responsible has proven to be an effective strategy for achieving sustainability in operation and maintenance of systems (Bolt & Fonseca, 2001). However to date, such responsibility has typically been limited to funding of system management and O&M costs with, in some cases, a minor contribution to capital costs. Inclusion of the capital costs related to system construction, enlargement or replacement, as well as for the necessary institutions to support community managers requires different models. Such models are also crucial to replicating community based management models across entire districts or regions. In particular, models
need to shift from looking at the financing of individual systems in isolation to that of service provision to entire populations.

Figure 6.4 Sustainable cost recovery needs to meet all cost

The approach to cost recovery therefore looks beyond the three year horizon of most projects or programmes financed by support agencies, and aims to look beyond the individual water system and its users. It considers not only the construction, but the lifetime, rehabilitation and extension of water supply systems and all the elements that are necessary to providing longer term support to users in rural communities and urban neighbourhoods. Key items to be considered in this approach include:

- Tailoring of cost recovery frameworks to the special needs of the rural and urban poor (seasonal/irregular payment, payment in kind, etc.)
- Developing frameworks for transparent cross subsidisation of capital and recurrent costs, with a focus on ensuring coverage of the poorest of the poor;
- Developing institutional arrangements and legal frameworks that ensure that money from cost recovery is used for service delivery;
- Identifying mechanisms for including in cost calculations, the development and maintenance (and capacity) of the institutions to support communities in managing their systems e.g. initial and repeat training, auditing, technical back-up etc;
- Identifying financial mechanisms to encourage demand management and avoid resource depletion;
- Including in cost recovery those costs related to waste water management;
Best practices reflecting the above mentioned points are available from some countries and regions in the world (IRC, 2003).

**Users contributions**

It is often stated that people are not able to pay because they are too poor. This may be true in individual cases, but many people are able to pay but not willing to put a priority on spending resources on improved water or sanitation. Willingness and ability to pay are regularly confused. Willingness to pay (WTP) is an expression of demand for a service, and is a strong prerequisite for cost recovery because it is a measure of user satisfaction and the desire of users to contribute to a functioning service.

Whenever people say they are not willing to pay, it is important to find out why and to ensure that action is undertaken to solve the underlying problem. Factors negatively influencing willingness to pay include a service that does not meet people’s demand, lack of transparency from the community committee, lack of financial capacities, political interference, beliefs about ‘free water’, competing water sources, etc.

Several methodologies are available to measure willingness to pay (such as behaviour studies, hypothetical behaviour studies, contingent valuation, etc.). While many of these studies will send a clear message that there is willingness to pay for improved services, policy very rarely changes as a result. In rural areas, we suggest limiting willingness to pay studies to survey and focus group discussions at community level, ensuring that the views of women as main water users are investigated and recorded separately from those of the men. This approach will also capture the possibility of community members providing voluntary labour for trench digging, transport, pipe laying, or providing local materials, such as gravel and sand.

**Willingness to pay for sanitation**

On-site sanitation is mostly a household responsibility and, as with non-networked water services there are usually no “user fees”. However, provision should be made for recovery of the following expenditures: pit digging, construction of the latrine slab; pit latrine/septic tanks emptying fee and rebuilding latrines.

There are two key reasons for dealing with these issues. In highly populated areas such as slums, there is a public health risk arising from neglect of appropriate latrine/septic tanks emptying. In rented houses, households are not willing to pay costly one-time payments for the mechanical emptying of septic tanks. They would rather pay a smaller fee to a manual emptier to removing the top layer of waste, which is then disposed in the vicinity. Excreta disposal situation in many African cities has become dramatic: thousands of tons of sludge from on-site sanitation installations – so-called faecal sludge – are disposed of daily, untreated and indiscriminately into lanes, drainage ditches, onto open urban spaces, into inland waters, estuaries and the sea.

Secondly, in rural communities where open-air defecation is common, demand for improved sanitation is often very low but has a gender dimension. Lack of effective demand can be traced to the lack of female voice in defining spending priorities and unwillingness on the part of male family heads to prioritise paying for sanitation services.

It is possible to determine inner-household differences when demands of women and men are investigated separately. However, sanitation does not rank high in a household priority-setting process and awareness campaigns. Strategies for increasing willingness to pay need to take advantage of modern marketing strategies which focus on basic human emotions, such as pride and shame, creating a greater willingness to pay among men. Such programmes could also, where
feasible, provide information about the potential for human waste to be used as a resource in agriculture.

### 6.7 Cost calculation and payments

In the calculation of the cost of water and sanitation services a range of cost elements need to be included.

- **Investment costs** (well drilling, construction costs, equipment, tools, housing, fencing etc. For these cost we need to take into account their life cycle (when they need replacement) to be able to calculate an inclusive tariff.
- **Recurrent costs** include the maintenance and the administrative tasks for the management of the system, e.g. wages of caretakers and other staff, equipment, materials (chemicals, grease, paint, uniform, gravel sand, cement) and spare parts (nuts, bolts, cupseals, bearings, main tubing, threads, pipe threads), and possible payments for larger repairs
- **Replacement and extension costs**
- **Depreciation** (equipment, facilities, construction, buildings)/life cycle

Suppose we have a handpump system with the following cost components (Table 6.1)

<table>
<thead>
<tr>
<th>Basic information</th>
<th>Cost in US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment cost</td>
<td>3500</td>
</tr>
<tr>
<td>Recurrent (Functioning) cost per year</td>
<td>700</td>
</tr>
<tr>
<td>Estimated replacement-extension costs = 25% of functioning costs/year</td>
<td>25%*700 = 175</td>
</tr>
<tr>
<td>Recovery of investment costs (RIC) = estimated 10% investment cost</td>
<td>10%*3500 = 350</td>
</tr>
<tr>
<td>Depreciation* = Cost (equipment, buildings etc.)/life cycle</td>
<td>2000/10 = 200</td>
</tr>
<tr>
<td>Provision for risk and inflation = 15% of depreciation costs</td>
<td>15%*200 = 30</td>
</tr>
<tr>
<td>Number of users</td>
<td>250</td>
</tr>
</tbody>
</table>

#### Table 6.1 Example of the cost of a handpump system

**Tariff calculation**

With the data of Table 6.1 we can estimate the required tariff. In Table 6.2 different options are being presented.

<table>
<thead>
<tr>
<th>Tariff</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum tariff (covering O&amp;M and basic management costs)</td>
<td>(700/12)/250=0.23 US$ per user per month</td>
</tr>
<tr>
<td>Sustainable service tariff(^1)</td>
<td>(700+200+350+200+35)/250 = 5.94/12 = 0.49 US$ per user per month</td>
</tr>
<tr>
<td>Sustainable service tariff(^2)</td>
<td>700+200+350+200+35+350+350)/250 = 8.74/12 = 0.73 US$ per user per month</td>
</tr>
</tbody>
</table>

1) The investment costs have been paid by an international NGO and the community does not need to pay interest nor repay the grant.
2) The community has taken a loan and needs to pay an interest of 10% (350) and has to repay the loan of 3500 roughly representing another 350 per year.
**Payments**
The most common way of billing for water and sanitation services is by producing a bill. Whatever the system used for billing, the most important principle is clarity: bills must contain enough information for users to understand how much they have to pay and why. It is useful to think about ways and timing of presenting bills to water users, providing one or more places where water bills can be paid. In some cases monthly payments are fine, but in other cases it may be better to charge after the harvesting season or to charge per bucket of water.

Other important issues include who collects the money as this need to be people that are trusted by the community and where is the money kept in a bank account or in a safe and is it generating interest or is it loosing its value because of inflation.

### 6.8 Setting up a cost collection system

The recovery of the basic operational cost is essential for the sustainability of a water supply system. In fact more than the cost of operating and maintenance should be recovered - but also the cost of the organization managing the system and the cost of large repairs and system improvements.

In setting up a cost recovery system a number of considerations are important:

- **Rationalizing expenditures** – in other words making sure that the system is operated in a cost-effective manner;
- **Deciding on the tariffs** – who pays what and what to include in the user tariffs (see also the concerned chapter). This should preferably widely discussed and widely known so as to increase the willingness to pay
- **Setting up an effective billing system**
- **Having a transparent administration** – in principle for every body to check, so there is confidence and (again) willingness to pay.

This section concerns setting up a cost collection system and intends to briefly explain the different steps involved. It is based on the most common ‘improved system’ in rural Pakistan, i.e. piped water supply with house connections. An effective cost collection system meets the following requirements:

- **Easy to handle** – in this respect fixed charge systems are far more easy than metered systems\(^\text{12}\).
- **Delivers the ‘goods’** – enough income to provide the services in a sustainable way
- **Source of confidence and agreement**.

**Steps in a cost collection system**
The following are the subsequent steps in setting up a cost collection system:

- Agree on tariffs, connection charges and penalties
- Prepare customer register
- Prepare monthly bills
- Manage the payments
- Take action against defaulters

\(^\text{12}\) For rural water supply systems fixed charges are recommended – to avoid the hassle of meter reading and the distrust that comes with this. When there are large differences between houses and households, different fixed charges can be considered based on the house size for instance.
• Improve willingness to pay
• Undertake additional activities.

**Agree on tariffs, connection charges and penalties**
The operation of a water supply system inevitably requires expenditures, yet the cost of not having safe water (in costs of medicine or time lost) is always much higher. Tariffs should cover the cost of running the system (energy costs, chemicals for water treatment and for an up-to-date stock of spare parts, staff costs, cost for basic repairs and preferably ‘buffer’ money to improve the system or do larger repairs). The tariffs and changes in the tariffs should be mutually agreed and widely announced.

The same applies to connection charges and reconnection charges as well as penalties for late payment.

![Image of a cost collection system](image)

**Figure 6.5:** Effective cost collection system consisting of monthly bills, receipt system, ledger and penalties for late payment in Rehamadabad, Punjab.

**Prepare customer register**
A customer register is to be prepared with number given to each customer. Many systems in Pakistan have more than 100 connections, so it is important there is a systematic register to serve as the basis for the billing system.

**Prepare monthly bills**
Monthly bills are preferred – to manage the cash flow of the organization and to not run bills too high, particularly in case of late payment.

Bills should be prepared in time and they should be hand-delivered to the different customers. Preferably a pre-printed bill is used. The bills should mention:

- The customer and his number in the register
- The amount due
- The arrears
- The last date for payment

The bill can also be used – in case of a pre-printed bills – to remind customers of the basics rules of the water supply systems, such as:

- If one is to connect a pumpset to the water supply line, one will be disconnected
- If one is to work around the house with the risk of damaging the water mains, one needs to inform the water management committee. In case of damage to the water supply system this will have to be paid by the person that caused the damage
- The surcharge for late payment and system for disconnection
- The importance of not wasting water and closing the tap after use

**Manage the payments**

There are several steps in managing payment of the bills:

- Have fixed timing for payment and display these publicly and mention these on the bill. It is generally better and easier if customer come to pay the bill at fixed times/ days rather than the water committee ‘chasing’ payment;
- On payment issue a receipt to the paying customer. One system is to prepare the bill in such a way that on payment half of the bill is retained by the customer, whose half is stamped on payment. The other half of the bill is retained by the water management organisation
- Enter the payments in a ledger, with entries for each customer so a payment record of each customer is ready.

**Take action against defaulters and illegal connections**

There need to be clear and fair rules and understanding on how to deal with non-payment. The usually consist of:

- Agreement on surcharges and disconnections
- Announce the disconnections in advance, in other word give ‘last warnings’
- Disconnect, when the grace period for late payment has lapsed
- Reconnect, when a reconnect fee has been paid.

**Ensure good willingness to pay**

Willingness to pay is essential in a cost recovery system. There are several activities that will greatly enhance willingness to pay:

- Have clarity on fees and charges and announce these for instance on a poster for all to see;
- Have a transparent and up-to-date administration, that can be inspected by all. This will concern files with monthly statements of income and expenditures; files with bank statements and copies of the ledger;
- Ensure that basic repairs are done in time: if (house) connections are out of order or malfunctioning, the willingness to pay the bills is usually reduced significantly. If the water
supply committee maintains a stock of the most essential spare parts and has a trained mechanic at hand

- Avoid illegal connections. If the committee functions well and provides services and arranges payment as above than it will also be in position to deal with illegal connections. If no one cares, a different picture emerges and illegal connection may become the order of the day, undermining the management of the water supply system.

**Undertake additional activities**

Well-functioning water committees can undertake additional activities that contribute to local public health and improve the standing of the committee, such as:

- Cleanliness drives and organize solid waste disposal
- Improve local drainage to prevent stagnant water becoming sources of vector diseases
- Promotion of safe sanitation
- Cooperate in health surveys, particularly for water-related diseases – which will also help increase awareness
- Awareness campaigns on safe water handling
- Ensure and improve the protection of the water source.
7. Water safety plan development

A wide range of water supply systems exist in the world. These systems may incorporate different technologies, from relatively simple systems such as wells with handpumps to sophisticated treatment plants with house connections. A common feature of many of the smaller water supply systems is that they are operated and maintained by local operators including small Community Based Organizations (CBOs) with limited specialist skills, (financial) resources, amounts of time, formal training and back-up support.

The water supply systems may be old and already incorporate many problems and operators may have very few tools and equipment to identify and rectify faults. In theory they may have support from external bodies (usually an arm of local or national Government) to provide support for problems beyond their capacity but in practice this is often not existing or it is not timely and not effective.

An important way to support these water operators is to help them develop a Water Safety Plan (WSP) to manage their water supply system safely. A WSP is an effective means of consistently ensuring the safety of a drinking-water supply through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer (Davidson et all, 2005).

A WSP is part of a broader framework for safe drinking water supply (Figure 7.1). This framework comprises three components:

- **Health based targets**, representing the policy objectives for water safety as defined by what is considered an acceptable risk. These targets that are reflected in water quality criteria are not static and may change over time. Criteria for turbidity levels in the USA for example have fallen from 10 NTU in the 1960s to 1 NTU today.
- **Water Safety Plans** to assist the water operator to provide water that is safe for consumption (as will be discussed below); and
- **Independent surveillance**, to help ensure that water operator meets the required targets. Whereas this is an external control function its main orientation needs to be to provide support to water operators to help them overcome the difficulties in operating their water supply system.
The primary objective of a water safety plan is to ensure safe drinking-water by:

- Preventing contamination of source waters;
- Treating the water to reduce or remove contamination that could be present to the extent necessary to meet the water quality targets; and
- Preventing re-contamination during distribution, storage and handling of drinking-water.

These objectives are equally applicable to large piped drinking-water supplies, small community supplies and household systems and are achieved through:

- Development of an understanding of the specific system and its capability to supply water that meets health-based targets;
- Identification of potential sources of contamination and how they can be controlled;
- Validation of control measures employed to control hazards;
- Implementation of a system for monitoring the control measures within the water system;
- Timely corrective actions to ensure that safe water is consistently supplied; and
- Undertaking verification of drinking-water quality to ensure that the WSP is being implemented correctly and is achieving the performance required to meet relevant national, regional and local water quality standards or objectives.

A Water Safety Plan (WSP) comprises three essential components that are the responsibility of the water operator in order to ensure that drinking-water is safe. These are:

- A comprehensive system assessment to prioritize the health hazards involved;
- Effective operational monitoring to facilitate timely intervention; and
- A management plan describing actions to be taken.

To develop a WSP for one or more locations a number of steps can be envisaged:

- Establishment of a WSP development team
- Prepare a description of the system
- Assessment of hazards and establishment of risks
- Identification of critical control points and measures
- Establishment of critical risks
- Development of a risk monitoring system
- Identification of corrective actions
- Documentation and sharing with the water operator and water users
- Verification / evaluation
The WSP concept has been developed for water supply systems but the reality in many
communities is that people may use multiple water sources. Sometimes they use these sources for
all purposes, but in other cases they dedicate some water sources for specific use. At community
level it is therefore necessary to understand the water system as to include all possible water
sources that people use for domestic use and particularly for human consumption and food
preparation. To underscore this broader concept we introduce the term Community Water Safety
Plans (CWSP). A CWSP reviews the risk involved in the water use patterns of the community as a
whole. This implies that it looks at the risks the consumers face as part of their water consumption
habits looking at all water sources and water chains from source to consumption.

7.1 A comprehensive system assessment

The comprehensive system assessment aims to determine whether the drinking-water supply
chain (up to the point of consumption) as a whole can deliver water of a quality that meets the
prevailing targets. It includes the systematic and detailed assessment and prioritization of hazards
in the system as a whole. In the literature this assessment is focused on the aspects that are
under the control of the water operator. In rural water supply, however, a broader approach is
needed that also actively involves the users as they may re-contaminate the water and therewith
put in jeopardy the work done by the operator. They also may use different water sources in
parallel or during a period of the year, making it necessary to look at all water sources and the
water habits of the population to establish the basis for the CWSP.

Although there are numerous contaminants that can compromise drinking-water quality, not every
hazard will require the same degree of attention. The risk associated with each hazard or
hazardous event may be described by identifying the likelihood of occurrence (e.g., certain,
possible, rare) and evaluating the severity of consequences if the hazard occurred (e.g.,
insignificant, major, catastrophic). The aim should be to distinguish between important and less
important hazards or hazardous events.

A semi-quantitative scoring can be used relying to a significant extent on expert opinion to make
judgments on the health risk posed by hazards or hazardous events. A “cut-off” point must be
determined, above which all hazards will require immediate attention. On the other hand, there is
little value in expending large amounts of effort to consider very small risks.

It is important to take an action oriented approach from the beginning. The review of the different
systems will show a number of hazards which sometimes may be very serious. It does not seem
fair to just leave the community and write a report instead of already exploring possible
‘emergency’ improvements the water operator or community members can make. In high risk
systems for example it can be considered for example to suggest as a minimum that water needs
to be boiled, chlorinated or treated by solar disinfection at household level at least for children and
elderly people.

The system assessment usually comprises:

- Water quality analysis
- A sanitary inspection
7.2 Water quality and testing

Water used for drinking and other domestic purposes should be free of any substances that can result in rejection or disease among users, or in deterioration of the water supply system and domestic utensils. A good quality is also important to protect the adequate functioning of water meters, which are increasingly being used to enhance efficient water use. For aesthetic reasons it is desirable that the water be clear (low turbidity) and that it be free from taste, odour and colour.

The contamination of a water source with excreta from people or animals introduces a great variety of bacteria, viruses, protozoa and worms. Insufficient protection of water sources, or inadequate treatment, thus puts the community at risk of contracting infectious diseases. Poor water quality may be particularly harmful for children and old people with defects in their immune systems. For these two groups the infectious dose is significantly lower than for the rest of the population (WHO, 2005). An important problem is that the risk of bacteriological contamination may not be perceived by the community as the pollution is often not visible. Local people may value the water supply and the taste and appearance of the water, but not its bacteriological quality. However, their appreciation of water quality may be influenced for example by information campaigns such as those that were organized in Latin America after the Cholera outbreak in 1991 (Galvis, 1999).

There are few chemical components that produce an acute risk for users, except for situations where accidents occur in industry or through the spraying of pesticides and herbicides. In such cases, the water is often rejected by the consumers. Chemical pollution may, however, bring a chronic health risk associated with long periods of exposure, as can be seen from the incidence of arsenic poisoning in, for example, Bangladesh or fluoride in India and the Rift Valley countries in Africa. Chemical pollution can also cause discomfort – for instance high iron level (smell) or magnesium (stomach ache).

Chemical pollution control is therefore important, but of a secondary order in comparison with severe bacteriological contamination (WHO, 2005; Craun et al., 1994). Particularly in countries with a less developed infrastructure, the acute risk associated with bacteriological contamination is more important than the chronic risk related to chemical components that may be present or may develop as a by-product of chlorination. The latter happens for example when chlorine reacts with organic material in the water. The potential health risk of disinfection by-products should not be ignored; however these risks should always be considered in the context of the benefits provided by disinfection, which reduces the much larger threat of waterborne infectious disease (Craun et al., 1994).

Water quality is an issue under debate, as some argue that being too clean entails the risk that humans do not develop resistance to disease. They argue that water quality standards in the industrialized countries may be becoming too strict. Furlow (2005) quotes Frost saying that “microfiltration may move people into a pathogen-free bubble. Without protective immunity from mildly contaminated drinking water illness from periodic contamination, or from other sources of infection like infected salads greens, will be more severe”. Yet Frost also says that his thought-provoking ideas, which are supported by some others, particularly relate to microfiltration which completely removes exposure to some protozoans such as cryptosporidium. For more serious bacterial and viral pathogens, the aim should still be complete elimination from the water supply (ibid). These ideas show that water quality needs to be seen in the context of local conditions. In an area where there are numerous other potential routes of disease transmission, the impact of less stringent water quality norms may be lower than in very clean environments.
7.2.1 Water quality guidelines

The WHO has established extensive water quality guidelines, which form the basis for water quality regulation in many countries (WHO 2005). These guidelines provide desired concentration levels for physical-chemical and bacteriological parameters that allow the provision of drinking water that is pleasant for consumption and does not involve a significant public health risk. These guideline values are meant to help developing national water quality norms that need to be established taking into account, the local socio-economic and cultural conditions and need to be embedded in the legal and institutional framework of the country concerned.

National drinking water standards have been developed by the Ministry of Health and have been published in 2007. The standards were developed with support from WHO and reviewed by the leading authorities in Pakistan including the Pakistan Standards Quality Control Agency (http://www.hsa.edu.pk/aboutus/news/2008/Microsoft%20Word%20-%20Final%20DWQ%20Standards%20for%20Pakistan.pdf)

The development of guidelines is relatively recent. Some 50 years ago less than ten parameters served as water quality guides for drinking water supply. These guidelines assisted in the reduction of infant mortality rates to below 20 per 1000 births, and the increase in life expectancy to values above 70 years in the western industrialised countries. By 1980, the number of parameters had been increased to more than 40 (Tavos, 1981 cited in Galvis 1999), and today the new WHO guidelines include about 150 parameters. The first application of water quality norms at federal level in the USA, was based on the Safe Drinking Water Act (SDWA) of 1974, when Congress requested the US Environmental Protection Agency to develop reliable regulations (Pontius, 1990). This regulation was expected in 1975 but became effective only in 1977, covering micro-biological, organic, and inorganic pollutants as well as turbidity. The SDWA was revised by Congress in 1986 resulting in the development of new regulations between 1986 and 1991. This includes the obligation to adopt disinfection in all public water supply systems and provides the conditions under which filtration of surface water is required.

The establishment of norms need to take into account the health risks as well as the technical and economic viability. Norms that do not take into account practical considerations concerning the water sources, available treatment options, water surveillance practice and support available for system management, do not provide the desired results (Lloyd and Helmer, 1991). When the norms are not met, the underlying cause needs to be explored and remedied. One option is to establish interim norms for the medium term and use water surveillance as a tool to orient corrective actions to those communities that are facing the highest hygiene risk.

The Pakistan Council for Research in Water Resources and the Pakistan Standard Institution drafted drinking water quality guidelines for Pakistan, but the endorsement of these guidelines is still pending. These two sets of guidelines are given in annex 1.
7.2.2 Water quality guidelines for community water supply

Acknowledging the difficulty of assessing and monitoring water quality in rural communities and municipalities with limitations in infrastructure, WHO developed a much less prescriptive approach for these situations (WHO, 1997). The guidelines for such situations propose a combination of the use of a few water quality parameters and the implementation of sanitary inspections. The water quality parameters include:

- \( E. \ coli \) counts, or, as an alternative, thermo-tolerant coliform counts, usually referred to as faecal coliform counts (FCCs)
- residual chlorine (if applied)
- pH (if chlorine is applied)
- turbidity.

In table 7.1, the WHO guideline values for \( E. \ coli \) and turbidity are presented together with some other key parameters that are important for users’ acceptance of the service and for the application of filtration and disinfection systems. The availability of portable water quality analysis equipment facilitates the analysis of these parameters. Equipment for measuring turbidity, pH, residual chlorine and colour is also available in a very basic form that can be used directly by system operators with a low level of formal education. If a water source for community water supply is subject to other (industrial) contamination, not covered by the basic parameters, the national or regional health authorities need to provide additional support or training to the community to monitor these risks.

Regular measurement of these few parameters is still complex in rural settings. The FCC in particular requires special equipment or the transportation of the sample under controlled conditions to a laboratory. Also the measurement is based on spot samples that may not be representative of the general situation, particularly not if the sampling frequency is low. Therefore WHO suggests that water quality testing needs to be combined with sanitary inspection to establish the risks and hazards involved in the supply system (see Box 1).

In the case of surface water sources, the hydrological cycle may have a considerable influence on quantity and quality. Waste-water discharge may have a strong impact on water quality, particularly in the dry season and also during the first runoff at the beginning of the rainy season, which can create high bacteriological, and sometimes chemical, pollution. In micro-catchments these changes are sometimes of short duration and therefore difficult to detect with occasional water quality testing.
Table 7.1 Guidelines for basic drinking water quality parameters (based on Lloyd and Helmer, 1991; WHO, 1997)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Guideline value</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. coli; faecal coliforms</td>
<td>Not detectable in 100 ml</td>
<td>If the distribution system contains between 0.2 and 1.0 mg/l free residual chlorine; pH&lt;8; turbidity &lt;5 and preferably &lt;1, presence of faecal coliforms is highly unlikely</td>
</tr>
<tr>
<td>Turbidity</td>
<td>&lt; 5 NTU</td>
<td>Preferably &lt; 1 NTU for effective disinfection</td>
</tr>
<tr>
<td>Colour</td>
<td>&lt; 15 PCU</td>
<td>In order to avoid rejection by the users and the formation of disinfection by-products</td>
</tr>
<tr>
<td>Flavour &amp; smell</td>
<td>Not detectable</td>
<td>Often a major cause for users complaints</td>
</tr>
<tr>
<td>Iron</td>
<td>&lt; 0.3 mg/l</td>
<td>Flavour and possibility of staining clothes can cause rejection</td>
</tr>
<tr>
<td>Manganese</td>
<td>&lt; 0.1 mg/l</td>
<td>Possibility of staining clothes - provisional health guide &lt; 0.5 mg/l</td>
</tr>
</tbody>
</table>

If regular FCC testing proves difficult than an option may be to rely on the combination of sanitary inspections, turbidity measurement, and residual chlorine testing. In the Greater Vancouver water basin, the strategy relies principally on watershed protection and chlorination, which does not eliminate all risk of waterborne disease transmission. It was found however that no gastrointestinal events resulted from disinfected water with a turbidity of less than or equal to 1 nephelometric turbidity unit (NTU) (Aramini, 2000). It is important to note that the basin is well protected and chlorine dosing is well controlled. Although this may not be the case in many other situations, the approach provides a direction for a search for a simple form of water quality testing that can be managed by local operators without fancy equipment, occasionally supported by an external analysis that would include testing for faecal coliforms.
Box 1 Sanitary Inspections
The sanitary inspection involves a systematic review of the water catchment area, the water source and the water supply system, preferably by experienced sector staff together with community members involved in the management of the system. The inspection aims at identifying all potential factors in the catchment area and the water supply system (intake, transmission main, treatment, storage and distribution), that may lead to contamination of the supply and that put the users at risk (Lloyd and Helmer, 1991; WHO 1997).

The sanitary inspection and the water quality analysis are complementary activities that are preferably combined. Whereas the sanitary inspection identifies potential risks, the water quality analysis shows if and to what level the water was contaminated at the time of sampling. The inspection is essential for the interpretation of the test results and for prioritizing remedial actions. Against the background of problems with water quality testing, extra emphasis has to be placed on the sanitary inspection. However, further research is needed to establish effective indicators that permit the monitoring of community-managed systems with little external support.

7.2.3 Designing water surveillance
The new water quality guidelines of WHO acknowledge the difficulty of monitoring the large number of dispersed community water supply systems. They suggest that surveillance has to be well designed and geared more towards a supportive role to enhance community management than towards enforcement of compliance. They refer to the limited capacity of the community to undertake process control and verification. They indicate that “frequent visits to every individual supply may be impractical because of the very large numbers of such supplies and the limitations of resources for such visits. However, surveillance of large numbers of community supplies can be achieved through a rolling programme of visits. Commonly, the aim will be to visit each supply periodically (once every 3–5 years at a minimum) using either stratified random sampling or cluster sampling to select specific supplies to be visited. During each visit, sanitary inspection and water quality analysis will normally be done to provide insight into contamination and its causes” (WHO 2004 p. 89).

7.2.4 Water quality testing
Measuring water quality is important, as the water may comprise substances that are detrimental for health. In this section testing of some key parameters will be briefly described. For further information readers can consult the water quality guidelines from WHO (http://www.who.int/water_sanitation_health/dwq/en/). In water quality testing it is always important to keep in mind that it only provides a snapshot of the situation. The sample may not be representative of conditions at other moments. This makes it so important to combine it with a sanitary inspection and with consultations of the water operator and/or community members about the situation. They will be able to tell for example if the turbidity of the water is always the same and also if for example there are many children with diarrhoea.
Turbidity

Turbidity is the cloudiness of water caused by individual particles (suspended solids) that are generally invisible to the naked eye. Water can contain suspended solid matter consisting of particles of many different sizes. Some of these particles, the settleable solids, will be large and heavy enough to quickly settle if a water sample is left to stand. Others including very small particles will settle only very slowly or not at all if they are if a colloidal nature. These particles are responsible for the turbidity of the water.

Turbidity can be measured with a turbidity meter (nepholometer) which is an instrument that works on the principal that particles will scatter a light beam which is focused on them. The part of the light that reaches the detector at the side of light beam is an indication of the turbidity of the water. More light reaches the detector if there are lots of small particles scattering the source beam than if there are few. The units of turbidity from a calibrated nephelometer are called Nephelometric Turbidity Units (NTU). To some extent, how much light reflects for a given amount of particulates is dependent upon properties of the particles like their shape, color, and reflectivity.

E. coli counts

Measuring all the pathogens potentially present in the water on a routine basis would be far too complex. It is therefore normal practice to detect only what are called ‘indicator’ bacteria, “which are always excreted in large numbers by warm-blooded animals, irrespective whether they are healthy or sick” (Cairncross and Feachem, 1983 p.28). Their presence suggests faecal contamination and thus a potential health risk, as this contamination may contain pathogens. The indicator that is mostly used is “faecal coliforms, mainly comprising Escherichia coli. They are a subgroup of the total coliform group and they occur entirely, or almost entirely, in faeces” (Ibid, p 28). Two methods are being used to test the water for coliforms, the MPN test and the plate count method (Figure 7.2).

![MPN based on 5 day multiple tube fermentation test](image1)

![Coliform counts based on a plate count of the filter pad through which 100 ml of the water is passed and after 24 hrs of incubation at 44°C](image2)

**Figure 7.2** Two methods for measuring the coliforms in water

In collaboration with UNICEF PCRWR has developed a number of low cost tests for important drinking water parameters. This includes the following test for arsenic.
7.3 Sanitary Inspection

A sanitary inspection consists of a systematic review of possible hazards that may occur in the water catchment area, the water source and the water supply system. Preferably this is done by experienced sector staff, together with community members and staff from the local organization responsible for the management of the system. After some training, subsequent inspections can be carried out (several times per year) by the local operator or water committee without external specialist support.

The inspection aims at identifying all the hazards that are potential and actual causes of contamination of the supply. It is concerned with the physical structure of the supply, its operation, and external environmental factors. It involves looking at all water sources and systems in a community (water catchment area, well, handpump, water intake, transmission main, treatment system, water storage, distribution network and water use) to identify possible risks for the users (WHO 1997).

Sanitary inspections are the basis to establish corrective actions in the system, the community, and community habits, to eliminate or reduce the hygiene risks. Figure 7.3 shows an overview of the sanitary hazards in a shallow well.

Sanitary inspections and water quality analysis are complementary activities that preferably are carried out at the same time. Whereas the sanitary inspection identifies potential risks, the water quality analysis establishes the level of contamination at the point and the time of sampling. The sanitary inspection is essential for the interpretation of the results of the water quality analysis and to prioritize remedial actions.

![Figure 7.3 Pollution hazards in an open bucket well (WHO, 1997)]

Possible hazards include:
- Potential sources of pollution (latrines, ponds or pools) close to the well. Harmful substances from these sources may travel underground to the well. The minimum safety distance (MSD) depends on local conditions including the type of subsoil and direction of groundwater flow.
- Problems with the well lining, headwall and cracks in the well cover
- Unhygienic handling and storage of the bucket

Climate conditions may have an important influence on water quality. Particularly in micro-catchments these changes can be of short duration and may be difficult to detect with occasional water quality
testing. The sanitary inspection can be of great help in such case. Waste water discharge often is more critical in the dry season when less water is available. First rains after a dry spell can severely enhance the microbial and chemical contamination of a water source and increase turbidity levels.

The community is an important source of information. They know about changes in water quality during and over the years in terms of turbidity, colour and taste (salinity, iron). Also they may be able to give an indication of the incidence of water borne diseases in the community. Hence their information can help to confirm the findings of a sanitary inspection. One would expect a high incidence of diarrhoea if the sanitary inspection shows that there are considerable sanitary risks from the source and/or inadequate hygiene habits.

7.4 Operational monitoring and control measures

The comprehensive assessment will allow identifying measures that will collectively control identified risks and ensure that targets are met. See Annex 1 for an example of a generic water safety plan for a handpump system on a deep borehole. Measures may range from immediate repairs of deficiencies to longer term improvement projects, strengthening operation and management of systems and improvements in water handling and storage.

In addition to essential repairs and improvements it will be needed to identify the water provision and water quality improvement processes and identify for each of these ‘control measures the appropriate means of operational monitoring to ensure that any deviation from required performance is rapidly detected in a timely manner. The water safety plan should propose control measures for both microbial and chemical hazards where possible. However, in most cases, particularly the control of chemical hazards must be addressed at the design stage.

Operators of small systems may not have the necessary equipment for water quality testing. They may have to rely on sanitary surveys in combination with feedback from their users on possible outbreaks of diarrhoea. This underscores the necessity for occasional checks by a water surveillance agency.

The level of control applied to a hazard should be proportional to the associated ranking. Assessment of control measures involves:

- Identifying whether existing control measures for each significant hazard or hazardous event from catchment to consumer control the risk to acceptable levels;
- Evaluation of possible alternative or additional control measures preferably based on the multi barrier concept to reduce the risk of contaminants passing through the system.

7.5 Management plans

Management (and repair) plans are needed that describe actions to be taken during normal operation or incident conditions as well as the necessary upgrading and improvement steps. These plans also need to include the monitoring and communication plans and establish the required external support. Most local operators of community water supplies will require support to develop system-specific water safety plans. This may be done by developing generic water safety plans for particular technologies to be applied across a region or country (as the one shown in Annex 1) or provide an example plan as presented in Annex 2 and ensure that it comprises all of the types of water sources and problems are included. Most likely this is not sufficient however and additional
support will be required from more experienced staff to develop a plan for each water supply system.

The management plan needs to include:

- The organizational structure of the water provider including external support
- The main responsibilities of the key actors and reporting lines
- A description of the (financial) administration
- A description of the water supply system
- An overview of the normal operating procedures including monitoring
- A description of emergency operating procedures
- An overview of the main risk that have been identified and the remedial actions

7.6 Improvement options

Once the risks involved in the different water supply systems are known, a plan needs to be made to improve upon the situation. It may be expected that in a considerable number of communities a broad range of risks will exist that cannot be solved at the same time. In that case priority actions will have to be identified and these need to be discussed with the users to ensure that soonest access to safe water supply is being established. It is therefore essential to distinguish between:

- Emergency actions which may include for example the identification of safe sources, or the repair of one or more sources in such a way that safe drinking water can be obtained here, whereas other sources can be used for other purposes. This will only be effective if people also be careful with water transport and water storage. Providing a safe source may also include the approach followed in Pakistan where safe drinking water treatment units are provided on a few selected locations. As an alternative people may be encouraged to adopt water treatment at home either by chlorinating or boiling the water, particularly for weaker family members (young children and elderly people). They may also contemplate to adopt solar disinfection. The key word is organised collective action. People can do a lot to improve upon their situation if they join hands, understand what they can do, how they and their children will benefit, and see some short-term results.

- Short term actions which can be implemented by the community itself without much external support such as cleaning of pump sites and drains, avoiding open field defecation particularly close to water points, simple repairs of cracks and joints. Improvement of preventive maintenance and for example the management of water supply and treatment systems.

- More complex actions including the repair of water supply systems. The replacement of faulty distribution systems. The development of a campaign to improve the sanitary conditions (latrine construction, better drainage etc.)

7.7 Capacity building

Part of the activities needed to improve the situation will require building capacity at the local level and providing back-up support. Important limitations may exist for example in tariff collection which in turn makes adequate operation and maintenance of the system difficult or impossible. A lot of illegal collections may exist among others because the village committee or the operators do not know how to best deal with this. Preventive maintenance requires skills and attitudes that may be lacking.
Hence it may be expected that capacity building will be a key component of the management plan to improve the situation. An interesting experience in this respect is the development of community training centres that is taking place in Colombia. These centres adopt the concept of peer training. Members of water committees and water operators train people from other communities with a little external support in issues they have learnt themselves. They use adult learning approaches and include practical on the job assignments which are well appreciated by trainees. The fact that they are peers and speak ‘the same language’ is an important asset as it helps to build trust and make trainees feel at ease.
8. Further reading

If you want to explore these issues in more detail you may wish to access a number of additional titles in the internet (or on your cdRom) that are mentioned in this section. The list includes a considerable number of titles from the IRC as this organization has developed a broad range of titles particularly dealing with community water supply. So it may be worthwhile to also visit their website (www.irc.nl).

8.1 Water supply and water resource protection

http://www.irc.nl/content/download/2562/26426/file/op23e.pdf

http://www.irc.nl/content/download/25104/278851/file/TP46_FacilitatingCWS.pdf

Bolt E., Fonseca C. *Keep It Working: a field manual to support community management of rural water supply*. IRC Technical Paper Series 36; IRC, International Water and Sanitation Centre, the Netherlands
http://www.irc.nl/content/download/2602/27266/file/TP36_KeepItWorking.pdf

http://www.irc.nl/content/download/9525/141513/file/ScalingUp_CM.pdf

http://www.irc.nl/content/download/8160/126955/file/TOP7_CostRec_03.pdf

Smet J., Wijk-Sijbesma C. (2002) *Small community water supplies: technology, people and partnership*; Technical Paper Series 40; IRC, International Water and Sanitation Centre, the Netherlands; Only the introduction is available online:
http://www.irc.nl/content/download/14611/195586/file/tp40e01.pdf

Schouten, T., Moriarty P.; *Scaling up the community management of rural water supply* Waterlines, Volume 23, Number 2, October 2004 , pp. 2-4(3); Publisher: Practical Action Publishing Authors;
http://practicalactionpublishing.org/?id=waterlines_23-2
8.2 Actor analysis and gender aspects

http://www.irc.nl/content/download/25104/278851/file/TP46_FacilitatingCWS.pdf

Bolt E., Fonseca C. Keep It Working: a field manual to support community management of rural water supply. IRC Technical Paper Series 36; IRC, International Water and Sanitation Centre, the Netherlands
http://www.irc.nl/content/download/2602/27266/file/TP36_KeepItWorking.pdf

Schouten, T., Moriarty P.; Scaling up the community management of rural water supply
Waterlines, Volume 23, Number 2, October 2004 , pp. 2-4(3)
Publisher: Practical Action Publishing Authors:
http://practicalactionpublishing.org/?id=waterlines_23-2

http://www.irc.nl/content/download/2562/26426/file/op23e.pdf

Sustainable development of water resources, water supply, and environmental sanitation; Women, well-being, work, waste and sanitation. Snel, M and Jayaweera, 2006. Paper presented at the 32 WEDC conference
http://wedc.lboro.ac.uk/conferences/pdfs/32/Snel.pdf

The Gender and Water Alliance http://www.genderandwater.org

8.3 Water supply and sanitation in Pakistan

Bridges (2007) Country Chapter Pakistan in Asian Water Development Outlook, Manila, ADB


Pakistan Water Gateway
http://www.waterinfo.net.pk/index.asp

8.4 Community management

If you want to explore these issues in more detail you may wish to access a number of additional titles on the internet (or on your CD-Rom) including:
8. Further reading

Schouten, T., Moriarty P.; Scaling up the community management of rural water supply. Waterlines, Volume 23, Number 2, October 2004, pp. 2-4(3); Publisher: Practical Action Publishing Authors:
http://practicalactionpublishing.org/?id=waterlines_23-2

Bolt E., Fonseca C. Keep It Working: a field manual to support community management of rural water supply. IRC Technical Paper Series 36; IRC, International Water and Sanitation Centre, the Netherlands
http://www.irc.nl/content/download/2602/27266/file/TP36_KeepItWorking.pdf

http://www.irc.nl/content/download/9525/141513/file/ScalingUp_CM.pdf

8.5 Water treatment
If you want to explore these issues in more detail you may wish to access a number of additional titles in the internet (or on your cdRom) including:

http://www.irc.nl/content/download/28202/297431/file/TOP15_MFS_06.pdf

http://www.irc.nl/page/1917

http://www.irc.nl/content/download/25104/278851/file/TP46_FacilitatingCWS.pdf


8.6 Operation, maintenance and finance
http://www.lboro.ac.uk/well/resources/Publications/Briefing%20Notes/BN16%20Agbenotheri.pdf

Bolt E., Fonseca C. (2001) Keep It Working: a field manual to support community management of rural water supply. IRC Technical Paper Series 36; IRC, the Netherlands
http://www.irc.nl/content/download/2602/27266/file/TP36_KeepItWorking.pdf

http://www.irc.nl/content/download/8160/126955/file/TOP7_CostRec_03.pdf

Operation and Maintenance of rural water supply and sanitation systems; A training package for managers and planners.


8.7 Water quality and water safety plans


ACE, HALCROW. 2002b. *National Water Policy, Background Information and the Policy*. Islamabad: ADB.


Brikke, F. (2000). *Operation and Maintenance of rural water supply and sanitation systems; A training package for managers and planners*. Delft: IRC


PCRWR (2007) *Technical assessment survey report Wahula water supply scheme*


Schouten, T., Moriarty P.; *Scaling up the community management of rural water supply*. Waterlines, Volume 23, Number 2, October 2004 , pp. 2-4(3); Publisher: Practical Action.


Waterlines Special Issue. Scaling up rural water supply. Vol. 23 No. 2 October 2004. (www.itdgpublishing.org.uk/content/wl23_2.htm)


WHO (1983). Minimum evaluation procedure (MEP) for water supply and sanitation projects.


### Annex 1: Functional/ non functional status of rural drinking water systems in Pakistan

<table>
<thead>
<tr>
<th>NWFP</th>
<th>Districts</th>
<th>No of schemes surveyed</th>
<th>Functional</th>
<th>Non-Functional</th>
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<tr>
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<td>75</td>
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</table>

Source: PCRWR Assessments

This WSP is based on the model developed by Davidson at all (2005)

<table>
<thead>
<tr>
<th>Hazard event</th>
<th>Cause</th>
<th>Risk and hazard</th>
<th>Control measure</th>
<th>Critical limits</th>
<th>Monitoring</th>
<th>Corrective action</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingress of contaminated water</td>
<td>Direct draining of polluted water in the well (cracks in platform, inadequate backfill, inundation)</td>
<td>Low risk</td>
<td>1) crack repair 2) proper backfill (ceiling) of the borehole 3) prevent puddles around borehole</td>
<td>No cracks No puddles Adequate backfill</td>
<td>Presence of cracks and / or puddles Presence of turbidity in water</td>
<td>Sanitary &amp; Technical inspections(including Water analysis if relevant)</td>
<td>Operator And Yearly Health official Repair cracks Improve drainage away from the borehole Random-based water analysis under the control of health authorities.</td>
</tr>
<tr>
<td>Direct contamination during maintenance and repairs</td>
<td>Pump rods touching unwashed hands and the ground</td>
<td>Considerable risk, limited effect</td>
<td>1) Good maintenance and repair instructions and skills. 2) Disinfection borehole after intervention</td>
<td>Prevent pollution or take remedial action</td>
<td>Evidence of unclean interventions</td>
<td>1) visual inspection At times of (surveillance) visits</td>
<td>Water committee Users Health official 'Clean' repairs Disinfect borehole or pump with chlorine before replacing pump head Random-based water analysis under the control of health authorities.</td>
</tr>
<tr>
<td>Ingress of contaminated ground water</td>
<td>Groundwater contamination from surrounding sources (sanitation, waste dump, chemicals)</td>
<td>Very low risk, high effect</td>
<td>Provide adequate setback distances; Remove potential sources of pollution</td>
<td>No intrusion of contaminants</td>
<td>Negative Water quality test WQ testing Sanitary Survey</td>
<td>(Bi)annually At times of disease outbreak</td>
<td>Operator (Water committee ) Health official Remove source of pollution Treat water close pump water analysis under control of health authorities</td>
</tr>
<tr>
<td>Leaching of metal parts of the pump</td>
<td>Aggressive ground water (high pH).</td>
<td>Low risk</td>
<td>Use un-corrosive pump</td>
<td>No leaching</td>
<td>High iron content Visual corrosion of internal pump parts</td>
<td>Technical inspections Check with consumers on taste problems</td>
<td>(Bi)annually Operator Replace pump with corrosive resistant model Surveillance visit</td>
</tr>
</tbody>
</table>
A2.1 Introduction

This report summarises the community water safety plan of (community in .......). It was developed in the period (xxxxxxxx) by a group of people from the community with external support (see Annex 1 for the participants).

Safe drinking water and sanitation is of essence to ensure public health, bring down child mortality, improve work productivity and childrens cognitive development and avoid unnecessary burdens on family budgets. This report adheres to the general objectives of water safety plan for a community water supply which aims at:

- preventing contamination of source waters;
- treating the water to reduce or remove contamination that could be present to the extent necessary to meet the water quality targets; and
- preventing re-contamination during distribution, storage and handling of drinking-water.

It is important to stress that the plan looks at all water sources the community uses for domestic water supply.

This water safety plan comprises four main components:\n
- The description of the water supply situation looking at all available water sources
- The assessment of the risks involved in each of the water sources
- A review of the management of the different water systems
- A summary plan for improvement measures

A2.2 The water supply situation

In this section the general situation in the community is briefly presented with special emphasis on the water supply situation. It is important to realize that the plan looks at all water sources that the community uses as in many situations it has been found that community members use different water sources even if an improved water source is available. Particularly the poorer community groups may not use the improved system for which they may have to pay.

In table 1 a number of general characteristics of the community are being presented. In table 2 an overview is given of the different water supply systems that are being used by the community. This involves all systems including piped supply, wells, handpumps, open ponds etc., also giving an indication of the percentage of users that make use if a specific system.

---

More detailed information on water safety plans can be found in the training modules. Here only an annotated outline of the plan is presented. It is important to develop the plan with the water committee or with other community members knowledgeable about the water supply system. It is also important to try to get gender specific data as views and perception may be very different between men and women.
### General data from the community

<table>
<thead>
<tr>
<th>Item</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of community</td>
<td>Wahira</td>
</tr>
<tr>
<td>Population size</td>
<td>2000</td>
</tr>
<tr>
<td>Main occupation (s)</td>
<td>Farming, cattle raising</td>
</tr>
<tr>
<td>Type of water supply systems</td>
<td>Piped supply, handpumps, ponds</td>
</tr>
<tr>
<td>Water coverage (% using improved water systems as only source for drinking water)(^{14})</td>
<td>80% (dry season) 60% (wet season)</td>
</tr>
<tr>
<td>Sanitation coverage (% with improved facilities)</td>
<td>40% (latrines)</td>
</tr>
<tr>
<td>Quality sanitation systems (spot sample in few houses)</td>
<td>Latrines are not very well kept and involve health risk (fly breeding)</td>
</tr>
</tbody>
</table>

The water coverage percentage refers to the estimate of which part of all families in the community use improved systems. Often this is lower in the wet season when more water sources are available.

### Overview of water supply systems

<table>
<thead>
<tr>
<th>Type of system</th>
<th>Users(^1)</th>
<th>Water quantity</th>
<th>Water quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piped water supply</td>
<td>60/40</td>
<td>Intermittent supply, but people are satisfied with quantity and pay</td>
<td>Good taste, no chemical contamination but considerable risk of bacteriological contamination</td>
</tr>
<tr>
<td>Handpumps</td>
<td>20/20</td>
<td>Continuous functioning, people are satisfied and pay</td>
<td>Good taste, very low risk of contamination, chemical quality not known but seems not to pose a risk</td>
</tr>
<tr>
<td>Ponds</td>
<td>20/40</td>
<td>Some sources reduce in quantity in dry season</td>
<td>Good taste (according to population), very high risk of pollution</td>
</tr>
</tbody>
</table>

1. Coverage (% of users) in dry season / coverage in wet season.

\(^{14}\) Improved water systems according to WHO/UNICEF are: household connection, public standpipe, borehole, protected dug well, protected spring, Rainwater collection. In practice many of these systems do have water quality problems and some also water quantity problems.
A schematic overview of the location of the different water systems is presented in Figure 1. For each of the systems a summary description and an assessment have been made that are presented in tables 2.1, 2.2 and 2.3. The description only provides information on the main aspects. (If needed or felt useful a more detailed description can be added as annex)

Figure 1 Schematic overview of the water supply systems (Insert drawing of community with an indication of the main water supply systems also showing main roads, piped network and estimated distances. It is very rewarding and a good start of further collaboration to develop the drawing with the water committee or other community leaders).
**Table 2.1: Assessment of piped water supply**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump</td>
<td>Electrical pump (2 yrs old) with generator (5 yrs old)</td>
<td>Borehole not protected, preventive maintenance is lacking, repairs needed, water production and fuel consumption registered daily</td>
</tr>
<tr>
<td></td>
<td>Bulk water meter</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>Chlorination</td>
<td>Equipment broken beyond repair</td>
</tr>
<tr>
<td>Water storage</td>
<td>Two overhead tanks in community (1 km from well)</td>
<td>In good shape but never cleaned or flushed</td>
</tr>
<tr>
<td>Water distribution</td>
<td>2 km distribution network 5 yrs old, HDP pipe with 2 stand posts and 100 house connections</td>
<td>Maintenance is insufficient. Pipes are exposed; stand posts are muddy and unclean. Water loss is estimated at 50%</td>
</tr>
<tr>
<td>Water transport and home storage</td>
<td>Water transport and storage is mostly done in closed plastic jerricans</td>
<td>Safe way of transport</td>
</tr>
<tr>
<td>Water disposal</td>
<td>Waste water is not properly drained leading to puddles</td>
<td>This may lead to mosquito breeding and unpleasant smell</td>
</tr>
<tr>
<td>Coverage</td>
<td>60% of the community use the piped system in the dry season and 40% in the wet season</td>
<td>People try to cut cost by using other sources when easily available or for certain activities like cloth washing</td>
</tr>
<tr>
<td>Continuity of system</td>
<td>Water supply is available 8 hours per day</td>
<td>People are satisfied with the 8 hours, but some at higher locations face low water pressure</td>
</tr>
<tr>
<td>Continuity of source</td>
<td>Water table has fallen two meters in 5 years</td>
<td>It need to be explored with higher level authority what is the cause and whether this will affect long term sustainability</td>
</tr>
<tr>
<td>Quantity</td>
<td>60 lpcd, but stand post users use only 20 lpcd</td>
<td>House connection use some 116 lpcd</td>
</tr>
<tr>
<td>Cost</td>
<td>People pay 10 cent per 10 litre of</td>
<td>Cost family with standpost 30 Birr/m</td>
</tr>
</tbody>
</table>
Annex II Example of a community water safety plan

Water at standpost and house connections pay 100 Birr/month. With house connection 100 Birr/n but at standpost rate it would be 1740 Birr/m.

**Water culture**
People like the taste of the water; very few treat it at home (boiling, disinfection).

**Quality**
Sanitary survey indicates that the water is safe at the source, but some risk exist of infiltration through the well head; high risk of infiltration because of intermittent supply and pipes crossing poorly drained areas.

Water should be considered a bacteriological risk. Would be good to obtain confirmation from water quality test. Treatment/disinfection at source not an option as contamination is afterwards and is disperse.

**Overall assessment**
The system requires better maintenance and needs upgrading to reduce water loss. The water involves a considerable hygiene risk and will require treatment. This however is not useful at the source as contamination occurs in the distribution system. So disinfection may be considered at the standposts (would require extra storage tank) or at household level.

Often a somewhat more detailed report of the sanitary survey is included in an Annex.

<table>
<thead>
<tr>
<th>Table 2.2 Assessment of hand pumps</th>
</tr>
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<tbody>
<tr>
<td><strong>Item</strong></td>
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<tr>
<td>Pumps</td>
</tr>
<tr>
<td>Treatment</td>
</tr>
<tr>
<td>Water transport and home storage</td>
</tr>
<tr>
<td>Water disposal</td>
</tr>
</tbody>
</table>
### Coverage

20% of the community use the handpumps both in the dry and wet season. Several people use also other water sources when easily available.

### Continuity

Water supply is available 6 hours per day. At other time pump is locked. People are reasonably satisfied with the 6 hours.

### Quantity

On average people use some five jerricans of 20 liter per day. On average people use some 20 lpcd, which is on the low side hence it confirms the use of other sources.

### Cost

People pay 2 Birr/month per family. Cost does not adequately cover O&M cost.

### Water culture

People like the taste of the water; very few treat it at home (boiling, disinfection). One of the two pumps is not kept clean by users.

### Quality

Sanitary survey indicates that the deep well is reasonably protected but the water from the shallow well has a very high sanitary risk because of infiltration possibilities and presence of nearby latrines. Water in the shallow well should be considered a bacteriological risk. Would be good to obtain confirmation from water quality test. Disinfection of the well may be an option in combination with the removal of potential sources of pollution.

### Overall assessment

Both pumps require better maintenance and need repairs. The water in the deep well is reasonably safe, but the shallow well has a high sanitary risk which requires improvement (or household level treatment). In both cases home storage is needed and this is often done in unprotected containers, hence also involving a considerable hygiene risk. This requires improved storage or household level treatment.

---

1. Often a somewhat more detailed report of the sanitary survey is included in an Annex.
### Table 2.3 Assessment of ponds

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Remark</th>
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<tr>
<td><strong>System</strong></td>
<td>Four open unlined ponds exist that are used by household, cattle and wildlife</td>
<td>Ponds are not protected by a fence. People and animals enter the pond to fetch water</td>
</tr>
<tr>
<td><strong>Treatment</strong></td>
<td>No treatment</td>
<td>A few people boil water at home</td>
</tr>
<tr>
<td><strong>Water transport and home storage</strong></td>
<td>Jerricans and open containers. Some use donkey for transport</td>
<td>Jerricans are a safe way of transport. Few containers are closed with a lid</td>
</tr>
<tr>
<td><strong>Water disposal</strong></td>
<td>Waste water is not properly drained leading to puddles</td>
<td>This may lead to mosquito breeding and unpleasant smell</td>
</tr>
<tr>
<td><strong>Coverage</strong></td>
<td>40% of the community use the ponds in the wet season and 20% in the dry season</td>
<td>People try to cut cost by using pond water instead of other sources.</td>
</tr>
<tr>
<td><strong>Continuity</strong></td>
<td>Water supply is available continuously in the wet season, but two ponds dry up in the dry season</td>
<td>People are partly satisfied with the pond but don’t like ponds to dry up</td>
</tr>
<tr>
<td><strong>Quantity</strong></td>
<td>On average people collect some three jerricans of 20 liter per day for their family</td>
<td>On average people use some 12 lpcd, which is on the low side. Some however supplement with water from other sources and washing is done at the pond</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>People do not pay</td>
<td>People have indirect cost as the ponds are at a distance of 20 minutes</td>
</tr>
<tr>
<td><strong>Water culture</strong></td>
<td>People like the taste of the water; very few treat water at home (boiling, disinfection)</td>
<td></td>
</tr>
<tr>
<td><strong>Quality¹</strong></td>
<td>Sanitary survey indicates that a huge sanitary risk exist in all four ponds</td>
<td>Water involves a high bacteriological risk. Treatment/disinfection of the pond is not an option</td>
</tr>
</tbody>
</table>
Overall assessment | The ponds are contaminated hence the water involves a considerable hygiene risk and will require treatment. Treatment at household level can be an option (solar disinfection, chlorination, boiling). An alternative is to use safe drinking water from the deepwell pump or selling treated water from a standpost (equipped with extra storage tank and disinfection) or a water kiosk.

1. Often a somewhat more detailed report of the sanitary survey is included in an Annex
A2.3 Water supply management

The three different systems fall under different management arrangements which are presented in this section. Table 3.1 provides an overview of the management of the piped water supply, which has a water committee, a pump operator and plumber, an assistant operator and two paid standpost attendants who collect the users’ contributions (Table 3.1). Table 3.2 shows that the two handpumps are managed by another committee which has been established with the help of an NGO. This is not uncommon in many places but is not effective in terms of management. It is crucial to see the available water sources and system in an integrated way to be able to help establish the best possible solutions for the community.

Table 3.1 Management of piped water supply system

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management</td>
<td>Water committee with 5 male members already in place for 5 yrs.</td>
<td>It is necessary to explore if gender interests are properly safeguarded and how the committee can become more balanced</td>
</tr>
<tr>
<td>Training</td>
<td>Administrative and technical training were provided during construction.</td>
<td>No refresher training is provided and no training was received on management issues and consumer relationship</td>
</tr>
<tr>
<td>Daily operation</td>
<td>Operator and an assistant are responsible for pump management, (small) repairs and new connections</td>
<td>Preventive maintenance is virtually absent and repairs and new connections do not meet quality standards. Current supervision and backstopping is not sufficient.</td>
</tr>
<tr>
<td>Financing</td>
<td>Tariffs have been set to cover operation and maintenance cost. No funding is available for larger repairs</td>
<td>People with a house connection pay less per m³ than people collecting water from standposts. With the aging of the system cost are increasing and repairs are needed. This needs to be discussed with users and relevant authorities.</td>
</tr>
<tr>
<td>Tariff collection</td>
<td>Two standpost attendants collect the tariff from the users. The house connections need to pay to the treasurer of the water committee</td>
<td></td>
</tr>
<tr>
<td>Conflict management</td>
<td>Conflicts exist between the water committee and standpost attendants and some users</td>
<td>Conflict management is not an issue that the water committee has learned and no trained external support is available either.</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Spare part management</td>
<td>Very few spare parts are stored in the community</td>
<td>High risk of longer repair periods if no spares are available. Also cost of spares tend to increase over time, hence good to invest user contributions in spares.</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Typical breakdown instead of preventive maintenance is applied</td>
<td>Preventive maintenance is essential and often less costly in the long run.</td>
</tr>
<tr>
<td>Back-up support</td>
<td>An area mechanic is supposed to give backstopping</td>
<td>In practice the area mechanic only comes if called for repairs. His interventions are strictly technical leaving a big gap of management support.</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Data of pump operation and fuel consumption and users contributions are registered.</td>
<td>Monitoring schedule is too limited and not used to support management of the system.</td>
</tr>
</tbody>
</table>

**Table 3.2 Management of handpumps**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management</td>
<td>A community health committee with 3 male and 2 female members was established by an NGO 5 yrs ago.</td>
<td>It is necessary to explore the link between the water committee and the health committee as better to keep water supply in one hand.</td>
</tr>
<tr>
<td>Training</td>
<td>Administrative and technical training were provided during construction.</td>
<td>No refresher training is provided and no training was received on management issues and consumer relationship.</td>
</tr>
<tr>
<td>Daily operation</td>
<td>Pump caretaker looks after both pumps</td>
<td>Preventive maintenance is virtually absent. Supervision and backstopping is not sufficient.</td>
</tr>
<tr>
<td>Financing</td>
<td>Tariffs have been set to cover</td>
<td>With the aging of the pumps maintenance.</td>
</tr>
<tr>
<td>Operation and maintenance cost. No funding is available for larger repairs</td>
<td>cost may increase somewhat. This needs to be discussed with users and relevant authorities.</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Tariff collection</td>
<td>Two standpost attendants collect the tariff from the users. The house connections need to pay to the treasurer of the water committee</td>
<td>The health committee collects the tariff</td>
</tr>
<tr>
<td>Conflict management</td>
<td>Sometimes conflicts arise among users jumping the queue</td>
<td>Conflict management is not an issue that the committee has learned and no trained external support is available either.</td>
</tr>
<tr>
<td>Spare part management</td>
<td>Very few spare parts are stored in the community</td>
<td>High risk of longer repair periods if no spares are available. Also cost of spares tend to increase over time, hence good to invest user contributions in spares</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Typical breakdown instead of preventive maintenance is applied</td>
<td>Preventive maintenance is essential and often less costly in the long run.</td>
</tr>
<tr>
<td>Back-up support</td>
<td>An area mechanic is supposed to give backstopping</td>
<td>In practice the area mechanic only comes if called for repairs (and usually only after several days). His interventions are strictly technical leaving a big gap of management support</td>
</tr>
<tr>
<td>Monitoring</td>
<td>No data are registered except for tariff collection.</td>
<td>Monitoring schedule is too limited and not used to support management of the system</td>
</tr>
</tbody>
</table>
Table 3.3 Management of ponds

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management</td>
<td>Ponds are not managed</td>
<td></td>
</tr>
<tr>
<td>Financing</td>
<td>No cost are charged for using pond water</td>
<td>Because of high level of pollution indirect cost (health, loss of working days) are high</td>
</tr>
<tr>
<td>Conflict management</td>
<td>Sometimes cattle owners push their way to the pond if water get scarce</td>
<td>Conflict management is not dealt with</td>
</tr>
<tr>
<td>Maintenance</td>
<td>No maintenance is applied</td>
<td>Ponds are gradually deteriorating.</td>
</tr>
<tr>
<td>Monitoring</td>
<td>No data are registered</td>
<td>Gradual deterioration and volume reduction is not becoming visible through monitoring</td>
</tr>
</tbody>
</table>

A2.4 Improvement plan

This section presents a number of actions that need to be taken distinguishing between short, medium and long term activities. It is very clear that only a small part of the community has access to potable water and that urgent action is needed. Also the different systems are not performing well, are not adequately managed and lack adequate back up. The required actions to improve upon the situation involve different actors. Therefore the leading actor is indicated for each activity.

A2.4.1 Short term action

The short term action aims at taking immediate steps that do not require mayor intervention, reconstruction and considerable external resources. The focus is on doable actions within existing means.
### Table 4.1 Short term action

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Description</th>
<th>Remedial action</th>
<th>Actor</th>
</tr>
</thead>
</table>
| Access to potable water       | Only one handpump provides potable water; piped water system is intermittent thus involving a health risk | Inform the community about alternatives:  
• using handpump water for drinking  
• disinfection at home  
• solar disinfection in plastic bottles  
Initiate hygiene promotion activity | Health worker with water committee and health committee |
| Lack of chlorine              | Chlorine can be used to disinfect water at home, in the well or in the piped supply | Explore the possibility to supply chlorine to disinfect the well with the rope pump and possibly for home treatment. The piped supply cannot be treated as contamination enters in the distribution system | Water technician in consultation with the health worker and the community |
| Lack of maintenance           | Both preventive and some corrective maintenance are needed                   | Make a good overview of the necessary activities; explore with the operators and the committees what can be initiated and what requires additional resources (see table 4.2) | Operators and committees with support from water technician |
| Lack of monitoring            | Good monitoring can very much enhance performance and is crucial to plan interventions | Develop and introduce a monitoring system | Water technician with water committee and health committee |
| Lack of coordination          | The current piped water supply and the handpumps fall under responsibility of different committees which is not very effective and efficient | Initiate the discussion between the two committees to explore how best they can collaborate or possibly merge | Water technician or other external agent |
A2.4.2 Medium term action

Medium term action concerns issues that need relative quick intervention say in the next six months to one year, but which require more resources. It implies that more time is available to develop proper plans and explore possibilities to finance improvements. Table 4.2 shows a number of medium term actions. Several of these actions do require external support which in the table in several cases is expected to be provided by the water technician. This implies however that the water technician also needs to have a background in management issues. If not other external staff will be needed to facilitate or train (including perhaps peer training by water committee members or operators from other communities).
### Table 4.2 Medium term action

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Description</th>
<th>Remedial action</th>
<th>Actor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contamination of piped water supply</td>
<td>The piped supply is contaminated because it is intermittent. Disinfection at the source therefore is not helpful and opting for continuous supply requires upgrading of the distribution network.</td>
<td>Explore the possibility to construct small storage tanks at the public standposts and introduce disinfection in these tanks.</td>
<td>Water technician and water bureau in collaboration with the water committee</td>
</tr>
<tr>
<td>Contamination of shallow well with rope pump</td>
<td>Possible contamination from two nearby latrines and cracks in the well structure.</td>
<td>Repair cracks and explore the possibility to relocate the latrines improve the well to avoid contamination</td>
<td>Water technician in consultation with water and health committee and the community</td>
</tr>
<tr>
<td>Lack of skills and knowledge of committees and operators</td>
<td>Maintenance and repair is not adequate and committees do not really manage</td>
<td>Initiate a training programme for both the operators and the (united) water committee</td>
<td>Water technician with other external authorities</td>
</tr>
<tr>
<td>Inadequate conflict mediation</td>
<td>Problems exist between the water committee and the pump attendants and several users</td>
<td>Assist the committee to better handle conflicts (training) and if needed initiate conflict mediation with support of the water technician, the health worker and/or external mediator</td>
<td>Water technician with other external authorities</td>
</tr>
<tr>
<td>Lack of financing</td>
<td>Part of the maintenance is not taken care of because of lack of</td>
<td>Explore possibilities to: • Increase the tariff (look also at difference between standposts and house connections</td>
<td>Water technician with water committee</td>
</tr>
</tbody>
</table>
### A2.4.3 Long term action

The long term action concerns more structural interventions that require often the work of external agencies or very important financial resources. The water technician is envisaged to either initiate this type of action or to direct the community (water committee) to relevant agencies and help them to take appropriate action using for example the water safety plan to explain the situation to these agencies. This often will also include several actions that go beyond the community level requiring a more regional or even national approach.

| funding | Obtain external resources  
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quickly repair some of the leakages in the system to reduce pumping cost</td>
</tr>
<tr>
<td>Hazard</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Contamination of piped water supply</td>
<td>The piped supply is intermittent and has a high water loss.</td>
</tr>
<tr>
<td>Environmental contamination</td>
<td>The inadequacy of the local sanitation practices result in a wide spread bacterial contamination which contributes to water contamination</td>
</tr>
<tr>
<td>Falling ground water table</td>
<td>Ground water table is falling possibly from over abstraction by nearby farmers</td>
</tr>
<tr>
<td>Changes in operators and/or water committee</td>
<td>Operators and water committee members may change over time, which implies training of new people to ensure adequate management and maintenance</td>
</tr>
</tbody>
</table>