# Urban and Peri-Urban Water Supply Surveillance Programme

*Report on Water Supply Surveillance in Ten Selected Urban Areas of Uganda*

*Abridged International Version*

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# Executive Summary

This report covers selected activities undertaken by the Urban and Peri-urban Water Supply Surveillance Project, which is based in the Environmental Health Division, Ministry of Health and receives support from the Department for International Development (UK) and the World Health Organization. The project is designed to develop low-cost approaches to water supply surveillance in Uganda and to develop approaches that can be utilised in other low and middle-income countries. The project forms part of the work leading to the 3rd Edition of the WHO *Guidelines for Drinking-water Quality*.

The report is a summarised version of a more detailed report that was published in Uganda in 1999. Much of the detail of interest to an Ugandan audience has been omitted here, as it may be of less relevance to other audiences. However, if further information is required about any of the subjects discussed here, please contact the authors directly.

The routine surveillance of water supply is a key mechanism for the protection of public health and aims to provide reliable information on the risks posed to the health of the population from poor water supply. In addition, surveillance programmes provide information about the accessibility of the population to safe water supply, the barriers to improved access to safe water supply, and the major causes of water quality failure. Surveillance data can lead to the identification of required improvements in water supply and hygiene practice and the ways in which these can be achieved. To date the project has acted as a pilot designed to develop tools and approaches that can be implemented at reasonable cost. However, water supply surveillance has now been included in the minimum health services package and health policy of Uganda and there is a proposal to develop a national programme of District-level surveillance of water supplies in both urban and rural areas.

In Uganda, the principal focus of this pilot project has been the Public Health Departments in 10 selected urban areas. The staff of these Departments collect and analyse data, whilst the Ministry of Health provides a supporting role through training, support supervision and technical advice. Local-level surveillance is more cost-effective than centralised systems and ensures that information generated at a local level can be used to support the primary stakeholders in water supply – communities and households. The use of environmental health staff is appropriate because they work and inter-act closely with the communities within their area, have skills in water supply and health education and can act effectively to improve water supply and hygiene practice.

Urban areas covered by the Project are zoned using a multi-factorial index (population density, socio-economic status and likely water use patterns) in order to focus surveillance activities on those at greatest risk. This has been shown to effective in predicting vulnerability to higher incidence of epidemic diseases. To date detailed assessments of the types and numbers of water sources available in the urban areas covered have been carried out. Taps are the principal source of water available to the not-served population in 8 of the 10 towns. However, in 5 of these towns piped water collected is usually from neighbours with a direct connection rather than from public taps. The water from both neighbours and public taps are some of the most expensive forms of water supply available. Water vendors charge even higher amounts, but use of this water in low-income areas seems limited.

Water usage studies have been conducted in Kampala that provides more accurate information regarding the sources used by the population and the reasons for selection of different sources. Up to 60% of the population without direct piped water connection in Kampala uses taps as the principal source of water. However, point sources are common in most towns and are heavily used. 60% of the low-income population with a choice of water source at a Parish in Kampala uses protected springs for at least part of their domestic water needs. There is no apparent differentiation in use of protected springs and taps.

Both assessment and routine monitoring of water quality have been undertaken with data from 3,500 sanitary inspections and nearly 6,000 water analyses available. The activity has covered piped water supplies, point sources and household water. This represents a significant database and a resource for the health and other sectors.

The quality of the water provided by the National Water and Sewerage Corporation is generally of good microbiological quality. Compliance rate with international norms is high in Kampala, although elsewhere performance has been poorer. In many cases failure is due to contamination within customer mains, but a significant number of supply failures are noted. However, many NW&SC supplies suffer from poor chlorine maintenance and have frequent interruptions in supply and signs of leakage, both of which may put the health of the users at risk. More crucially, access to higher service levels (yard or in-house) remains low and this requires attention as these levels deliver health benefits not seen with communal sources. Municipal and community-managed piped water supplies show a far poorer microbiological water quality and in the two towns covered by the project, urgent attention is needed to improve these water supplies.

Boreholes are found in several towns, although many are non-functional. The quality of water from boreholes is generally good, with the exception of Mbale, which may be partly explained by poor siting and different hydrogeological regime. The principal reasons for failure appears to be latrines within 10m, although in Soroti the presence of other pollution such as solid waste is an equally important cause of failure. Protected springs are very common in most towns and the quality of water shows significant seasonal variation and is typically less good than boreholes. The principal causes of failure appear to relate to the poor maintenance of sanitary protection measures and only in certain parts of Kampala are latrines likely to have any impact. As well as poor maintenance, the design of these springs is poor with limited ability to remove contamination. A recent pilot project to re-protect springs in Bwaise using a improved design, has shown that major improvements in water quality are possible and that these springs can be designed and maintained to provide a quality of water that represents limited risk to health. The high use of these springs in Kampala and the apparent association between the numbers of cholera cases during the epidemic of 1997/98 and the use of springs, indicates that improving their quality is essential.

Household water quality is poor in many areas although steady improvements have been seen in Kampala. The role of surveillance to promote safe water handling appears important in Kampala but less effective elsewhere. An evaluation of available health education tools is underway and greater attention will be paid to promoting improved water source management and water handling in the future by Public Health Departments.

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## Section 1: Introduction

This report is based on information generated through a pilot project to develop low-cost approaches to surveillance of water supply in urban areas of Uganda. The project is funded by the Department for International Development (UK) through their Knowledge, Action Research programme of the Infrastructure and Urban Development Division. The project is co-ordinated by the Environmental Health Division of the Ministry of Health, with expert advice from a consultant from the Robens Centre for Public and Environmental Health, University of Surrey UK (now at WEDC). At present, 10 towns are included in the project. Work started in Kampala in 1997 and this was followed by work in Mbale, Soroti and Tororo in early 1998. The project was extended to Kabale, Mbarara and Masaka in late 1998 and in 1999 activities were initiated in Entebbe, Jinja and Mukono.

The independent assessment and routine surveillance of water supply is an essential component of public health protection. Inadequacies in water supplies, whether determined by access, reliability, quality or quantity have profound impacts on the health of the population in urban areas. The surveillance of the water sector allows inadequacies to be identified and their importance to health evaluated. This allows the identification of priorities for improvement. In terms of operation and maintenance of water supplies, the routine monitoring of water quality and sanitary inspections are key measures of the performance of the water supply and the success or failure of operation and maintenance programmes. Routine monitoring enhances operation and maintenance through the rapid identification of failure or risk of failure in water quality, allowing both preventive and remedial action to be carried out.

Surveillance of water supplies also has important social objectives as it aims to provide ongoing assessments of equity in water supply and the identification of vulnerable groups and priority areas. Indeed, one of the key functions of surveillance programmes should be to provide support to vulnerable communities and households and to lobby for improvements in most needy areas and population groups.

The purpose of surveillance is not to focus on monitoring the quality of water provided through the 'preferred' water supply in urban areas – i.e. piped water. This would inevitably provide further support to already privileged groups who have higher incomes and better access to services. The purpose of surveillance is to focus on the poor and communities with least access to services and at greatest risk from ill health. Thus all types of water sources used by urban populations and water consumed in the home are monitored.

### *Project Institutional Arrangements*

As the purpose of the project is build local capacity to undertake water supply surveillance, it is important to clarify the roles of the different players in the activities undertaken with project funding and to outline the long-term implications and responsibilities.

#### Municipal Public Health Departments

The primary focus in the project are the Municipal Public Health Departments who undertake the field assessments, collect data and use the information generated in working with communities to improve water supply and hygiene practices and to develop strategies for improving water supplies in their town. Surveillance at local levels is preferable because effective links can be made between the results of surveillance and the communities that are affected by poor water supply. Environmental health staff are well placed to carry out surveillance activities because their training includes the impacts of poor water, sanitation and hygiene on health. They have skills in low-cost water supply provision and the delivery of health education and they work in the communities they serve.

In the long-term, surveillance can only be sustained if it operates at a local level and serves local needs and demands. There is growing evidence of demand for surveillance to be carried out from communities within the towns participating in the project as the staff report requests being made to them to test water quality. In areas not covered by the project, there is also a demand for surveillance. Requests have been made by Katakwi and Kumi local administrations for Public Health Staff from Soroti to undertake assessments of water quality. In Masaka, the Municipal Council has received requests for support in water testing from NGOs in the area and was also able to follow up on a dysentery outbreak by testing the water supply. In Kampala, when cholera cases have been identified, Public Health staff has undertaken testing of water.

### Ministry of Health

The role of the Ministry of Health is to provide training, support supervision and consolidation of data at the national level. Water quality surveillance has been included in the minimum health services package and the Ministry views the development of capacity for routine surveillance of water quality as important. The role of the Ministry in this project is consistent with the National Government role, which is focused on the development of policy and support to local Governments in improving service delivery. The Ministry of Health has also been instrumental in obtaining and analysing the other data collected, including socio-economic, demographic and rainfall data. In addition, the Ministry maintains a water quality database for all the towns included in the project. A key element in the database is flexibility in allocating risk scores in sanitary inspection, which greatly facilitates the analysis of importance of different sanitary risks. The water quality and sanitary risk database will be established in the Municipalities in early 2000 to allow greater capacity for data storage and analysis at local level.

The Ministry will continue to provide support to the development of surveillance at a national level through training, supervision and technical advice. The Environmental Health Division will continue the development and dissemination of materials to support field workers to carry out routine surveillance and Municipalities to use data to promote improvements in water supply and hygiene behaviour. The Ministry is in the process of developing a plan for a national programme of District-based surveillance.

### National Water and Sewerage Corporation (NW&SC) and other stakeholders

The project has developed excellent links with water suppliers and in particular with the National Water and Sewerage Corporation (NW&SC). Results of water quality monitoring programmes are shared with water suppliers and they have reciprocated. NW&SC have been supportive of this project and has provided useful data. The project has assisted NW&SC in acquiring portable testing kits for towns which they supply and which are at a substantial distance from Kampala; this allows quality control monitoring to be carried out more frequently and efficiently. In addition to links with NW&SC, the project has held round table meetings with stakeholders including Municipal Councils, Government Ministries, donor agencies and NGOs to present and discuss the findings of the project. This collaboration and dialogue should be maintained in the future as it represents an important mechanism for continuous improvements in water supply.

NW&SC has the responsibility to undertake water quality control and this is carried out in all towns that they serve. In Municipal water supplies, quality control is less well developed and at present there would be little point in duplicating the surveillance activities carried out by Municipal Public Health Departments. However, for the future, it is important to recognise that surveillance by a standards enforcing authority, and quality control by water supplier, are distinct but complementary roles. Therefore capacity should be built in those Municipal Councils that operate water supplies to be able to undertake routine monitoring of the quality of water they supply.

### *The Project Cycle*

The initial stage in each town is to carry out an inventory of all the sources available to the population not served by a direct connection to the piped water supply. Details on ownership, payment for water, construction agency, operation and maintenance responsibility and activities, repair work carried out, restrictions on availability and source reliability are collected at this time. This is supplemented by data on direct connections obtained from the water supplier in order for the zoning process to be carried out, which is described later. Following the inventory, training is provided to Public Health staff and representatives of the water suppliers in surveillance techniques. Such training events are typically of one-week duration, with follow-up refresher courses of two to three day duration after work has been ongoing for some time.

After initial training, the Public Health staff undertakes a baseline assessment of water quality in their towns, with samples taken from piped water supplies, point sources and household drinking water containers. Based on this data, combined with data on direct connections and the population served by different water types, a routine surveillance programme is planned. The data from water quality tests and sanitary inspections are kept by the Municipal Health staff and reported back to communities and the Ministry of Health on a monthly basis.

The project uses on-site, portable water quality testing kits. These kits are able to carry out analysis of thermotolerant (faecal) coliforms, an accepted surrogate for *E. coli,* the principal microbiological indicator bacteria. In addition, the kits include equipment for the analysis of chlorine residuals (both free and total), pH and turbidity. Thus these kits analyse for the ‘critical parameters’ identified in the WHO Guidelines for Drinking-water Quality. The use of on-site equipment overcomes the problems of delays in result reporting and sample deterioration encountered when using a laboratory based approach. Centralised laboratories fulfil important functions in terms of providing a wide selection of water testing analysis. However, in most low-income countries the development of such facilities to serve all the water supplies in the country is too expensive for reliance on this approach. Furthermore, on-site equipment has been shown to produce results as reliable as those made in laboratory.

In addition to water quality analysis using on-site testing equipment, local health staff carry out sanitary inspections of water supplies visited. Such inspections are essential for surveillance and both WHO and the American Water Works Association (AWWA) include sanitary inspections as recommended practice. The purpose of the sanitary inspection is two-fold:

- When contamination is found, it allows an assessment of the likely cause and therefore of the remedial action required
- It provides an ongoing assessment of the risk of the supply to water quality failure and identifies design, construction and operational failures

The cost of routine surveillance activities is reasonable, with a cost of consumables from international suppliers being approximately US$ 0.18 for full analysis of one source. Given the value of the surveillance data, this allows an effective mechanism for local public health departments to perform their responsibilities with regard to water as well as provides an essential service. One person can undertake between 6 and 14 samples within one day and therefore the time commitment is not excessive.

Routine monitoring programmes are developed with the local Public Health Departments so as to reach a balance between the need for comprehensive coverage of the urban area and the likely resources available in the future for surveillance activities. The current programmes typically involve between 3 and 5 half-days of work each month and have numbers of samples that provide a comprehensive coverage.

In addition to the routine surveillance of water quality, evaluations are underway of water use patterns in target groups and development of health and environmental education tools to promote better operation and maintenance of community supplies. To date, both a pilot and full study of water use in low-income Parishes that have a choice of water source have been undertaken and further studies are planned in Soroti and Masaka. This has yielded useful information for the zoning process and development of routine monitoring programmes. An evaluation of the PHAST tools is planned in December 1999 to develop appropriate materials and approaches for use by field staff in improving maintenance of the safe water chain and community water source management.

The project provides reports generated through by the software developed at the initial stage of the project. Reports are provided to each town for each month's sampling. It is planned to establish databases in each town to facilitate local information storage and use. This will be done in early 2000. In addition, data is stored on EpiInfo and copies of this software will be made available to each town to store their databases.

Whilst this project is only a pilot level activity, it is hoped that the tools and approaches developed to date can be more widely applied in the urban areas of Uganda and linked to a national programme of District-level water supply monitoring. In addition, the project experience will form part of the 3rd edition of the WHO Guidelines for Drinking Water Quality.

## Section 2: Targeting Surveillance Through Zoning Approaches

A stated aim of surveillance in urban areas is to target the poor who are the people who have least access to services at higher levels and who as a consequence are the most vulnerable to diseases. In order to target this group, it is important to define those areas of greatest interest, a process that leads to a zoning of the town or city. In addition to targeting the most vulnerable areas, zoning assists in focusing sampling on the sources of greatest importance. Furthermore, as in many sampling programmes, stratification allows resources to be used more cost-effectively and produces information to be directly related to the issues of interest.

The project has developed a system of urban zoning in order to target activities on those Parishes deemed at greatest risk from poor water supply. The zoning looks at a variety of factors. It does not simply relate to the water quality of sources, but also to the levels of service, differentials in charges for water supply, expected per capita volume use of water and likelihood of re-contamination.

The zones are made up based on estimates of:

- Socio-economic status
- Population density
- Parish water economy

### Socio-economic status

Socio-economic status is used because there is relationship between the relative wealth of communities and susceptibility to water and sanitation related infectious disease. Clearly, the poorer the community the greater the risk of disease because of numerous factors such as nutritional level, quality of housing, access to health care, educational level, ability to access higher service levels of water supply and their sanitation arrangements. Such groups commonly live in environments that promote ill health. By contrast, higher socio-economic groups will have both access to better services in general and will be likely to have higher levels of education and better nutritional status. Socio-economic status has been defined for each Parish in Kampala based on a multi-factorial index using data from the 1991 census and participatory evaluation of selected variables. This was carried out with field staff from Kampala City Council and professionals from the Ministry of Health in 1998.

### Population density

In high-density areas, particularly when these have a low socio-economic status, the intensity of environmental pollution resulting from inadequate disposal of wastes increases the likelihood of water contamination and general exposure to pathogens. Higher population densities will also allow the transmission of pathogens through food and person-person contact and increased environmental pollution will make exposure to pathogens more likely.

Estimated population density for each parish is calculated by extrapolating growth since 1991.

### Water use

Water collection and use strategies are important as the use of different service levels of piped water and types of communal water supply will exert a significant impact on the risk of disease transmission. The service level will determine the likely volume of water used by individuals. Higher levels of service are associated with increased water use and therefore improved personal hygiene. Households that must collect water from a communal source typically use far lower volumes of water and those households can be expected to have poorer personal hygiene and more restricted options for waste disposal. For instance, a study in Jinja indicated that users of communal sources typically use 15.5 litres per capita per day, whilst those using a yard tap use 50 litres per capita per day. This figure rises to 155 litres per capita per day when water is piped into the house (WELL, 1999[1]). The value of increased volumes of water to effectively 'wash-away' pathogens can be highly significant. Whilst good hygiene is possible at very low volumes of water, this requires a great deal of discipline and therefore appreciation of the value of good hygiene. In most cases, very low volumes of water used will translate into poor hygiene practices.

The type of communal source will also exert an important influence on susceptibility to diseases. Cholera, like many other faecal-oral diseases, is easily transmitted through contaminated water and it is estimated that viable *V. cholera* can survive in drinking water for up to 30 days and for up to 190 days in source waters.

### *Water Supply Surveillance Zones*

The protocol developed has allowed the derivation of the zones shown in table 2.1 below.

**TABLE 2.1: Number of different Zones in Kampala**

| Zone | Description | Parishes | Priority |
|---|---|---|---|
| LHMX | Low income, high density, mixed water source use | 22 | 1 |
| LMMX | Low income, medium density, mixed water source use | 10 | 2 |
| LHPP | Low income, high density, principally piped water use | 5 | 3 |
| LLMX | Low income, low density, mixed water use | 7 | 4 |
| LLPP | Low income, low density, principally piped water use | 3 | 5 |
| L/MMMX | Low-medium income, medium density, mixed water use | 2 | 6 |
| L/MLMX | Low- medium income, low density, mixed water use | 5 | 7 |
| L/MMPP | Low-medium income, medium density, principally piped water use | 2 | 8 |
| MEDM | Medium income, direct connections and use of communal piped water use | 16 | 9 |
| HIGH | High income, direct connections coverage very high | 17 | 10 |

As the table illustrates, these zones can be ranked in terms of their risk. High and medium socio-economic Parishes will represent a relatively low risk of disease incidence. In the low socio-economic group, risk is more complicated to calculate as the density of population and water use will interact to determine susceptibility. Medium and high-density areas are at greatest risk of epidemic diseases and this is clearly an important factor in determining vulnerability. In medium and high-density areas, the water use pattern is probably very important as significant numbers of households use non-piped water, including protected and unprotected springs, scoop wells and water from the lake.

A retrospective analysis of the cholera incidence in the 1997/98 outbreak has been carried out using SPSS and this showed a strong correlation between zone priority ranking and the number of cases recorded (R=0.650, significant to the 0.01 level). This emphasises the need

[1] Guidance Manual for Water and Sanitation Programmes. WELL, London, 1999.

for surveillance of water quality in the priority zones given the high possibility of water transmission route for *Vibrio cholera*. Not only is this zoning exercise useful for planning of surveillance of water quality, but as there is a strong correlation between the priority ranking of the zone and cholera incidence, it provides a mechanism to identify areas where cholera preparedness is most needed to prevent future outbreaks.

The zones can also be used as a simple tool in determining priority areas for water and sanitation improvements as well as where the need for health education is most urgent. The programme is using this approach to guide municipal field staff in interventions in water and hygiene education.

### Zoning of piped water supplies

Zoning of piped water supplies is a well-developed technique which is widely used in industrialised countries. It forms an integral part of the EC directives on water quality, with the number of samples to be analysed by water suppliers or surveillance agencies defined on a zone basis. Work has been ongoing with NW&SC to zone their water supplies in Kampala to be able to focus monitoring on key areas.

Zoning is a form of stratified sampling and the purpose of the zones is to define sampling areas that share a common characteristic such as being served by a particular service reservoir. Different service reservoirs and treatment plants may provide water of very different qualities and unless it is known where the water being sampled comes from, it is difficult to identify a specific supply problem, such as deterioration in quality during storage.

Zoning provides benefits to suppliers in ensuring that monitoring information is useful for management decision-making. In the case of Kampala, a key reason to zone the piped water system is that certain areas of the City were reporting consistent lack of residual chlorine as well as other water quality problems. The numbers of samples to be taken within each zone can be calculated according to population served, allowing more targeted monitoring based on actual demand of water.

The piped water system in Kampala can be zoned as follows:

Zone 1: Gaba low-level
Zone 2: Muyenga zone
Zone 3: Gun hill zone
Zone 4: Naguru zone
Zone 5: Rubaga zone
Zone 6: Mutungo booster and high-level zone
Zone 7: Buziga low-level booster
Zone 8: Makindye booster
Zone 9: Kololo tanks zone
Zone 10: Namirembe booster

## Section 3: Current Levels of Access to Water Supply

The project is assessing levels of access to water supplies on an ongoing basis. This data is drawn from reviews of direct connection data, inventories and in Kampala, the water usage studies.

### *Direct Domestic Connections*

All the towns covered by the project, with the exception of Mukono, have a piped water system either operated by NW&SC or the local Council. At present, access to higher levels of service shows great disparities within towns with wealthier sections typically enjoying almost universal coverage and poorer areas having very limited coverage. For example, in Kampala, direct connection coverage in 1998 varied from under 3% to 100% throughout the City. These figures relate solely to the coverage of the population with a direct household connection, whether piped into the house or in the yard. Connection rates have been calculated using the domestic and institutional categories of connection used by NW&SC.

The domestic connection coverage is calculated by multiplying the number of connections by the average household size. To this is added the adjusted population residing in 'servants quarters' taken from the 1991 census, as it can be assumed that the vast majority of such people enjoy at least a yard level of service. The numbers of served by government/institutional supply is calculated by taking the number of people living in flats and free or subsidised public housing, as these are the households likely to be served by such connections. Data from NW&SC illustrates that institutional/government category connections are supplied both to flats and to large houses owned by Government or Kampala City Council.

The limited access to safe water for much of the urban population in Uganda, as in rural areas, stems from poverty. However, there are specific monetary issues that act as barriers to access to some form of improved or safe water supply. The impact of the cost of water to the consumer exerts a highly significant influence on the choice of water source and whether the household will commit to purchasing water from suppliers.

Current practice by NWSC means that a minimum charge of USH 30,000/00, equivalent to $75m^3$ of water, is levied on all public taps. Evidence from a number of sites in Kampala suggests that this greatly over-estimates actual demand, which may be no more than $45m^3$ per month at the most heavily used taps. Such approaches both limit the attractiveness to communities to establish a public tap and make many of those unsustainable.

Given that in many urban areas, most water collected from taps is done through purchase of water from neighbours, the actual costs to much of the urban population is much higher. Average cost of water purchased from neighbours is USH 50/- or almost 4 times the unit charge collected by NW&SC.

In terms of access to a direct connection, it is not only the aggregated unit cost of supply that limits access to water supply, but rather the ways in which payment is required for different components of the water tariff. For instance, to gain a household connection to a NW&SC supply requires a connection fee of USH 125,000/00 (approximately US$100), a sum that covers the installation of the meter and can essentially be seen as a 'joining' fee. In addition, the household wishing to connect is also required to pay for the materials and labour to install the customer main from the supply main and to ensure that this is done properly to limit the potential for leakage. Thus average total connection costs may be around USH 500,000/00 (in the region of US$ 450-500).

Increasing access to water supplies at higher levels of service, at least in the yard and preferably within house, remains the main challenge to the urban water sector. Experience elsewhere in Africa suggests that subsidising connection can be effective. For example, in the Côte d'Ivoire, the utility (SODECI) provides 75 % of their connections with no direct connection fee and as a result maintains a connection rate of 70% in urban areas with connections growing at 5-6% per annum. It should be noted that the service provided by this company are rated as amongst the best in Africa, with low unaccounted-for-water and very limited commercial losses whilst maintaining tariffs no higher than those of neighbouring countries (Sharma et al, 1996[2]).

It may not be actually necessary to provide grants to increase direct connections. Unlike their rural counterparts, the urban poor primarily operate within the monetary economy and are both willing and able to pay for services and goods. Whilst incomes may be unstable and low, they nonetheless exist. The principal problem for the poor is that they cannot access credit on favourable terms for capital-intensive investments such as connection to the piped water supply. Therefore the development of approaches that increase the access of the urban poor to credit to support major household capital expenditure may be effective in increasing access. Some low-income communities and households in Kampala suggest that payment of connection fees by instalment or access to credit to allow purchase of materials and labour would make such costs more tenable.

### *Water Availability and Use in Non-served areas*

The previous section has provided some overview of coverage of the urban population with access to a personal/household connection. As noted, the majority of the population in most towns does not have such levels of water supply service. In section one, it was discussed that the first stage of the project cycle in each town is an inventory of sources available to the non-served population in order that subsequent assessments and routine monitoring programmes can be developed and the initial zoning of towns undertaken.

#### Availability of sources

Inventories are undertaken with an attempt to capture all publicly available water sources. It should be stressed that these are sources used by the population for domestic purposes and those that are used for non-domestic use are not included. A questionnaire is completed that includes information about age of the supply, construction, sponsorship, management and maintenance, costs and whether there are restrictions on the use of the source. Obviously it is easier to identify point sources than all the taps, but field staff has overcome this by asking local inhabitants where they get their water.

The inventory shows that in terms of availability, piped water sources are the most common in most towns, with only Soroti and Mukono having a greater proportion of protected point sources than taps. In the case of Mukono this is because there is no formal piped water supply. Only in Jinja are no protected point sources seen. In general the range of taps is 40-

[2] Sharma, NP, Damhang, T, Gilgan-Hunt, E, Grey, D, Okara, V, Rothberg, D (1996) African Water Resources: Challenges and Opportunities for Sustainable Development. World Bank Technical Paper No. 331, World Bank, Washington DC, USA.

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60% in most towns, with protected point sources accounting for 30-40%. In some towns, unprotected sources make a large proportion of non-piped sources available and this is of particular concern as this implies that in times of discontinuity in the piped water supply, the population are likely to use unprotected, and in all probability, highly contaminated sources. This clearly makes such people at greater risk from both endemic and epidemic disease.

In most towns protected point sources are commonly available for use by the population lacking a direct household connection. In general, protected springs are the most common form of point source available in most towns. Boreholes are less commonly found and only in two towns are these more common than springs. However, it should be noted that many boreholes are non-functional at any one time. Breakdowns are common and downtimes lengthy.

### Use of sources

Whilst the inventories provide useful information regarding the types of water source available and which are used by some of the population, it provides limited information about how many people use this water and for what purposes different water source types are used. The former is important to know because if only very few families use a source, the frequency of testing will drastically reduce in order to retain cost-effectiveness. Furthermore, surveillance is designed to monitor the quality of water used for consumption – drinking and food preparation/cooking and not water used for other purposes. In some countries, a 'rationality factor' has been observed in areas where there are multiple source types available. In these cases, water from supplies deemed of lower quality by households is not consumed, water used for drinking and food preparation being collected from sources of higher perceived quality. Clearly, in most Uganda urban areas both taps and point sources can be accessed within a reasonable distance and therefore it could be viewed as possible that such a rationality factor may come into play.

The water use study in Kampala indicates that taps are the first choice water supply for about 60% of the population (a figure consistent with a pilot water usage study), with protected springs accounting for over 30% of first choice sources. Few people use unprotected springs or other types of water source (including scoop wells, vendor or rainwater and purchase from water tankers).

However, there is a wide variation between different Parishes in terms of the type of source selected as the first choice source, with taps ranging from 20% to 100%. Protected spring use as first choice ranged from 0% to 75.6%. In only a few Parishes were unprotected springs used as the first choice source, but in one Parish these sources accounted for 31.1% of households. Other source use was equally uncommon, although in one Parish where access to piped water is particularly low, 35.8% of households used other sources, primarily scoop wells, as their principal source of water. Few households collected water from vendors (17.2%), although collection of rainwater was common (66.9%), suggesting that certainly in some areas promotion of rainwater harvesting could be feasible. Of the households that collect rainwater, over 50% do this using guttering and a drum/tank, although these are primarily restricted to the outlying areas where space is greater.

Almost 50% of households use more than one source as noted in the table below. Use of more than one source was noted as being most significant when taps were used as a first choice source, perhaps indicating that supply unreliability and costs may be important. Of the second sources used most are protected springs.

The reasons for selecting different sources were also investigated as this provides useful information regarding how water supply improvement can be made. The data indicates that distance is the major reason in selecting the source of water for all source types except those classified as 'other', which as already noted are largely unprotected sources and whose use was primarily determined by lack of alternative supplies.

It should be noted that distance was indicated as a reason for source selection by a significantly greater percentage of households using taps as a first source and those using springs. Thus it is likely that the principal advantage perceived by users of taps is that they can be located close to the home. This suggests that households that sell water to their neighbours are likely to continue to be very common and that these may be attractive than public taps. This should be borne in mind as improvements in water supply are considered as the sustainability of taps may be primarily determined by proximity.

It is encouraging to note that over 50% of respondents using taps quoted quality as a reason for selecting the source and that so few users of unprotected or other sources listed quality as a reason. However, there remains a strong perception that protected springs provide water of good quality, indicating that further attention to health education is required.

When reviewing the reasons for use of a second choice source, it is clear that other factors apart from distance are more important. The mere availability of the source was sufficient to encourage use. The households are in this case not differentiating between the quality of different sources. The large percentage of people listing quality as the reason for selecting a tap as a second source indicates that some progress is being made in promoting safe sources. Distance, cost and reliability are all critical factors in selection of protected springs as a second source.

The water use study has highlighted that protected springs are commonly used by the Kampala's low-income citizens who lack a direct house connection. This stresses the importance of ensuring that the springs are improved to reduce the degree of contaminated water consumed by the low-income population.

Whilst there is some recognition that the quality of water provided through the piped network is better than alternative sources, the overall reporting of quality as a factor in source selection remains low and this clearly needs to be addressed through health education. It appears that distance is the principal factor determining source selection and therefore if more public taps are to be provided, it is essential that these are closer to households than alternative supplies if their use is to be sustained. Cost often relates to distance in this regard. Households may be prepared to pay for water if it is significantly closer than the alternative source. However, if such sources are equidistant or the tap is further, then use of the alternative can be expected. The reliability of the supply is also clearly important in selecting sources and in particular the choice of a second source.

The water use study has illustrated that routine surveillance of protected springs is required in Kampala and in particular in high-density areas where reported use was intensive in several communities. For instance, use of protected springs as a first choice source in two inner-city low-income, high-density Parishes was around 50%, and about 40% were using protected springs as their second choice source. This is despite the fact that many of these springs are low yielding and of very poor quality. The use of protected springs as a first choice source was even higher in another similar Parish (62.5%). Given the level of use, greater attention must be given to improve the water quality of these springs. This does not necessarily imply that all springs require rehabilitation or re-protection because, as discussed below, many of the problems relate primarily to poor community operation and maintenance. In these cases, significant improvements in water quality maybe achieved solely by improving community management skills and O&M practices without investment in infrastructure.

## Section 4: Water Quality Results and Discussion

The following sections review the water quality and sanitary inspection data collected to date from the programme and discusses the operational performance of water supplies in urban Uganda and the likely causes of microbiological failure.

### *Piped Water*

The staff of Municipalities have been undertaking routine testing of the piped water systems in each town, with the exception of Mukono which as already noted has no formal piped network in the town. In seven of the towns the piped water systems is supplied by NW&SC, the remaining two have Municipal piped water systems, whilst in Kabale a number of community-managed gravity-fed piped water systems exist. The situation regarding management of piped water supplies in each town is shown in Table 4.1 below.

**Table 4.1: Piped water supply by urban area**

| Town | Type of piped water supply |
|---|---|
| **Kampala** | NW&SC |
| **Tororo** | NW&SC |
| **Mbale** | NW&SC |
| **Soroti** | Municipal |
| **Masaka** | NW&SC |
| **Mbarara** | NW&SC |
| **Kabale** | Municipal & community gravity-schemes |
| **Jinja** | NW&SC |
| **Entebbe** | NW&SC |
| **Mukono** | No formal supply |

In the rest of this section, the discussion will focus primarily on Kampala to provide an indication of the use of surveillance data. Brief mention is made of other town and types of piped water supply. For more detailed information on the different towns, please contact the authors.

#### NW&SC supply, Kampala

The water supplied by NW&SC in Kampala is generally of good microbiological quality. Few failures are noted against standard end-product indicator values (at present the commonly accepted approach to water quality standards). Overall the water as supplied to the population shows a high degree of compliance with international norms.

In the period from January 1998 and September 1999, a comprehensive testing programme has been underway in Kampala, with a total of 1459 samples analysed for faecal coliforms, turbidity, chlorine residuals and pH, see Table 4.2. The numbers of failures recorded during this period is low as shown in Table 4.3 below. This data suggests an overall compliance rate of 97.5% with a 0 FC/100ml standard; a figure that compares well with many urban piped water supplies in Africa.

**Table 4.2: Samples analysed for faecal coliforms by quarter; Kampala**

| Division | 1st 1998 | 2nd 1998 | 3rd 1998 | 4th 1998 | 1st 1999 | 2nd 1999 | 3rd 1999 |
|---|---|---|---|---|---|---|---|
| **Central** | 28 | 27 | 30 | 63 | 23 | 47 | 34 |
| **Kawempe** | 30 | 21 | 48 | 54 | 50 | 52 | 60 |
| **Makindye** | 30 | 32 | 63 | 86 | 74 | 18 | 42 |
| **Nakawa** | 0 | 36 | 49 | 63 | 52 | 58 | 39 |
| **Rubaga** | 31 | 9 | 38 | 42 | 47 | 44 | 39 |
| **Total** | **119** | **125** | **228** | **308** | **246** | **219** | **214** |

**Table 4.3: No of samples failing 0 FC/100 ml by quarter (and range)**

| Division | 1st 1998 | 2nd 1998 | 3rd 1998 | 4th 1998 | 1st 1999 | 2nd 1999 | 3rd 1999 |
|---|---|---|---|---|---|---|---|
| **Central** | 4 (2-266) | 0 | 0 | 0 | 0 | 0 | 0 |
| **Kawempe** | 1 (6) | 0 | 0 | 0 | 2 (16-18) | 1 (3) | 0 |
| **Makindye** | 2 (3-4) | 2 (1) | 1 (14) | 8 (1-17) | 1 (1) | 0 | 3 (1-2) |
| **Nakawa** | - | 3 (2-66) | 1 (3) | 0 | 2 (1-2) | 1 (30) | 1 (23) |
| **Rubaga** | 2 (1) | 1 (1) | 0 | 0 | 0 | 0 | 0 |
| **Total** | 9 | 6 | 2 | 9 | 5 | 2 | 4 |

The performance in supply is actually better when more detailed analysis of the likely cause of water quality failure is examined.

**Local risks** are the following aspects taken from the sanitary inspection:

1) A leaking tapstand
2) Surface water collecting around a tapstand
3) The area uphill of a tapstand being eroded
4) Pipes exposed close to tapstand
5) Human excreta on the ground within 10 m of a tapstand
6) A sewer within 30 m of a tapstand.

**Supply risks** noted are:

7) Discontinuity within 10 days previous to sampling
8) Sign of leakage
9) Reported pipe break within one week previous to sampling
10) Main pipe exposed.

When assessing supply compliance, i.e. ignoring failure attributable only to local failure, it is important to review the sanitary inspection data and consider the chlorine levels. It should be noted here that assessing compliance is not always easy, without highly detailed immediate assessment, which is not undertaken in Kampala as it is expensive and largely unnecessary as no direct enforcement action is being taken.

One problem in this approach is that in some cases where only local risks were identified, chlorine residuals were inadequate. The dosing of chlorine at the plants is known to be adequate (data from the immediate post-plant area shows free residuals of 3.0mg/l and higher) thus the loss of chlorine could be ascribed to one of two mechanisms. Firstly, the loss could be due to use of chlorine in oxygenating contaminants derived from local sources. In this case it is difficult to assign blame to the supplier as they have provided water with an adequate residual for protection, but the level of local contamination is too high to inactivate bacteria. The alternative scenario is that chlorine is lost during distribution, either due to poor maintenance and cleaning of service reservoirs and pipeline or due to loss by volatilisation during storage. In these cases, the supplier is at fault as they have failed to operate the system properly to provide adequate protection. Loss of chlorine in bulk storage is common throughout the world and is a particular problem in tropical countries where high ambient temperature make volatilisation more likely, particularly where water is stored for significant periods of time. The Kampala system has been zoned on the basis of service reservoirs and this allows some attempt at deciding whether local risks combined with loss of chlorine can be ascribed as a supplier fault.

Table 4.4 summarises the percent of samples taken from Kampala that meet a generally recommended guideline of 0.2mg/l in piped distribution systems.

**Table 4.4: Percent samples with at least 0.2 mg/l free chlorine by quarter.**

| **Division** | **1st 1998** | **2nd 1998** | **3rd 1998** | **4th 1998** | **1st 1999** | **2nd 1999** | **3rd 1999** |
|---|---|---|---|---|---|---|---|
| **Central** | 0 | 0 | 10 | 96.8 | 100 | 80.9 | 100 |
| **Kawempe** | 57.1 | 44.1 | 51.1 | 57.1 | 81.6 | 90.2 | 84 |
| **Makindye** | 36.7 | 53.1 | 37.5 | 76.9 | 68.2 | 52.9 | 41.9 |
| **Nakawa** | - | 2.8 | 0 | 0 | 0 | 37 | 25 |
| **Rubaga** | 0 | 0 | 2.7 | 0 | 0 | 2.6 | 9.4 |

In Nakawa and Rubaga, it is believed that much of loss of residual chlorine occurs during storage in the reservoirs in Naguru, Mutungo and Rubaga, whilst in Makindye, problems appear to be most related to lines served by Rubaga reservoir and the Makindye booster tank. The only two cases of microbiological failure in Central Divisions occurred during a time when no samples reached 0.2mg/l free chlorine. Thus, a total of 28 cases of microbiological failure may due in part to supply faults, giving an adjusted compliance rate of 98.1%, still a commendable figure. Work is ongoing with NW&SC to identify the problem areas and to find appropriate solutions.

Chlorine residual maintenance has been steadily improving in much of Kampala during the period over which samples have been taken. Particular improvements are seen in Kawempe and Central Division and NW&SC is to be commended for improving chlorine residual maintenance in these areas. However, in Nakawa and Rubaga Divisions as well as parts of Makindye Division, maintaining of chlorine residual remains problematic and the supply stays at risk.

Sanitary inspection is a valuable tool for assessing operation and maintenance performance. By using the sanitary risks identified some conclusions can be drawn about the performance of O&M in Kampala. Initial inspection forms concentrated on the immediate area around the sampling point, but these were revised in mid-1998 to include 4 questions relating to major supply risks, thus analysis of data is based on a 12 month period. Sanitary inspection of urban piped water supply is complicated as many of the problems such as leaks may not be easily observable, but the approach used gives an overview of supply faults.

It should be noted that discontinuity in particular has been substantially reduced during the reporting period and this shows that the operational performance of the Kampala system is improving significantly. However, discontinuity remains a problem in both Rubaga and Nakawa Divisions and this is likely to be contributing to the loss of chlorine residual. These two Divisions also have more problems with leakages, suggesting that these areas are not receiving as prompt an action as those more centrally located. However, this may also be due to less prompt reporting of problems by consumers in these areas. The two remaining supply risks remain relatively insignificant, although mains exposure is more common in Makindye, perhaps reflecting the erosion of murram roads leading to the exposure of mains laid along roadsides. However, overall there is substantial evidence of improved O&M and it is hoped that these trends will continue and risks will decrease further.

### Other NW&SC Supplies

Details on the results obtained from the other towns supplied by NW&SC are not discussed in detail here. In the case of Mbale and Tororo, routine surveillance has been undertaken since 1998. Compliance rates are lower than for Kampala (in part influenced by a lower number of samples taken) but remain between 87 and 90%. In Mbale in particular, investment is required in to reduce discontinuity and leakage.

Data from a further 4 towns was restricted to assessments when the report was being prepared. These data illustrated a general good performance in three towns with a compliance rate of 87.5-100% although in the fourth town, the compliance rate fell to below 75%, indicating weaknesses in operation of the chlorine dosing system and poor distribution management. Discontinuity and leakage were significant faults in two of the towns, indicating the need for improvements in O&M. Overall, the supplies operated by NW&SC outside of Kampala show greater water quality problems and weaker O&M performance.

## *Municipal and Community-managed Piped Water Supplies*

Municipal and Town Councils are responsible for the piped water supply in two towns covered by the project – Soroti and Kabale. Community-managed gravity schemes are also common in Kabale.

The Municipal supplies appear to be less well operated and maintained than those operated by NW&SC. This is likely to be due to institutional weaknesses, but also include technical problems and poor revenue collection due, in part, to inadequate information about the numbers of connections, the latter being a particular problem in Soroti. A further problem faced in these towns is that the technology used (conventional treatment) has expensive consumable requirements. The possibility of using more robust and lower-cost technologies such a multi-stage filtration deserves greater attention.

The microbiological quality of water from the urban authority managed supplies is significantly poorer. For instance in Soroti, the compliance rate is low (40% and less) and a similar scenario is found in Kabale, although here microbiological quality is better due to high dosing rates for chlorine (free residuals of 1.5mg/l and more). Kabale also suffers from periodic high turbidity within the system. Supply faults such as discontinuity and leakages are common in both towns and in Kabale in particular, major O&M problems remain.

In the initial assessment of the gravity-fed community-managed systems in Kabale, most were found to be contaminated. It appears that this contamination is occurring due to source contamination, contamination during storage and distribution and local contamination sources. Clearly the absence of chlorination makes such supplies more vulnerable to recontamination.

### *Conclusions for Piped Water Supply*

The quality of piped water supplied by NW&SC is significantly better than that supplied through the Municipal Council operated supplies. Compliance rates are generally good, although much better in Kampala and Entebbe. It is likely that higher revenue base in Kampala is facilitating improved O&M and this may also be the case in Entebbe. Significant problems with maintaining a supply of adequate continuity and quality appear to be present in many areas, although improvements are being seen. Overall the water supplied by NW&SC represents a relatively limited risks to health in comparison with alternative supplies.

The Municipal supplies and community-managed supplies have significant water quality problems, most notably in Soroti. Some improvements are being noted and should these Councils take up the conditional grants for O&M, significant further improvements are likely to be seen. In the case of Soroti, much work also needs to be done to improve the revenue base in order to invest in O&M. The technologies used in Municipal supplies significantly raise costs and it is hoped that alternative approaches can be investigated.

### *Point sources*

In most towns protected point sources, including both boreholes and protected springs are common. Protected point sources are common in many towns and make up the majority of sources available to the population without a direct connection to the piped water supply in Soroti, Mukono and Kabale. The point sources available are primarily protected springs in 6 towns (Kampala, Mbale, Tororo, Kabale, Masaka and Mukono), with boreholes and dug wells in 3 towns (Soroti, Mbarara and Entebbe). Both assessments and routine monitoring have been undertaken of these sources.

#### Boreholes

Several towns have boreholes within their boundaries, but are most significant in Eastern Uganda. The boreholes are generally of good construction, although it would appear that many are temporarily or permanently out of action. In the case of Kabale, virtually all the boreholes are now non-functional, whilst in Soroti and Tororo at any one time up to 40% of the boreholes are non-functional. Down-times appear to be significant and this clearly raises an issue about the sustainability of this technology.

Table 4.5 below illustrates that with the exception of boreholes in Mbale, the microbiological quality of these sources is generally good. In the case of Soroti, boreholes have, to date, provided better quality water than the piped network. In general contamination, when found, is low and in general lower than that of protected springs. However, in Mbale there have been two samples where contamination was too numerous to count, implying that in this town there are serious water quality problems with the boreholes.

**Table 4.5: Summary of results from tests of bore hole water quality**

| Town | No. samples | No. failures | Range FC/100ml |
|---|---|---|---|
| **Mbale** | 29 | 23 | 1-85 |
| **Soroti** | 162 | 11 | 1-8 |
| **Tororo** | 53 | 1 | 1 |
| **Mbarara** | 6 | 1 | 1 |
| **Total** | 250 | 36 | 1-85 |

The sanitary inspection data indicates that overall operation and maintenance of boreholes is good, with sanitary risk scores in the low bracket. The low overall levels of risk appear to correlate well with the far lower levels of contamination in boreholes compared to protected springs. However, it should be noted that there are some operation and maintenance concerns regarding those boreholes that are functional, in particular the general poor maintenance of fences and, with the exception of Mbale, significant numbers with faulty drainage that allows water to build up close to the borehole. Ponding of water appears most significant in Tororo as does damaged aprons, but clearly neither is having significant impact on the water quality at present. However, it should be stressed that in all of these towns, the risks currently present should be addressed to prevent deterioration in water quality.

Reviews of sanitary inspection data indicate that in Mbale, the presence of any contamination appear to be related to the presence of pit latrines uphill and for contamination above 10FC/100ml because pit latrines are either uphill or within 10m of the borehole.

In Soroti, the only other town to show a significant number of contaminated samples taken from boreholes. The cause of failure appears to relate to both the presence of latrines uphill and within 10m of the borehole as well the presence of other pollution (for instance solid waste dumps or animal enclosures). However, the level of contamination is far lower than that found in Mbale.

### Protected springs

The monitoring of protected springs is ongoing in all towns on a rolling programme designed to ensure that springs are tested regularly and in particular during the wet seasons. In Kampala, a longitudinal study was undertaken of springs that yielded useful information regarding the variation in quality seen in different areas and different times of the year. In Kampala it is clear that springs show a marked deterioration in quality with season and recent investigations into alternative faecal indicators have shown that significant daily variations are seen at most springs in response to heavy rainfall.

The results illustrate that seasonal influences on protected springs are profound, but that in general even in areas where contamination would be expected to be highest outside of extreme climatic events, median coliform values are within the guideline for drinking water from untreated water supplies in Uganda (50 FC/100ml), although this is a high level of contamination. Furthermore, springs in low-density areas, show a median value by quarter that would meet a relaxation of 10 FC/100ml suggested by WHO as being appropriate for small community-managed water supplies that are not chlorinated (WHO, 1997[3]).

[3] Guidelines for Drinking-water Quality, Volume 3. WHO, Geneva, 1997.

The longitudinal study of springs ran from April 1998 to March 1999. The springs selected for this study were chosen to reflect the overall distribution of results from the initial assessment. The repeated sampling of these springs appears to have had a limited, but discernible beneficial impact on communities as the quality of water taken from springs not covered by this study show higher levels of contamination as shown by the reduction in the number of springs meeting the WHO relaxation and National water quality guideline.

The problems with protected springs stem both from poor design and poor maintenance. The backfill media used offers little or no filtration. In general large aggregate is used that does little more than canalise water from the spring eye to the outlet pipe. The poor maintenance of the immediate protection areas in terms of maintaining diversion ditches, retaining walls, backfill areas and fences all allow pathways for pollution to enter the springs.

The sanitary inspection data shows that operation and maintenance of protected springs has been weak, with overall risks high. Even the simple tasks of keeping the immediate area around the spring protection works appear not to be carried out. Very few springs have a functional fence and in a large number of cases the uphill diversion ditch has been allowed to become either non-functional or requiring attention. In addition, in many communities the wastewater ditch is blocked and allows water to back up into the collection area. This may result in ingress of contaminated stagnant water into collection vessels as water is collected and clearly also to an increased likelihood of mosquito and other vector breeding.

In terms of the sources of pollution there are four critical factors. Latrine proximity is rarely a major problem and only in Kampala is this reported with any significant frequency. In all cases, the ability of animals to access to within 10m of the spring is notable and initial investigations have certainly shown that indicators specific to animal faeces can be isolated from many of these springs. It should also be noted that the presence of surface water uphill is important in both Kabale and Masaka and that the presence of pollution sources such as solid waste dumps being uphill of springs is a particularly important risk factor in Kampala and Kabale.

Sanitary inspections include both pollutant pathways and pollutant sources and it is likely in the majority of cases that it is a combination of source and pathway that leads to contamination events. The data from Kampala suggests that the presence of pollution uphill such as solid waste represents the most important source of contamination. Although initial recording is high (48% of cases), increases in reporting of this risk at higher levels of contamination is consistent with increased microbiological contamination derived from such sources during rainfall events. The convergence of the reporting of poorly maintained diversion ditches, erosion of backfill, access for animals within 10 metres and other pollution uphill suggests that a principal mechanism at work is the inundation of backfill areas with contaminated surface water. Indeed a review of data of springs with this combination of risks and no latrine or surface water pollution nearby shows the highest median thermotolerant (faecal) coliform count and the greatest variation in results. The importance of limiting these risks is further emphasised by initial results from springs re-protected by Save the Children Fund in Bwaise, where the wet season count has dropped from by two logs to 13 FC/100ml, despite the presence uphill of latrines and other sources of pollution.

### Conclusions for point water sources

The point sources in urban areas of Uganda show a marked difference according to source type. Boreholes appear to provide high-quality water sustainably, with the exception of

Mbale. Contamination has not been found in any borehole in Tororo, whilst in Soroti the small number of failures have all been below 10FC/100ml. Where contamination is found, it appears likely that latrine proximity and siting exerts an important influence, particularly in Mbale where a possibly different hydrogeology make latrine-borehole siting more important.

Protected springs show a much poorer quality and pronounced seasonal variation. Outside of Kampala, the proximity of latrines appears to have little influence on the microbiological quality of the springs. In Mbale, where the impact of latrines on boreholes is noted, there is little evidence of a strong association with springs and it would appear that as with other towns the strongest influence is exerted by the presence of pollution on the surface uphill of the spring, lack of diversion ditches, eroded backfill area and flooding of the collection area.

In the case of Kampala, it appears that there is an influence from pit latrines at certain sites, although the strongest influence relates to the presence of uphill pollution such as solid waste with the development of direct pathways caused by a lack of diversion ditches and eroded backfill. These risks all show increasing importance with the degree of contamination, as does faulty masonry and flooded collection areas. However, the highest median count and greatest range of results are associated when four factors – uphill pollution other than latrines, eroded backfill, lack of diversion ditches and animal access - combine. This association is seen when latrines and masonry defects are not noted. However, between 26 and 40% of all inspections where any form of contamination is found indicates a pit latrine as a risk factor. Analysis of the data is ongoing to define relative risks of different factors.

### *Household Water Quality*

Routine testing of household water quality has been carried out by Municipal staff since mid-1998, although testing was delayed in Kampala because of the longitudinal study of spring water quality. Testing of household water is important as this is the water actually consumed. Where water is collected from communal water sources recontamination is common, thus whilst sources of water may be good, the water consumed may still be highly contaminated.

#### Kampala

The testing of household water quality also provides a good way to evaluate the effectiveness of health education messages regarding the safe water chain and boiling of drinking water. In the water usage studies carried out in Kampala, the number of households reporting that they boil water prior to drinking has been high (85.6 and 92% respectively). It should be noted that in both studies, households were not directly asked whether they boil water, but whether they did anything to their water before they use it. However, this appears to have had little impact on the numbers reporting that boiling is carried out. Where water is boiled and a safe water chain maintained, it is expected that there should be no faecal coliforms in the samples taken. It should be noted that household water testing has been primarily in Parishes with low overall rates of direct connection to the NWSC supply and therefore water is being transported from the source to the home.

**Table 4.6: Number of household water samples analysed and range of contamination as FC/ 100ml**

| Division | 1998 | | Jan-Mar 99 | | Apr-Jun 99 | | Jul-Sep 99 | |
|---|---|---|---|---|---|---|---|---|
| | *N* | *Range* | *N* | *Range* | *N* | *Range* | *N* | *Range* |
| Central | 15 | 0-73 | 35 | 0-3 | 30 | 0-3 | 26 | 0 |
| Kawempe | 18 | 0-TNC | 27 | 0-TNC | 29 | 0-78 | 40 | 0-13 |
| Makindye | 20 | 0-TNC | 22 | 0-TNC | 9 | 0-4 | 32 | 0-TNC |
| Nakawa | 16 | 0-100 | 21 | 0-110 | 33 | 0-102 | 50 | 0-127 |
| Rubaga | 20 | 0-TNC | 11 | 0-4 | 29 | 0-5 | 46 | 0-15 |
| **Total** | 89 | 0-TNC | 116 | 0-TNC | 130 | 0-102 | 194 | 0-TNC |

**Table 4.7: Median FC/100 ml and percent recorded 0 FC/100ml in household water samples in Kampala**

| Division | 1998 | | Jan-Mar 99 | | Apr-Jun 99 | | Jul-Sep 99 | |
|---|---|---|---|---|---|---|---|---|
| | *Median* | *% 0* | *Median* | *% 0* | *Median* | *% 0* | *Median* | *% 0* |
| Central | 0 | 86.67 | 0 | 94.29 | 0 | 93.33 | 0 | 100 |
| Kawempe | 9 | 38.89 | 28 | 22.22 | 3 | 20.69 | 1 | 45 |
| Makindye | 24 | 35 | 3 | 22.73 | 1 | 44.44 | 3 | 43.75 |
| Nakawa | 0 | 56.25 | 29 | 4.76 | 42 | 6.06 | 11 | 16 |
| Rubaga | 50 | 35 | 0 | 72.73 | 0 | 93.1 | 0 | 84.78 |
| Total | 1 | 48.31 | 1 | 45.69 | 0 | 51.54 | 2 | 54.12 |

These tables show interesting results from which both positive and negative conclusions can be drawn. In most Divisions, with the exception of Nakawa, the median FC/100ml count found in household water has generally fallen since the start of the programme. In Central Division, median contamination has been consistently zero and for Rubaga this is also obtained for tests carried out in 1999, despite initial high levels of contamination. In both Kawempe and Makindye, median values have dropped but still remain above zero.

The reduction in median contamination suggests that the health education messages regarding safe water use are beginning to have an impact. However, whilst the range of contamination found has dropped in all Divisions except Makindye, the upper values of faecal contamination found remains high in Kawempe and Nakawa Divisions. This shows that whilst some headway is being made in improving water handling practices, there remain significant numbers of households that do not follow good water hygiene practices. In Central Division, the numbers of samples meeting 0 FC/100ml has been consistently high and in Rubaga there has been a very significant increase of about 50% since the programme started. In Kawempe and Makindye, improvements have been seen in the last quarter and only in Nakawa do the rates of compliance remain low.

Overall, it would appear that the process of household testing itself is having a significant impact in most Divisions as shown by the decrease in median contamination and increasing numbers of samples meeting 0FC/100ml. This suggests that water quality testing can be an effective component in health education and in particular the feedback of results to households is important to achieve better in-house water quality. The lack of progress in Nakawa remains of concern and this will be addressed.

It would appear that in many Divisions the source water quality exerts a significant influence on quality of water in the home and this may explain the lower levels of compliance in Nakawa. In Rubaga, results from 1999 consistently indicate that contaminated household samples are those where the family has collected water from protected springs. This is in many ways not unexpected given that the majority of households use Jerry cans with a narrow neck and a screw on top to collect and store water. This may imply that health education messages should place a greater emphasis on use of safe sources for drinking and food preparation/cooking rather than boiling of drinking water.

The difference between stated boiling and quality of water in the home is an issue of concern as it suggests that whilst most households accept the need for boiling, a very significant proportion of household do not translate this into practice. Boiling of drinking water has in many ways become a socially desirable response for low-income families where questioned about household management of water but not something that is perceived as being essential.

The reasons for the lack of sustained boiling are likely to derive essentially from the cost to household of routine boiling of water. The energy requirements to boil significant quantities of water are high and given that likely daily consumption will be in the region of 1-2 litres per capita, this translates into a high household expenditure on kerosene and other energy sources. Given that the low-income group has many competing demands on limited household budgets, these costs may be perceived as unnecessary for much of the time. It is likely that compliance with boiling will be much higher during and in the immediate aftermath of an epidemic as such events represent crises for the family. Outside such events, the perception of the family may be that the importance of boiling is greatly reduced. Alternative approaches to household water treatment using chlorine tablets and on-site chlorine generation have been successfully used in both Bangladesh and Ecuador.

The cost to households of such approaches may be significantly lower than boiling, but may raise other problems such as acceptability. Alternative approaches have used UV from natural sunlight as a disinfectant, but it should be noted that such approaches are time consuming and require households to leave bottles in areas that they may feel are insecure. Alternative approaches to household water treatment may be worth investigating in Uganda, but clearly this would require significant support through health education to ensure that compliance was higher than for boiling. If such approaches were to be tried, it is recommended that they be done at a pilot level in a few communities in the first instance to assess their appropriateness in the Ugandan setting.

### Mbale, Soroti and Tororo

Routine testing of household water quality has also been carried out in the towns in East Uganda that participate in the project. The household water quality testing has been most aggressively undertaken by Soroti who have sustained high numbers of samples for each quarter. This reflects the generally good performance of staff in this Municipality. The numbers of samples from Mbale and Tororo have been lower, in the case of Tororo because this is a much smaller town.

The results illustrate that in both Soroti and Tororo, significant numbers of households' drinking water is grossly contaminated. The range of contamination in these towns has not dropped during the period of project, which implies that the success noted in Kampala in using surveillance of household water to promote improvements in water quality is not occurring to the same extent in these towns. In Soroti and to some extent Tororo, household contamination also appears to relate to the use of clay pots with a rough interior. These containers will allow bacterial populations to develop and survive to a far greater extent than plastic Jerrycans. In Mbale, the range of contamination has dropped markedly in 1999, although the smaller numbers of samples may in part be the cause. However, as the predominant source type available is piped water and connection rates relatively high in Mbale, the limited amount of contamination is likely to relate to safe source water to a large extent.

### Conclusions for household water quality

Household drinking water quality remains poor in many towns and this is an issue of serious concern particularly with regard to the potential for water-borne transmission of cholera and other pathogens. The process of household testing has yielded benefits in Kampala, although elsewhere there has been a less significant impact. The fact that Kampala was severely affected by the cholera epidemic in 1997/98 and the greater awareness of the poor quality of springs may also be significantly contributing to this improvement.

Health education messages around water are not, however, appearing to be effective. Whilst knowledge is certainly present in most households, this is not being translated into practice and boiling of water has become a socially desirable response rather than a critical household activity. The project is about to review the PHAST tools and it is hoped to strengthen health education in the towns covered by the project in identifying materials and approaches to health education around the safe water chain. This is likely to include the promotion of safe sources and emphasising good handling practices as a way to reduce ill health.

It should be emphasised that using a variety of health education techniques is likely to yield the greatest results and therefore simply producing more posters or running more messages through the mass media may not yield the changes in hygiene practice that is desired. The nature of the responses in the water usage questionnaire also indicates that more attention should be given to maintaining good hygiene practice in communities. It is also interesting to note that in a recent workshop held with two community water committees in Kampala, the participants developed a bye-law to be submitted to the village council that dirty Jerrycans should not be allowed at the re-protected springs. The use of local health promoters and educators may represent an effective way of improving water handling in many communities and deserves further investigation.

## Section 5: Surveillance to improvement of water supply

The purpose of monitoring and surveillance is to promote improvements where there is inadequate provision of water services or identified failures in water quality. The management use of surveillance data is essential to translate monitoring into management decisions. Surveillance data can contribute to improvements in water supply at policy and planning levels as well as technical and hygiene education interventions. Much of this has been discussed during the report under different sections, but the following sections outline progress to date in the use of the surveillance data and future needs.

### *Policy and Planning Levels*

At a policy level, reliable and accurate assessments of access to water supply, water quality and risk data has already yielded results. In terms of focus on most vulnerable groups, the routine monitoring of water supply plus assessment of access to higher levels of service has allowed a number of local councils to prioritise interventions in water supply in most needy areas. Examples include plans by Central Division in Kampala to provide both improved protected springs and public taps. Other Divisions in Kampala and Tororo have both used the surveillance data as a means of raising funds for water supply improvement. This is already demonstrating the practical value of surveillance activities.

It is also encouraging to note that several Councils are accepting the need to improve the protected springs within their administrative areas given the high degree of spring use in low-income areas. Whilst the use of protected springs is not the preferred solution to poor water supplies in urban areas, a realistic assessment of the likelihood of increasing access at higher levels of service make their improvement essential in the short to medium term. Initial experience with an improved design shows that such water sources can provide water of much higher quality that represents a very limited risk to health. However, the improvement of springs must include training to improve operation and maintenance by communities and some tariff should be levied on users to ensure sustained O&M. The role of water user groups and associations are believed to be essential to sustain improvements in water quality of point sources.

The use of the zoning approach adopted by the project has also shown that it is possible to define and predict those Parishes that are likely to be at greatest risk from large-scale epidemics. It is hoped that both the Ministry of Health and local Public Health departments can use this information in planning for potential future outbreaks.

There still remains a number of issues at a policy level that would substantially contribute to improved water supply. In terms of piped water, without doubt the greatest need is to increase the numbers of direct connection. Indeed if this was achieved, there would be a greatly reduced need to provide communal water points. At yard and higher levels of service, the quantities of water used increase significantly and health is improved as a result. There is also a strong equity argument for increasing access to higher levels of water service and there is little doubt that much higher numbers of connections will do much to reduce poverty in urban Uganda. Such increases in direct connection would contribute very significantly to improved financial viability of many water supplies as the income derived would increase. There is a particular need to review the costs of connections, which appear extremely high and act as a disincentive for many poorer households. In other African countries, subsidies have been provided for connection, with losses offset by increases in tariff. However, even the simple provision of credit with terms of re-payment that are realistic to households with low and fluctuating incomes may be equally as effective.

In terms of the provision of public taps, the current application of a minimum charge on metered supplies is a further disincentive to establishment of more public taps that would contribute to reduce risk of disease. It is not clear why minimum charges should be applied on metered connections as the whole purpose of such connections is to ensure that users pay for what they use. Minimum charges may contribute to wasting water as there is little incentive to conserve water below the minimum charge. Furthermore, the current charge appears to greatly over-estimate actual use, particularly in the wet season when many people collect at least part of their domestic water requirement through rainwater collection. There is a risk that such minimum charges will limit the potential for sustainable public taps and create a negative image of NW&SC, particularly as these are comparatively higher than for other connection categories. Previous recommendations of consultants engaged by NW&SC regarding minimum charges should be implemented and the minimum charges either dropped or greatly reduced.

### *Technical and Social Issues*

Surveillance provides a mechanism for monitoring operation and maintenance of water supplies. The role of surveillance in promoting better O&M in towns with a Municipal water supply has already yielded benefits in Soroti and it is hoped that this can be continued. There is need to improve O&M further in most towns and the links between health departments and water supply offices (whether Municipal or NW&SC) should continue to be emphasised. At a local level, surveillance should be used to promote the better protection of the area immediately surrounding taps to reduce the potential for local contamination of otherwise good water supply.

As already noted, the improvement of springs in urban areas is already underway. Currently 4 Divisions in Kampala (Central, Kawempe, Makindye and Nakawa) are either undertaking or considering improvement of protected springs and similar actions have occurred in Tororo. The project has developed an improved design for protected springs that incorporates greater sanitary protection and filtration by using a gravel backfill overlain with sand, clay and murram. This design is being piloted in Kawempe Division in collaboration with SCF-UK. Initial results from the first spring re-protected showed a dramatic reduction in contamination from over 200 FC/100ml to below 10FC/100ml in the wet season. This is being supported by training of water committees in maintaining their spring. This focuses not just on technical issues but also the need to raise finances to support operation and maintenance through levying a small tariff on all users of the spring and developing bye-laws to govern the use of the spring. Copies of the improved design have been given to the Divisions in Kampala and this will be provided to other towns in the near future. A manual is being prepared and will be disseminated throughout the participating towns and this design, if it continues to prove effective should be used more widely.

Concerns remain, however, about the operation and maintenance of point sources, as this is general appears to be poorly carried out. Staff working in Municipal Public Health Departments are beginning to focus increasingly on working with communities to improve operation and maintenance of point sources and to encourage the improvement of management of the sources. Much of the water quality problems could be resolved through simple measures in maintaining the areas around the source. In addition, tools have been developed to help communities monitor operation and maintenance and these will be piloted in the near future.

The use of surveillance data in promoting improved quality in the water stored in households has already been shown to be effective in Kampala and this experience is being disseminated in other towns participating in the project. The project is planning to undertake a review of the PHAST tools and other health education materials in December 1999, to provide better support to local staff in promoting safe water chains and reduced risks to health from poor water quality.

However, concerns remain about the continued emphasis on boiling of water as the main strategy for controlling re-contamination. There is substantial evidence that whilst knowledge about the need to boil water is high, this is not being translated into improved practices in the home. There needs to be a greater emphasis on the promotion of safe sources and on preventing contamination by ensuring water collection and storage containers are kept clean and that water is handled in way that limits the potential for contamination. There may also be a value in piloting alternative approaches to household water quality treatment such as chlorination through the use of tablets. Household water filters may also be effective, particularly in institutions. However, filters do not always produce water of a high quality and the only filters that provide reliable disinfection of water are those that use iodine resins.

## Section 6: Conclusions

Local level surveillance in urban areas has certainly proved to be possible and cost-effective. To date, a total of over 3500 sanitary inspections have been carried out and nearly 6000 samples analysed. The surveillance of water by public health staff is important in terms of protecting health and has already yielded benefits in many areas in terms of planning, water source improvement and health education. The project has defined target groups and vulnerable areas and focused attention on these as they at greatest risk from disease.

Overall the water quality provided by NW&SC is generally of limited risk to health and failures relate often to local contamination. However, outside of Kampala, significant problems remain and these should be addressed. Despite the good quality of the water provided by NW&SC, direct connection rates remain low and many people continue to use point sources for at least part of their domestic water needs. Until much higher rates of direct connection are achieved, it is likely that springs and boreholes will continue to be used and in many cases will put the health of the users at significant risk. The establishment of more public taps may help overcome some of these problems, but it is doubtful that provision of such facilities alone will cause an abandonment of the springs. Encouraging connection at least to a yard level will lead to improvements in equity of access to water supply, health of the users and financial stability for the suppliers.

Municipal piped water supplies are generally of much poorer quality, partly because they lack the technical staff to operate the systems effectively, have a limited revenue base and use technologies that raise costs of production. In Soroti, the quality of piped water is lower than that of boreholes, which raises a concern about trying to promote connection to the piped water supply. In Kabale, initial assessment data of water quality in the Municipal piped water system showed widespread contamination but subsequent data has shown that this has been reduced by high levels of chlorine dosing, although the supply remains with significant problems with turbidity. It is also of concern that no formal piped water supply exists in Mukono, although it is believed that this is being addressed.

Point sources are widely available and commonly used by the urban poor. The quality of boreholes is generally good, but springs shows seasonal variation and overall a lower quality. However, the poor quality of the springs largely results from poor sanitary completion and poor operation and maintenance, although in parts of Kampala there is some influence from latrines. Initial work on a new design for the springs, shows significant improvements in quality. Where boreholes are contaminated, this largely derives from latrines if they are within 10 metres, although other sources of pollution are also important. Further analysis of current data will provide more information on the relative importance of different risk factors and the influence of latrines on water quality.

The quality of water stored in households has been improving in Kampala, although it remains lower than acceptable in roughly 50% of households and in towns outside Kampala, household water is often of very poor quality. Health education in promoting safe sources and placing an emphasis on safe water chains is essential.