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System assessment to develop water safety plans

C. Niwagaba, S. Godfrey, A. Gisagara , G. Howard, Uganda

WATER SAFETY PLANS (WSPs) are risk management tools designed to assure the safety of drinking water. WSPs have the advantage that they help minimise the risks to water contamination through identification and management of vulnerable points within a water supply system, which could allow microbial hazards to enter. This paper discusses one of the crucial elements in establishing WSPs, the system assessment. It outlines findings from fieldwork undertaken on a UK, Department for International Development (DFID) funded project on development of WSPs in Kampala, Uganda.

Materials and methods

System assessment is described by Davison *et al* (2003) as "*a preliminary assessment to see whether the water quality targets as set are likely to be met using the existing infrastructure.*" It is an important step that must be done correctly for two reasons:

- To understand the risk profile of the water supply system;
- To determine the ability of existing barriers within the water supply system to minimise risk to an acceptable level.

A four-stage process for undertaking system assessment for the Kampala water supply system is presented.

Stage 1: System analysis/zoning

With the assistance of the National Water and Sewerage Corporation (NWSC) senior engineers and staff from the operations department, the map of the Kampala distribution system was divided into 5 supply zones (with 22 sub zones). The basis for delineation of the supply zones was according to the hydraulics of the system with consideration of water flow patterns from both the two treatment plants and the five major service reservoirs. The distinction between high and low-pressure distribution pipelines was also key issue in the zoning of the supply. Hazardous areas in close proximity to the primary and secondary pipe infrastructure based on both population density (as a surrogate for faecal loading), location of pipes (i.e. pipes laid in low-lying areas and close to sewers, channels and road crossings), known points of failure (prominent pipe bursts/leakage and intermittent supply) and susceptibility (estimated number of people that may be affected as a result of microbial risk at a specific point of supply). From this data 152 key inspection points were identified. A4 block maps for each inspection point were printed and a route/schedule planned for inspecting each of the points.

Stage 2: Development of inspection checklists for the different facilities

In order to assess the sanitary integrity of the identified inspection points within the system, sanitary inspection (SI) forms were developed. The sanitary inspection forms were developed to enable comparisons of sanitary risks of varying facilities within the network. These were based on existing examples of SI forms developed in Uganda between 1997-2000 (Howard *et al*, 2002). For each facility, a form was phrased using local terminology (see Figure 1).

To test the applicability of the forms for the Kampala network, the SI forms were tested by local partners over a one-month period. Proposed improvements to the forms were noted and the forms were amended to suit local conditions. For example field testing of the forms at the service reservoirs revealed individual design differences between the service reservoirs. In order to maintain comparability in the SI forms, sanitary risks common to all reservoirs were identified. These included the potential contamination of stored water by bird faeces from Marabou stalks defecating on top of reservoirs and the potential for tree branches to provide access for birds/rodents to vents and for tree roots to damage the reservoir walls.

For standpipes, questions were also phrased to include the detail of information from consumers regarding the intermittence of the supply as well as the detail on the immediate hazardous environment. Observations were made to ascertain the state of the environment at for example standpipes, valve boxes, service reservoirs and supply tanks.

Stage 3: Field assessment

Field assessment was carried out to identify inspection points within the distribution system to obtain complementary information to the initial system analysis. The assessment was carried out on a total 183 (the original 152 plus 31 additional points identified in the field) spread through out the entire distribution system (Godfrey *et al*, 2002). The assessment was done over a period of 7 weeks by 3 persons working 2 days per week and covering 10 to 15 inspection points per day. In the next paragraph, we describe the steps that were followed during field assessment.

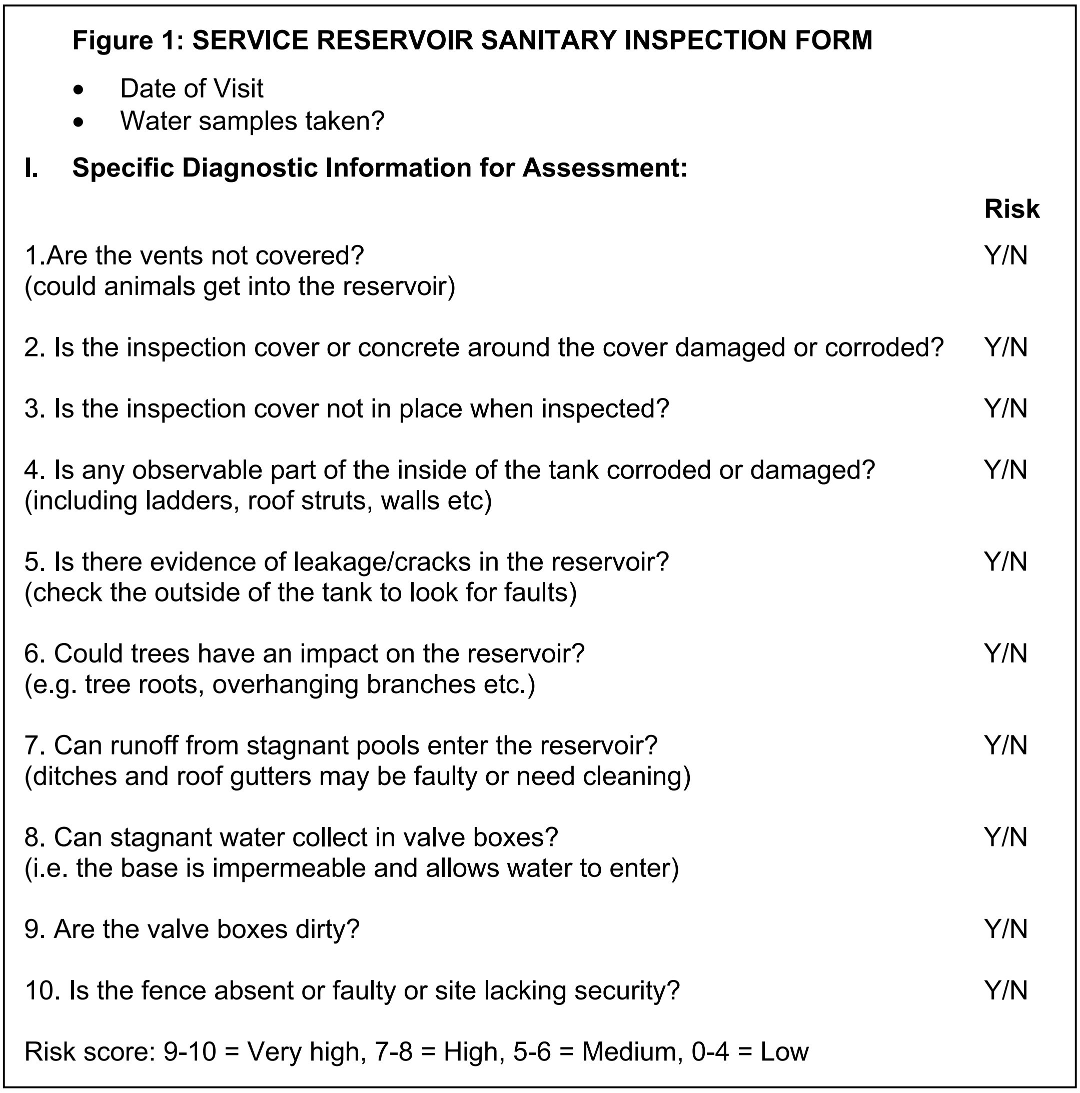

Figure 1: SERVICE RESERVOIR SANITARY INSPECTION FORM

- Date of Visit
- Water samples taken?

I. Specific Diagnostic Information for Assessment:

	Risk
1.Are the vents not covered? (could animals get into the reservoir)	Y/N
2. Is the inspection cover or concrete around the cover damaged or corroded?	Y/N
3. Is the inspection cover not in place when inspected?	Y/N
4. Is any observable part of the inside of the tank corroded or damaged? (including ladders, roof struts, walls etc)	Y/N
5. Is there evidence of leakage/cracks in the reservoir? (check the outside of the tank to look for faults)	Y/N
6. Could trees have an impact on the reservoir? (e.g. tree roots, overhanging branches etc.)	Y/N
7. Can runoff from stagnant pools enter the reservoir? (ditches and roof gutters may be faulty or need cleaning)	Y/N
8. Can stagnant water collect in valve boxes? (i.e. the base is impermeable and allows water to enter)	Y/N
9. Are the valve boxes dirty?	Y/N
10. Is the fence absent or faulty or site lacking security?	Y/N

Risk score: 9-10 = Very high, 7-8 = High, 5-6 = Medium, 0-4 = Low

During the field assessment, sanitary inspection was carried out on each inspection point using standardised sanitary inspection (SI) forms described above. For each point, the inspector observed its physical state and condition of the environment. He/she encircled either YES or NO on the SI form. On-site analysis was done for free chlorine residual, turbidity, pH and temperature and; additionally, GPS coordinates of each inspection point were recorded.

Stage 4: Risk maps

The results of the above were plotted in Auto Cad to produce risk maps. A combination of field data from the system assessment and existing surveillance data was used to compose the risk map of the Kampala network (Godfrey *et al,* 2002). Sanitary risks scores collected for each inspection point were calculated and stored in an accompanying database. These scores were a composite of SI data, pipe condition and proximity to hazards. Risk scores for each of these were then recorded as rasta points within the network using a process of vectorisation to compute risk scores for individual sections of the pipe network. These are marked as ⊕ in figure 2.

Discussion

The Kampala water supply system has some generic design and operational problems. Sanitary risks at the service reservoirs were found to be in the range of 10-50% risk and a median value of 40% risk. The main problems that were commonly identified were: uncovered vents, missing inspection covers, corrosion inside the reservoirs as well as poor security at the site. The conclusion here is that apart from corrosion inside the reservoir, the rest of the risks were simple operational issues that could be easily remedied. This therefore provides evidence of weakness in ensuring water safety and therefore action should be taken to safeguard the integrity of the water supply system. This

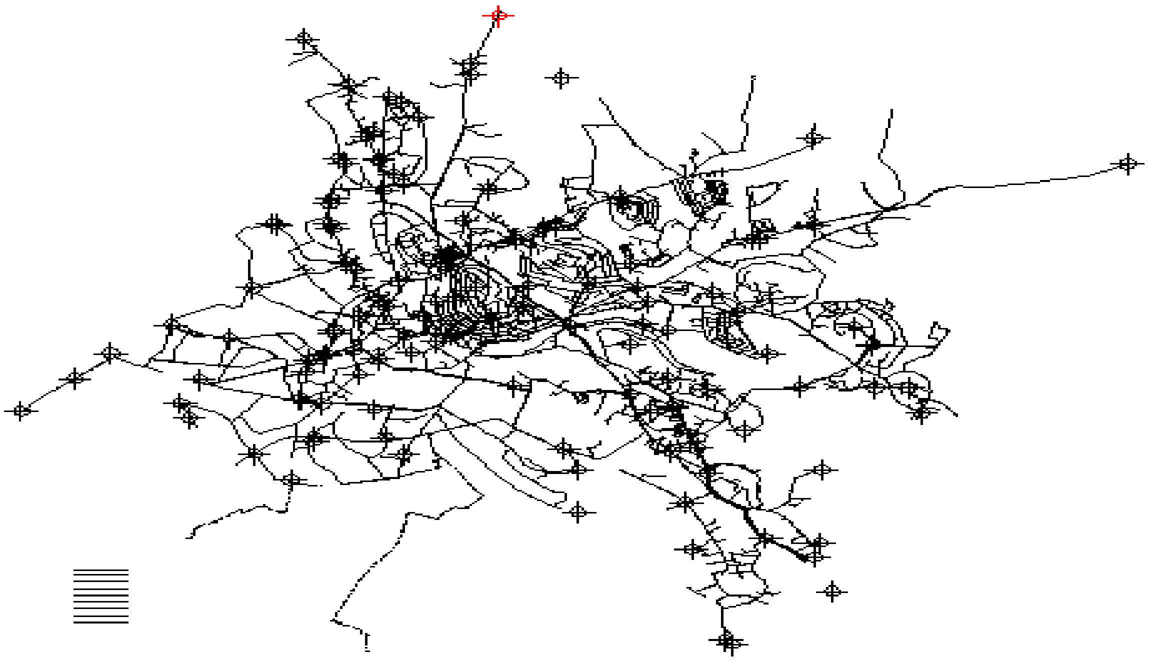

Figure 2. Inspection points

calls for training and guidance on the basic hygiene for the operators.

Table 1 outlines selected results from the survey. This data set has been chosen as it offers a comparison between a standpipe located at an end point of the network, a service reservoir as well as a valve box. The facilities are located in different supply zones. Total chlorine levels in the reservoirs and at consumer points in the distribution system were found acceptable apart from one reservoir (Gun Hill). Residual chlorine levels in comparison were low in the majority of the network suggesting either potential chlorine decay or consumption into biofilm matrices and/or consumption due to ingress in the pipes during distribution. Temperature data was used as an indicator of likely incremental biofilm formation. As noted by Geldreich (1996) water temperatures above 15°C (58°F) accelerate the growth of biofilm. As noted in table 1, average temperatures in the Kampala network were >25°C suggesting potential acceleration in biofilm formation.

Sanitary inspection of valve boxes presented difficulties as many of the selected valves were not visible These valves were buried as a result of road upgrading works making their inspection impossible. This will make it difficult to control the water flow, especially if some portion needs to be isolated, e.g., during maintenance and repair works. This suggests that during road upgrading works, the water supply utility organisation (NWSC) should liase with the Ministry of works and Kampala City Council (KCC) so

Table 1. Sample results from system assessment

Date	Time	Sampling Point Station	Sampling Point Category	Supply Zone	GPS coordinates	Temperature	Free Cl_2	PH	Turbidity	% SI Risk Score	SI risk Score
26/6/2002	2:23 P. M	End point CRN3322/27	STANDPIPE	MUYENGA	36N0054964 UTM0029592	26.7	<0.1	7	<5.0	0	LOW
05/7/2002	2:13 P. M	Buziga Tank	SERVICE TANK	BUNGA	36N0057116 UTM0028480	27.3	<0.1	7.14	<5.0	60%	MEDIUM
12/7/2002	9:51 A. M	Albert Cook/Kalema Rd Junction	VALVE BOX V1248	BUSEGA	36N0050147 UTM0034246	23.4	0.1	6.72	<5.0	N/A	N/A

that the works do not affect the status of the valve boxes and other water supply infrastructure.

Samples for on-site analysis in some cases had to be taken far (up to 1 km) away from the valve box due to non-existent sampling points at/near the valve boxes. This can of course introduce gross errors. As a result it was recommended that inaccessible valves should be located and re-housed in valve chambers. Inspection cover keys for each of the identified valves in the system should then be made available to the Water Quality Control Department (WQCD) and each valve should be equipped with copper sampling taps to facilitate regular water quality monitoring.

Coordinates for each inspection point were recorded on the network using either GPS or physical readings. It should be noted that although the use of the GPS assists in the plotting of the sampling points on a digitised map, the coordinates, often when plotted, may lie 7 – 12 m off the actual point on the map. It is therefore equally as reliable to rely on physical plotting of points based on knowledge of the pipe and road network.

Findings from the system assessment revealed the need to provide support to ensure that WQCD staff have a better understanding of the system. This can be done by developing a route map based on block maps as well as providing mark posts and naming them by local areas of where they are located.

Conclusions

- The fieldwork part of the system assessment for a large water supply system like that of Kampala is a very important process and one that can result in a reduction in monitoring and verification costs.
- For a proper and accurate system assessment there is need to have a correct understanding of the water supply system which result in the identification of key control points.
- Greater attention should be paid to monitoring of surrogate indicators such as residual chlorine and sanitary inspection in the vast of the water supply system and less time on end product microbial testing e.g., only for key control points.
- Through the monitoring and management of key control points greater water safety can be assured.

References

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CHARLES NIWAGABA, Teaching Assistant, Dept. of Civil Engineering, Makerere University, Kampala, Uganda,

SAM GODFREY, Assistant Programme Manager, WEDC, Loughborough University, Leicestershire, UK,

ALEX GISAGARA, Chief Engineer, National Water and Sewerage Corporation (NWSC), Kampala, Uganda,

GUY HOWARD, Programme Manager, WEDC, Loughborough University, Leicestershire, UK.