Success or failure: demonstrating the effectiveness of a Water Safety Plan

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ABSTRACT

The Water Safety Plan (WSP) concept has become a globally recognised and accepted approach to drinking water supply management and operation. Many countries around the world are adopting this proactive, risk-based model for ensuring consistent confidence in drinking water safety, accessibility and affordability. While it is widely accepted that the WSP concept is an appropriate tool for ensuring drinking-water supply efficiency, the process for gathering the required evidence to demonstrate this continues to be rather vague. The problem may lie fundamentally in the way WSPs are developed and implemented. This paper discusses the need for establishing performance targets, identifying key performance indicators and monitoring these to build a body of evidence that would be instrumental in demonstrating whether WSPs are effective or not.

Key words | drinking water, key performance indicators, monitoring and evaluation, targets, Water Safety Plan

INTRODUCTION

Water Safety Plans (WSPs) are widely regarded as one of the most effective means for ensuring drinking water safety (WHO 2004; Hrudey et al. 2006; Mahmud et al. 2007; Summerhill et al. 2010). This comprehensive, systematic and proactive risk-based management approach provides suppliers with greater confidence in their supply compared to the more traditional, product quality control approach which relied entirely on end-point testing. Water-borne disease outbreaks such as Milwaukee, (Wisconsin, USA) in 1993, when Cryptosporidium contamination of the public water supply caused more than 100 deaths and over 400,000 illnesses, Walkerton (Ontario, Canada) where in 2000 an Escherichia coli O157:H7 (E. coli) contamination resulted in the death of seven residents and 2,300 ill people, and similar, but small-scale outbreaks in New Zealand (Ball 2006) have exposed the serious limitations of relying primarily on end-point testing. The WSP approach overcomes these limitations by encouraging a paradigm shift from the reactive, product quality control to a more systematic and proactive process quality control.

Globally, there has been a sharp increase in the application of WSPs; however, these have primarily been within utility supplies in developed countries (Mahmud et al. 2007). More recently, there have been several initiatives centred around small community-owned supplies in developed and developing countries – most notably the World Health Organization (WHO) driven programmes in the Pacific (Mudaliar et al. 2008) and Asia (Davison & Deere 2006).

While there is little doubt that the WSP approach improves supply performance and provides greater confidence in drinking water, demonstrating this has been problematic. Indeed one of the most significant issues emerging from the Lisbon Water Safety Conference (held in 2008) was the need to establish a more compelling evidence base of benefits associated with WSP implementation (Williams 2008).

This lack of compelling evidence of benefits associated with the implementation of a WSP should not come as a surprise, though. The problem may lie partially in the way WSPs are developed, implemented and evaluated.

THE ISSUE

The process for developing a WSP varies slightly from country to country, but the core components are almost always identical – a detailed system description, thorough risk assessment and prioritisation, Improvement Schedule, Monitoring Plan and Evaluation (Figure 1). The problem lies in the way these steps are applied at the time a WSP is being written. For instance, a review of WSPs written by utilities in Pacific Island Countries shows that a lot of emphasis is placed on writing the document (Steps 1–5); however, little or no emphasis is placed on monitoring and evaluation (M&E) of the WSP system once the document is implemented. Thus the WSP documents were complete and thorough in terms of risk assessment and management, but in terms of monitoring and evaluating the effectiveness of control measures and improvements, the plans were found to be lacking.

Another problem is to do with the lack of an established benchmark to measure the effectiveness of a WSP against. Davison & Deere (2006) suggest that key public health and operational targets should be used to evaluate a WSP. Targets provide a benchmark against which the adequacy of elements of the WSP may be evaluated. A majority of the PIC WSPs reviewed were found to be lacking any measurable performance targets directly associated with the plan. Without these targets, it is almost impossible to conduct a meaningful evaluation. To measure these targets, Key Performance Indicators (KPIs) that help track progress in achieving the set targets need to be identified. These should be directly related to the WSP, covering individual systems and processes and measurable in the short-term.

The final problem lies in deciding how to evaluate these targets. Evaluation of a WSP should go beyond just assessing compliance with water quality targets and should include a more systematic verification and validation of the plan itself as well as verification and validation of individual systems and processes within the overall supply. Compliance monitoring, on its own, is not an appropriate evaluation as it does not truly reflect performance improvement as a result of changes catalysed by a WSP.

DISCUSSION

As described above, the biggest challenge for suppliers with a WSP is to collect the evidence required to demonstrate that it is in fact working. The problems may lie in the way WSPs are developed, implemented and evaluated, and can be addressed as follows:

Figure 1 | The Water Safety Plan process.
1. Public health and/or performance targets should be set during the development of a WSP,
2. KPIs should be identified and described in the WSP,
3. Monitoring of these KPIs should be integrated with the monitoring plan,
4. Documentation and record-keeping should be adequately outlined in the WSP, and
5. The procedures for evaluating a WSP should be included in the plan.

**Setting targets**

Setting targets is a means of prioritising the goals and objectives of a WSP and defining the expected results that may be achieved through implementation of one. The targets of a WSP should not be confused with the overall goals and objectives of the supply. It is essential that suppliers maintain a distinction between the goals and objectives of the supply and those of the WSP because an evaluation of the WSP is not necessarily an evaluation of the overall supply, and vice versa. The goal of a WSP is to improve infrastructure, and optimise systems and processes that would ultimately lead to improved performance of the supply and thus reduced risk to consumers’ health.

WSP targets can be set at two levels: macro-targets – measuring health outcomes and overall performance improvement as a direct result of implementing a WSP; and micro-targets – measuring the improvements in performance of individual systems and processes from implementing a WSP. Table 1 lists possible targets for a WSP.

**Macro-targets**

Davison & Deere (2006) suggest that health based targets should be the basis for all WSPs. In a study done at a German Hospital (Dyck et al. 2007) a clear link between WSP implementation and resulting positive health outcomes (reduction in hospital acquired infections and neonatal sepsis) was established. However, the relationship between a successful WSP and positive public health outcomes are not always very obvious (CDC 2010). In fact, measuring health-based targets may be challenging for some supplies, particularly if access to readily available and reliable data on disease rates in the community are lacking.

‘Evaluating the impacts of a WSP, therefore, requires a much broader analysis than simply looking at health improvements’ (CDC 2010). It is probably simpler to set performance targets that imply a relationship between successful WSP implementation and health outcomes. The association may be indirect, but is not unreasonable and is certainly quite measurable. For example, in Bangladesh risks of microbial contamination were reduced by improving water supply infrastructure and changing to safer sources (Mahmud et al. 2007), seemingly leading to reduced incidence of diarrhoeal disease. Although the health benefits are only implied, the association is reasonable and valid.

**Table 1** | Some examples of WSP targets

<table>
<thead>
<tr>
<th>Water quality targets</th>
<th>Operational targets</th>
<th>Institutional targets</th>
<th>Targets for small supplies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement in regulatory compliance</td>
<td>Supply infrastructure improved</td>
<td>Improved risk communication</td>
<td>Supply achieves water quality target (e.g. 0 E. coli)</td>
</tr>
<tr>
<td></td>
<td>Procedures improved</td>
<td>Knowledge and understanding of risks improved</td>
<td>Sanitary practises around collection, storage and use of water improved</td>
</tr>
<tr>
<td>Source water quality improved</td>
<td>Instruments are accurate and reliable</td>
<td>Operator perceptions and attitudes towards WSPs improved</td>
<td>Infrastructure is sound and well maintained</td>
</tr>
<tr>
<td>Risk of re-contamination in distribution reduced</td>
<td>Operational cost reduced</td>
<td>Operator competency improved via training</td>
<td>Operators identified and trained</td>
</tr>
<tr>
<td></td>
<td>Number of incidents are reduced and response improved</td>
<td></td>
<td>Operators are aware and have ownership of the WSP</td>
</tr>
</tbody>
</table>
Improvement in infrastructure, optimisation of systems and processes, and improved procedures are tangible targets because these are common means of reducing risks associated with the supply and are also relatively easy to measure once a clear M&E framework is in place.

Targets can also be expressed in terms of costs (and benefit) to a supply as a result of implementing a WSP. A cost–benefit analysis of WSP implementation in Palau (Hasan & Gerber 2010) for example shows a return of US$6 worth of health benefits for every US$1 invested in developing, implementing and maintaining a WSP at the Koror-Airai water treatment plant.

Micro-targets

Bartram et al. (2009) proposed that targets should be set for every control measure identified in the WSP. Generally, control measures are identified in a typical risk matrix (Table 2) in a WSP, however the means for ensuring that these measures are operating optimally are rarely included. By assigning targets to each control measure, and measuring their performance towards these targets, their effectiveness can be assessed on a regular basis. For example in Western Australia (Walker 2010), the Water Corporation set targets for chlorination (Contact time (Ct) >15 min for first customer, and >0.2 mg/L Free Available Chlorine (FAC) at furthest point in reticulation) in their WSPs, and measured performance of chlorinators against this target. While initially there was significant variance in Ct and FAC values between sites, this was reduced by adjusting Chlorinator set points, thus achieving more consistent Ct and FAC values between sites.

Performance targets for control measures can be easily integrated into the risk tables (shaded column in Table 2) and in doing so, reasonable benchmarks are established for evaluating the effectiveness of each control measure.

Setting targets for small supplies

Particular care must be taken when setting targets for small supplies. It may not be possible for small supplies to measure performance targets for every control measure identified in the WSP; however, simple, innovative, measurable targets may be devised that could indirectly measure performance of those control measures. These could be quantitative or qualitative or a bit of both. Mahmud et al. (2007) describe how a grading system based on the level of E. coli in village wells and bores was used as targets for small supplies in Bangladesh. Supplies were graded from A to E, with A signifying best quality supply (i.e. 0.0 E. coli per 100 ml) and E grade indicating an extremely hazardous supply (>1,000 E. coli per 100 ml). By the end of the first phase, the proportion of supplies previously in the E grade dropped by 20%. For a supply that previously was in the extremely hazardous category but managed to improve and achieve a better grade, the change is quite obvious and the evidence that the WSP was effective is quite compelling.

Defining KPIs

Once targets have been established, a system of measuring progress and/or performance against each target must be put in place. This situation is commonly achieved by identifying performance indicators. In a WSP context, it is common to measure indicators based on drinking water quality. However, water quality indicators are not always the true indicators of performance. The scope should be broadened to include other, usually inconspicuous indicators, such as

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Event</th>
<th>Risk</th>
<th>How would you know this control measure is working? (Performance Target)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbial contamination in distribution</td>
<td>Cross contamination through leaks in the pipework</td>
<td>Likely Medium High</td>
<td>Yes. FAC residual maintained in distribution FAC in distribution maintained above 0.2 mg/L</td>
</tr>
<tr>
<td>Low pressure in distribution</td>
<td>Leaking reservoirs</td>
<td>Possible Major Very high</td>
<td>Yes. Reservoir in good condition Reservoir structure in sound condition (no cracks or leaks)</td>
</tr>
</tbody>
</table>
cost, institutional awareness and communication, credibility of instrumentation, staff competency, clarity of procedures and completion of items in the improvement schedule, among others. Examples of possible KPIs for large and small supplies are listed in Table 3.

Additionally, KPIs can be assigned to monitor performance of each control measure identified in the WSP and these can be easily incorporated in the risk assessment matrix. This is particularly useful in monitoring the performance of existing control measures to ensure they are functioning optimally. Table 4 describes how this may be achieved.

### Setting KPIs for small, community-owned supplies

Small supplies are generally less complex and often lack the resources and technical know how available to larger utility supplies, therefore KPIs for small community-owned supplies should be simple, low-cost and appropriate for the size and type of supply. Lessons learned from Bangladesh (Mahmud et al. 2007) demonstrate how simple *E. coli* monitoring of dug-out wells coupled with monitoring of sanitary practises in communities provided the evidence to indicate WSP success. Monitoring that requires analysis in a laboratory involves costs that are often beyond the means of small communities. Innovative alternatives need to be considered. One monitoring tool that has been quite successful in rural villages in Fiji is the Hydrogen-Sulphide (H$_2$S) paper-strip test (Live and Learn Environmental Education 2008). This simple and low-cost, presence-absence test for bacteria (including *coliiform*) was used successfully to mobilise rural communities in the interior of Fiji’s main island to better manage their drinking water supplies. Simple visual checks on key supply infrastructure such as the source, the storage tanks, treatment (if any) and pipe-works are also good KPIs for a small supply. Issues around small, community-owned supplies are often to do with the attitudes, behaviour and practices of individuals. Therefore monitoring of behavioural changes such as sanitary practise, hand-washing and proper household storage of water are also reasonable KPIs for small supplies.

### Monitoring KPIs

Monitoring of KPIs is essential to build a body of evidence that demonstrates whether targets are achieved or not. It relies on establishing the ‘what’, ‘how’ and ‘when’ principles.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Some examples of WSP KPIs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water quality KPIs</strong></td>
<td><strong>Operational KPIs</strong></td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>FAC/UVT</td>
</tr>
<tr>
<td>pH</td>
<td>Flow</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Pressure</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>Calibration</td>
</tr>
<tr>
<td>Transgressions</td>
<td>Alarms</td>
</tr>
<tr>
<td></td>
<td>Pumps</td>
</tr>
<tr>
<td></td>
<td>Reservoir level</td>
</tr>
</tbody>
</table>

UVT = UV Transmittance.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Setting monitoring KPIs for control measures in risk assessment tables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Is this risk under control?</strong></td>
<td><strong>Performance target</strong></td>
</tr>
<tr>
<td>Yes. FAC residual maintained in distribution</td>
<td>FAC in distribution maintained above 0.1 mg/L</td>
</tr>
<tr>
<td>Yes. Reservoir in good condition</td>
<td>Reservoir structure in sound condition (no cracks or leaks)</td>
</tr>
</tbody>
</table>
The monitoring plan in a WSP documents the procedures and strategies for monitoring the various aspects of the supply to maintain confidence in the safety of the supply and should include the following information:

- What to monitor?
- How to monitor?
- When (or how often) to monitor?

Typically, the monitoring plan mirrors the routine monitoring regime already established by supplies as part of compliance monitoring. However, it is quite easy to integrate aspects of monitoring in the risk assessment matrix (Table 4).

For each KPI identified in the WSP, it is important to define the critical limits. Critical limits (or trigger limits) are useful indicators of any deviation in the systems and processes. These can be readily interpreted at the time of monitoring and corrective action (Table 4) can be taken in response to a deviation in time to prevent unsafe water being supplied to consumers. For example the critical limit for residual chlorine in the distribution zone may be 0.1 mg/L FAC. If the FAC level falls below the critical limit then this indicates that corrective action is required. The corrective action may involve adjusting the chlorine dosage.

### Table 5 | Some examples of WSP documents and records

<table>
<thead>
<tr>
<th>Documents</th>
<th>Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations manual (Methods and standard</td>
<td>Monitoring records (water quality results,</td>
</tr>
<tr>
<td>operating procedures, hygiene practises, etc.)</td>
<td>sampling logs, visual inspection logs, etc.)</td>
</tr>
<tr>
<td>Maps, schematics and flow charts</td>
<td>Calibration records</td>
</tr>
<tr>
<td>Organisational structure and staffing</td>
<td>Staff training and competency records</td>
</tr>
<tr>
<td>Contingency plans</td>
<td>Incident/event records</td>
</tr>
<tr>
<td>Improvement schedule</td>
<td>Consumer complaints</td>
</tr>
<tr>
<td>Monitoring plan</td>
<td>Sanitary surveys</td>
</tr>
<tr>
<td></td>
<td>Improvement progress reports</td>
</tr>
</tbody>
</table>

**Verification**

In general terms, *Verification* can be described as a system of ‘determining that a procedure is performed according to the intended design’ (Sperber 1998). In the WSP context however, verification means determining that the WSP system is in compliance with the WSP plan.

In New Zealand, the Health (Drinking Water) Amendment Act 2007 (HDWAA) sets the framework for verification of a WSP (NZMoH 2002; Barrott & Webster 2008) and a technical manual developed by the NZMoH ensures a standardised approach to auditing the implementation of a WSP. These auditing functions typically rest with the local Public Health Units (PHUs) as the regulatory agencies.

As is the case in New Zealand, the WSPs should ideally be verified independently by an external auditor (such as the health agency). However, these auditors will need to be appropriately trained and qualification requirements should be established. For example, most WSP evaluation in New Zealand is done by a Drinking Water Assessor (DWA), a specialised regulatory officer under the HDWAA, who is appropriately trained and is required to undergo a stringent accreditation process.
An auditing plan should be developed that includes the time and frequency of the audits, scope of the audit and assessment and reporting criteria. Processes, specifying corrective actions to be taken, should also be in place for when the WSPs are not found adequate, including timeframes for rectifying the identified issues.

The HDWAA requires that a WSP must be implemented within 30 days following approval of the plan by a DWA. A DWA may conduct an ‘implementation assessment’ of the WSP – usually a year after approval of the plan and annually thereafter. This implementation assessment is a thorough and systematic external verification of the WSP which involves careful evaluation of the systems in place and how these align with the plan itself.

**Validation**

Generally speaking, *validation* is the ‘determination that the intended result has been achieved’ (Sperber 1998). It is common to interpret this as meaning ‘achieving compliance with standards and/or legislation’, which is often the most popular measure suppliers rely on to demonstrate that supply performance is satisfactory and therefore the WSP must be effective. However, in the context of a WSP, *validation* goes beyond just achieving compliance. It is the determination that the WSP is accurate in all its elements and that the indicated hazards and risks have been adequately managed and the control measures have been effective. This situation means a thorough ‘internal’ assessment of all operational and management systems and processes against set performance targets. In New Zealand, validation is commonly undertaken by the suppliers themselves.

**CONCLUSION**

The concept of WSPs was formally introduced in 2004 through the WHO Guidelines for Drinking Water Quality (3rd edition). Half a decade later, suppliers and WSP practitioners are still struggling to gather evidence to show that the benefits attributed to this approach are real and not just hypothetical. This apparent lack of a compelling body of evidence of benefits from WSP implementation could be a result of inadequate – or a complete lack of – an effective M&E process.

It should be recognised from the outset that evaluation of a WSP is not the same as evaluation of a supply itself, therefore performance measures employed for evaluating the overall supply performance do not necessarily indicate the performance of a WSP, and any benefits to the supply may not necessarily be due to implementation of a WSP. To link water supply benefits back to a WSP, strategic M&E components need to be built into the document itself making it a self-evaluating plan.

Setting WSP targets is a good starting point for an M&E process. The targets identified should relate to the goals and objectives of the WSP. To monitor the progress to achieving those targets, indicators need to be identified. These indicators need to be realistic, tangible, directly related to the WSP, within the resources and competencies of the supplier, and should be measurable in the short, medium and long-term. The KPIs should ideally be quantitative; however, qualitative indicators are also useful in measuring change, especially for small supplies.

Finally, suppliers need to establish a systematic monitoring regime for these KPIs and their performance should be diligently documented and records well maintained. This ensures that a body of evidence is available for a meaningful evaluation to take place through internal processes (review or validation) or external audits (verification) or ideally a combination of both.

Collecting evidence to demonstrate the effectiveness of a WSP is not as difficult as it may seem. With a little bit of forward planning, careful selection of targets and KPIs, defining monitoring regimes and diligent record-keeping it is quite possible to build a body of evidence to evaluate WSPs. But it does involve going back to the basics and getting the process right from the very initial stages of developing a WSP.

**REFERENCES**


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