A comparative assessment of institutional frameworks for managing drinking water quality
Zarah Rahman, Jonny Crocker, Kang Chang, Ranjiv Khush and Jamie Bartram

ABSTRACT
The global burden of disease attributable to contaminated drinking water calls for effective strategies for ensuring drinking water quality. To characterize institutional and policy approaches towards water quality management, we compared national and sub-national institutional frameworks for drinking water provision and management in nine developing countries, focusing on roles, responsibilities and capacity for water quality monitoring. Responsibilities for operational and surveillance (compliance) water quality monitoring of formal urban water supplies are typically well defined, with attention placed on both activities. Legal requirements for surveillance monitoring of community and smaller supplies are generally also in place, however, standards for operational monitoring vary considerably between countries. In practice, resources and capacity for consistent operational and surveillance monitoring of rural and informal urban supplies are limited. To improve oversight and management in these settings, we hypothesize that surveillance agencies could increase the use of audit-based water quality data collection from formal urban water suppliers and target the resulting efficiency gains towards increased direct surveillance of rural and informal water supplies. In addition there is a need for capacity building and technology development that supports increased operational monitoring and data reporting from resource-poor settings.

Key words | institutional arrangements, operational monitoring, surveillance, water quality, water quality testing

INTRODUCTION
Health and economic consequences of unsafe water

The burden of water-borne disease on public health and economic development is well recognized: diarrheal diseases are the second leading contributor to the global disease burden (as measured by Disability Adjusted Life Years – DALYs), and the majority of the diarrhea disease burden occurs in the least developed countries due to inadequate water and sanitation infrastructure and services (WHO 2008a). Hutton et al. (2007) estimate that the global economic benefits of meeting the Millennium Development Goal for water, including reduced health care costs and increased productivity, would total US $23 billion (2007).

The magnitude of the health and economic impacts that might be realized by reducing the prevalence of diarrheal disease accounts for the emphasis placed on improving access to safe water and improved sanitation facilities in the United Nations’ Millennium Development Goals and in international and national development programs (WHO 2008b).

Bacterial, viral and protozoan pathogens entering drinking water supplies through fecal contamination are a primary cause of diarrhea (Leclerc et al. 2002). Consequently, ensuring the quality and safety of drinking water by protecting water supplies from fecal contamination, by treating and disinfecting supplies to remove microbial
pathogens, and by monitoring water quality are fundamental public health priorities.

**Water quality monitoring best practices**

According to the WHO *Guidelines for drinking-water quality, 3rd edition* (GDWQ) monitoring of drinking water quality through the complementary activities of operational monitoring (or water quality control) by the water supplier and surveillance by an independent agency is fundamental to the delivery of safe drinking water to consumers (*WHO 2004*). Regular operational monitoring by suppliers is considered a key tool for maintaining process control and verifying water quality. Optimal operational monitoring triggers immediate corrective actions when test results indicate that a water supply system is compromised because a necessary process is out of its efficient operating range or because final water quality does not meet requirements. Operational monitoring should be carried out frequently, at the local level, and can often be limited to a set of critical parameters such as pH, residual chlorine, turbidity, *Escherichia coli* and observable factors related to the integrity of the system (*Lloyd & Bartram 1991; WHO 2004*). The frequency of operational monitoring and the number of samples tested should be determined by the population served and the nature of the control point concerned. The GDWQ also recommend that responsibility for operational monitoring be assigned to water suppliers in national legislation (*WHO 2004*).

Surveillance or ‘compliance’ monitoring, requires an agency that is independent of water service providers to assess the compliance of all drinking water supplies, including unimproved and untreated sources, with national standards (*WHO 2004*). The independence of surveillance agencies insures against potential reporting biases that might arise during self-monitoring by water suppliers. Unlike operational monitoring, surveillance monitoring can be infrequent but should include a comprehensive evaluation of the adequacy of supplies, including quality, quantity, accessibility, affordability and continuity (*Lloyd et al. 1987; Lloyd & Bartram 1991; WHO 2004*). Drinking water surveillance is ideally linked to resource allocation, planning for improvement of water supply systems, and oversight of suppliers.

There are two approaches to water quality surveillance: a direct assessment and an audit-based approach. When implementing direct assessments, the surveillance agency collects and analyzes water quality samples. In contrast, in an audit-based system, the surveillance agency reviews records, including water quality monitoring results, submitted by the supplier or by a third party laboratory undertaking analysis on behalf of the supplier. Surveillance agencies that employ an audit-based approach must verify the reliability of data (*Howard 2002*). For example, the surveillance agency may review and approve the suppliers’ water quality control plans, make periodic site visits to review records and ensure that the suppliers are carrying out operational monitoring and implementing safeguards in the production and distribution of water (*WHO 2004*).

Sanitary inspections, which are on-site evaluations of the safety and integrity of water supplies, are an important component of both operational monitoring and water supply surveillance (*Lloyd & Bartram 1991; Bartram 1999; WHO 2004*). However, in this study, we do not analyze the regulation or implementation of sanitary inspections.

**Urban versus rural settings**

Water supply types and management systems vary widely within both urban and rural settings. For example, regulated utilities operating piped networks serve many urban areas (*Montangero 2009; WHO & UNICEF 2010*). However, the urban poor, many of whom live in informal settlements and peri-urban areas, often do not have access to utility networks; and commonly rely on supply from water vendors, household wells, handpumps, boreholes, standpipes, and small private systems, with varying degrees of official recognition and regulation (*Aguilar & López 2009*).

According to the 2010 Joint Monitoring Program (JMP) report, overall access to improved drinking water sources is substantively lower in rural areas than in urban areas (*WHO & UNICEF 2010*). Rural areas are commonly served by a mix of: small utilities (often the municipal government); community supplies managed by (formally-established) water committees; and community or household sources lacking formal management structures. These community supplies include boreholes, wells, protected springs, hand pumps and small piped systems (*WHO 2004; Montangero 2009*). As noted above, these supply types and their associated management systems are also often found...
in small towns, and peri-urban settlements (Howard et al. 1999; Montangero 2009).

Here we use the term ‘utilities’ to refer to licensed and (in principle) regulated water suppliers (public or private) that manage distribution networks with household and/or public connections. Licensed water vendors and established community water committees are also considered formal water suppliers. We distinguish these from informal supplies, which include unlicensed vendors, community supplies without established management structures and individual household sources.

Comparing and contrasting institutional frameworks

The provision of safe drinking water is linked to diverse sectors and disciplines: environmental and public health, engineering, and both rural and urban development. Input and action at national and sub-national levels and across numerous stakeholders, including administration and policy, public health officials, and urban and rural water providers is, therefore, required to achieve sustainable access to safe drinking water (WHO 2004). For the following water quality monitoring activities, clear assignments of responsibility and effective coordination between stakeholders are necessary:

- development of appropriate regulations for water quality monitoring and enforcement;
- provision of adequate financial and personnel support for water monitoring programs;
- analysis interpretation and communication of water quality data; and
- committed public health and water management responses to water quality data (developed from WHO 2004).

Ensuring the proper implementation of these water quality management activities requires supportive institutional frameworks and policy environments. This study compares and contrasts institutional frameworks for water quality management and broadly characterizes the nature of monitoring activities in a range of developing country settings. We also evaluate consistency with WHO guidelines, as these are intended to be applicable to all water supplies. WHO notes ‘this would normally embody different approaches to situations where formal responsibility for drinking-water is assigned to a defined entity and situations where community management prevails’ (WHO 2004, 31). Given the differences in water supply governance between rural, peri-urban, and urban areas, this recognition that water quality management approaches must be tailored to the management context is critical, and in this paper we explore a range of governance models.

METHODS

We analyzed institutional frameworks for drinking water quality monitoring and management in nine countries: Bolivia, Brazil, Cambodia, Ecuador, Lao PDR, Malawi, Peru, Sri Lanka, and Vietnam. The countries analyzed range from low income to upper middle income, based on World Bank income level categorizations for 2008 and span the major developing country regions including South America, Southeast Asia, South Asia and sub-Saharan Africa (World Bank 2010). We do not assess all possible water management frameworks, nor attempt to quantify the impacts of different frameworks on water quality and public health. Rather, for a diverse set of countries, we compare and contrast existing institutional frameworks in both rural and urban areas.

We developed institutional framework ‘maps’, depicting institutional roles at three levels: (1) drinking water policy development; (2) surveillance and regulatory compliance assessment; and (3) service provision and operational monitoring (Figure 1a–i). Each country’s institutional map displays the primary institutions involved in drinking water delivery and operational and surveillance water quality testing for both urban and rural areas, but we do not attempt to list in detail all entities at each administrative level. Arrows indicate relationships between institutions and dashed lines indicate where an activity is mandated in standards but not carried out in practice. Institutional maps are displayed in income level groupings, beginning with low income and ending with upper middle income. Analysis of governance structures and institutional arrangements for public service delivery in general and in relation to water management in particular are common (Alaerts 1997; Jaspers 2003; Mitchell 2005). However, we see few examples of the method of
institutional mapping employed here. Examples in the water sector include institutional mapping as a basis for improving integrated urban water management (Da Silva et al. 2008) and as background for evaluating costs in the water sector (WASHCost India 2008). This study appears to be a novel application of institutional mapping specifically to water quality monitoring.

We analyzed the institutional maps, summarizing their content in a tabular format, and discussing patterns that emerge in the division of responsibilities, gaps in coverage, and factors that influence the actual scope of monitoring activities. Recognizing the potential influence of level of economic development, we evaluate observed outcomes with reference to the relative income levels of the countries analyzed.

Our maps are based on published reports, ‘gray literature’, policy documents and interviews with relevant water sector actors carried out by the Aquaya Institute and the University of North Carolina (UNC) as an activity of the Aquatest Research and Development Program, an initiative to design water quality management tools that are optimized for resource-poor settings (Rahman et al. 2010). Interviewees included representatives of national and regional offices of ministries of health, water ministries, water utilities, water sector regulators, academic institutions and UN family organizations such as UNICEF, UN HABITAT, and the Water and Sanitation Program of the World Bank. The institutional maps identify the major groups involved in drinking water provision and water quality management. However, they do not illustrate in full detail institutions and activities at every administrative level and as such, may not reflect all the complexities or subtleties of activity on the ground.

A key function of policy and legislation is to clarify roles and responsibility for sector agencies including responsibility for surveillance and operational monitoring. Thus water sector and water quality policy, legislation and standards (Table 1) were critical for developing these institutional maps.

RESULTS

Figure 1 (a–i) presents the institutional maps for water service provision and water quality management in both the rural and urban water sectors for each country studied. Arrows indicate relationships between institutions and dashed lines identify surveillance and operational monitoring activities that are mandated in standards or policies but do not appear to be carried out in practice. Institutional maps are displayed in income level groupings, beginning with low income and ending with upper middle income. Table 2 presents a summary of the characteristics of each country’s institutional framework for water quality monitoring alongside income level classifications.

Operational monitoring: actors and responsibilities

Across the nine countries that we surveyed, water utilities, usually serving urban areas, are the primary institutions that conduct operational monitoring. Although all standards reviewed indicate that water suppliers are legally responsible for operational monitoring, the definition of the term water supplier is generally vague in these documents, making it difficult to determine whether requirements for operational monitoring apply beyond utilities to all entities providing water: for example, community water committees, water vendors, and households.

In some countries, such as Vietnam and Lao PDR, the standards require operational monitoring for all types of providers (Figure 1g,b) (Ministry of Health Department of Hygiene and Prevention Lao PDR 2005; Ministry of Health General Department of Preventive Medicine and Environment Vietnam 2009). In contrast, Code of Practice for Drinking Water Quality published by the Ecuadorian Institute for Standardization (2005) limits the requirement for operational monitoring in Ecuador to formal Potable Water Service Providers (‘Entidades Proveedoras de Servicios de Agua Potable’) (Figure 1e). The Code of Practice for Drinking Water Quality states that Ecuador’s health authority is responsible for monitoring of water supplies managed either by rural Potable Water Service Providers or by non-professional community water committees (Juntas Administradoras de Agua Potable’). Bolivia’s National Regulations for the Control of Water Quality for Human Consumption (Ministry of Services and Public Works Vice-ministry of Basic Services Bolivia 2005) assign responsibility for operational monitoring to Potable Water and Sewerage Providers (‘Entidades Prestadoras de Servicios de Agua Potable y Alcantarillado Sanitario’), which are
defined as any organization with a recognized legal structure that is engaged in providing drinking-water (Figure 1d). Ultimately, despite these different regulatory requirements, our observations suggest that only utilities currently conduct operational monitoring in most countries; while operational monitoring of informal supplies in peri-urban and urban areas, or by community water committees in rural areas, is rare.

The GDWQ and many national water quality standards indicate that operational monitoring should be carried out for a limited set of critical parameters that screen for failures in source protection, treatment and distribution systems (Lloyd & Bartram 1991; WHO 2004; Ministry of Health Department of Hygiene and Prevention Lao PDR 2005; Ministry of Health Directorate of Environmental Health Peru 2006; Ministry of Health General Department of Preventive Medicine and Environment Vietnam 2009). Interviews and site visits confirmed that many utilities do limit frequent operational monitoring to testing of critical parameters, generally pH, turbidity, and free chlorine, which can be measured using simple, affordable means, including field tests.

Other than utilities in major urban centers of the developing world, such as Quito, Lima, Vientiane, and Phnom Penh, most utilities do not have the facilities or training to test for indicators of fecal contamination such as E. coli, despite high public health priority given to management of fecal contamination. For example, Ecuador’s Code of Practice on the Drinking Water Quality, quotes the WHO GDWQ in stating that ‘The severity of the possible consequences of microbial presence is such that its control and supervision should

Table 1 | Water quality policy, legislation and standards reviewed

<table>
<thead>
<tr>
<th>Country</th>
<th>Document title</th>
<th>Published by</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolivia</td>
<td>NB512/512R: National Regulations for the Control of Water Quality for Human Consumption</td>
<td>Ministry of Services and Public Works, Vice-ministry of Basic Services</td>
<td>2004/2005</td>
</tr>
<tr>
<td>Ecuador</td>
<td>INEN 1108. Ecuadorian Technical Standard: Drinking Water: Requirements</td>
<td>Ecuadorian Institute for Standardization (INEN)</td>
<td>2005</td>
</tr>
<tr>
<td>Peru</td>
<td>Code of Practice on Drinking Water Quality</td>
<td>Ministry of Health Public Health Ecuador</td>
<td>2008</td>
</tr>
<tr>
<td>Peru</td>
<td>Regulation of the official physical, chemical and bacteriological requirements that drinking water should comply with to be considered potable.</td>
<td>Ministry of Health Peru</td>
<td>1946</td>
</tr>
<tr>
<td>Brazil</td>
<td>Drinking Water Quality Regulation (not officially signed into law)</td>
<td>Ministry of Health Directorate of Environmental Health (DIGESA)</td>
<td>2006</td>
</tr>
<tr>
<td>Peru</td>
<td>Ordinance No. 518</td>
<td>Ministry of Health Office of the Minister Brazil</td>
<td>2004</td>
</tr>
<tr>
<td>Vietnam</td>
<td>National Technical Regulations on Drinking and Domestic Water Quality</td>
<td>Ministry of Health General Department of Preventive Medicine and Environment Vietnam</td>
<td>2009</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>Decision on the Management of Quality Standards for Drinking Water and Household Water Supply</td>
<td>Ministry of Health Department of Hygiene and Prevention Lao PDR</td>
<td>2005</td>
</tr>
<tr>
<td>Malawi</td>
<td>National Water Policy</td>
<td>Ministry of Irrigation and Water Development Malawi</td>
<td>2005</td>
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Cambodia: Cambodia’s Department of Potable Water Supply of the Ministry of Mines, Industry and Energy (MIME) develops policies and plans for urban water supply, supervises public utilities and conducts oversight monitoring of both public and private piped water utilities. Private utilities serve both rural and urban population centers. Few of Cambodia’s public water utilities have capacity for carrying out on-site operational testing for the full range of operational parameters. As a result, a number of public utilities only test for residual chlorine on-site and in some cases send samples to outside laboratories for microbiological testing. The majority of private utilities do not appear to carry out any operational testing. Private utilities are currently only monitored through MIME’s oversight monitoring program. Whether the requirement for operational testing, as stated in MIME’s Drinking Water Quality Standard, applies to both public and private utilities is unclear. The Department of Rural Water Supply of the Ministry of Rural Development (MRD), which supports rural source development, generally requires testing of rural water sources at installation; however, there is no regular operational monitoring of these supplies. Cambodia lacks an independent surveillance agency.

Lao PDR: The Department of Housing and Urban Planning of the Ministry of Public Works and Transport is responsible for urban service provision in Lao PDR, and the National Center for Environmental Health and Water Supply (Nam Saat) of the Ministry of Health supports rural infrastructure development and maintenance of rural supplies. The Water Supply Regulatory Committee (W SRC), established in 2005, regulates the urban water sector through its secretariat, the Water Supply Regulatory Office (WASRO). Major cities are served by provincial water utilities. In addition Nam Saat, through its provincial offices, carries out surveillance of both urban and rural supplies. Lao PDR's water quality regulations suggest that operational monitoring should be carried out for all supplies, including community and household supplies; however, in practice operational monitoring is limited to urban utilities (Ministry of Health Lao PDR 2005).
Bolivia: Until recently, the Superintendent of Basic Sanitation (SISAB) was responsible for regulating water and sanitation service provision in Bolivia. However, SISAB was replaced in 2009 by a new independent Authority of Oversight and Social Control of Water and Basic Sanitation (AAPS), which now oversees the water sector. Further research is required to understand the motivation for, and impact of, this recent change. Despite legislation stating that all water service providers, including both utilities and community water committees, should carry out operational testing in Bolivia, testing is limited in practice, to well-resourced urban utilities. Throughout the country, Departments of Health Services or SEDES are responsible for water quality surveillance.

Malawi: The Department of Water Supply of the Ministry of Irrigation and Water Development is the primary ministry responsible for water service provision, water sector policy and regulation in Malawi. Five parastatal government Water Boards under the jurisdiction of the MoIWD provide water services in Malawi’s major cities, towns and market centers. District Assemblies are responsible for managing rural supplies, although these are often developed by multiple actors including private contractors, and NGOs in addition to local government itself. Water Boards generally have laboratories for carrying out operational monitoring in their service areas. The Water Quality and Pollution Control Division of the Ministry of Irrigation and Water Development (MoIWD) has laboratory facilities in each of Malawi’s three administrative regions. MoIWD carries out direct operational monitoring of rural supplies and audits the water quality testing records of the Water Boards. Malawi lacks an independent surveillance agency.
**Figure 1e** | Ecuador: Municipal water utilities and community water committees respectively manage urban and rural supplies in Ecuador. Municipal utilities vary in their capacity for on-site operational testing and local water committees do not generally carry out operational monitoring. The Ministry of Health, through their Provincial Health Departments and local staff should conduct direct surveillance of both urban and rural water supplies and also provide technical support to community water committees. Capacity for surveillance varies greatly by province. Where utilities have strong capacity for operational monitoring, the Provincial Health Departments employ an audit-based approach for surveillance monitoring.

**Figure 1f** | Sri Lanka: The Ministry of Water Supply and Drainage and its implementing arm, the National Water Supply and Drainage Board (NWSD) are responsible for in both urban and rural water service delivery in Sri Lanka. However, NWSD is increasingly promoting private sector participation in urban areas and is encouraging local authorities, Community Based Organizations (CBOs), and entrepreneurs to take over the management of rural supplies (National Water Supply and Drainage Board Sri Lanka 2002). Although the Ministry of Health is responsible for water quality surveillance in Sri Lanka, the Ministry does not have sufficient laboratory facilities to fully support such testing, whereas NWSD has good laboratory infrastructure. As a result, NWSD not only carries out operational testing of their own supplies, but also analyzes samples submitted by public health inspectors from alternative supplies. Data from NWSD’s testing is submitted to the MOH to satisfy audit-based surveillance requirements.
Vietnam: Vietnam’s provincial public utilities, the primary service providers in urban areas, generally have capacity to carry out basic operational testing. Rural water supply managers, which range from local authorities, community water cooperatives to private enterprises, do not appear to conduct operational testing. The Ministry of Health, through the Provincial Preventative Medicine Centers (PMCs), is responsible for water quality surveillance but capacity is limited. The PMCs rely on fees from water utilities and other government agencies to support surveillance monitoring.

Brazil: Water suppliers in Brazil are mandated through national regulations to carry out operational testing. Most formal suppliers are able to comply with this requirement. The National Health Foundation or FUNASA, a department within the Ministry of Health, provides support for operational monitoring to small municipalities that lack sufficient internal capacity. Alternative supplies, without formal management, such as household wells and community supplies, also receive support from municipalities to carry out operational testing. The Centers for Health Surveillance of the State Health Secretariats and municipal health departments conduct surveillance.
always be a priority and must never be compromised’ (Ministry of Public Health Ecuador 2008). Yet we observed that in many cases microbial analysis only occurs when samples are sent to external laboratories, usually to fulfill regulatory (compliance) requirements. In addition to their operational monitoring, larger utilities with substantive laboratory facilities also test less frequently for parameters such as nitrate, fluoride, arsenic, manganese for regulatory purposes. Overall our findings show that microbial analysis occurs less frequently than physical and chemical analysis.

We also observed that capacity for operational monitoring of non-microbial parameters by utilities outside of major and capital cities varies considerably. Many utilities serving intermediate and small towns in Ecuador, Peru, Bolivia, and Cambodia do not have facilities for even basic physical and chemical sampling and testing. For example, nine out of a total of sixteen small public utilities in Cambodia have on-site laboratories, while the remaining public utilities and the numerous (~270) private piped suppliers (both licensed or unlicensed) lack laboratories and testing equipment.

In Brazil, we observed an unusual example of institutional support for operational monitoring by small suppliers. The National Health Foundation (FUNASA) supports operational monitoring among small municipal suppliers; and municipal governments are required to assist with operational monitoring for community or household supplies that lack professional management (Figure 1h).

SURVEILLANCE MONITORING: ACTORS AND RESPONSIBILITIES

In the majority of countries analyzed, responsibility for water quality surveillance lies with health authorities (Figure 1; Table 2). Regional public health departments in Bolivia, Brazil, Ecuador, Lao PDR, Peru, and Vietnam serve as independent, external auditors of the quality of water service provision, and water quality standards and policies in these countries clearly allocate responsibility for surveillance to specific health system institutions (Figure 1). The majority of these health agencies rely on a direct surveillance approach for all water supplies. Ecuador's Ministry of Health utilizes an audit-based approach to surveillance of water utilities that have a strong capacity for operational monitoring, although they maintain direct surveillance of

[Figure 11 | Peru: While Peru's largest utilities have laboratory facilities and technical staff for carrying out operational testing, smaller municipal suppliers often do not. Water Suppliers in Peru are regulated by the National Superintendent of Sanitation Services (SUNASS), an autonomous regulatory body under the Office of the Prime Minister established to ensure that service providers meet performance standards (Salazar 2010). Regional departments of the Directorate of Environmental Health (DIGESA) of the Ministry of Health not only carry out surveillance but also provide technical support to the local water boards that manage rural supplies. It is difficult to determine whether the requirement for operational testing in Peru's new draft standards applies to these local water boards; however, they generally lack capacity to test their supplies.]
other supplies through their provincial laboratory facilities (Figure 1e).

As highlighted in Table 2, Malawi and Cambodia lack independent surveillance agencies. Nevertheless, in both countries, government ministries responsible for drinking water supply do carry out oversight monitoring of the supplies under their jurisdiction (Figure 1a,c). In Malawi, drinking water is provided through a combination of parastatal Water Boards, which serve Malawi’s major cities and regional market centers, and rural water schemes that are managed by district assemblies. The Ministry of Irrigation and Water Development (MoIWD), which is responsible for overall water sector policy and ensuring service provision, tests rural supplies directly and audits operational monitoring reports submitted by the Water Boards (Figure 1c). MoIWD’s dedicated Water Quality and Pollution Control Department conducts testing at regional laboratories.

In Cambodia, the Department of Potable Water Supply of the Ministry of Mines, Industry and Energy (MIME), which is responsible for regulating piped service provision, also plays an oversight monitoring role (Figure 1a). MIME independently collects and analyzes water samples from public and licensed private piped supplies. In the case of public suppliers with internal testing capacity, this surveillance activity complements operational monitoring carried out by the supplier. However, operational monitoring by both public and private utilities is limited. While MIME’s testing ensures some oversight of piped supplies (although not fully independent), it does not reach beyond piped systems. As the majority of Cambodia’s rural services are provided by private piped networks or non-piped systems, the majority of Cambodia’s rural water supplies are tested rarely.

Sri Lanka presents a hybrid form of surveillance. Sri Lanka’s Ministry of Health and Nutrition is the country’s
surveillance body for water quality, however, it does not have sufficient laboratory infrastructure to conduct independent comprehensive surveillance monitoring. In order to achieve monitoring goals, the Ministry of Health and Nutrition utilizes the National Water Supply and Drainage Board (NWSDB)’s laboratory facilities with Public Health Inspectors collecting samples from community managed supplies and delivering them to NWSDB laboratories for analysis (Figure 1f). The Ministry of Health and Nutrition then audits results from all tests carried out at NWSDB’s laboratories, including results from both NWSDB and community managed supplies.

Even where institutional responsibility for surveillance is well established, surveillance agencies are commonly constrained by limited funding and human resources. For instance, Vietnam’s provincial health departments have trained staff and laboratory equipment for water quality testing but lack sufficient funding for regular sample collection and analysis. As a result, some provincial health departments appear to only carry out testing when water service providers or the provincial Center for Rural Water Supply and Environmental Sanitation (P-CERWASS) offices send in samples and pay a fee for the analysis. As a result, surveillance is sporadic, especially in rural areas. Low and lower middle income countries such as Bolivia, Ecuador, Lao PDR and Sri Lanka, as well as upper middle income countries such as Peru and Brazil, all experience challenges in reaching isolated rural areas with water quality surveillance programs (Table 2).

In several countries, health authorities have dual responsibility for water quality surveillance and for providing support to community water supply managers in rural areas. For example, in Lao PDR the Center for Environmental Health and Water Supply (Nam Saat) is responsible for ensuring access to safe water in rural areas and for surveillance of all drinking water supplies. Similarly, the regional health departments in Ecuador and Peru actively support community water groups that manage rural supplies. In rural areas, water quality testing for surveillance purposes is often the only source of water quality information and, although infrequent, can directly motivate improved water management. Where rural surveillance is weak, source testing at the time of installation may be the only occasion when the quality of rural supplies is evaluated.

OTHER REGULATORY BODIES

In addition to water service providers and health sector surveillance agencies, our research identified independent, third party regulators as an additional authority involved in water quality management in some countries. These regulators, such as the National Superintendent of Sanitation Services (SUNASS) in Peru and the Water Supply Regulatory Committee (WSRC) in Lao PDR oversee diverse aspects of the provision of services by water utilities (Figure 1i,b). In fact, in some cases these regulators play a surveillance role for urban supplies, as defined by the WHO (2004); ensuring that suppliers meet water quality standards, and comply with tariff regulations, environmental protection, and other industry standards related to quality of service. Regulatory agencies may also be charged with strengthening utilities and ensuring their financial viability.

In Peru, SUNASS plays a central role in water quality management for piped urban supplies. Every three months, utilities are required to submit water quality reports to SUNASS, which subsequently alerts the DIGESA when water quality data indicate a health risk. In addition, SUNASS conducts spot checks of the quality of service through annual testing for a limited number of water quality parameters. Peru’s water quality regulations state that, together, operational monitoring by utilities and audits by SUNASS constitute ‘water quality control’ (Ministry of Health Directorate of Environmental Health Peru 2006). Peruvian standards indicate that although SUNASS’ activities ensure frequent assessment of the quality of service provision, they do not eliminate the need for independent surveillance by DIGESA. SUNASS currently only regulates suppliers in large urban centers, but will soon expand its jurisdiction to include utilities in smaller cities and towns (Salazar 2010).

In Lao PDR, WSRC sets performance obligations, undertakes tariff reviews, supports provincial authorities in issuing licenses to utilities, and otherwise provides guidance and oversight of the sector (Water Supply Regulatory Committee 2009). However, WSRC views water quality reports infrequently and, it appears, primarily in order to produce an
annual sector report. Both SUNASS in Peru and WSRC in Lao PDR do not have jurisdiction over rural water supplies or unlicensed urban or peri-urban providers (Figure 1b).

Current water sector policies in Cambodia and Sri Lanka state the intention of establishing water sector regulatory agencies; however, to date such bodies have not been formed in either country (MIME (personal communication); NWSDB 2002). Cambodia’s draft Water Supply Policy, which has not yet been promulgated as law, states that the key functions of such a body would include regulating private sector participation in the water sector, and increasing credibility, quality of service and public confidence in the water supply (MIME (personal communication)).

DISCUSSION

Understanding current practice

Despite a range of regulatory requirements, in practice, operational monitoring is limited to utilities, and capacity within this group varies significantly depending on size and resources. Operational monitoring by community water committees and informal providers such as unlicensed water vendors or households is infrequent, even in well-regulated, relatively wealthy contexts. We did not assess monitoring capacity among licensed water vendors. In practice, water quality monitoring of non-utility supplies is primarily conducted through surveillance programs.

Water utilities commonly limit operational monitoring to a set of critical parameters, including pH, turbidity and chlorine residual, as recommended by WHO. However, despite the emphasis on testing for fecal contamination in WHO guidelines and most water quality standards, operational monitoring for fecal contamination rarely extends beyond the largest utilities. There are a variety of potential explanations for why microbiological testing is minimal even when it is recognized as important; these include lack of sufficient trained staff, financial resources, or appropriate, low-cost field-testing technologies.

Although institutional responsibility for water quality surveillance lies with the health sector in most countries reviewed and is generally linked with a broader public health framework, there are cases, such as Cambodia and Malawi, where responsibility for surveillance monitoring has not been established (Table 2). The World Bank classifies both countries as low income, and it is tempting to speculate that the absence of surveillance agencies is due to a lack of resources. However, Lao PDR, also a low-income country, does have a formal surveillance agency, suggesting that factors apart from income influence institutional arrangements. Neither Cambodia nor Malawi clearly specify institutional frameworks in their policies or standards, nor is there evidence that the establishment of a surveillance agency for water management is a sector priority.

In both Cambodia and Malawi, oversight monitoring by the ministries responsible for drinking water promotes the safety of water supplies in the absence of an independent surveillance agency. However, the inherent conflict of interest that arises undermines this approach. Independent surveillance is not only an important mechanism for gathering unbiased data but is also critical for developing national strategies for ensuring the safety of water supplies, particularly remote systems, non-piped sources and peri-urban supplies. Strengthening of surveillance monitoring, ideally through the public health sector, logically represents a public health priority in such countries.

In a number of countries, health agencies not only conduct surveillance monitoring but also provide support to community water committees and to informal actors involved in drinking water provision. Although this dual support and surveillance role creates a conflict of interest, in reality strict regulation of community-managed supplies is challenging, and perhaps inappropriate. Given the prevalence of contamination of small community managed water supplies and the limited resources available to water committees, it is unclear what benefit strict third party surveillance for the purpose of regulating compliance would provide (Lloyd & Helmer 1990; Howard 2002). In this context, experts argue that surveillance agencies should play a role in supporting improvement, rather than citing violations (Lloyd & Helmer 1990; Howard 2002). Further research is required to understand whether surveillance agencies provide effective supply management support to managers of informal supplies in urban and peri-urban areas.
Strategies for building capacity

The limited capacity for operational and surveillance monitoring in many countries and contexts suggests a need for strategies to drive improvement in both areas. Funding for operational monitoring may come from user fees or, potentially, central and local government funding mechanisms. However, there is a need for institutional mechanisms that increase access to technical assistance for operational monitoring of small utilities and community water supplies. For example, in Brazil both FUNASA and municipal governments provide support for water quality oversight to small suppliers. This is an example of the type of post-construction support to rural supply managers that many authors assert is critical for the sustainability of rural water supplies (Lockwood 2002; Davis et al. 2008; Whittington et al. 2009). We did not identify other examples of such external assistance that were specific for operational monitoring, though we identified health agencies that provide general technical support and guidance to rural supply managers. We hypothesize that Brazil’s greater capacity for supporting smaller water supply management is linked to both clarity of institutional roles and its higher economic status.

In terms of technical approaches, the complexity and expense of standard methods for microbial water quality testing, suggest that capacity development for operational monitoring where it is as yet absent might begin with the monitoring of process control parameters, such as turbidity and residual chlorine levels for supplies where treatment and disinfection are employed. Sanitary inspections and approaches that combine risk assessment and risk management such as Water Safety Plans may be most appropriate for routine risk management (Lloyd & Helmer 1990; Lloyd & Bartram 1991; Mahmud et al. 2007; Bartram et al. 2009). Due to the burden of diarrheal disease associated with fecal contamination of drinking water, verification testing for microbial indicators of fecal contamination is an essential component of effective monitoring and should be incorporated in surveillance monitoring especially where operational monitoring does not include microbial indicators.

Improving capacity for operational monitoring by utilities should allow surveillance agencies to increasingly rely on audit-based approaches for surveillance of formal water suppliers. We hypothesize that greater audit-based surveillance of utilities would free-up resources for direct surveillance of rural and informal urban supplies. The WHO guidelines endorse such a strategy, stating, ‘In countries where urban water suppliers have established effective quality control, the surveillance agency may choose to place greater emphasis on the problems of less well served populations’ (WHO 1997). However, no local authorities or experts in the study countries identified this strategy, and we conclude that further activity is needed in order to maximize the efficient use of a limited capacity for testing programs.

Urban regulatory bodies that maintain political and financial independence from central government could potentially facilitate strong operational monitoring by formal suppliers and complementary audit-based surveillance. Such regulators can play a role in water quality monitoring where suppliers have a clearly defined legal responsibility to meet water quality standards (Howard 2002). In fact, we note that where regulators exist, their role to comprehensively evaluate the adequacy of supplies under their jurisdiction coincides with the WHO’s definition of surveillance and that there may be an overlap or division of responsibility for surveillance between regulators and health agencies (WHO 2004). SUNASS in Peru, for example, is responsible for collecting and reporting operational monitoring data to the DIGESA, which, in turn, enforces necessary sanctions (Figure 11). SUNASS’ active engagement with audit surveillance complements the Ministry of Health’s infrequent direct surveillance of urban piped systems in Peru.

Our data is insufficient to determine whether the presence of urban regulatory bodies in Peru and Lao PDR, or the use of audit surveillance by the Ministry of Health in Ecuador, have resulted in more effective surveillance monitoring programs outside of major cities. There is a need for further research on the impact of these strategies and for policy advocacy based on the findings.

Finally, we also note the need for clear assignments of responsibility for water safety management in water quality standards and policy. Greater clarity will promote institutional accountability and improve sector efficiencies by reducing the redundancy of roles.
CONCLUSION

A key finding from our analysis is the relative clarity of institutional responsibility for operational monitoring by formal urban suppliers, including utilities and licensed vendors. Among these suppliers however, capacity for operational monitoring varies greatly. Whilst only the largest utilities maintain fully equipped chemical and microbiological laboratories, utilities in many secondary towns attempt to maintain some equipment and staff for monitoring critical control variables. In contrast, small utilities in even relatively wealthy countries lack this basic capacity, an area that requires strengthening.

In contrast, legal responsibilities for operational testing by community water committees and informal suppliers are often poorly defined. In some cases, standards or policies exempt such suppliers from the requirement for operational monitoring, whereas in other cases the legislation implies universal applicability. In reality, even where community water committees are in place, technical capacity and resources are insufficient to support significant operational monitoring. Given the lesser technical and managerial capacities available for these supply types, it may be beneficial to strengthen monitoring techniques such as sanitary inspections, which may be sufficient to inform necessary risk management actions, as a prelude to full operational monitoring.

Independent surveillance, usually by public health agencies, is implemented through at least two distinct approaches: in rural areas, direct assessment of water supplies is the norm, whereas in urban settings, the same approach may be taken or utilities with comprehensive testing programs may supply the surveillance authority with water quality data from their facilities as part of an audit-based surveillance approach. We hypothesize that relying on audits of utilities can allow surveillance agencies to reduce costs while effectively discharging their responsibilities to the populations supplied in this way and at the same time direct greater effort towards surveillance of rural and informal urban supplies; and potentially also smaller towns. This dual approach to surveillance monitoring appears prudent in optimizing the use of available resources, although further research is required to understand its impact.

Increasing audit-based surveillance of formal urban suppliers, however, also poses significant challenges. First, audit-based surveillance requires high-quality operational monitoring by suppliers and, as noted above, many formal suppliers will require assistance in developing this capacity. Policies that clearly specify operational monitoring requirements can support improvements in practice. Independent regulators can also take on responsibility for enforcing operational monitoring requirements and in collecting audit-based surveillance data. In addition, in order for audit-based approaches to be credible there must be confidence in the reported data. Though experience with this is limited, strategies for ensuring credibility include third party certification, participation in inter-lab comparisons, and periodic laboratory inspections by the surveillance agency.

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