Policy reform to deliver safely managed drinking water services for schools in rural Bangladesh

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Policy reform to deliver safely managed drinking water services for schools in rural Bangladesh

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Disclaimer:

This report is a background working paper supporting the SafePani model proposed in the report titled 'Policy reforms for safe drinking water service delivery in rural Bangladesh' (Hope *et al*. 2021). Hence, parts of the text and figures from this report have also been published in Hope *et al*. (2021).

Cover photo by Rob Hope.

Authors

- **Dr Alexander Fischer** | School of Geography and the Environment, University of Oxford, UK
- **Prof Robert Hope** | School of Geography and the Environment & Smith School of Enterprise and the Environment, University of Oxford, UK
- **Dr Patrick Thomson** | School of Geography and the Environment, University of Oxford, UK
- **Dr Sonia Ferdous Hoque** | School of Geography and the Environment, University of Oxford, UK
- **Mohammad Monirul Alam** | WASH section, UNICEF Bangladesh
- **Prof Katrina Charles** | School of Geography and the Environment, University of Oxford, UK
- **Dr Nassim El Achi** | School of Geography and the Environment, University of Oxford, UK
- **Dr Saskia Nowicki** | School of Geography and the Environment, University of Oxford, UK
- **Syed Adnan Ibna Hakim** | WASH section, UNICEF Bangladesh
- **Dr Md Sirajul Islam** | Environmental Microbiology Laboratory, International Centre for Diarrhoeal Diseases, Bangladesh (icddr,b)
- **Prof Mashfiqus Salehin** | Institute of Water and Flood Management, Bangladesh University of Engineering and Technology
- **Prof David Bradley** | School of Geography and the Environment, University of Oxford, UK
- **Muhammad Ibrahim** | Additional Secretary, Local Government Division, Ministry of Local Government, Rural Development & Cooperatives, Government of Bangladesh
- **Md Emdadul Hoq Chowdhury** | Joint Secretary, Local Government Division, Ministry of Local Government, Rural Development & Cooperatives, Government of Bangladesh

Executive summary

Bangladesh's global leadership in the Sustainable Development Goal (SDG) for water reflects the country's unique challenges of securing water services against threats of groundwater contamination, monsoon flooding, and cyclonic storms. Ensuring safe and reliable water services for its 40 million students in over 150,000 public primary and secondary schools is a massive challenge. Over the past two decades, there has been notable progress in increasing access to improved water sources in schools. However, sustaining progress to safe and reliable services for every student every day will require rethinking current policy, monitoring systems, and service delivery models.

As per the Primary Education Annual Performance Report 2019, 97.4 per cent of all government primary schools (total 38,916) and new nationalised primary schools (total 26,613) have their own water source; however, only 64 per cent have a functional improved source (tubewell or tap) that is free from arsenic (DPE, 2019a, p.149). This is comparable to national household level data from the Multiple Indicator Cluster Survey (MICS) 2019, which shows that although 98.5 per cent households have access to an improved water source, the percentage drops to 42.6 per cent when faecal and arsenic contamination are taken into account (BBS/UNICEF 2021). The issue of functionality and safety of school water infrastructure has been long recognised with increasing attention and funding to address the issues in the Primary Education Development Programs contributing to around USD7 billion in annual education funding.

This report draws on research from 150 primary and secondary schools in Chandpur district to analyse the status of drinking water services, in terms of access, quality, quantity, functionality, and costs. Key findings from the analysis include – a) an average of 1.7 tubewell per school and 125 students per tubewell, b) an estimated water use of around 4 litres per day per student, c) three-fifths of schools had at least one tubewell failure over 12 months, with most being fixed in under 10 days (65 per cent), though more expensive parts lead to a month or more before being fixed, d) the average cost of repairing a tubewell of BDT 1,192 (USD 14), e) 37 per cent of schools had at least one water quality parameter exceeding national safety standards, with 26 per cent exceeding two or more parameters, f) in all but one case, managing waterpoints is the responsibility of the school administrators.

The report is based on collaborative research by the REACH programme [Bangladesh University of Engineering and Technology (BUET), the International Centre for Diarrhoeal Diseases, Bangladesh (icddr,b), and the University of Oxford], UNICEF and the Government of Bangladesh, including the Water Supply Wing of the Local Government Division (LGD), the Department for Public Health and Engineering (DPHE), the Directorate of Secondary and Higher Education (DSHE), and the Directorate of Primary Education (DPE). The work is complemented by a sister-study in coastal Bangladesh (Hoque *et al*., 2021) and informed by the recent national water quality assessment (BBS/UNICEF, 2021), which contributes to the design of the SafePani model (Hope *et al*., 2021).

The SafePani model aims to provide safe drinking water services for all in rural Bangladesh through reforms in three areas – institutional design, information systems and sustainable finance. Institutional reform can aim to clarify roles and responsibilities allocated from national to local levels. Strengthening local and national information systems will support monitoring timely and accurate information of safety, functionality, and affordability of water services. In turn, this information will advance how to combine public resources with new sources of results-based funding to address the increased costs of delivering higher level services. Professional service delivery models to manage and monitor clusters of schools with a results-based contract will promote more efficient and effective use of resources, and be positioned to attract global interest in results-based funding.

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Data logger installed on a handpump at Bordia High School. Photo by Rob Hope.

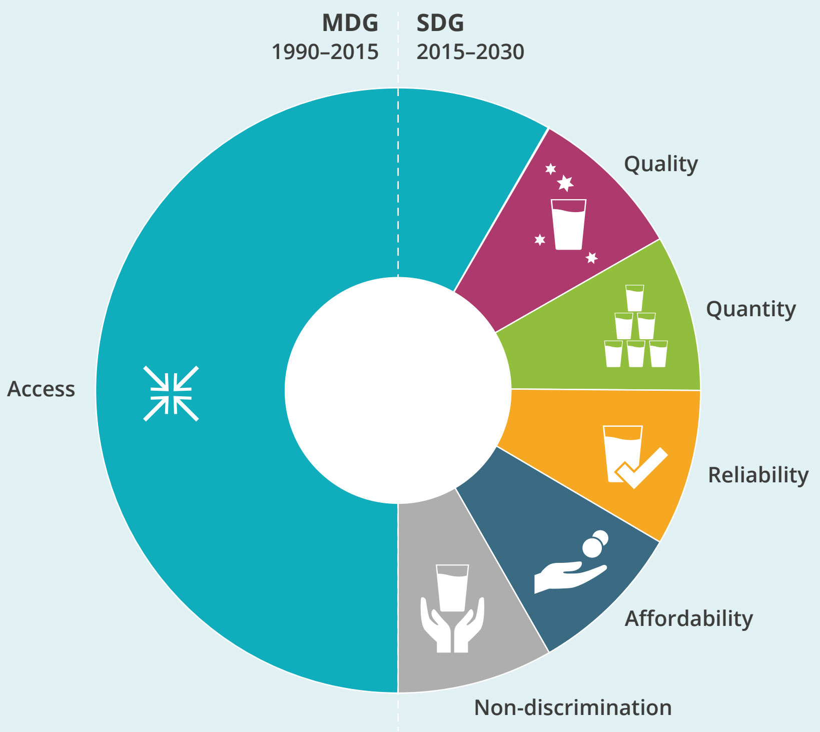
1. Introduction

Safe and reliable drinking water services are key components of a 'safe, non-violent, inclusive and effective learning environment' in schools, as articulated in the Sustainable Development Goals (SDG) (Targets 4a and 6.1) (WHO/UNICEF, 2018). In Bangladesh, the access to improved water infrastructure in primary schools increased from 83 per cent in 2010 to 97 per cent in 2018 (DPE, 2019b, p.136), with that in secondary schools increasing from 85 per cent in 2012 per cent to 96.8 per cent by 2016 (BANBEIS, 2013).

There are 134,147 public primary schools (as of 2018), of which 70,775 (52.8 per cent) were under the direct responsibility of the Ministry of Primary and Mass Education (MoPME) (DPE, 2019a) and 20,449 secondary schools (as of 2016) under the responsibility of the Ministry of Education (MoE) (BANBEIS, 2016). Decisions related to drinking water services in schools impacts nearly 30 million primary school aged students, 10.5 million secondary school students, and a total of 619,517 teachers across the country (BANBEIS, 2016). With over 18 million public and private tubewells being installed in households, schools and communities across the country (Fischer *et al*., 2020), there is a huge need to pay attention to operational functionality and water quality safety .

Unlike Target 7c of the Millennium Development Goal (MDG), which focused on increasing 'access' to technologically improved sources by installing water supply infrastructure, SDG 6.1 offers a comprehensive 'service delivery' approach including indicators on infrastructure functionality, service reliability, water quality, affordability and non-discrimination (Figure 1). However, the current public policy narratives remain anchored by provision of access measures which are reported in national and global policy reports (Fischer, 2019). This expanded focus raises questions around the effectiveness of existing institutional model in terms of the ways in risks and responsibilities are allocated among public and private actors at national and local levels, the sustainability of sectoral financing, and the adequacy of existing information systems for monitoring progress.

Figure 1: Moving from MDG to SDG



In Bangladesh, capital investments on water supply infrastructure in schools is centrally financed through the MoPME and MoE, with the Primary Education Development Program (PEDP) being one of the largest projects allocating funds for installing or upgrading WASH facilities in schools since 2005. Installation is led by the Department of Public Health and Engineering (DPHE) with subsequent operation and maintenance (O&M) responsibilities being delegated to individual school administrators who finance these costs from the overall annual school budgets. It is estimated that USD 10 per student needs to be spent on the construction of school WASH facilities and USD 1.40 per student needs to be spent annually on all recurrent costs, including direct support for hygiene promotion activities (Snehalatha *et al*., 2015). However, the funds channelled to schools through PEDP-III (2011 – 2016) and via the School Level Improvement Plan (SLIP) grant, were only enough to cover 30 per cent of the needs (Tiberghien, 2016). While there is yet no specific national plan of action for school WASH, PEDP4 (2018-23) seeks to have at least one source of safe drinking water, with annual monitoring of water quality for tubewells installed under PEDP4 (DPE, 2018). Though the latter is yet to be implemented it indicates a shift in attention from hardware to software approaches, aligned with the SDG targets.

Data on infrastructure access and coverage are obtained through the Annual Primary School Census (APSC) led the Directorate of Primary Education (DPE) and the Education Survey led by BANBEIS for post-primary institutionsand maintained through the Education Management Information System (EMIS).

The APSC and Education survey questionnaires are filled by the Head Teachers of individual schools collecting self-reported data on infrastructure type, functionality at the time survey, presence of arsenic, and *E. coli* testing (DPE, 2019, BANBEIS, 2016), which are insufficient to provide a comprehensive picture of adequacy, quality, reliability, and maintenance of water supply facilities.

As the Government of Bangladesh and international finance partners continue to invest in PEDP, this report explores opportunities for experimentation of school financing, infrastructure management, and monitoring that would advance the nations' progress to achieve SDG 6.1. Globally, new rural service delivery models are differentiating responsibility between financing the infrastructure and managing water services to achieve the desired outcomes. The commitments to achieve SDG 6.1 offer a policy transition to advance new approaches to share responsibilities between national government agencies, local government authorities, school administrators, and other stakeholders.

1.1 Scope of the report

This report analyses the current state of drinking water services in public primary and secondary schools in Bangladesh, drawing on five years of collaborative research by the University of Oxford in partnership with Bangladesh University of Engineering and Technology (BUET), the International Centre for Diarrhoeal Diseases, Bangladesh (icddr,b), and UNICEF, with support from the Local Government Division (LGD), Directorate of Primary Education (DPE), Directorate of Secondary and Higher Education (DSHE), and Department of Public Health and Engineering (DPHE) of the Government of Bangladesh. It is one of the two background documents contributing to the design of the SafePani model – a revised institutional framework for delivery of safe drinking water in rural Bangladesh (Hope *et al*., 2021).

The study area includes sections of Matlab Dakshin (South) and Matlab Uttar (North) upazilas of Chandpur district and Daudkandi upazila in Cumilla district, covering a population of 230,185 people in 53,226 households (as of 2014). There are 165 primary and secondary schools, not including BRAC or Madrasah institutions serving a reported 46,531 enrolled students, 19,445 of which are female students. The area was originally defined by icddr,b as part of a multi-decade health and demographic surveillance research site, with a specific focus on health-related outcomes related to cholera and diarrheal diseases. Through analysis of multiple sources of primary and secondary data, outlined in the following sub-section, this report seeks to address the following objectives:

- To assess the performance of drinking water infrastructure systems across national standards and SDG indicators; and
- To propose reform to the institutional design and delivery of safe drinking water in public schools in rural Bangladesh.

1.2 Research methods

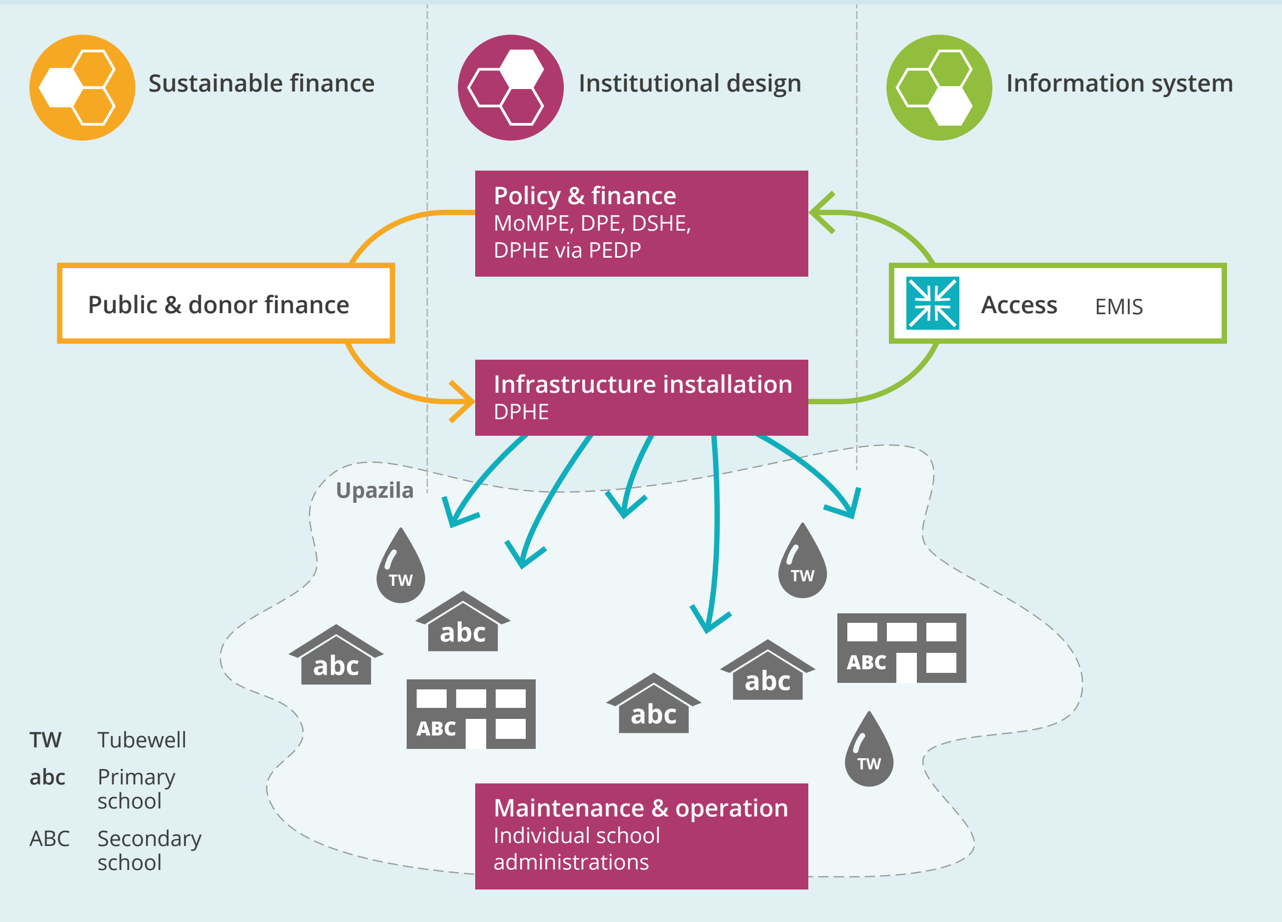
Ethical permissions for the research design followed the University of Oxford and icddr,b protocols to ensure informed consent, confidentiality, and protection to all human subjects who participated in the studies. Data collection was carried out in four stages:

1. **Situation analysis (2017–2018)** – The form-based interviews with 170 school administrators which identified 277 water points for government, BRAC, and Madrasah schools in the study area. The surveys provided insights into the current management practices for all handpump and electric pumps from tubewells in schools, recollection of functionality and ongoing operational costs, use by students and faculty, and concerns for water quality and safety. The situational analysis further gathered secondary data at national levels including project documents for PEDP stages 1 through 3. The structured interviews and infrastructure inventory audit were administrated through electronic forms developed and deployed using ONA software, (https://ona.io/), a mobile survey platform which provided a hosted server for uploading, editing, viewing, and submitting survey forms.
2. **Daily monitoring of water usage (2019)** – This involved deployment of 150 handpump data loggers to capture hourly water use patterns at schools. The data loggers, provided by OxWater (www.oxwater.uk), are automated sensors which utilise machine learning algorithms to analyse accelerometer data fitted to the handles of the No.6 handpumps.
3. **Water quality analysis (2019)** – Water samples were collected from 125 handpumps across 107 schools (17 schools had samples taken from two handpumps, and one from three handpumps) by icddr,b team in December 2019 and tested for seven parameters including arsenic, *E. coli*, manganese, chloride, salinity, iron, and turbidity. Faecal contamination, as measured by the presence of *E. coli* bacteria, was measured at three points: at the tubewell with decontamination representing groundwater water quality, at the tubewell without decontamination representing water as collected, and at the point of use representing water as consumed.
4. **Outtake surveys (2019)** – When removing the data logger at the end of the study, enumerators conducted outtake surveys with 150 school administrators to triangulate findings and update information on water point use and management.

2. Institutional design for drinking water services in rural public schools

Progress towards achieving safely managed and reliable drinking water services in rural geographies is increasingly reliant on risk-based governance approaches and blended sources of finance. The current water service delivery model for rural schools in Bangladesh is designed to transfer risk-management responsibility from the national government after financing and installation of infrastructure to individual schools and their administrators (Figure 2).

Figure 2: Existing institutional design for water supply in primary and secondary public schools in rural Bangladesh



The number of WASH facilities in schools is estimated to be in the hundreds of thousands with many schools having multiple water points. To understand the strengths and opportunities of the current institutional design, we start by considering who maintains formal versus informal responsibility for service delivery and thus risk management. This is followed by a summary of the national context and knowledge of risks facing water services and concluded by a discussion of current finance flows for schools.

2.1 Responsibility of national government and individual school administrators

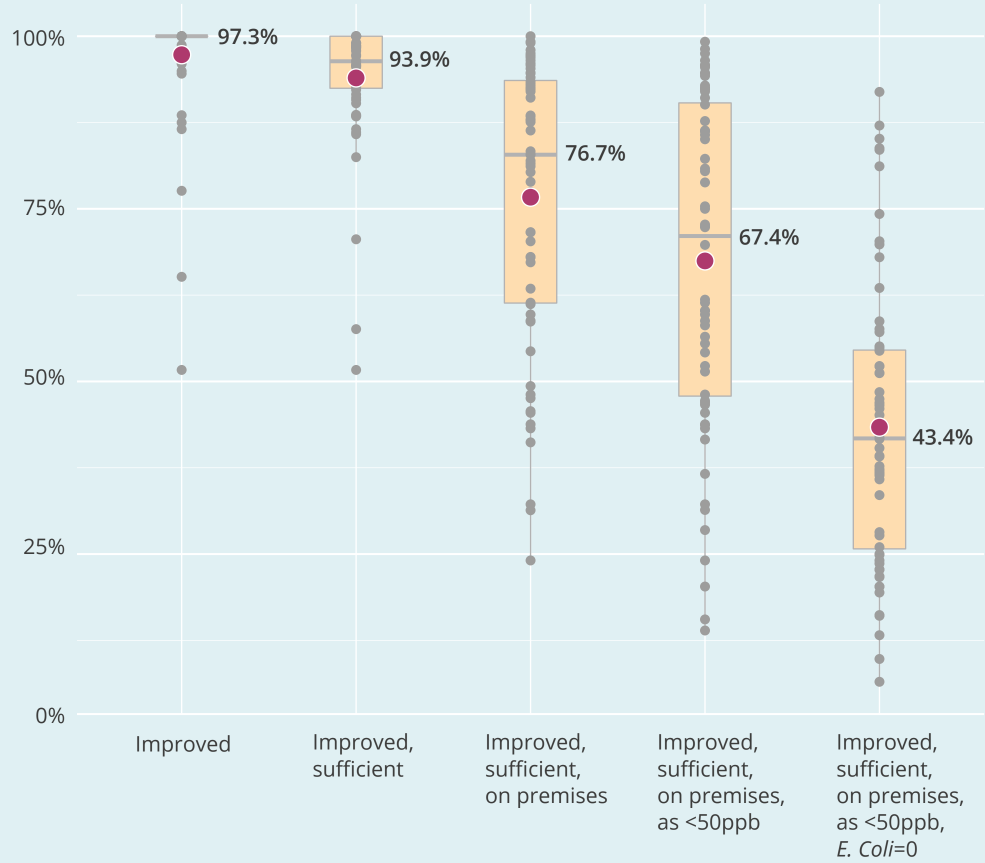
In the current institutional model, the national government is responsible for provision of drinking water infrastructure in schools, while subsequent operation and maintenance activities are delegated to individual school administrators. The government and development partners allocate funds for capital investments through the MoPME and the MoE which are responsible for budget allocations and decisions around school policy and programs, with DPE and DSHE as the respective implementing agencies. PEDP is one of the largest project mechanisms where funding has been allocated for schools to install or upgrade water and sanitation infrastructure. Nearly 30,000 deep tubewells and 10,000 other tubewells were financed by PEDP-3, with the recent PEDP-4 (2018-23) planning to install an additional 15,000 waterpoints and construct or upgrade 58,000 WASH blocks in primary schools within five years (DPHE, 2020). As part of PEDP-4, DPHE technicians will conduct water quality tests on 65,000 water points installed previously in schools and provide maintenance on water points installed by PEDP-3. The financial reliance on the capital expenditure for installation, and approval from the national government agencies leaves significant decision responsibility at the national level.

Once the funds are allocated, the installation of water supply infrastructure is carried out by DPHE, ensuring that the water quality meets national standards at the time of installation. Once installed, individual schools are responsible to manage the O&M of the infrastructure as part of the wider facility management, using funds from their overall annual budget for the school. With a push to increase infrastructure access for schools away from single handpumps into WASH Blocks with electric pumps and distributed pipes for multiple water points, the complexity of infrastructure management and reoccurring costs are much higher than previous No.6 handpump systems. Further, school administrators would be responsible for managing water quality within their premises, after being tested upon installation, based on testing protocols that were formalised in the early 2010s (DPHE, 2015).

2.2 Risk factors and information

The SDG framework identifies water quality, reliability accessibility, affordability, and equity of access as key for achieving the goal of safe and reliable services. National figures for households from UNICEF/MICS (2019) provide insights relevant for schools demonstrating high rates of faecal contamination; however, figures revealing water services in primary and secondary schools are not available in any publicly aggregated data source or at the scale (Figure 3).

Figure 3: State of drinking water services across 64 districts based on SDG indicators (Red points showing mean of districts) (Data source: MICS 2019)



The national EMIS is rapidly evolving to provide information for individual school administrators, regional leaders, and national policy makers. It contains information around facility infrastructure as well as administrative data about the school management and student body, which are obtained through the APSC and Education Surveys by DPE and BANBEIS, respectively. The EMIS system has helped inform the PEDP process by providing estimates for the number of schools without water points or sanitation facilities. This provides the most comprehensive data set at a national level; however, it is limited for public viewing (http://emis.gov.bd/). The Primary Education Annual Performance Report 2019 reported that 97.4 per cent of all government primary schools (total 38,916) and new nationalised primary schools (total 26,613) have their own water source, of which 8.4 per cent have a tap, 86.1 per cent have a tubewell and 5.5 percent have a pond/filter. Of the tubewells, 78.4 per cent were functional at the time of survey of which 86.8 per cent were free from arsenic contamination, while 84.1 per cent of the taps were known to be arsenic free (DPE, 2019, p.149). The issue of functionality of school water infrastructure has been part of the national narrative for decades, with newspaper articles reporting concerns of dysfunctional handpumps, contamination of water quality, and drinking water scarcity in school facilities ("Four thousand tubewells are dysfunctional in primary schools of 16 zillas," Ittefaq (in Bangla), 1993, "Scarcity of pure water, most arsenic free tube wells of Hajiganj Government primary school are now not functioning," Ittefaq (in Bangla), 2013).

While this perspective on functioning infrastructure improves understanding of access, there is significant uncertainty around the aggregate annual scale of infrastructure malfunction events in schools, and even greater unknowns around the rate and speed of repair. Monitoring the temporal dimensions of functionality have proven difficult at scale (Carter and Ross, 2016; Foster *et al*., 2019), and overlook critical questions on reliability and sufficient quantity of water being available per student per day.

The discovery and public recognition of naturally occurring arsenic in predominantly shallow groundwater aquifers across Bangladesh raised questions about scale of exposure for children in both residential and school contexts to unsafe water as part of a national blanket survey of 5 million tubewells conducted between 2000-2005. After a series of government studies in the late 1990s identified the spatial uncertainty of arsenic contamination (Kinniburgh and Smedley, 2001; van Geen *et al*., 2003), Bangladesh conducted one of the largest water quality screening efforts ever made, testing and labelling an 5 million out of the estimated 8.6 million tubewells (Johnston and Sarker, 2007). Arsenic was detected in concentrations above 50 μg/l in 29 per cent of the shallow tubewells and 2 per cent of the deep tubewells tested (Ahmed *et al*., 2006). As per the UNICEF/MICS (2019) data, in 22 of the 64 districts more than 20 per cent of the surveyed households are exposed to arsenic above 10 μg/l, with the highest risks being recorded in Chandpur, Cumilla, Sunamganj and Gopalganj districts.

Within the analysis screening inventory and the National Arsenic Mitigation Information Centre (NAMIC), there was limited focus on water quality risks facing rural public schools. Not only is arsenic a carcinogen which accumulates over time, a concern for young children, but research studies link arsenic exposure to negative impacts on children's developmental progress and declining school performance (Haque *et al*., 2017,Wasserman *et al*., 2004). Indicative arsenic contamination rates are available in relation to administrative districts, upazilas, unions and villages for domestic consumption; however, this does not give accurate perspective on schools, which have more formal installation and testing procedures than private self-supply and community water systems. Without an explicit focus on schools within the arsenic database analysis, as well as merging other monitoring efforts around additional water quality parameters, it increases the uncertainty around achievement of the water safety targets in schools.

Microbial contamination is also a significant concern for tubewells, as shallow aquifers can be contaminated during and post installation, while abstracted water can be contaminated during collection and transportation to the point of use. During monsoon, heavy rainfall creates local floods which often contain faecal matters from open latrines and animals. Outside of monsoon season, contaminated water can often slowly leach through soil layers and contaminate the shallow aquifers. Recent research has identified the need to monitor *E. coli* levels across the pre-monsoon, monsoon, and post-monsoon seasons (Alam *et al*. 2017). There is currently limited data exploring this seasonal variation of bacteria and heavy metal contamination in tubewells. Emerging evidence also highlights that manganese may also be prevalent at levels of concern in Bangladesh and of particular relevance in schools due to impacts on cognitive development and behaviour (WHO, 2020).

2.3 Finance

In the FY2019-2020, the Government of Bangladesh has committed to ensuring an annual education sector budget of BDT 370.1 billion for MoE and BDT 240.4 billion for MoMPE, equivalent to USD 7.5 billion (DailyStar, 2019). This is complemented by multiyear multilateral and foreign aid projects, including the PDEP-III which provided over USD 4.1 billion. While this represents significant public sector investment, there are no direct and explicit provisions for O&M funding in the budgets. It is estimated that USD 10 per student needs to be spent on the construction of school WASH facilities and USD 1.40 per student needs to be spent annually on all recurrent costs, including direct support for hygiene promotion activities (Snehalatha *et al*., 2015). However, the funds channeled to schools through PEDP-III and via the School Level Improvement Plan (SLIP) grant, were only enough to cover 30% of the needs (Tiberghien, 2016). Any O&M budgets are derived from wider allocations to overall facility budgets, which are dispersed based on school administrator and school management committees.

Photograph: Handpump in Matlab

3. Research findings from Matlab

Here, we present the results from the Matlab study in terms of the core service components critical to delivering safely managed drinking water services: equitable access, reliability, functionality, safety, and costs. Each of the following sections discuss both the existing performance of school water facilities, as best understood using the data collected, and the possibility of how to utilise enhanced information systems in support of designing new service models. This builds a perspective on achieving the safely managed services, as framed and defined under the SDG 6.1, and is summarised in the first section of this report.

3.1 Access and coverage

This component of sector progress, both in national and international platforms, is guided by targets for access defined by binary categories of facilities having or not having drinking water infrastructure installed (DPE, 2019). By looking at coverage in schools, it raises questions if the improved infrastructure access is sufficient both in terms of spatial distance to users and the number of users-per-infrastructure. The Government of Bangladesh targets 100 per cent access to adequate WASH infrastructure in school facilities, however targets for coverage per student are not defined. The 2011 Water Supply and Sanitation Sector Development Plan (FY2011-2025) defines target coverage ratios as 50 people per tubewell for domestic settings, recognising that this target does not account for multiple geographic, environmental, and socio-cultural dimensions (GoB, 2011).

Access rates provides clear assessment in relation to sector targets and widely recognised coverage indicators, service providers will be accountable to ensure access defined beyond simple facility level access rates to increasingly include indicators of equitable coverage for all students and staff and minimum volumetric supply per student per day. In Matlab, 99 per cent of the primary and secondary public schools reported having an improved water supply infrastructure. Two-thirds of the 256 tubewells were reported as deep tubewells while one-third as shallow tubewells.[1]

1 This reflects a distinction of drilling depth of the tubewell. Deep tubewells are consistently defined as drilled depth greater than 150 meters (490 feet). Shallow tubewells are considered anything less than 150 meters deep, with the shallow aquifer system generally considered to be a depths less than 30 meters (100ft)(GoB, 2004).

Depth, which when below 150m is assumed to low risk for microbial and arsenic contamination (Howard *et al*., 2006; Winston *et al*., 2013), is difficult to confirm or identify after installation as manual dippers or electric probes. Initial interviews confirmed that the depth of tubewells installed are not recorded and thus rely on administrators' ability to remember depth.

Table 1. Summary of water points for school facilities in Matlab study area

School type	Total no. of schools	Total estimated students 2017	Estimated tubewells (2019)	Estimated no. of schools electric pumps (2017)	Estimated no. of schools electric pumps (2019)	Handpumps with data loggers (2019)
Primary Schools	136	28,596	202	33	48	123
Secondary Schools	28	18,229	54	19	18	27

We estimated an average coverage of 1.7 tubewells per school and a median of 125 students per waterpoint (range 27 to 904 students per waterpoint). Only one school reported using a neighbouring handpump outside of school ownership and managerial responsibility.[2] The number of water points per student is an important measure for schools, specifically facilities providing for large student bodies who need more than one water access point.

In that two-year period, school administrators reported six new WASH blocks and over a 26 per cent increase in the number schools maintaining electric pumps, from 52 schools in 2017 to 66 schools in 2019. This has major implications for O&M with additional costs being incurred for electricity and different spare parts being needed for service. To achieve the coverage targets, policy makers and technical experts would need to define ratios and incorporate them into any service delivery specifications or contract.

3.2 Handpump use patterns

There are no known national policy standards or targets for minimum provision quantities per student per day or week. Here, we present the current usage patterns across both per student use and fluctuations of demand between days of the week and the school year, drawing on 54,970 hours of usage data from data loggers on 45 handpumps.

2 In a related study of handpumps in Matlab enumeration zone used by households and public facilities, we identified an additional 77 tubewells reported as used by both households and schools (Fischer et al forthcoming).

The majority of handpumps (92 per cent) are reported as being used for drinking water compared to just under half of the electric pumps (44 per cent). Electric pumps, often linked to new WASH blocks, were reported by administrators as being most frequently used for cleaning (66 per cent) and washing (59 per cent). Only two handpumps were reported as used for cooking, suggesting limited to no school meals programs. Each use type implies different quantity of water demanded, although it remains unclear the proportional difference.

Recent work by Hanchett *et al* (2014) explore reasons why water sources are used and perceived differently in the context of households. Their study identified water quality, location, and cultural practices as influencing use behaviours. There is no known research into these use decisions within the school environment in Bangladesh, however as we see in later sections, factors influencing might include trade-offs between multiple water points, water quality and flow.

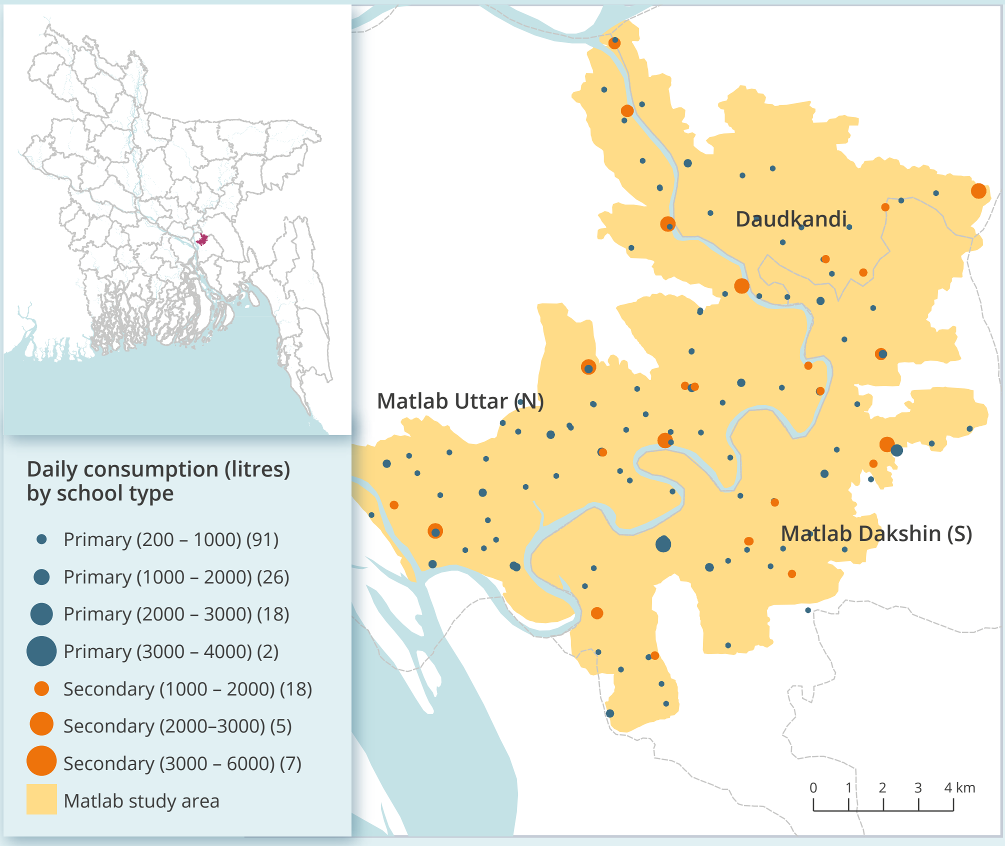
Table 2. Proportion of electric and handpumps used for each purpose. Each water point could have multiple uses in the survey question structure

Use of water	Washing (e.g. dishes)	Drinking	Cleaning (e.g. class rooms)	Cooking	Sample Response
Electric Pump	59%	44%	66%	0%	41
Handpump	89%	92%	79%	1%	236

The daily volume of water pumped ranged from 0.5 to 11.8 litres per student per handpump per day (median 3.9 litres),[3] which is equivalent to an average of 920 litres per day per pump, with a maximum daily use recorded at 1840 litres and a minimum average daily use at 205 litres during the school holiday period. This is greater than what any student would drink in one day and reflects usage for non-drinking purposes as well as by the neighbouring households. These variations in the current consumption level between schools (Figure 4) do not reflect estimates or suggestions for the minimum standard service needs related to quantity of water per day per pupil. Instead, they suggest the need for services to be designed to accommodate for different use types and volumetric use.

3 This number could decrease slightly if factoring in faculty and school staff, however those figures were not available for these calculations.

Figure 4: Daily water consumption at 150 primary and secondary school tubewells in Matlab (Note: Estimation based on number of students in each school times average consumption of 4 litres per student per day)

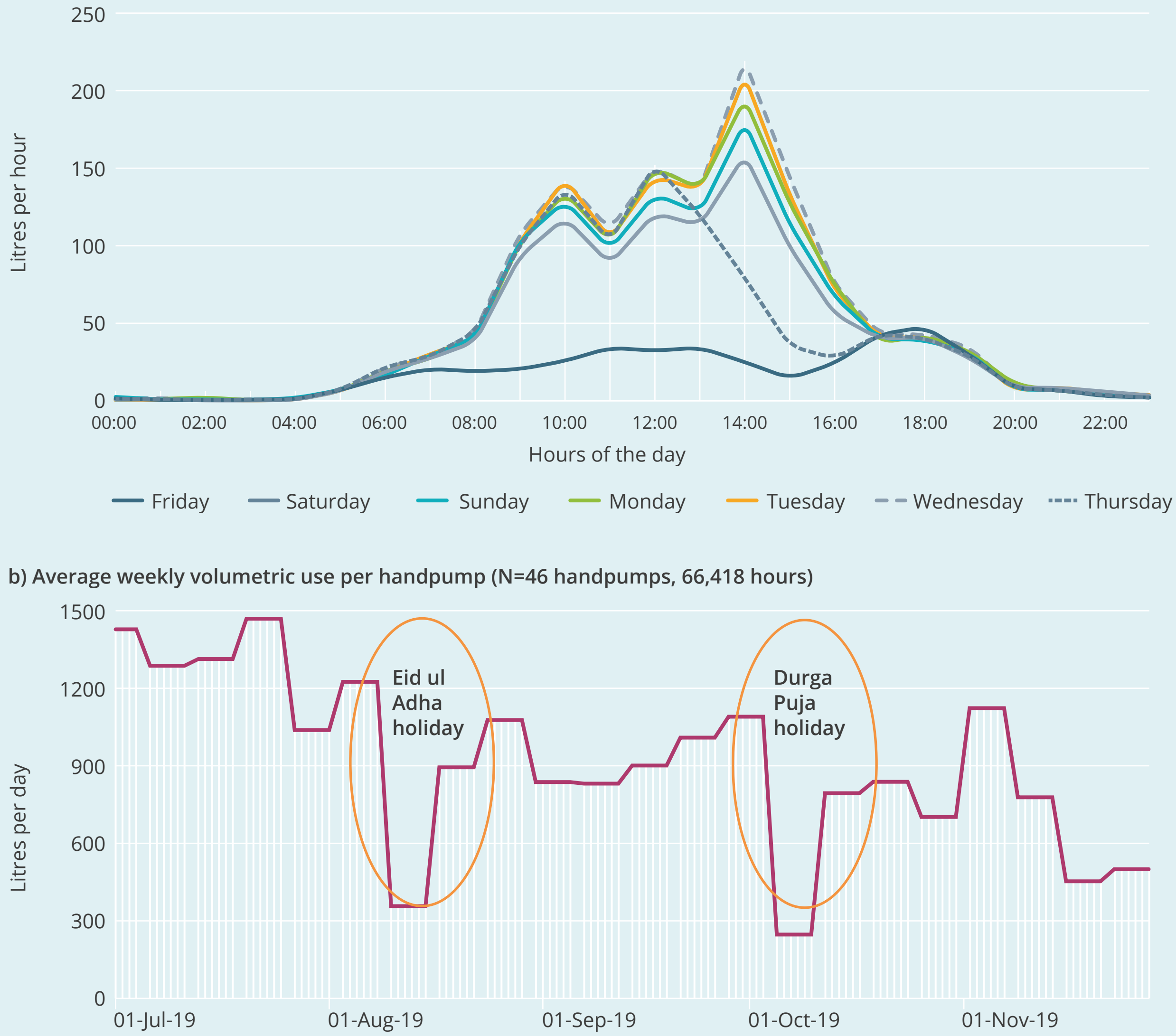


Analysis of volumetric usage by time of the day, day of the week, and over several weeks provides insights into both average use patterns and how monitoring of individual water points can reveal deviations in use patterns relevant to functionality, reliability, and demand functions. This information becomes immediately useful for national policy and service design for zones of potentially linked school services, individual school patterns, and tracking individual school functionality and use on daily or weekly basis.

As shown in Figure 5a, the beginning of the school day corresponds with a spike in use between 8am and 9am at the start of school hours at 9:30am. Bangladesh schools follow a double shift schedule with grades 1 and 2 in the morning and grades 3 to 5 in the afternoon, however, this may vary region-to-region (Tiberghien, 2016). Water demand and use is greatest in the afternoon between 1pm and 3pm. Handpump use largely corresponds to hours of the day when schools are open, with Saturdays and Sundays having much lower average use than Mondays through Thursdays (Figure 5a). Thursday shows a dramatic drop off after noon, linked to the school hours of 9:30-2:30pm that day of the week.

Figure 5: Water usage patterns for school tubewells in Matlab

a) Daily use patterns, hourly average (N=61 schools, total hours: 78,893)



The data loggers also reveal a social benefit provided by school water infrastructure beyond the children. The data loggers showed use outside of school hours varied by handpump, some with more significant use (Figure 5a). This type of data, once verified through qualitative methods, could lead social policy to focus on who is using the water and why. Initial qualitative interviews suggest this might be related to community members without their own safe water point and some of the most vulnerable members of the community.

The use of daily or day-of-the-week averages is useful for planning minimum service provision levels and demand over time, however, they obscure changes such as school closure during holidays and seasonal variation. The preliminary results from the first five months reveals a significant drop in use during school holidays, although not to zero use suggesting activities were still held at the schools or continued use by community members (Figure 5b).

There was also a decline in average daily use, for reasons unclear although possibly a seasonal affect or a smaller sample size due to technology glitches. A 12-month deployment of data loggers is required in the next phase of this project to understand annual cyclical demand.

3.3 Functionality of handpumps

Functionality of handpumps has received extensive attention in the context of rural drinking water service provision in multiple geographic contexts, from Africa to parts of South East Asia (Foster *et al*., 2019). Definitions of handpump functionality is increasingly looking to indicators beyond binary flow/no flow at time of survey data to use differentiated sub-measures including rate of permanent abandonment, frequency and duration of breakdown events over the course of a year, and minor versus major breakdowns events (Carter and Ross, 2016).

Data around the functionality of handpumps, particularly in rural contexts, is limited whereas urban utilities provide more robust estimates for multi-user piped schemes from administrative data. Monitoring handpump and small-scale infrastructure functionality is possible if aggregating government engineers' administrative reports and or private sector service records, when available. This section shows the potential application of sensors to monitoring functionality in relation to use patterns. Additionally, this section interrogates infrastructure audit results where water point managers' report breakdown events in the past 12 months. However, the nuance on type of break down and limits of memories, or incentives to over or under report, can shape accuracy. This study uses data loggers to verify and triangulate reports from school administrators, where feasible.

No.6 handpumps are ubiquitous across rural Bangladesh, being designed to be low cost and have low levels of maintenance, specifically enabled by the private market adoption and scale (Black, 1990). Malfunction rates are reported through the operational versus non-operational dichotomy, with estimates of nationally provided public water points having 91.5 per cent functional as of 2018 (DPHE, 2018). The closeout survey in December 2019 found 23 of the 150 handpumps (15.3 per cent) were not functioning two years after first visit, a rate higher than the public domestic-use water points. Weekly status checks with administrators, although not consistent across all handpumps, suggest that this higher rate includes could be higher due to abandoned points after the installation of new hand and electric pumps in schools.

The majority of handpumps, or 60 per cent, have reported malfunction events in the past 12 months. However, functionality is more nuanced. Schools with student enrolment reported under 200 or over 800 had a far greater rate of malfunction than schools in the 200-800 student size range (Figure 6a). Just over 60 per cent of malfunction events were repaired within 10 days, with bucket and washer repairs occurring faster than handpump handle, cast iron body, pipes or rods (Figure 6b). Administrators showed uncertainty around which month the breakdowns occurred, with only 30 per cent of those breakdown events being directly attributed to a specific month.

For administrators who could place breakdown events by month the rate suggests between 0 and 5 per cent of handpumps required monthly reactive maintenance (Figure 6c). Despite explicit language of zero-flow events in the questions posed to administrators, there remains a possible confusion between non-function and repair or malfunction. Future studies can gain further insights into this accuracy by aligning use data to reported breakdown events.

Figure 6: (a) Reported breakdown rate by school student size; (b) Duration of handpump breakdown events; and (c) Monthly rate of non-functionality events for school handpumps

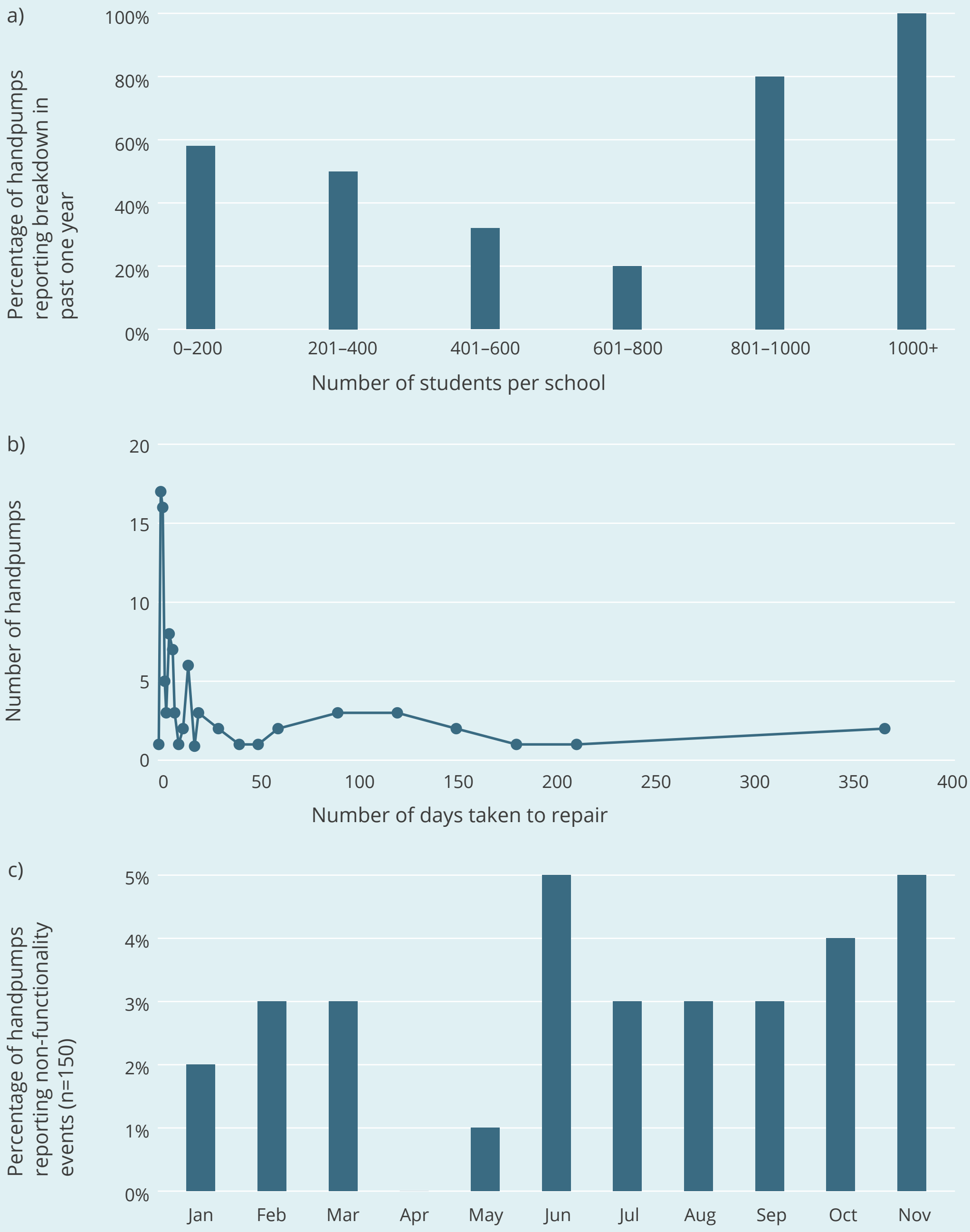
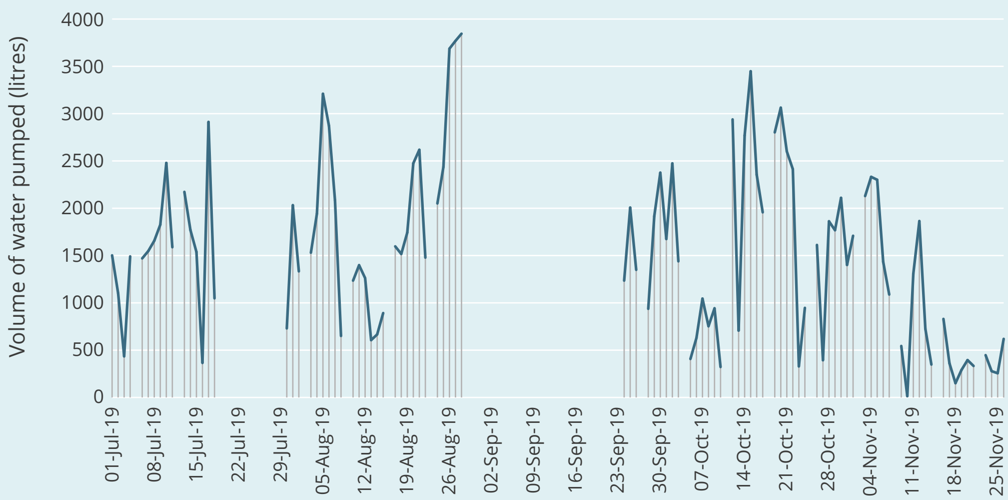


Figure 7 demonstrates how the data logger results can be applied to identify use behaviour outside average use. The large dips include Fridays when there are no students in the schools. This provides one way to calculate and understand average daily use, by day of the week, and identify when there are significant deviations from that mean which require verification for reasons. We identified holidays, malfunction events, changed source, school construction, and community events as events with significant impact on daily use patterns.

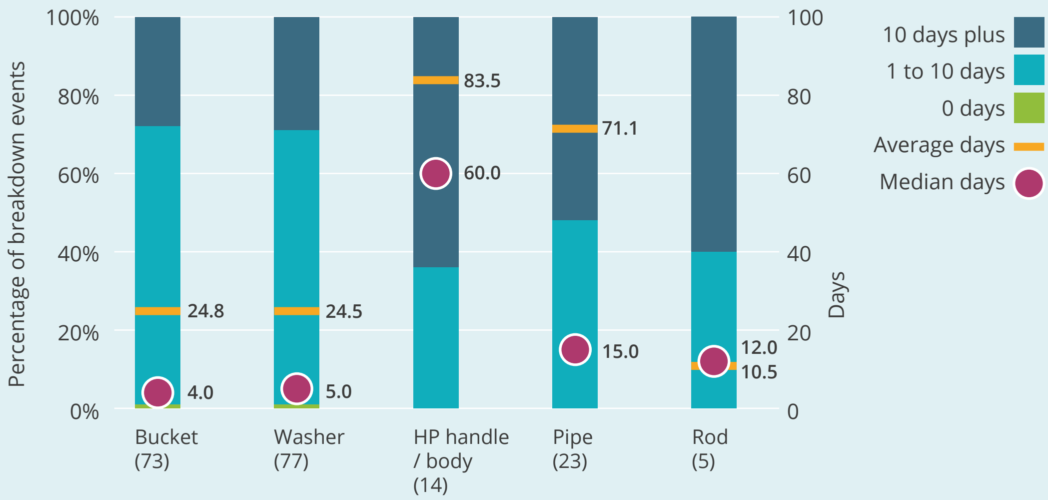
Figure 7: Data logger results showing use patterns and confirmed non-functioning event with corresponding reduced use for one handpump



All except for one school reported that the maintenance was the responsibility of the school administrators, while the 82 per cent of schools reported initial capital expenditure to build water infrastructure was provided by the central government agencies. Further, 80 per cent of school administrators reported conducting the repairs themselves, with the remaining 20 per cent reporting private paid vendors being hired. The O&M model for handpumps is reactive, replacing components once broken. Buckets and washers were the most frequently repaired component, 70 per cent of which are repaired within 10 days of breaking (Figure 8). Handpump handles, cast iron bodies, pipes, and rods were far less frequent and more than 50 per cent took over 10 days before being repaired.

This data, while limited in sample in this study, provides a basis for service enterprises to begin estimating the frequency of repair types which enables cost estimates for business plans and risk management. It further allows for a transition away from reactive repairs to preventative maintenance based on average age or intervals between bucket and washer repairs, and predictive maintenance if use patterns measured by data loggers are identified as suddenly declining or becoming erratic. This enables service enterprises to begin to anticipate and model potential operating budgets to provide maintenance service needs around a monthly cycle, not include major events such as cyclones damaging infrastructure.

Figure 8: Average repair time by breakdown type for school tubewells in Matlab



3.4 Water quality

Multiple chemical and microbial contaminants can be found in Bangladesh's drinking water that can create risks for the health of children and adults if concentrations exceed guidelines or standards. The Government of Bangladesh defined the national drinking water quality standards in the 1997 Environmental Conservation Rules. This set the thresholds which were later used by DPHE as the compliance standards for water quality when new water points were installed (DPHE 2015) (Table 3).

Table 3. National and international standards for drinking water quality

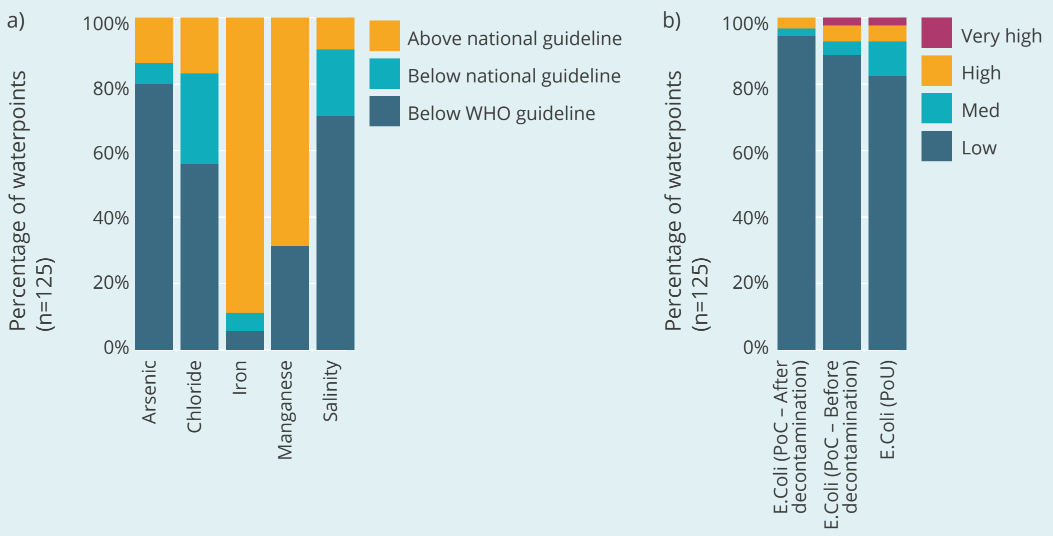
Parameter	Relevance	Guidelines
E. coli	Water can contain types of bacteria, viruses or other small organisms that can be pathogens and may cause disease in humans that consume them. For example, diarrhoea and vomiting can be caused by drinking water that has pathogens in it. These pathogens often come from human or animal faeces, so water is especially likely to contain pathogens if it has been in contact with human or animal faeces. The presence of *E. coli* indicates recent faecal contamination, and could indicate the presence of pathogens. *E. coli* are a subgroup of faecal coliforms that are more specific to faecal contamination.	No *E. coli* detectable in 100ml drinking water

Parameter	Relevance	Guidelines
Arsenic	Arsenic is a naturally occurring substance in the ground. Because of this, water that is pumped out of tubewells can sometimes contain high amounts of arsenic. Consuming arsenic for a long time can cause health problems like skin damage, numbness, leg pain, and sometimes cancer. The Bangladesh Department of Public Health Engineering recommends not drinking or cooking with water that has more than 0.05 milligrams of arsenic per litre of water.	<50 µg/l in Bangladesh <10 µg/l recommended by WHO.
Manganese	Manganese is a substance that naturally exists in the ground. Because of this, water that is pumped out of tubewells can sometimes contain high amounts of manganese. Consuming low amounts of manganese is healthy for humans. But consuming high amounts might cause children to have more difficulty with learning. Manganese in water can also cause staining of laundry.	<0.1 mg/l for Bangladesh and for taste (WHO) <0.08 mg/l for health (WHO 2020)
Iron	Iron is a metal that naturally exists in the ground in many places. Because of this, water that is pumped out of tubewells can sometimes contain high amounts of iron. Consuming iron is healthy for humans because it helps to make blood strong. But high amounts of iron in water can make the water taste bad and can also create a reddish-orange-brown colour, especially after water has been stored for a while. Iron in water can also cause staining of laundry and may also change the colour of food that is cooked with it.	For aesthetic reasons, WHO recommends <0.3 mg/l and Bangladesh recommends <1 mg/l
Chloride	Chloride comes from both natural and anthropogenic sources, such as the use of inorganic fertilizers, animal feeds, industrial or septic tank effluents, irrigation drainage, seawater intrusion in coastal areas. No health-based guideline value for chloride in drinking-water is proposed, although chloride concentrations in excess of about 250 mg/l could impair the potability of water for aesthetic reasons.	<250 mg/l for aesthetic reasons (WHO) <600 mg/l NaCl Bangladesh
Salinity	Salinity can result from naturally occurring salts in the ground or from the saline intrusion and coastal flooding, and be increased by human land use and over abstraction of groundwater. Though guidelines are set for aesthetic reasons, recent studies highlighted the link between drinking water with high salinity with cardiovascular diseases and abdominal pain. (Chakraborty *et al*., 2019; Nahian *et al*., 2018)	< 600mg/l WHO < 1000 mg/l Bangladesh

While DPHE is responsible for ensuring water safety at the time of installation, post-installation responsibilities lie with the school administrators who operate under the authority of MoMPE and MoE. None of the schools in our study were able to produce written documentation of the results of the initial water quality testing or information on the wider set of water quality parameters. We collected 125 water samples from 107 primary and secondary schools in Matlab in December 2019.

Only 20 per cent of the 125 systems provided safe drinking water that met Bangladesh's health guidelines for arsenic, chloride, manganese and *E. coli*. In half the systems, a single contaminant was identified above the standard, but in 24 per cent multiple water quality risks were identified. Across the schools, the most common contaminant was iron which may discourage use of the tubewell water due to taste and colour, but is not detrimental to health (Figure 9a).

Figure 9: (a) Water safety compliance and risks by parameter; and (b) Faecal contamination (*E. coli*) in school drinking water. The graph demonstrates the increasing risk from contamination across the water system, from low risk in the groundwater (sampled at the tubewell after disinfection, left), to increasing risk of contamination at the point of collection (middle), to the highest risk at the point of use (right).



Manganese was the health parameter that most commonly exceeded the Bangladesh guideline, with concentrations above 0.1 mg/l being detected in 68 per cent of waterpoints (n=86). Recent evidence on manganese in drinking water highlights the link to behavioural issues and lower cognitive functioning in children which is especially concerning in schools (WHO 2020).

Arsenic concentration was above the national threshold of 50 µg/l in 11 per cent (n=17) of samples putting an estimated 4300 students across 11 primary and five secondary schools at risk. However, data was not collected on the use of these or alternative waterpoints with schools. According to UNICEF/MICS 2019, Chandpur is one of the most arsenic contaminated districts in the country, with an estimated 42 per cent of households having >50 µg/l of arsenic in their main source of drinking water, compared to the national average of 10.6 per cent. In fact, 38 per cent of the district's residents drink from water sources with arsenic levels as high as 200 µg/l. This suggests that schools are more likely to provide safe drinking water to students than in their household setting. This is likely explained by the formal protocols and procedures required by DPHE when installing water points in schools, whereas private households are able to install water points through more informal markets without standardised rules (Fischer, 2020).

Presence of *E. coli* was measure at the point of collection (PoC) both before and after decontamination of the tubewell mouth and also at the point of use (PoU). Among the 125 waterpoints, 9 per cent (n=14) of samples were contaminated with *E. coli* at PoC (Figure 9b). Following decontamination, the percentage dropped to 5 per cent (n=7) indicating that while sources themselves might be free of faecal contamination, hygiene of PoC would still impede the access to *E. coli* free water. This difference reflects previous studies conducted by REACH in Khulna (Hoque *et al*., 2021) and by iccdr,b in Cox Bazar (Mahmud *et al*., 2019). As shown in Figure 9b, 15 per cent (n=22) of the samples were contaminated at PoU putting an estimated 6300 students, along with teachers and workers at risk.

Regular monitoring of water quality at schools, though essential, is not currently implemented or regulated. Nationally representative household water quality sampling has highlighted the seasonal variability of drinking water, requiring seasonal monitoring to assess safety (BBS/UNICEF, 2021). Of the schools in this study, five with arsenic greater than 50µg/l reported having the water point tested at installation and believing it was arsenic safe reflecting changes in the water quality over time. Additional monitoring is needed, at appropriate intervals, for the multiple water quality hazards identified, with written results to be shared with schools for records. At present, there was no identifiable funding or agency mechanism to trigger if water points are found to be unsafe, leaving that responsibility to the school administrators. Though some schools have an alternative water source available, testing will be required before a switch can be advised. Those without an alternative will require development of new water supplies or installation of treatment to ensure safe drinking water access.

3.5 Operation and maintenance investments

The current investment model of public sector funds is structured around central government funding new installation of capital costs for water infrastructure with individual schools assuming all ongoing O&M responsibility. School administrators draw from annual operational budgets allocated to the school by regional education agencies, or through revenues generated through student fees and parent contributions (Tiberghien, 2016).

The challenge is to understand the resources required beyond initial installation of water distribution infrastructure and how schools can individually, or under a pooled financial structure, enable greater financial security, specifically as new technologies including electric pumps, increase the annual operation and maintenance budgets.

This study did not conduct a structured full analysis of school expenditure on water services. Previous work conducted by BRAC and IRC on WASHCosts (Snehalatha *et al*., 2015) provide initial estimates on capital and maintenance expenditure in schools sampled from 117 schools across multiple regions of Bangladesh, both rural and urban. WASHCosts methodology provides a framework to assess financial resource requirements for capital expenditure; operational and minor maintenance; larger maintenance; and staffing. WASHCosts analysis provides preliminary considerations for budget planning; however, their model is premised around individual school committees managing maintenance activities and combined water, sanitation and hygiene activities.

In our study, school administrators reported a total expenditure of BDT 101,132 (USD 1,197) on repairs in 2019 for 90 handpumps, resulting in an average of BDT 1,192 (USD 14) per handpump (range BDT 100 to BDT 8,000). This suggests that in 2019, BDT 4.25 (USD 0.05) was spent per student on repairs. These do not represent needed expenditure, as seen earlier, the handpumps remain non-functional for various reasons. The study did not collect an accurate and comprehensive record of the replacement parts per each handpump breakdown. With 80 percent of repairs reportedly conducted by school staff, that implies that the only costs were the replacement value of the broken parts, no additional cash expenses. Further research is needed to understand the costs to expenditure ratios, and annual budgetary allocation processes.

4. Conclusion

Provision of safe drinking water services to all primary and secondary school children and staff in rural Bangladesh remains a challenge, particularly in areas with arsenic and salts in groundwater and frequent exposure to cyclones and floods. This report draws on multiple data sources from 150 schools in Chandpur and Comilla districts to address two objectives: first, assess the performance of school drinking water infrastructure systems across national standards and SDG indicators; and, second, propose reform to the institutional design and delivery of safe drinking water in public schools in rural Bangladesh.

The performance of rural water systems for 40 million students reveals significant achievements in primarily providing high levels of access through tubewells across the country's 150,000 public primary and secondary schools. Recent national evaluation of water quality highlights that water quality (*E. coli* and arsenic) is the primary barrier to safely managed drinking water in households, and that water quality risks increase seasonally and with climate shocks. Across the schools studied, considering also risks of manganese and salinity, only one quarter of schools had access to safe water from tubewells, with the remainder exposing children to risks to diseases that would affect their ability to come to school and to learn. The first daily assessment of water usage in the Matlab schools reveals insights into the quantity of water being consumed and associated functionality challenges. Over half the schools have at least one tubewell repair and while the simple faults are fixing in a week or less, the major faults can take a month or more. Though most schools have around two tubewells, the implications of tubewells not working for a month on handwashing, menstrual hygiene management, cleaning the school, preparing food as well as drinking water are concerning. While we also see the increase in new technologies, such as electric pumps, this will not resolve existing water quality, functionality or environmental risks. Each school is left to address these challenges with limited budgets on their own. Some clearly perform well, others struggle as they balance multiple commitments.

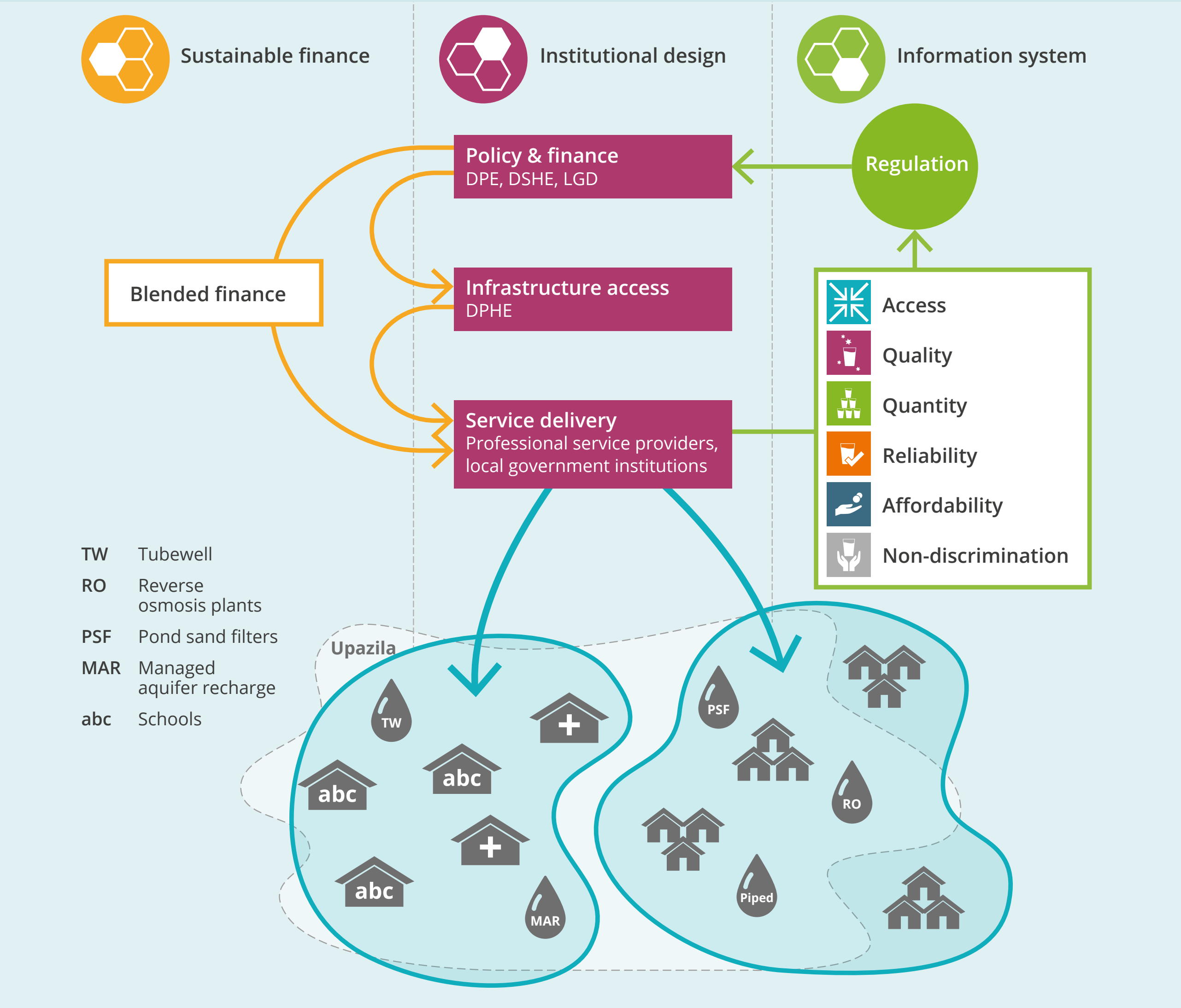
Education is one of the best-managed and highly-funded sectors in Bangladesh. COVID-19 has amplified the critical need for water for handwashing in schools and in turn the institutional design of managing and monitoring these services. Funding is not limitless and existing resources have to be used efficiently to justify more support. The SafePani model advances three core ideas to contribute to future policy and planning (Figure 10, Hope *et al*., 2021).

First, information systems can be strengthened to ensure key operational data on water quality and functionality are monitored regularly and reported transparently. Second, institutional design promotes devolving water service delivery to clusters of schools to professional service providers. Bangladesh boasts a highly entrepreneurial but largely uncoordinated network of water enterprises (Hoque *et al*., 2021).

With new contracting arrangements, clear incentives and strict regulation, professional service delivery models can ensure high quality services are delivered to primary and secondary schools to comply with education and water mandates aligned to the SDG6 goal of safe and reliable drinking water.

Long-term and sustainable funding for school water services will be critical. There is global evidence that results-based funding models can deliver high quality results for rural water services at affordable costs (McNicholl *et al*., 2020). This requires separation between policy, regulation and service delivery. It is proposed that the education sector can rethink its current regulation and monitoring of school water services and pilot professional service delivery to determine the most appropriate design suitable for the Bangladesh context. The SafePani model offers a framework for government and sector partners to learn and improve progress to safe water for all demonstrating its global leadership in the SDG agenda. The SafePani model offers a framework for government and sector partners to learn and improve progress to safe water for all demonstrating its global leadership in the SDG agenda.

Figure 10: Proposed SafePani design for rural water service delivery in Bangladesh. Source: Hope et al., 2021.



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About REACH

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