

Risk Narratives and Institutional Responses:

Charting the Evolution of Unregulated Drinking Water Services in Rural Bangladesh, 1972-2016



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ABSTRACT

Progress towards achieving safely managed and reliable drinking water services in rural geographies is increasingly reliant on risk-based governance approaches and private finance. This thesis argues that by framing risk as the outcome of previous decisions, institutions can be redesigned to more effectively confront the unintended consequences of past actions and balance responsibility between pooled and self-governed structures. Explored in the context of Bangladesh, the thesis questions how the construction of overlapping public risk narratives render problems visible in manners which facilitate institutional transitions through the reallocation of blame and responsibility.

As with other social-ecological systems framed by the Sustainable Development Goals, the rural drinking water sector is at an inflection point of multiple risk logics. Public mandates are shifting from ones structured around provision of services, specifically improved infrastructure access, towards ones focused on managing supply resilience, water quality, system reliability, and equity of access. Adopting a risk-based perspective challenges previous narratives of hard-won infrastructure gains by redefining sector performance gaps and efficacy of service models.

Several interconnected themes are at the centre of how these service models evolve in geographies characterized by minimal data, changing infrastructure preferences, and institutional transitions through a consideration of multiple epistemological perspectives debating uncertainty, danger, and decisions. A set of risk discourse filters are proposed in order to identify the construction, contestation, and limits of self-critical public narratives. These filters, applied to an inventory of newspaper articles and academic publications specific to drinking water issues in Bangladesh between 1980 and 2016, reveal three distinct periods of drinking water concerns directly linked to national and international development agendas and the shift between cholera, arsenic, and environmental pollution concerns. By delineating the grammar of risk debated by social theorists, the thesis challenges existing sector narratives and identifies an overlooked problem, and opportunity, linked to unregulated self-supply infrastructure.

These findings are further explored in the context of national infrastructure growth, changing investment patterns, and design of information systems. National tubewell infrastructure data estimated using village-level inventories in three regions merged with national demographic data to estimate that for every new public water point installed between 2012 and 2017, forty-five unregulated tubewells were installed through private market suppliers. This explicitly defines the proportion of household investment relative to public financing, suggesting that households now contribute upwards of one third of the total sector expenditure. This growth unintentionally reallocates risk-responsibility to self-managed systems beyond the devolving mandate of public services provided by central governments or community collectives.

These institutional arrangements, reinforced by public risk narratives, have neglected to clearly establish reflexive regulatory authorities over individual and private enterprises in order to mitigate water insecurity. The shift in risk logics, new information technologies, and growth of private capital implies an opportunity to leverage blended finance with pooled-risk structures, thus addressing performance gaps identified by the Sustainable Development Goals.

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ACRONYMS

BBS	Bangladesh Bureau of Statistics
BSG	British Geological Survey
BAMSP	Bangladesh Arsenic Mitigation Water Supply Project
BWDB	Bangladesh Water Development Board
DPHE	Department of Public Health and Engineering
DPhil	Doctor of Philosophy
GLAAS	UN- Water Global Analysis and Assessment of Sanitation and Drinking-Water
GoB	Government of Bangladesh
GWP	Global Water Partnership
IWRM	Integrated Water Resource Management
LGED	Local Government Engineering Division
LGI	Local Government Institutions (municipal governments)
MDG	Millennium Development Goals
MDIP	Meghna-Dhonagoda Irrigation Project
MICS	Multi-indicator cluster survey
MIS	Management Information System
MKW	Main Key Word
NAMIC	National Arsenic Mitigation Information System
ORS	Oral Rehydration Solutions
RWSN	Rural Water Supply Network
SDG	Sustainable Development Goals
UNICEF	United Nations International Children and Education Fund
USAID	United States Agency of International Development
WASH	Water, Sanitation, and Hygiene
WARPO	Water Resources Planning Organization
WHO	World Health Organization

1 INTRODUCTION

1.1 RATIONALE AND CONTEXT

The adoption and design of the universal Sustainable Development Goals (SDG) in 2015 continues to transform global development paradigms and national strategies as they seek to reconcile poverty alleviation agendas with risk-based paradigms focused on managing social and environmental uncertainties. Across multiple sectors, geographies, and political systems, this shift in development focus manifested in relation to debates around whether to frame risk as an opportunity or a danger, and how to reallocate blame and responsibility between collective and self-managed governance models. As identified in the seminal work by Beck (1992, 2016) and discussed by multiple risk scholars, these changes to policy raise questions of the utility of extending risk-theory as a framework to understand individual and collective responses to changing institutional designs. The redefined targets draw specific attention to the process of changing formal and informal rules used to govern society, political economies of risk, and consequences of reflexive decision-making (Matten, 2004; O'Malley, 2004; Rayner, 2007). The launch of the SDGs presented an opportunity to research how institutions, information, and infrastructure systems adapt, or are constrained by, these universal global goals and further, how the intention for national flexibility is designed and downscaled.

These shifts in development practice paradigms helped clarify a problem-oriented research approach for this dissertation. For many sectors, the performance of the goals expanded the targets through new indicators and additional complexity of overlapping social, ecological, economic, and political risk logics. The modified monitoring approaches, and growing recognition of what Beck (1992) argued is the unintended consequences of past decisions, challenged the effectiveness of previous actions and policies by redefining service thresholds and standards.

These widening service gaps frame institutions as underperforming which requires social, technical, and political narratives to renegotiate the boundaries of public concerns. This raises questions of how competing public narratives are used to interpret the performance of institutions, shape which problems are managed, and influence how the resulting blame, responsibility, and uncertainty are distributed in tandem to the transforming risk logics. The diminished performance of the public sector service models opens questions to how, and why, governance structures allocate risk responsibility between collective pooled-management structures and self-governing and private enterprises models (Rayner, 2007). The process of downscaling global goals into national policies provide a unique opportunity to observe how pluralistic risk-based governance paradigms evolve across multiple levels of institutions.

The rural drinking water sector, like many other social-ecological systems, is at an inflection point in the conceptualization of these multiple risk logics, specifically transitioning from the provision of infrastructure access to mitigation of individual and collective water insecurity. Innovations in global measurement methods and data collection techniques are rapidly advancing composite indicators which reinforce the expansion of SDG 6.1¹ to include targets of infrastructure access, water safety, supply reliability, equity, and user affordability. The growing standardization of safety thresholds and ability to quantify these expanded targets has redefined the global performance narrative in the Water, Sanitation, and Hygiene (WASH) sector; the distance from targets shifted from 795 million lacking improved access to over 2.19 billion people lacking safe,

¹ SDG 6.1 defined the target: “By 2030, achieve universal and equitable access to safe and affordable drinking water for all”. The indicator is defined as 6.1.1 Population using safely managed drinking water services. For full analysis see Table 3 in Chapter 2.6. (WHO/UNICEF, 2017).

reliable drinking water (UNICEF, WHO, & JMP, 2019). Although this quantifies greater scales of people at risk, it does not change the daily lived experience of those living in conditions of water insecurity. While these gaps are extensively documented at sub-national scales and in specific sub-sector technical literature, the standardized targets directly impact policy debates around institutional mandates and implementation strategies.

The globally comparative indicators reinforce questions regarding the effectiveness of existing and pluralistic service delivery models, from state provision to community management to market-based enterprises (Hope, 2015; Koehler, Rayner, Katuva, Thomson, & Hope, 2018; Moriarty, Smits, Butterworth, & Franceys, 2013). However, as discussed in later sections, there is a gap in academic and policy debate around the consequences of the increasing, yet largely unmeasured and unregulated, scale of privately financed small enterprise service providers and or individually managed infrastructure with a limited number of users, or what is widely described as self-supply systems². The estimates of population dependency on small and self-supply systems, most robust in context of the United States of America and European Union, project around 13percent of the population depending on water sources outside public or collectively managed systems (Dieter et al., 2018; Hulsman & Smeets, 2011), with some European countries ranging from 22percent in Albania to 57percent in Moldova (Olschewsk A., 2016). Estimates in non-European or North American contexts are far more varied and uncertain, with greater focus on potential impact rather than existing coverage (Smits & Sutton, 2015). While these rely on estimates, not careful inventories, it shows a significant portion of

² Definitions and self-supply are further defined and discussed in Chapter 2.6 and Chapter 5.

populations outside the larger service models and many components of the regulatory system. The research is thus motivated by concern that rural drinking water institutions are failing to adapt to, and specifically regulate, the consequences of increasingly complex, uncertain, and self-governed reflexive risks.

Theories of why risk matters, and how they are managed within the process of societal change, are explored across this thesis in relation to rural drinking water security in Bangladesh. Geographically demarcated by the world's largest delta, Bangladesh is located inside the confluence of multiple large river systems, which, when combined with the annual monsoon cycles, creates significant contrast between flooding events and growing water variability in the dry season (Rahman & Salehin, 2013). This variable water supply converges around one of the most engineered and densely populated deltaic plains in the world. The hydro-geological conditions of high-water tables enable a widely accessible shallow aquifer. These environmental conditions converge with government facilitated investment and modification of the suction handpump technology, infrastructure which is now ubiquitous in rural areas. This public attention allocated to drinking water services in relation to widespread cholera and diarrheal disease has persisted between governance periods from East Bengal under British colonialism into the Government of East Pakistan and responding to the independence movement culminating in 1971 (Black, 1990; Briscoe, Ahmed, & Chakraborty, 1979; GoEP, 1964). These infrastructure decisions seen as solutions to water safety concerns, as discussed across this dissertation, were undermined by the uncertainty of naturally occurring arsenic found in the shallow aquifer systems (Caldwell, Caldwell, Mitra, & Smith, 2003; Smith, Lignas, & Rahman, 2000; van Geen et al., 2003). Academic and media portrayals of Bangladesh emerge from this

convergence of both environmental hazards and the unintended consequences of policy and infrastructure choices.

The country of Bangladesh is further characterized as one of the most complex social-ecological systems for institutions to deliver safe water to the estimated 160 million people as of 2010 who live within the nation's boundaries, of which 105 million are considered rural and 31.5 percent are classified as "poor" by the Government of Bangladesh (GoB, 2015a; Hoque et al., 2019; World Bank, 2018b). Technocrats have repeatedly framed the country as having national success achieving high percentage of drinking water access despite lower GDP per capita of neighbouring countries (Churchill et al., 1987). The government continues to report positive economic transformation and declining rates of extreme poverty; however, the central government and local municipalities continue to face widespread administrative, fiscal, and information challenges regulating and delivering access to affordable, sufficient, and safe drinking water systems.

This challenge provides a unique environmental and social context to explore the response to multiple, overlapping risks defining rural water security and the paradox of improved sector progress. The process of integrating SDG 6.1 into national development strategies and sector policies ran parallel to the dissertation and informs the focus on information systems and recommendations in the conclusion. In October 2015 during my first period of field work in Bangladesh, national government agencies were in the process of completing their Seventh Five-Year Plan, which guides budgetary spending and implementation priorities (GoB, 2015a). During this first visit, I observed the national plan being reframed to incorporate the SDGs. The updated

plan did not however incorporate the expanded SDG 6.1 ambitions, focusing instead on maintaining previous approaches defined around provision of public water points defined as safe.

The revised national strategies recognized, in qualitative terms, water safety concerns including arsenic contamination, but did not focus on rural specific approaches to ensure “safe” drinking water services outside of the public provision models. The plans relied on previous information systems and metrics built around population access to improved infrastructure, specifically the ratio of population-to-government provided “safe” alternative infrastructure (GoB, 2015a, p. 702). These population-based ratio indicators have guided over four decades of water and sanitation specific policies, strategies, and acts, as summarized by Black (1990). These targets rely on assumptions that by providing alternative infrastructure systems defined as safe, individuals would continue to choose to use the public water points over private ones to reduce their potential arsenic exposure.

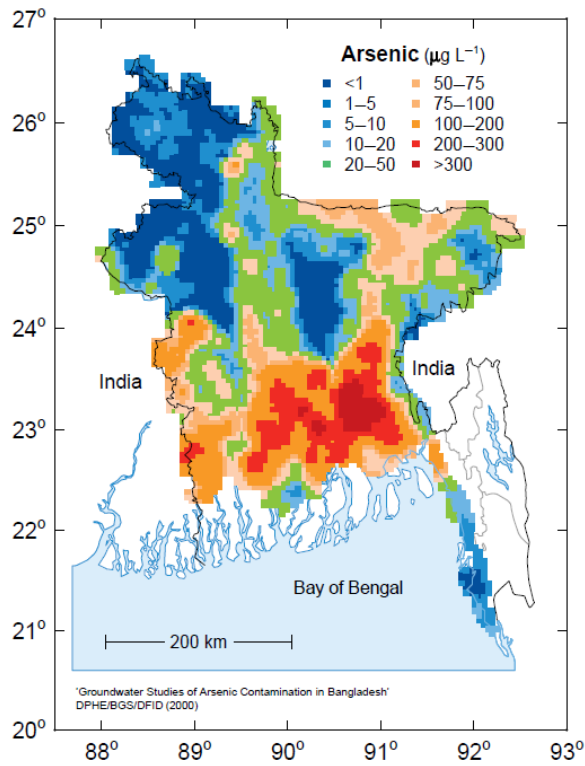
The limited modification of official reported statistics in the rural sector, however, stands in contrast to policies and other monitoring innovations underway across other government activities in Bangladesh. The Government of Bangladesh, in partnership with UNICEF, was one of the first countries to incorporate water quality testing of the main household drinking water source into the Multi-Indicator Cluster Survey (MICS), including arsenic and E-coli. As presented in Chapter 6, this MICS data suggested that national indicators proximity-to-target had dropped from a national average of 98 per cent improved access to 34.6 per cent of households when factoring in reliable access to improved infrastructure, on-premise, and with water quality determined safely below arsenic and e-coli thresholds (BBS/UNICEF, 2009; BBS, 2015). This reverse in progress away from nearly universal access to improved water points reported since

early 2000s remains politically complicated and difficult to communicate, posing an inconvenient problem by undermining previous narratives of successful provision of near universal coverage.

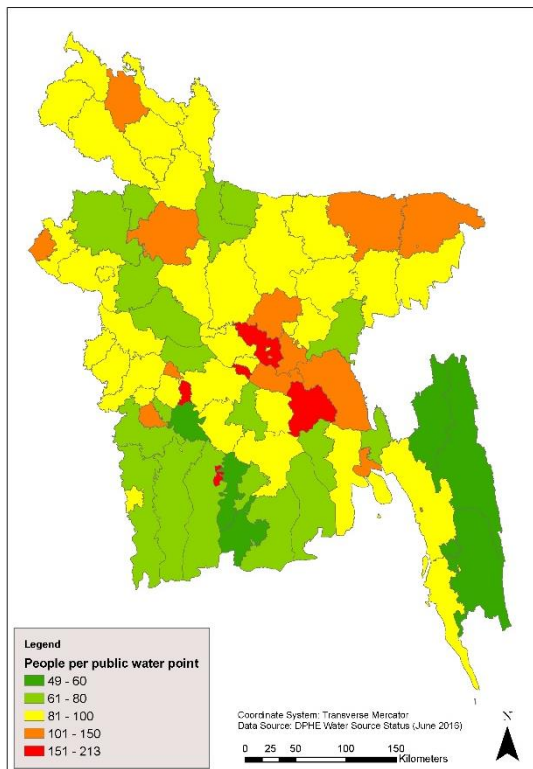
This additional complexity of multiple risks implies that different modes of knowledge and forms of discourse are needed to render the concerns visible in ways which yield action. While these questions around service delivery are raised in the context of the rural drinking water sector, there is a significant body of literature from sociologists and institutional scholars that seek to understand the process and methods of how risks are imagined and rendered visible, either as real hazards or as social, political, and economic constructs used to interpret and manage decisions. Similar to the observed debates in 2015, Beck (1992) advances the understanding that risk society is a socially and technically negotiated concept, but also one which is mediated by political interests. As shown in Map 1, these concerns over how and where arsenic poses potential problems in Bangladesh are imagined and mapped through different perspectives of uncertainty, danger, and decisions, including:

- Map A: The first national estimates of arsenic levels in aquifers seeking to understand spatial uncertainty of contamination (Kinniburgh & Smedley, 2001);
- Map B: The first household survey results which mapped safe drinking water access based on water quality testing of main sources (BBS, 2015; WHO/UNICEF, 2017);
- Map C: The government administrative decisions allocating public infrastructure investment measured through 'safe' water points-to-population (DPHE, 2016a);
- Map D: The Ittefaq newspaper coverage of where articles explicitly identified the location of arsenic contamination and health impacts (A. Fischer, 2019).

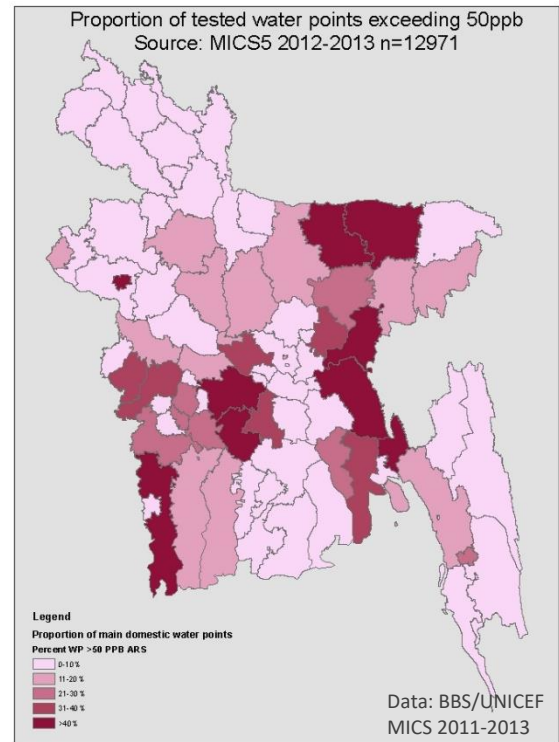
Map A: 2000 Estimated Arsenic Concentrations
BGS National Water Point Survey



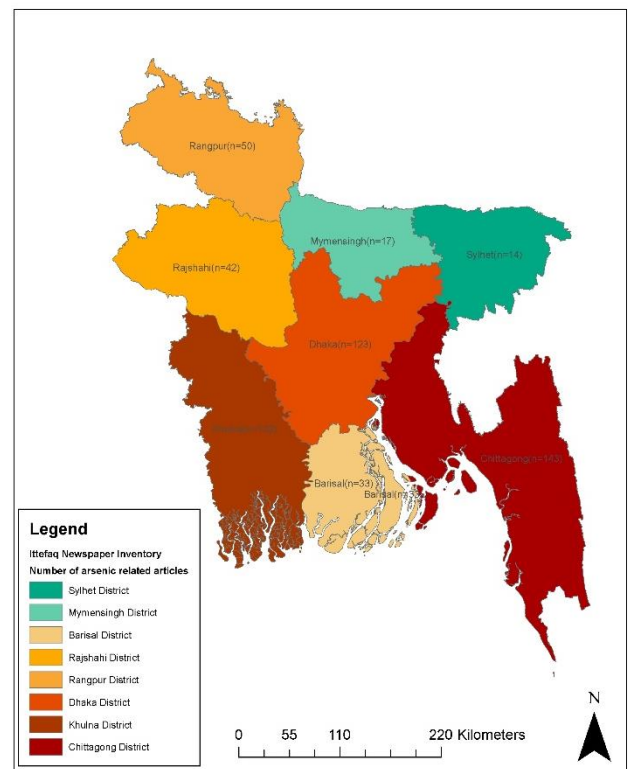
Map C: Ratio of population to safe/functioning public water points
DPHE administrative data 2016 (Red lowest coverage)



Map B: 2011 Proportion of population drinking water
with arsenic exceeding GoB Standard
Household Survey Data (MICS)



Map D: Arsenic coverage in Ittefaq newspaper articles
(1980-2016)
Main subject of article arsenic or arsenicosis



Map 1 Comparing maps visualizing arsenic risk and responses. Map(a) reprinted from Kinniburgh and Smedley (2000); maps (b) (c) and (d) compiled by author.

Although these maps simply illustrate a high-level representation of multiple perspectives on the same problem, the results show where there are converging and diverging allocations of technical concerns and administrative responses. Both contribute to the public narrative defining arsenic as a problem. The technical studies in 2000, estimating probabilities of groundwater contamination (Map A), correspond to geographies identified with the highest proportion of households with drinking water exceeding national safety thresholds ten years later (Map B). However, these areas of the country defined as problematic by technocratic analysis are not spatially analogous with socio-political narratives and responses. The areas of the highest density of public safe water points (Map C), and the divisions with the greatest explicit attention in the Ittefaq newspaper articles given to arsenic (Map D), are not consistent with these previous technical risk assessments; the greatest divergence of these perspectives are in the north eastern districts of Sylhet and Mymensingh.

This underscores a broader question of how risk assessments inform government allocation of public resources in response to defined concerns and how public narratives are framed in ways influencing public and private actions. The formal government acts, policies, and plans, as discussed in greater detail in Chapters 2 and 6, consistently emphasize the state's central role in facilitating citizens access to basic levels of water and sanitation services. However, the responsibility for fiscal investment, maintenance, and water quality safety steadily shifted away from the central government towards regional and municipal authorities and later to private self-organized collectives, both under community models and private user groups. Policy debates have primarily focused on establishing institutional arrangements supporting the provision of rural drinking water services through the public sector services. This policy focus has neglected

to clearly establish regulatory authorities, or enforcement capacity, for the growing number of individual and private enterprises models, infrastructure changes more specifically quantified in Chapter 5. The public narratives have avoided direct identification of private sector responsibility, as discussed in Chapters 4 and 6.

The thesis will therefore argue that there has been a largely unintentional, unmanaged, and informal institutional shift of responsibility from public to private actors. These temporal periods of water quality crises, technology preferences, and institutional responses are recognized, but have not been synthesized into a multi-decadal perspective of accompanying institutional transitions, specific to Bangladesh. For the rural drinking water sector, the SDGs indicators are redefining sector performance by expanding measurements of targets and challenging the effectiveness of previous implementation and service models. The redefined gaps of performance imply the need to reassess the allocation of responsibility, information needed, and regulatory rules to guide multiple decision-making processes. This raises questions of how institutional rules and decision responsibility are adapted in relation to the constructed risk narratives which dominate scholarship across multiple disciplines. This provides a core rationale for later chapters of this thesis.

1.2 FRAMING THE RESEARCH

As seen in the context of Bangladesh, there are ongoing media, policy, and academic debates around how risks-based approaches challenge previous allocations of responsibility and redefine the boundaries of expected performance for rural drinking water services. This negotiated process of risk definition further encircles the contested design of collective versus self-governed risk-management techniques. Sociologists studying risk provide a set of core phenomena, outlined in Chapters 2 and 6, that provide an analytic framework to challenge previous state-based provision models as unable to manage the unintended consequences of past decisions and increasingly individualisation of responsibility. One of the core implications emerging from this body of scholarship on risk theory is the shift away from what Beck (1992, 2008, 2016) influentially describes as the governance mentality focused on a positive logic of acquisition such as income, social services, health, or infrastructure to one which also includes the management of systemic 'bads' or negative logic of disposition of wellbeing (Beck, 1992, 2013). These debates provide a critical lens of how negotiated public narratives problematize multiple overlapping concerns while also setting constraints around limits and approaches to respond.

These tensions within risk theory are identified and present within the sustainable development agenda but examined through the lens of water security. Water resources provide an example of the dual risk framing as both a danger and an opportunity, two approaches which have been enshrined in the widely referenced and influential scholarship by Grey and Sadoff (2007) who define water security as both the provisioning of acceptable quality and quantity of water for productive and consumptive uses, and management of acceptable level of related risks (Grey & Sadoff, 2007; Sadoff et al., 2015). This frames water-related risks as both an opportunity for

productive uses, echoing the influential economist Knight (1921) who focused on uncertainty as an economic driver for risk-taking enterprise, and risk as a destructive force, as framed by Beck (1992), where increasingly uncertainty and catastrophic dangers threaten society.

Multiple disciplines, geographies, and governance systems debate these framings of risk, which directly and indirectly shapes whether risks are managed through pooled or individual responsibility structures. Classical and social liberalism for example are organized around the view that risks create dangers which institutions are able to minimise by mitigating, collectivising, and distributing through different forms of state regulation, pooled insurance, or mandatory pooled social security saving (Ewald, 1991; Girdwood, 2007; O'Malley, 2004). This is contrasted by neo-liberal perspectives built around theories of risk as an opportunity which seeks to incentivise self-governing enterprises unhindered by state interventions and or infringements on private property rights to ensure greater economic and personal freedom of choice and agency (Bakker, 2005; Mascini, Achterberg, & Houtman, 2013). The thesis explores how the rural drinking water sector is increasingly contingent on which risk framing and how risk narratives are used as an underlying approach to allocate institutional responsibilities.

While uncertainty and risk management have been defining concepts in the broader water resource management sector for decades (Allan, 1999; Wescoat & White, 2003), the rural service delivery models and analysis have only more recently expanded beyond a provision-based analytic and policy model (Bradley & Bartram, 2013). Rural drinking water service delivery in low-income countries, particularly across African and South Asian contexts, have been defined for decades by the governance techniques and approaches attached to the thinking of the late 1960s, and policy and technology innovations taken in the 1970s and early 1980s (Falkenmark,

1980; Kalbermatten, Julius, Mara, & Gunnerson, 1980; Pineo & Subrahmanyam, 1975; Saunders & Warford, 1976). These actions corresponds to the politics of international development agendas focused on addressing lagging poverty alleviation goals in rural areas and perceived limitations of public service models, thus extending government infrastructure investments outside urban areas and beyond public piped networks utility models (Black, 1998). This dissertation explores how the prevailing policies, which emerged from a specific period of global attention, have situated governance apparatus in what Arlosoroff et al (1987) advocated as responsibility allocated to community water supply strategies and village level operation and maintenance (VLOM) models. These have remained the dominant service model decades later.

The devolved decision-making structures to community-based groups and self-organized user groups are now being widely challenged as underperforming. As community systems are increasingly identified as failing to ensure safe water and reliable services due to both hardware and management challenges (Foster, 2013; Hutchings et al., 2015; Moriarty et al., 2013; Whaley & Cleaver, 2017). Scholars have long identified deficiencies in public sector ability to ensure safe and reliable rural drinking water services at scale, including concerns of “turn-key” and community management models (Carter, Tyrrel, & Howsam, 1993; Drangert, 1993). Cairncross (1987) identified the role of private-sector investment remains critical outside the widespread community models, while Hope (2015) later explores performance-based structures to incentivize private finance and enterprise service providers as alternatives to public provision models. In the past decade, a body of academics and practitioners have identified the growth and prominence of self-supply systems (J. Grönwall, 2016; Sutton, 2004, 2017) and expansion of private small and medium enterprises (Gero, Carrard, Murta, & Willetts, 2014; Koehler, Thomson,

& Hope, 2015; Opryszko, Huang, Soderlund, & Schwab, 2009) across Sub-Saharan Africa and South and South-East Asian contexts. However, these privatized service models are devolving power beyond the influence of state processes, including regulatory authorities, and require additional scholarship to identify what Hope and Rouse (2013) identify as the institutional, operational, and financial frameworks needed to ensure performance.

The remainder of this chapter seeks to define the core questions of this dissertation around how risk-theory provides new perspectives to interpret institutional design and performance; how risk-based approaches change sustainable development frameworks defining drinking water security; and how specific water risks have shaped service challenges in the context of Bangladesh. This framing outlines the main research objectives and guides the structure and sequence of the following chapters. The introduction closes by identifying the research collaborations surrounding the various initiatives.

1.3 CORE RESEARCH QUESTIONS

The central problem framing this research is: *The discursive processes constructing risk narratives are constraining the salience of problems and ability to reallocate risk-management responsibilities within institutions which hinders individual and collective actions to ensure safely managed and reliable drinking water services in rural settings.*

The core research question of this thesis is: *How do the socio-political and technical dimensions of risk theory enhance the explanation of how institutions and individuals respond to changing narratives of universal, safely managed, and reliable drinking water in rural Bangladesh?*

The thesis explores these questions through a series of sub-components, summarized in Figure 1, and explored in the context of rural drinking water sector changes in Bangladesh from 1972-2016. The historic perspective of how Bangladeshi institutions responded to multiple water quality and quantity concerns, both acute and chronic, offers an opportunity to delineate the processes of how multiple levels of an institution have adapted to changing infrastructure, information, and allocation of responsibilities in several periods of political and economic development agendas. The research questions posed in this thesis seek to explore how risk theory is a relevant lens to interpret institutional design through discourse analysis methods. It further explores how to apply risk-based frameworks to understanding the downscaling process of global goals into national country frameworks. Through that process, the research address gaps in comparative methodological tools analysing the production of risk narratives while also providing new empirical perspectives on infrastructure and development in the context of Bangladesh.

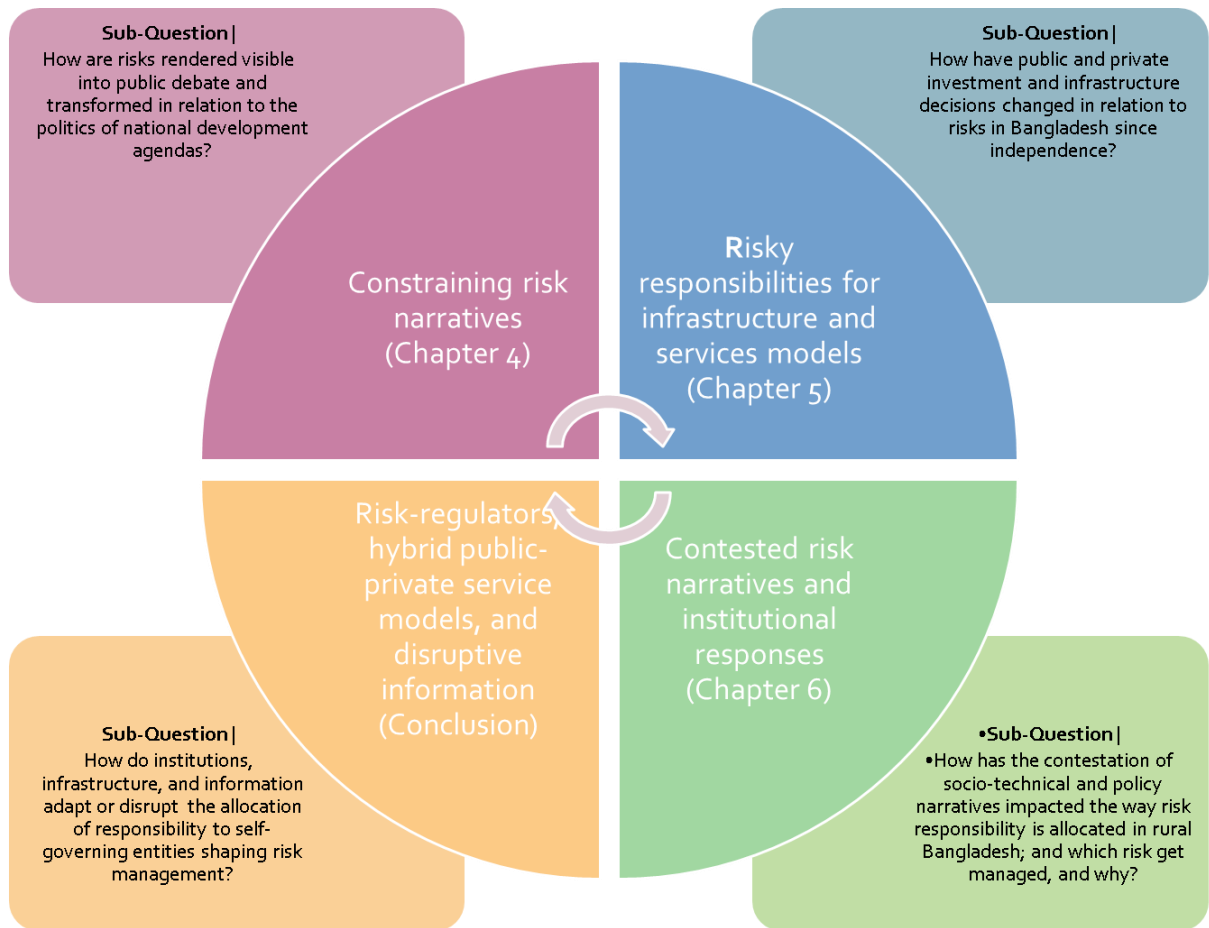


Figure 1 Summary of research questions by chapter

In order to extend risk theory, an interdisciplinary framework is explored to overcome the limits in previous comparative methods, analytic tools, and data for temporal analysis of institutional change, discussed in detail in Chapter 3. The overarching policy relevance of the research remains framed, as discussed in the previous section, by the global SDG goals which are being debated across multiple sectors and contexts, and specifically explored in literature advancing water security frameworks.

1.4 NOTES ON THESIS FORMAT

The thesis is organized in seven chapters with additional information in the appendices. After this introduction and the summary of the overarching gaps addressed by this thesis, the literature review (Chapter 2) considers an interdisciplinary body of scholarship that, once linked, provides insights into the core problem of managing multiple drinking water risks through polycentric institutions. This review provides more detailed discussion of the theoretical and empirical gaps that result from different epistemological views of risk. This chapter is followed by a discussion of the study methodology (Chapter 3) and more detailed synopsis of the study site in Bangladesh and limitations of the data and collection approaches.

This thesis takes the form of the “paper” route, which requires the three substantive chapters to be submitted to academic journals for peer-review. The three articles provide the substantive core research chapters investigating risk narratives, rural drinking water services, and institutional allocation of responsibility in Bangladesh. They form an overarching argument, linked together and discussed in Chapter 7, seeking to make empirical, methodological, and theoretical contributions. The thesis concludes with a discussion of the potential contributions and limitations of the research, and future avenues to extend these initial findings.

The text, figures, and tables for each of the core these chapters are the same as published or presented in the version submitted to the journals. Therefore, some of the introductory material in those papers are similar or repetitive of other material in this thesis introduction, literature review, and methods section. It also leads to some inconsistencies in formatting and grammar, as each journal requires different styles, including the papers written in American English and the

other chapters presented in British English. The references to figures and citations have been standardized to provide a coherent format throughout the thesis. The references have been summarized into a single list at the end of the thesis.

Published Journal Article

Fischer, A. (2019) 'Constraining risk narratives: a multidecadal media analysis of drinking water insecurity in Bangladesh.' *Annals of the American Association of Geographers*, 109 (5), pp 1433-1453. <https://doi.org/10.1080/24694452.2019.1570840>

Submitted/Under Review

Fischer, A., Hope, R., Bradley, D., Hakim, A. 'Risk narratives and institutional responses: the evolution of drinking water safety in Bangladesh, 1980-2016.' Submitted to *Cambridge Journal of Regions, Economy and Society* in May 2019.

Fischer, A., Hope, R., Manandhar, A., Hoque, S., Hakim, A., Foster, T., Islam, M.S., Bradley, D. "Risky responsibility for rural drinking water institutions: the case for regulating self-supply in Bangladesh." Submitted to *Global Environmental Change* June 2019.

1.5 STATEMENT ON RESEARCH COLLABORATIONS AND JOINT PUBLICATIONS

The thesis research design has been motivated by efforts to address core challenges and problems surrounding delivery safe and reliable drinking water services to rural communities. This research therefore seeks to contribute content and analysis to a range of actors in Bangladesh, international organizations, peer academics, and private sector enterprises. The ability to make this contribution was enabled through a multi-partner collaboration and aligning additional policy briefs and blogs to the global policy debates surrounding the Sustainable Development Goals and drinking water security scholarship.

While I am solely responsible for the thesis research including the design, survey tool development, data collection, analysis, and writing, the overall project was situated within a broader collaboration coordinated under the auspices of the REACH Programme (<https://reachwater.org.uk/>). The REACH Programme aims to improve water security for poor people by influencing policy and practice through interdisciplinary and transformative research across eight ‘water security observatories’ in Sub-Saharan Africa and South Asia. The seven-year REACH Programme seeks to enhance evidence-based decision-making through scientific leadership and investment in platforms which advance policymakers understanding of the social and behavioural dimensions of water security risk in a context of global change. This is advanced through a global science-practitioner partnership where research initiatives and activities are aligned with practitioner interventions. The main global practitioner partner is UNICEF, with additional support through the International Water Association, Rural Water Supply Network (RWSN) and IRCWASH.

The research was supported through the REACH Bangladesh programme team. The Institute for Water and Flood Management in the Bangladesh University of Engineering and Technology (BUET) is the lead research partner coordinating the three observatories in Bangladesh. The project portfolio is directed by the REACH Country Director, Professor Mashfiquis Salehin, with support of Professor Mohammed Abed Hossain and Project Manager Md. Muammer Jumlad. The BUET country program team supported the thesis by hiring of two research assistants from University of Dhaka to support data entry for the Ittefaq newspaper inventory and review of DPHE government documents. They further facilitated and coordinated portions of my travel logistics while doing field work in Bangladesh, the total trips listed in Table 1. The REACH country program includes collaborations from other senior academics from the University of Dhaka including Prof. Mahbuba Nasreen and Prof. Mohammed Abu Eusuf. The REACH research collaborations have resulted with the Matlab Water Audit survey tools and methods, described in Chapter 3, being updated and replicated in Polder 29 in Khulna.

The International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b), coordinated by Dr Md. Sirajul Islam, hosted the majority of the dissertation's field work in Matlab field site and provided the administrative support to hire enumerators to collect data for the Water Audit and provide secondary datasets.

The UNICEF Programme in Bangladesh is a core REACH partner and is led by the Chief of WASH, Dara Johnson and his colleagues Syed Adnan Ibna Hakim, Md. Monirul Alam, Tazrina Habib Ananya, and Nargis Akter. The UNICEF-Bangladesh office provided critical support linking both REACH project teams and my dissertation project to Government officials for interviews, observation of national policy debates around adapting to the SDGs, and to obtain official

permission for installing data loggers on handpumps in schools, an ongoing project and extension of this thesis findings. They further provided a three-year record of their daily WASH newspaper article clippings in support of the media analysis.

The Government of Bangladesh provided support in multiple ways including interviews, archival documents, and field support visiting public water facilities. The Department of Public Health and Engineering (DPHE) was the primary counterpart including the office of the Chief Engineer, the Research and Development Division, the office Planning Division, the office of the MIS and GIS Unit, and the Executive Engineer of Chittagong Circle.

Through these multiple project partners, coordinated under the REACH Programme's country observatories, it formed several collaborations which have advanced the quality and content of the thesis papers and lead to additional papers and multiple conference presentations with members of DPHE, icddr,^b and UNICEF—listed in Table 2 and the Appendix.

Additional support outside of REACH Programme was provided through the United Nations Sustainable Development Solutions Network (SDSN) who offer a global network of United Nations agencies, multilateral financing institutions, academic institutions and education programs, the private sector, and civil society to accelerate joint learning and promote integrated approaches that address the interconnected economic, social, and environmental challenges.

As part of this research collaboration, I invited co-authors for two out of the three chapters. The Appendix has co-author declaration forms detailing the role of each co-author and certifying that I designed, managed, analysed, and wrote the text of the papers. However, the work was not possible without collaborators and they each provided inputs critical to produce the final articles.

Table 1 Summary of field work in Bangladesh

Date	Purpose and activities	Collaboration
Oct 2015	Partnership development and secondary data collection	Icddr,b UNICEF, BUET, U. Dhaka, BRAC, DPHE
Jan/Feb 2016	Research design for field work, site visit to Matlab and preliminary informal interviews	Icddr,b (Dhaka and Matlab offices), Municipal government Matlab, household and schools, BRAC
Nov/Dec 2016	Qualitative interviews with government agencies and project collaboration	UNICEF, icddr,b, World Bank, USAID, DPHE, LGD, WARPO, WASA-Dhaka,
Jan 2017	Training of field team and piloting of survey tools	Icddr,b, UNICEF, U. Dhaka, BUET
Feb/Mar 2017	Data collection in Matlab and archival research.	Icddr,b, UNICEF, U. Dhaka, BUET

Table2 Additional related academic, conference and policy papers produced during DPHIL but not included in final dissertation.

Paper Title	Author (s)	Role
Machine Learning of Impacts of Flood Protection in Bangladesh, 1983-2014	Achut Manandhar, Alex Fischer, David Bradley, Mashfiquis Salehin, Robert Hope, David Clifton	Coordinated secondary data collection, initial analysis of data and GIS mapping, drafted portions of final paper, contributed to editing. Under Review.
Impact of Poverty on Water Quality, Diarrheal Morbidity, and Diarrheal Expenditure in Matlab, Bangladesh	M. Sirajul Islam, M. Hassan-uz-Zaman ¹ , M. Nayem Dewan, M. Shafiquel Islam, A. K. M. Zakir Hossain ¹ , Alexander Fischer, Tazrina Habib Ananya, Sonia Hoque ² , Mashfiquis Salehin, Quamrun Nahar, Niyaz Ahmed, John D. Clemens, David J. Bradley, Robert Hope	Designed sample selection and research sites, supported questionnaire design and review, trained enumerators, contributed to final manuscript. Under Review.
Reconciling polycentric administrative data to improve drinking water security in rural Bangladesh	Alex Fischer	Author for UNSDSN policy brief and full conference paper for International Conference on Sustainable Development, 2017
The Value of Water Information	Alex Fischer, Al Cho, Randolph Webb, Marc Levy, Paola Kim-Blanco, and Martin Doyle	Lead author for three of five sections. Published by Xylem Inc and presented at World Water Week 2017
Achieving and sustaining safely managed drinking water in Bangladesh	Alex Fischer, Rob Hope, Tazrina Habib Ananya (UNICEF), Md. Sirajul Islam (icddr,b)	Lead author for REACH Policy Brief, July 2017
Growth and investment in rural drinking water infrastructure	Alex Fischer, Rob Hope, Adnan Hakim (UNICEF), Md. Sirajul Islam (icddr,b)	Lead author for REACH Policy Brief, March 2018
Sustaining safely managed drinking water services in rural schools in Chandpur District, Bangladesh	Alex Fischer, Rob Hope, Patrick Thompson	Lead author for REACH Policy Brief, March 2018

2 REVIEW OF THE LITERATURE

2.1 OVERVIEW OF DRINKING WATER SECURITY, RISK SOCIETY, AND INSTITUTIONAL DESIGN IN BANGLADESH

This section provides a discussion and summary of the core bodies of literature and theoretical underpinning of this dissertation, expanding the previous section's framing of the overarching context and guiding research questions. The literature reviewed during this thesis, illustrated in Figure 2, is designed to elaborate the research gaps at theoretical, methodological, and empirical levels of questions pertaining to how institutions, information, and infrastructure systems can be more effectively designed to manage multiple risks and drinking water security in rural Bangladesh. The bodies of literature are discussed in this section, however they are repeated and expanded in the substantive chapters due to the structure of academic journal papers.

This chapter is sequenced to establish the core ontological and epistemological debates around the definition and role of risk in society. The framing is followed by a review of how discourse and communication studies are being applied to risk theory to advance new methodological

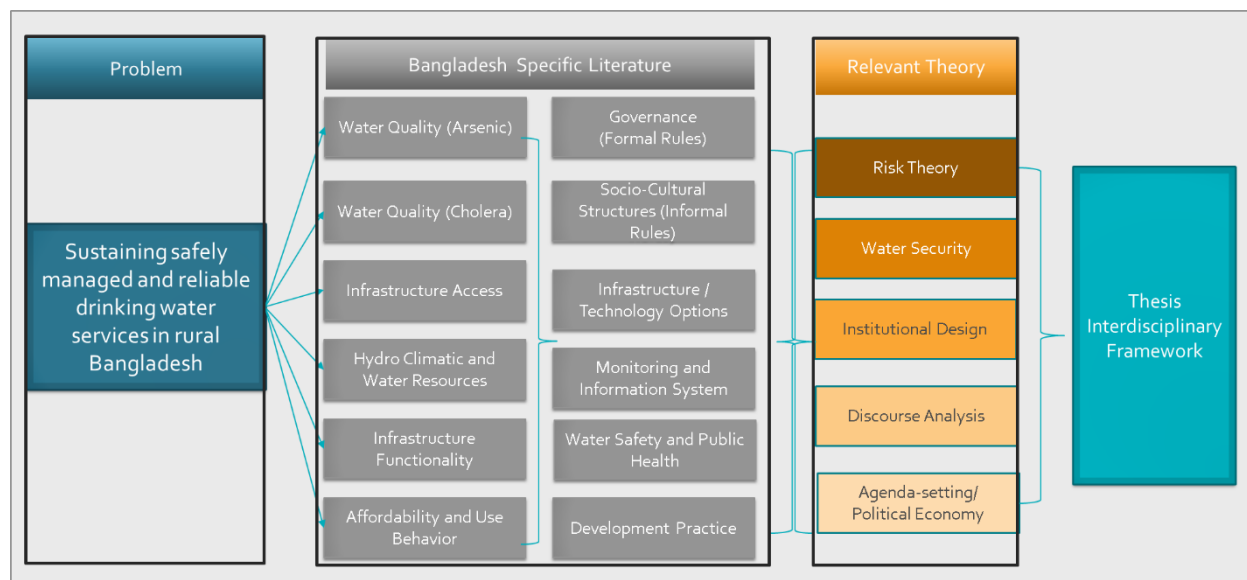


Figure 2 Summary of literature reviewed.

tools. This discussion highlights the existing interdisciplinary scholarship which merges discourse theory with political economy of development, including recent applications to media agenda-setting. The third section of the literature review addresses the identified limits of risk theory around analysis of institutional structures and specific processes of change by aligning the dimensions of risk with the components of institutional design principles across multiple levels of decision-making. The chapter is concluded with a review of how risk-based approaches have shaped the conceptual framing of drinking water security, the limited application to the rural geographies, and a summary of academic literature in Bangladesh related to drinking water variables and the historical progression of the formal dimensions of sector governance.

This literature review provides a wide-ranging basis to advance the arguments and empirical work in the following chapters. As discussed in the following methodology section, one of the strengths of interdisciplinary research is the ambition of bridging debates, but it also has limits. It is not feasible to summarize the entirety of each body of literature in multiple disciplinary fields, so I have done my best to define the key concepts, identify the current debates surrounding each theory, and draw out the linkages which unify the thesis. This necessary complexity is addressed by limiting the literature review to key debates and gaps which links risk theory as the primary analytic lens to related fields of research discussed in targeted ways. This acknowledges that the main findings, which primarily seek to define additional value of risk theory, directly and indirectly contributes to a wider set of interdisciplinary debates which will benefit from additional attention in future studies.

2.2 RISK AS AN ANALYTIC LENS

Partitioning risk phenomena: uncertainty, blame, and decisions

Risk has become a dominant and defining concept of modern society, providing a language for governance technologies while also challenging the capacity and politics of existing institutional designs. Situated within a plurality of ontological views debating ways to construct and react to risk, the thesis recognizes the diversity of these previous debates but focuses on the epistemological variations of how risk is rendered visible and translated into action through discursive and quantitative languages. This section reviews the continuum of definitions, from realists view of risk as a hazard identified through probabilistic calculations to constructivists who see risk as discursively constructed concept used to structure society and governance techniques (Bradbury, 1989; Dean, 1999b; Lupton, 1999a). Historically, this enabled diverging perspectives on how 'risk' is defined and reflects decades of debates which continue to structure the reaction and techniques to manage the defined concerns (Douglas & Wildavsky, 1982; G Mythen, Burgess, & Wardman, 2018; Rayner, 2012; Sørensen, 2018). These multiple ontological views call into question the epistemological approaches used to understand the process and methods of how risks are imagined and rendered visible, either as real hazards or as social, political, and economic constructs used to interpret and manage decisions.

This analysis leads to definitions of risk loosely grouped around three core concepts: uncertainty, blame, and decisions. There is a rich body of literature debating and applying these theories to multiple sectors; however, in the limited space of this literature review, I attempt to synthesize the core elements of the varying definitions of risk: techno-scientific realist perspectives of risk

defined as calculated probabilistic estimates of hazard, vulnerability, exposure, and impact (Hubbard, 2007); cultural theory which defines risk as a strategy for identifying danger and assigning blame (Douglas, 1992); critical and post structuralists who define risk as the possibility of damage resulting from the consequence of one's own decisions and thus a technique of governance to narrate, control, and regulate the production of problems as ways to manage populations (Beck, 1992, 2009; Ewald, 1991; Giddens, 1990; Luhmann, 1990; Rose, O'Malley, & Valverde, 2006). Within risk debates, the plurality of definitions is common and thus the language describing risk remains unstandardized despite the agreement that the concept is central to modern institutions and shaped by the formal and informal rules that guide individual and collective choices.

Controlling uncertainty through probabilistic language

The techno-scientific approach focuses on reducing uncertainty by defining risk as an observable hazard where vulnerability and magnitude of exposure is calculable through a range of probabilistic estimation and assessment methods (Lupton, 1999a). For the realist perspective, uncertainty is a manageable threat which can also create opportunities and is often measured by the extent of potential damage or harm that the hazard entails, multiplied by the probability of the outcome (Fischhoff & Kadvany, 2011). The driving focus is around protecting capital and welfare, including distribution of wealth and access to health and education services. It is situated within a wider framework of behaviour-orientated theories where individuals and organizations, who can be both risk averse and risk seeking as categorized by Kahneman and Tversky (1981), have agency and incentive to maximize the highest value of their decisions.

This view of risk leads to a wide range of analytic tools to reduce uncertainty and guide decision-making processes by identifying the level of concern and accuracy of predictive estimates. By seeing risk as a product of uncertainty, it leads to the perspective approach that anything and everything is measurable as argued by Power (2004) and Hubbard (2007) and thus forecastable to support decision-making. This dominant approach leads to what Rayner (2003) labels 'the age of assessment' with a wide range of techniques used to constrain or guide decisions, including calculating thresholds such as safety goals, exposure limits, standards, performance metrics to justify policy decisions across industries.

The result of these risk-based approaches are widely adopted across sectors and technologies of government, and from climate sciences to public health from agricultural to energy, with experts deploying an increasing number of risk analysis techniques ranging from cost-benefit analysis to dose-response curves to climate forecasting models (Rayner, 2007), thresholds of acceptability (Klinke & Renn, 2002), to modelling intervention decisions such as public health scoring to trade-offs in flood or land management (Shepherd et al., 2015). Extending Ewald (1991, p. 199), who argued that 'risk' depends on how one analyses danger, realists implicitly suggest that the value of information is contingent on how the object or concern being measured supports specific decision-making processes. Ewald (1991) further argues that insurance is a rationality and technique of government which depends on quantification of chance, hazard, probability, eventuality, or randomness. While insurance becomes a primary tool of risk management, governance tools are becoming increasingly reliant on expert techniques for reducing uncertainty in order to enable formal decision-making processes.

Constructing blame and danger

The techno-scientific perspective is contrasted by the epistemological view that risks are socially constructed through cultural and political processes, rendered visible through discourse and socially determined allocation of concern. This perspective on risk is characterized by what Ewald originally framed as “nothing is a risk in itself; there no risk in reality. On the other hand anything *can* be a risk; it all depends on how one analyses danger, considers the event” (Ewald, 1991, p. 199). This second overarching body of structuralist scholars agree on a core observations that what is problematized in public narratives and policy is not solely contingent upon the techno-scientific designations of concern to explain why certain issues are managed while others are not, a question explicitly posed by Conca (2015) in relation to the water sector.

While the key bodies of constructivist scholarship agree on the delineation of these questions as outside techno-scientific quantification, they propose different epistemological approaches to understand why and how risks are rendered visible. They start from largely similar points of agreement around four common observations, summarized by Lupton (1999a), including the increasing pervasiveness of risk as a defining concept in Western societies; risk being a central aspect of subjective human decision-making processes; risk as something that can be managed through institutional interventions; and risk are defined by concepts of choice, responsibility, and blame. These concepts, specifically the process of assigning blame and allocating responsibility, are areas extended throughout this thesis.

A large body of cultural theory scholarship raises questions of how social and cultural factors shape the construction of shared knowledge and how this interpreted knowledge leads to different outcomes of individual and collective organisation in response to the defined danger.

These theories build around the work of Douglas (1966; 1982) who questioned how particular kinds of concerns are identified as dangerous and selected for attention while others are not, and how these defined concerns are used to establish and maintain conceptual boundaries between the self and others. This perspective broke away from dominant views of homogenous rational choice and questioned how shared values shape decisions and preferences for organizing in response to socially defined risks. The early writings of Douglas (1966, 1992) specifically identified the process of attributing blame for danger as political, particularly when it threatens specific social groups. This concept is expanded in later thesis chapters in the context of Beck's view that new types of unattributable blame are challenging the spatially defined boundaries and capabilities of nation-states. The seminal work of Douglas identified the variation of how danger is constructed and perceived through cultural frames and how blame for certain risks is attributed varies from others. This explicitly differentiated the perspectives that risk are objective and techno-scientifically authenticated processes to ones which are contingent upon multiple individual and collective processes. One indirect application of these theories is seen in the anthropological studies by Hanchett et al (2014) and Sultana (2009) in the context of rural Bangladesh, which explores drinking water user behaviours in relation to culture and religious beliefs and socio-cultural designations of safety and purity.

The cultural theory of risk led to critiques of cognitive risk theories that focus on methodological individualism and decision making shaped by individual psychology through value creation and trust building. In contrast to risk rankings and heuristics, cultural theory identified that risk preferences are political, social, moral, and aesthetic, partially constructed through cultural frameworks that define social boundaries. This perspective provided a framework to describe

forms of collective organizing as risk-responses based on the social relations and interaction of values, risks, and levels of organisation (Douglas, 1999; Rayner & Gross, 1985; Tansey, 2004). The resulting grid-group organisation framework which provides four cultures of risk organization, is applied by Koehler et al (2018) to describe the plurality of rural drinking water management cultures and the resulting complexity. These theories extend the concept of culturally-defined shared categories of thoughts, or cognitive systems, as learning processes which shape the link between socially constructed knowledge and institutional learning and responses (Douglas, 2011). The feedback loops between the process of socially constructed knowledge and allocation of blame for identified dangers are related to the limits of institutional design in a risk society. However, they do not fully integrate theories on the political and technical process which allocate formal and informal responsibility within these cultural frameworks shaping organization.

Controlling the consequences of decisions

In contrast to cultural theory, although originating from similar ontological perspectives, Beck (2009), Luhmann (1990), and Giddens (1990) position their discussion of reflexive modernity by framing risk as the consequences of human decisions, in explicit contrast to danger which is seen as an objective condition of life. Luhmann (1990) differentiates risk as the possibility of future danger attributed to an external event. This group of scholars specifically differentiates their core focus away from cultural theorists use of 'danger' with a greater focus on construction of knowledge and consequences of past decisions.

Asking similar questions of the macro meaning and strategies of risk in society, Dean (1999a), Ewald(1991), and Rose (1991) engage risk theory from the perspective of Foucault's lecture on *Governmentality* (1991) which argues that risk is a calculative rationality and structured through

discursive negotiation. This perspective specifically identifies how conditions of thought are brought into being; not what makes risk calculable but what makes risk thinkable and manageable through techniques used to govern. The techniques include the risk rationalities and technologies of control that “tame the infinities of risk” (Aradau & Van Munster, 2007) through discourse, calculation, and institutional responsibility (Castel, 1991). The scholarship of this group of scholars focused on how risks are understood as a strategy of regulatory power by which populations and individuals are monitored and managed.

The work of this body of scholars led to a discussion of social regulation and control of the future through networks of interactive actors, knowledge, and practices rendered visible through the discursive process (Rose, 2001). This focus on how we exercise power over others and govern ourselves resulted with scholars focusing on the way that risk-responsibility is allocated. Ewald (1991) focused on collectivized or pooling risk management through insurance models. This was extended by Dean (1999a) who argued that beyond capital focused models of insurance, risk rationalities also include health and well-being through epidemiological, clinical, and case-management approaches.

Building from similar epistemological structuralist origins, O’Malley (1996) distinguishes risk mentalities as historic shifts in the assembly of discourse, rules, and practices which allocate responsibility. O’Malley specifically identified the transitions from collectivized approaches of risk-management through social contracts between the central state and citizens into social insurance models including social security and insurance, towards the increasingly dominant forms of neoliberalism where individuals are responsible to manage their own risks, from private savings instead of social security to limited government regulation or oversight. These

approaches, by focusing on how decisions are connected and controlled, interrogate authority and agency over populations, and thus imply formal and informal rules around constraining behaviour.

These multiple bodies of overlapping risk theory explore different ways of thinking about and reacting to risk. They agree in the social evolution of risk originally considered as an act of God or later as an act of nature, to one caused as a result of collective and individual decisions. Sociologists now widely agree, building from the seminal work of Beck's (1992) *Risk Society*, that we are in a new era of reflexive modernization, or a state of self-confrontation with the unintended side effects of past decisions and where social practices are constantly examined and reformed by incoming information about those practices (Beck, Giddens, & Lash, 1994; Dean, 1999a; Giddens, 1990, p. 38). By framing risk as an attribute of decision-making, it raises questions around freedom of choices and unintended consequences, what Luhmann (1990) labelled post-decisional regret. It is through this definition that the thesis seeks to expand the conceptual framing to address gaps in risk theory around the practical application of analysing institutional limitations. Although linked, risk theory from the sociological perspective does not provide extensive insights into the definition and historic evolution of institutional design and performance.

2.3 RISK SOCIETY AS A DEFINING FRAMEWORK

The thesis focuses on three defining features of risk theory framed around uncertainty, danger, and decisions, concepts which are interspersed across social scientists' approaches and explored using interdisciplinary methods, however often defined and applied differently. Despite clear differentiation of applications, Beck's theory of *World Risk Society* (Beck, 1992, 1996), later expanded into *Metamorphosis of the World* (Beck, 2016), seeks to reconcile these three themes and frame the debate to explain how and why risks matter within the process of societal change.

Beck's seminal work in *Risk Society* (Beck, 1992) illuminates what he described as the society-shaping forces embedded in the catastrophic nature of unknown consequences of industrial modernity, which in his view, are the fundamental challenge to existing social and political systems. For over four decades, Beck (1992, 2006b, 2006a, 2016) argued that the systemic production of risks by society, largely unintentional, has created seismic shifts in society and questioned the capacity of nation-states to respond. The consequences of manufactured uncertainties are interpreted as "poverty is hierarchic, smog is democratic" (Beck, 1992, p. 36). Beck argues this leads to the collapse of society based on wealth and class systems, replaced instead by a risk-based system defined by distribution of self-produced and undiscerning catastrophic risks. Beck (2013, p. 71) argues "risk, not class or war, is the determining factor of power, identity, and the future." This frames his contributions to macro-social critiques of globalization, individualism, and reflexivity in the context of changing nature of risk phenomena. While Beck's work is framed in terms of catastrophic damage, this thesis sees relevance and applicability of his observations to non-catastrophic concerns, specifically when addressing his

critiques of the institutional limits to managing unintended consequences of past decisions. This literature review does not seek to provide a detailed overview of all of Beck's theoretical contributions; instead, it seeks to discuss defining features of Beck's overarching theory to create an interpretive framework, and in return, address several criticisms. This includes extending the phenomena of risk society beyond non-catastrophic events to ones which share elements of manufactured uncertainty; interpreting the boomerang effects of previous collective and individual decisions; shifting risk mentalities in response to blame and responsibility; identifying limits of political institutions; and responding to the challenges of achieving reflexive governance.

Beck's views on the process of institutional change are incomplete. Beck (1992, 2006c, 2011) argued there is a fundamental shift in the politics of nation-state institutions as risks become global and the social contract between state and citizen is threatened by a decreasing ability to manage the unintended consequences of industrialization. Beck's core theories identify the shift from a positive logic of acquisition to a negative logic of disposition, what he argues is causing the collapse of class-based modernity. Beck argues for reflexive governance as the social-political response; an adaptive and self-critical institutional design. However, the nuanced description of these institutions is limited. Other scholars including Rayner (2007), Mythen (2005), and O'Malley (2004) have focused this discussion on the reallocation of responsibility, including the observed decline in collective risk pooling structures and shift away from techno-social authority. For Beck and others, this process of institutional change becomes dependent on reflexive responsibility, which is framed as contingent upon the way public risk narratives are negotiated between techno-scientific, political, and media discourses.

Manufactured uncertainties and the difficulty of allocating blame

Central to Beck's argument is the concept that institutions, which negotiate contested socio-technical knowledge, have lost control over the cause-and-effect relations resulting from the industrial foundations of modernity, what he labels 'manufactured uncertainty' (Beck, 2009). These observations are initially grounded in the context of catastrophic ecological destruction, specifically discussed in relation to climate change, industrial pollution, and nuclear accidents, but expanded after a range of critics identified the limit of these examples (Aradau & Van Munster, 2007; Bergkamp, 2017; Elliott, 2002; Gabe Mythen, 2007). By the mid-1990s Beck (1995) continued to emphasize examples of chemical, atomic, genetic, and climate related hazards which were defined by vulnerability that cannot be easily delimited spatially, temporally, or socially, thus challenging institutions designed to control and allocate these uncertainties. The changing nature of hazards results with a transition in society away from controllable 'unknown, knowns' to uncontrollable 'unknown, unknowns', or the politics decision-making within the context of 'non-knowledge' (Beck, 2009; Rayner, 2012). These questions of manufactured uncertainties challenge both the ability to 'govern by numbers' (Rose, 1991) and the allocation of blame for self-produced problems. This view of uncertain blame and manufactured problems becomes a central theme in the critical analysis of Bangladesh's drinking water services and infrastructure decisions, and wider development narratives. Beck therefore views the unintended and unforeseen side effects of modern life as backfiring on industrial modernity.

By confronting the concept of non-calculable risks through unknown unknowns, the unintended consequence of technological and social innovations challenge the allocation of blame, and thus accountability for previous decisions (Burgess, Wardman, & Mythen, 2018). Beck identifies an

increasing mistrust of corporations, scientific institutions, and government framed around how causality of hazards are attributed to past actions. This mistrust reflects a dilution of both the techno-scientific and social-political systems ability to confront itself and diagnose blame, which leads to Beck's core divergence from other risk scholars when he argues that new risks have become incalculable, thus non-insurable without clear blame and predictability. Previous social contracts where states assumed a risk-management role, often centred around insurance-based or collective saving models of varying forms, are suddenly undermined. The insurance model is designed to allocate blame for outcomes and is generated around the probabilistic understanding of unknown, knowns and controllability of nature and behaviour. The tension between controllable and uncontrollable risk, and growing challenge to allocate blame underpins Beck's view of risk is increasingly outside traditional quantification tools and no longer limited to specific geographies or time periods (Sørensen, 2018). Beck's writings suggest that institutions are designed to allocate blame in order to structure the response, however the self-confrontation of modernity's side effects creates a problem for this process and the socio-technical narrative.

Boomerang effects and shifting from a provision of goods to distribution of bads

This leads to a second core component of Beck's theories: the shift in risk mentality from a logic of wealth acquisition, including capital, income, education, health services, to one of disposition due to potential harm. Beck likens risks to wealth by viewing them both as objects of distribution. By viewing risk as distributable, visible through socio-technical narratives, Beck interprets the unintended consequences of individual and collective decisions resulting from an industrial society as non-discerning and universally threatening. These 'boomerang effects of risk

distribution,' (Beck, 1992, p. 37) implicate both those who perpetrate and produce the problems with those who are equally a victim, transcending previous social boundaries.

For Beck, these boomerang effects are creating a process fracturing previous patterns of class and nation-based society (Beck, 1992, p. 23). He argues that the newly self-produced dangers dissolve previous class boundaries by uniting populations under a logic of equal risk; the unforeseen ecological catastrophes which are no longer distributed according to wealth, social strata, or geographically defined state boundaries but now affect society as a whole. Beck later reinforces this by citing how Chernobyl, the 9/11 attacks, climate change, and the financial crisis are events that were inconceivable before they occurred, global in character, that critically transcended past class-based vulnerability. These theories have been heavily criticized as ignoring how class antagonisms and wealth are used to mitigate or differentiate risk vulnerability and exposure (Atkinson, 2007; Curran, 2013; Lash, 1993; Gabe Mythen, 2005; Rasborg, 2018). Beck addresses these critiques, acknowledging pollution follows the poor, but continued to argue that there is a difference between individual and systemic risk, and a difference of harm and catastrophe. Indirectly, Beck's discussion of this redistribution of goods to bads raises questions about the process of blame and thus responsibility, a question raised in the context of Bangladesh's water insecurity.

Politics of risk knowledge: the intersection of numbers and narratives

Beck argues that the production of these 'bads' differ from wealth in that they remain largely invisible until interpreted and negotiated by scientific, or 'anti-scientific', knowledge. This process of interpreting information frames the political contestation around monitoring and knowledge formation. Following the ontological perspective of other social risk theorists who see risk as constructed, Beck maintains the understanding that 'risk' is a socially and technically negotiated concept, but also one which is mediated by the political significance. His earlier work debated the role of technical expertise, with views that risks cannot exist beyond numbers or social interests (Beck, 1992, p. 28). This generated a series of criticisms that he advanced ambiguous and contradictory ontological positions, being labelled a weak social constructivist (Elliott, 2002; Lupton, 1999a; Rasborg, 2018). However, instead of treating Beck as advancing ontological debates, Dean (1999b, p. 176) argues Beck frames risk as pluralistic modes of knowledge and calculating rationalities which set different ways of ordering reality and forms of discourse to render the concerns visible. This view has been adopted by an emerging group of geographers developing concepts of 'riskscapes' or the socially produced collective imaginations where the complex, multiple, and overlapping temporal spatial phenomena of risk link the material dimensions of potential physical threats with the discursive dimension of how people interpret, communicate, and understand future (Müller-Mahn, Everts, & Stephan, 2018). These perspectives all seek languages and practices to render the future imaginable and as linked to present decisions and actions.

The intersection of techno-scientific perspectives and politics of risk also play out in Beck's early discussion of what determines acceptable or 'safe' toxicity levels. These questions were not

explored extensively beyond his earlier works; however, the question is seen in the case of Bangladesh around questions of if, and what, are acceptable arsenic thresholds and why they differ between national and international standards. Beck's prescriptive findings are based on the precautionary principle, stemming from his argument that risks are catastrophic and politically constrained.

The construction of risks can therefore be manipulated, or minimized, as they are open to social definition and negotiation. Beck (2009, p. 298) addressed critiques of his perspective in his later work by explicitly arguing that risk is a socially constructed collective understanding of making the future knowable through the discursive production and definition of risks that elude everyday physical perception. This places media, scientific, political, and legal professions as defining voices to risk narratives, including the role of negotiating and interpreting acceptable risk thresholds (Beck, 1992, p. 23). Beck's references to the media are not deeply explored and largely underdeveloped in relation to the discursive process related to social contestation around scientific and political framings of risk narratives; his early observations focus on media's intention to generate 'shock-value' to increase sales. These limitations, first identified by Cottle (1998), are conceptually addressed by Beck in later work clearly identifying that "without mass media, risks are nothing at all" (Beck, 2006a, p. 332). However, Beck's response does not provide insights into the process of how media renders risks visible. This thesis, in Chapters 4 and 6, seek to extend this analysis, and suggests that Beck's theories can be linked with other bodies of literature to more coherently explore the role of socially constructed risk narratives, specifically related to the evolution of institutional design and process of reallocating risk-responsibilities.

Reflexive risk governance

This thesis accepts Beck's core argument that society is in the process of transitioning away from post-industrial modernity and moving into an era of 'reflexive modernity' defined by the duality of both the risk logic of acquisition and one of risk mitigation as disposition (Beck, 2013, 2016; 1994). This process is what Beck defines as reflexive modernization: risks are not only external events linked to nature but are also, and increasingly, the side effects of self-produced problems (Beck & Holzer, 2007, p. 8). Similar to Beck, Giddens (1990, p. 38) defines reflexivity as the self-examination of social practices and focuses on how society adapts as a response to incoming information about those very practices. This mirrors a concept core to many adaptive governance models debated in the water sector and specifically discussed by Pahl-Wostl (2009) as triple learning feedback loops. Beck's thinking enters from a different approach in that he doesn't explore the specific processes of learning surrounding risk perspectives. Instead he focuses on a macro view of how the unintended side effects have exceeded the capacity of the techno-scientific calculation and thus, as a result, creates political reactions seeking to constrain how knowledge is produced. Bulkeley (2001) expands on this by identifying process of deemphasizing techno-scientific expertise after it becomes politicized in self-reflexive critique, shaping the extent of public deliberation of unintended consequences of past decisions. This is further advanced in the specific lens of sustainable development, where Voss et al (2006) argue problem solving is no longer linear, and that cycle of production requires interacting pluralistic perspectives to transcend complexity and overlapping arenas of decisions.

These arguments for reflexive learning processes are further adapted into debates around risk-based governance. A group of scholars argue that risk is an assemblage of strategies of

government and regulatory power by which populations and individuals are monitored and human decisions managed (Lupton, 1999a, p. 87; O'Malley, 1996; Rose, 1996). Bergkemp (2017) counters this argument by seeing the *Risk Society* framework as frustrating specific efforts to enable techno-scientific prioritization through risk assessments; encouraging democratized science undermining objective and value-free research; and instigating the dominance of precautionary approach requiring proof of no harm before any action. There are clear pragmatic limits to Beck's writings, although this thesis argues the framework provides further insights into how and why risk knowledge is formed and how responsibility is allocated between collective and individual arenas of action.

Reallocation of risk responsibility from the state to individuals

Beck's earliest work through to his final book argues, or at times implies, that conventional political forces, including representative governance systems, scientific institutions of industrial society, and the media are unable to provide the protection or control the uncertainties emerging from the unintended consequences of industrialisation. Beck (1992) observed a techno-political contestation around where blame for hazards is attributed, a negotiation between controllable nature versus a less controllable outcomes of industrialisation. This perspective has been indirectly applied in Bangladesh in relation to questions of how to allocate legal responsibility for the consequences of arsenic exposure, with a debate between nature and the organizations driving the expansion of shallow tubewells, discussed by Atkins et al (2006). This perspective highlights the attempt to allocate blame away from nature towards the consequences of previous decisions.

Institutional uncertainty emerges in part from the challenge to reassign accountability from nature, which has been previously framed as controllable, towards blame for the unintended and uncontrollable consequences resulting from the pursuit of industrialization (F. Fischer, 1998). The previous socio-political centrality of service provision is core to many social contracts between the state and citizens and shapes a risk-management mentality. However, this inadvertently limits the political capacity for self-reflexive politics, and as Beck (2006b) identifies, makes the very institutions responsible for managing risks part of the problem. This question is explored further in Chapter 6.

Beck's theories do not provide extensive insights into how or where responsibility is being reallocated or the process of socio-political negotiation to transition into self-reflexive governance models. Further, his work does not provide extensive analysis of the differentiated roles of state, non-state, and private sector actors, whereas Rayner (2007) observes that risk plays an essential role in the displacement of government responsibility towards private sector and NGO actors, while still facilitating new forms of government control over citizens. The process to reallocating blame, and thus responsibility, is likened to the process of identifying the 'trustees' in charge of managing these new risks. Who assumes this responsibility, and through which processes, becomes a central unanswered question within Beck's arguments of organized irresponsibility and how risks are constructed in relation to power relations and definitions.

There are a range of contemporary risk strategies, including what Dean (1999a) and O'Malley (1996) outline as social welfare, regulatory control, insurance over capital, public health through epidemiology and clinical management. Scholars of both Risk Society and Governmentality focus on the retreat of the welfare state and change in labour relations under economic liberalism.

Beck focuses on individualization of identities but does not identify and discuss individualization of responsibility within the process of institutional change and reflexive response to risks. O'Malley (2004), Hamilton (2014), and Mascini (2013) are among several scholars who extend Becks core observations to frame the transition of liberal governance models as a shift in the risk-responsibility framework from pooled risk models towards self-governing responsibilities. The change in labour laws and decline of social security saving models shows one area where safety nets are waning. Another example is that fixed nation-state political players are losing control over nonterritorial capital, finance, and commerce. The neoliberal model of risk management promotes self-governing and individualized risk management, an approach which enables entrepreneurship with limited interference or constraints to enhance risk-taking behaviours (Ericson, 2005). Risks are therefore being 'de-socialized' (Elliott, 2002, p. 304) or as Mythen (2005) argues, discourses promoting self-regulation under new governance strategies to conceal previous institutional responsibility. While these scholars look at capital and labour to identify the transfer of responsibility from collective pooling mechanisms to individualize management, this thesis argues the drinking water sector has similar trajectories.

In summary, social theory of risk, particularly Beck's writings on World Risk Society, provides an important analytic lens to question why, and to a lesser degree how, institutions are changing in response to self-reflexive risks. However, social theory alone does not provide sufficient insights into the discursive process of rendering risks visible and the politics mediating the construction of knowledge, or how and specifically where institutions are failing within a multi-levelled overlapping system of decision-making.

2.4 DISCOURSE, DECISIONS, AND RISK

Construction of knowledge and power through discourse across media, science, and politics

The question of how knowledge is formed in society is addressed across almost every major branch of social science and debated across a plurality of epistemological perspectives similar to risk theory. The wide body of research and academic literature analysing the socio-technical construction of knowledge largely aligns to define discourse as a complex bundle of interrelated linguistic actions—language-based and iconographic—which are used to exercise power, shape human perception, and affect individual and collective actions (Ruth Wodak, 2009). Jäger expanded this definition as the flow of knowledge across time which reflects institutionally consolidated speech, and determines “individual and collective doing and/or the formative action that shapes society” (Jäger, 2001, p. 33). The use of language attaches meanings to previously neutral concepts in order to render the future knowable, as potential opportunity or as a problem. This includes the example from risk scholars who use the object of an apple as an example of something that can be framed as either a source of nutrition or a cause of future harm from pesticides and chemicals. For example, a recent media story emerged in Bangladesh of formaldehyde contaminating apples (“Fruits not adulterated with formalin: experts,” 2018; Lupton, 1999a).

A full review of this literature is not the focus of this thesis, nor feasible in the limited space, thus this review does not consider cognitive psychology or individual-level use of language. Instead, I briefly review the following components: the context of discourse theory bridging planes of simultaneous and interrelated texts; methods used by communication studies including agenda-

setting and content analysis; and the perspective of manufactured narratives linked to political economy of each body of text.

Linguistic scholars emerging from critiques of power and language, developed a range of critical discourse analysis frameworks and methods to advance understanding of how texts, speech and imagery shapes societies construction of problems and accompanying action (Fairclough, 1995a; van Dijk, 1993; R Wodak, 1999). This body of scholarship argues that knowledge is formed through a collective and historic process and shapes what can, and cannot, be thought (Hajer & Versteeg, 2005). The scholars develop a range of grammatical structural analysis approaches focused largely on form, meaning, and to a lesser but important extent on context and situation. Jäger offers a typology of the structure of discourse, starting with ‘discourse strands’, or thematically uniform topics covering past, present and future. Each of these strands, such as drinking water, is comprised of multiple ‘discourse fragments’, or specific texts and ‘discourse planes’, or location where the speaking happens such as science, politics, media, etc (Jäger, 2001, p. 46). This provides a framework for the thesis to identify how drinking water is problematized over time, across and between different bodies of text, and through multiple planes from which discourse emerges. Despite this recognition, many discourse analysis methods have remained siloed around individual themes, single bodies of text, or individual planes. Through a specific discussion of risk, Bakir (2010) and Kristiansen (2017) identified that discourse analysis, although limited to their assessment to mass media, has significant gaps in the research methods enabling longitudinal, historic, and cross-text comparative perspectives linked through common risk definitions.

Methods to manufacture risk narratives

Evolving in tandem but differentiated from linguists, critical sociologists argue that 'risk' requires a language to render it visible and defines the process through which meaning is attached and negotiated. Post-structuralist scholars more explicitly advance arguments that power and knowledge are intertwined through bundled forms of discourse within a wider sociocultural framework. These construct specific types of governable risk by structuring ways of imagining social problems in order to make them manageable (O'Malley, 1996). Dean identifies four specific dimensions linking risk discourse with governmentality: what is the process through which we come to know and act upon different conceptualizations of risk; how are these conceptualizations linked to specific practices and technologies of government; how practices give rise to new forms of social and political identities; and how these constructed rationalities are attached to different political and social imaginaries (Dean, 1999a, p. 187).

Following this perspective, a growing group of scholars argue that discourse has shaped the rationalities of governance and allocations of responsibility, specifically reinforcing shifts towards self-regulation and individual action. This includes the work of Bakker (1999, 2013) who focused on discourses of drought and the construction of urban water binaries of public versus private models. These views of discourse provide approaches to trace power struggles but does not results with specific policy recommendations (Hajer & Versteeg, 2005). The work of this body of scholars provides a critical perspective on how shifting processes of knowledge production, mediated through discourse, provide critical insights into how institutional allocations of responsibility are designed and the embedded link to the politics of governance techniques.

A second and complementary body of literature further focuses on the political economy of media and communication of risk bridging both approaches from both linguists and critical sociologists. Communication scholars identify the contrasting perspectives of the role of media with a specific tension between the liberal-pluralist and Marxist views. The liberal-pluralist views the media as the guardian of public interests and watchdog on the exercise of power while Marxist scholars see media as a powerful tool to structure a class-based society and one constrained by the dominant interests of the political economy (Mullen, 2010, p. 674). This extends what Lippman (1922) famously argued is the media's role in shaping public opinion and manufacturing public consent to wider socio-political narratives. This leads into a body of literature focused on the what Entman (1993, 2007) describes as media having the ability to frame the selection and salience of information, including defining the problems, diagnosing the causes, making moral judgements and suggesting remedies. Luhmann (1996) further critiques of media as self-regulated and thus guided by a set of internal codes enabling the selection and interpretation of information.

Beck's writings identified these tensions between technical and politically mediated knowledge, and he indirectly identifies three central roles for mass media: social construction, social contestation, and social criticism (Cottle, 1998). This raises questions if the media is capable of reflexive contestation or criticism of the unintended consequences of past decisions, a topic explored in Chapter 6. These perspectives provide a series of specific methods adapted in later chapters of this thesis.

These approaches have been applied across an expansive body of literature, however the work from Herman and Chomsky (1988) provides a specific set of filters to analyse the reflexive

capacity of media and understand the specific contestation between technocratic control and power of the media to structure knowledge. Herman and Chomsky see filters as techniques to exclude certain content and messages and thus control the message. The analytic tools from *Manufacturing Consent* are detailed in Chapters 4 and 6, thus they are not repeated here. However, the limits of this approach remain clear and are addressed in these later chapters. The first is that the agenda-setting and risk communication fields provide limited methods to interrogate how public media, science, and policy texts are intertwined both in the perspective of contested narratives, competing interests, and inter-text criticism. This framing and application of how the interactions shape thought are tools critical to advance Beck's theories of reflexive modernization.

2.5 INSTITUTIONS AS RISK MITIGATORS

Institutional perspectives on reducing uncertainty of decisions

As discussed in the previous sections, risk theorists discuss drivers of institutional change without explicit placement within an institutional framework. The identified features of risk theory are conceptually linked to institutional design through the mutual focus on where and why decision-making occurs, the interpretation of uncertainty in that process, and the allocation of responsibility using formal-informal rules which place constraints on choice sets. Institutional theory therefore provides a complimentary perspective to deconstruct choice and action shaping behaviour, and design problems in the information or decision-making structures. Many of these theories build around problems of cooperation among two or more individuals or groups in relation to public and private goods (March & Olsen, 1984; North, 1990; E. Ostrom, 2010a; Williamson, 1993). Institutions are defined as a system of formal and informal rules, norms, and shared strategies which introduce order, replicability, and thus, predictability into processes of individual and collective decisions, and therefore structuring incentives to reduce uncertainty of behavioural outcomes (Crawford and E Ostrom, 1995; North, 1990). These decisions occur across multiple actors and organizational units in what V. Ostrom et al (1961) originally termed 'polycentric' institutional systems, what they identified as an overlapping system with multiple centres of decision-making responsibility and varying access to information, but linked through a common set of rules-in-use.

The body of literature surrounding these definitions originated in both political science and economic disciplines, with initial focus on empirical analysis of political behaviour, incentives of

various actors, and designing the optimal ways to enable exchange of private and public goods and information (Hassenforder & Barone, 2018; Hoff & Stiglitz, 2001). By the 1980s, at the same time as risk and discourse theory were reacting to environmental concerns, a group of scholars including the influential work of E. Ostrom, began to offer analysis which differentiated institutional theory from the previous economic models, challenging the duality of public and private goods, market and government systems, and assumptions of individuals making rational choices (E Ostrom, 1990; E Ostrom et al., 2007; V. Ostrom and E. Ostrom, 1999). This opened the way for an extensive corpus of case studies and analytic frameworks, with a dominant focus on natural resource management, exploring the complexity and uncertainty of what E. Ostrom (1990a, 2009) labelled social-ecological systems.

By identifying the replicable factors incentivizing and sanctioning the individual and collective decisions, theorists such as E. Ostrom argue this enables institutions to be designed around a set of common features which reduce uncertainty by limiting choices and behavioural outcomes. This body of literature challenged a series of assumptions which have been iteratively adapted by a range of social theorists. The theories range from questioning assumptions based on models of rational choice theory and homogenous communities (Hall, Cleaver, Franks, & Maganga, 2014; E. Ostrom, 2010a); to challenges the framing of nature as controllable through scientific knowledge without consideration of the socio-political processes (Rayner, 2003); to the perspective that institutions are designed to advance welfare-based performance and social entitlements instead of also mitigating risks (Beck, 2013).

Institutional theorists have generalized the variables describing how decisions are made across a range of contexts, reinforced by a set of replicable features described as the 'grammar of

institutions' (Crawford and E. Ostrom, 1995). While this literature focuses on core questions of choice, the roots of the inquiry originate out of a focus on provision of goods and services, with subtractability and competition of use the key framework to understand deprivation or disposition. Although this focus departs from risk theory which examines negative logics of danger and threats, the questions raised around the constraints over decisions are equally applicable. There is further overlap between institutional theories, including V. Ostrom et al. (1961, p. 832) and risk scholars, including Beck (1992), who question the indirect consequences, externalities, and spill over effects on public goods and bads which arise from efforts to control individual and collective behaviour. There is an opportunity to extend this perspective and further align the grammar of institutions with a grammar of risk phenomena and connect the replicable variables of institutional analysis with the way risk narratives influence the decision-making context. This thesis provides only preliminary insights into this connection, the primary focus of this thesis remains on interpreting risk theory, leaving potential for future cross-context analysis with a more explicit focus on institutional theory.

Design principles and the internal action situation

Institutional analysis has been developed over the past 35 years by a wide array of interdisciplinary scholars who provide a framework to understand the nested building blocks which shape decisions and interactions. Originally developed out of policy analysis, and frequently applied to issues of natural resource governance, the framework provides a set of micro and macro situational variables which influence individual and collective behaviour through physical and material conditions (resource units and systems), community attributes

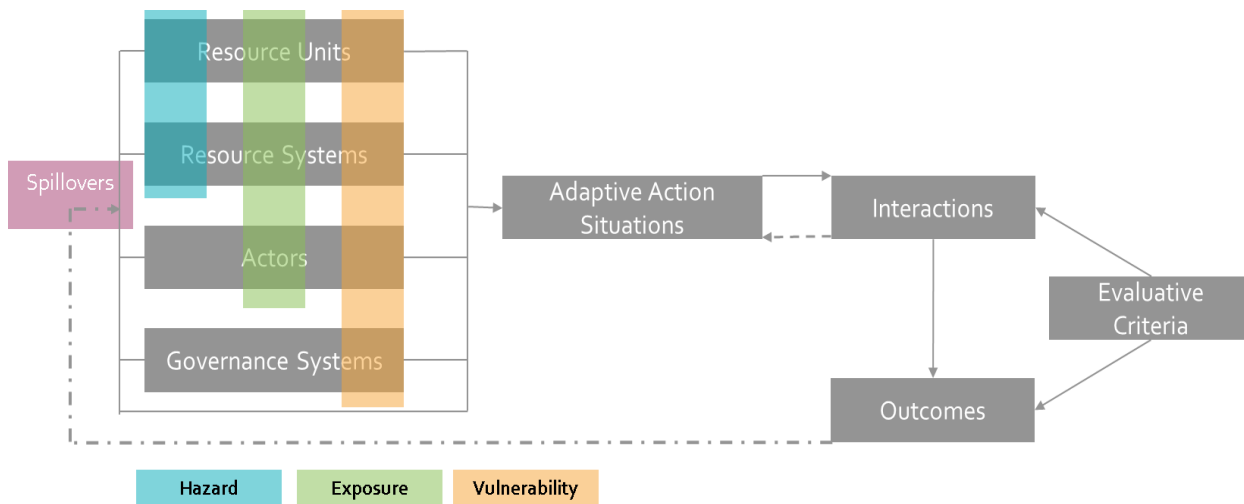


Figure 3 Risk-based IAD-SES Framework. Source Garrick et al. 2018

(actors), and rules-in-use (governance system) (Aligica and Boettke, 2011; Garrick et al., 2018; E. Ostrom, 2010a; Polski and E. Ostrom, 1999). These factors create the arena which positions individual and collectives to make decisions within an action-situation as relative to social and ecological variables.

The most explicit link between the institutional frameworks and risk, and specific to the water resource sector, is proposed by Garrick et al (2018) who aligns the techno-scientific risk framework of exposure, hazard, and vulnerability to the institutional analysis framework of the social-ecological action-situation. Figure 3, adapted from Garrick et al (2018), suggests how risk components are aligned within this institutional framework, with a focus on how shocks from droughts impact the action situation.

The analysis in the previous section of risk in the lens of social constructivists and post-structuralists, suggest there are additional phenomena beyond hazards, vulnerability, and exposure, which shape the internal dynamics of the action scenario, specifically the points of decisions and the learning process. The internal action-situation provides a structure to diagnose where and how to increase predictability of outcomes, the core design purpose of institutions

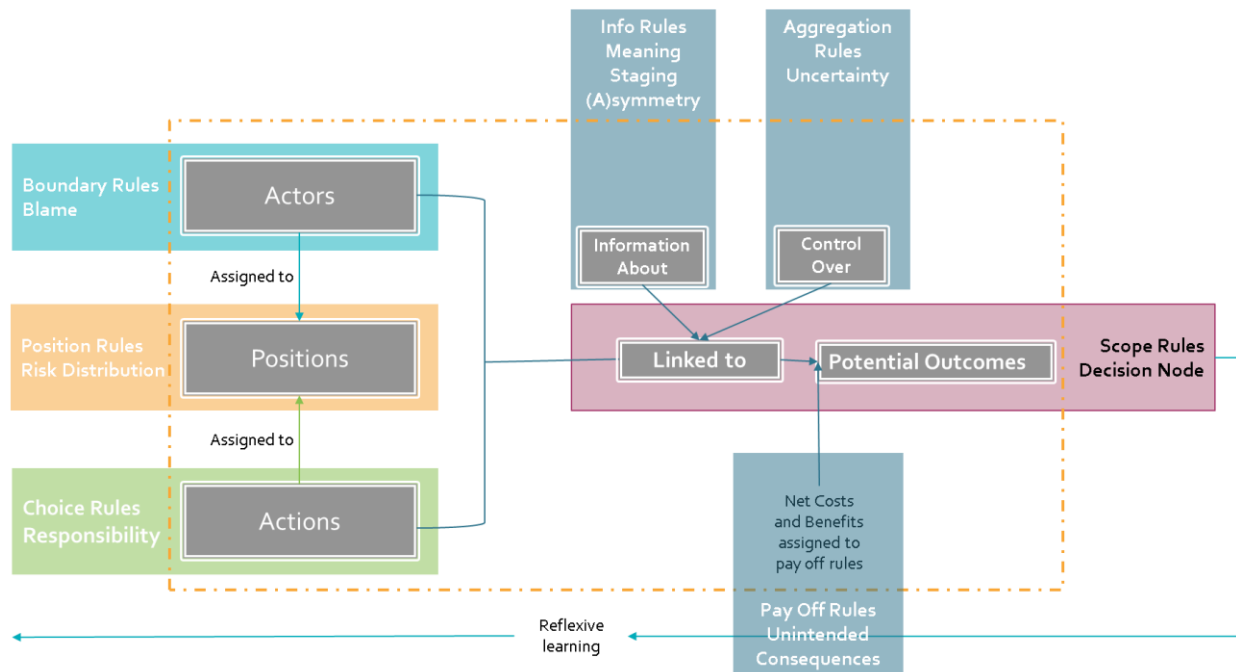


Figure 4 Grammar of risk theory overlaid with the Internal Action Situation. Source Author adapted from Ostrom (2010).

for mitigating risks. This includes characteristics of actors, positions they hold, set of actions they can take, information available, outcomes they can affect, and attribution of costs and benefits to the potential decision outcome (McGinnis and E. Ostrom, 2014; E. Ostrom, 2010a). Similar to the grammar of institutions, the grammar of risk theory—further detailed in Chapter 6—is applied to the internal action scenario in Figure 4, with specific attention to how rule-in-use shape decisions.

Beck argued institutions are fundamentally changing but did not define these institutions or provide specificity of how and where they are failing. To address this, the merged internal action situation helps frame where the new forms of blame and causality are changing how actors enter and leave positions; how choice and authority rules are undermined as a result of reallocated responsibility; how the universality of risk vulnerability changes the distribution and thus position of actors; how negotiated risk narratives interpret information linked to action; how new

unknowns undermine ability to map impact of decisions in aggregation rules; and how the forms of assessing cost-benefits of payoff rules is thrown into disarray with unintended consequences and self-reflexive risks. This framework is used indirectly in later chapters to address gaps in risk theory's perspective on how decisions within institutional settings are changing while also expanding earlier institutional theory with a new grammar of risk. This is a formative attempt to merge the two, and an area which can be greatly refined and expanded in future research.

Polycentric decision responsibility

Polycentricity provides an overarching conceptual language and body of scholarship to enhance risk theory's limited attention to where decisions occur across and within multi-actor and multi-levelled systems. First introduced by V. Ostrom, Tiebout, and Warren, the concept emerged out of analysis of multiple political units in metropolitan areas overseeing water resource management where authority and nodes of decision-making were distributed to create overlapping jurisdictions, formally independent of each other yet in some way taking each other into account, within a shared system of rules (V. Ostrom et al., 1961, p. 831). Heikkila and Weible (2018) further define several constructs critical to polycentric governance systems including multiple centres of authority which overlap through cooperation or competition; mechanisms for conflict resolution; and authority or power to influence other actors. The framing provides an alternative to characterizations of governments as centralized, or monolithic, systems and places a focus on multiple spheres of authority and decision-making.

The concept of polycentricity provides a framework to interpret and map the multiple institutional levels of action-scenarios and ways in which decision-making nodes overlap. It can

also help analyse the assignment challenges of allocating responsibility under different types of governance systems; from command-and-control systems of centralized governance, to market-based regulation of private enterprises, to decentralized local systems to reflexive and cooperative regulatory approaches aligned to polycentric systems (Garrick, 2018; Matten, 2004). This raises a question, similarly posed by Blomquist (2011) but in a different context, of where self-governing systems fit together or overlap with collective structures in this construct of polycentric governance.

A rapidly growing body of literature defining specific methods to help advance structured mapping of formal institutions, as discussed by Heikkila and Weible (2018), using text coding methods of formal documents to identify not only how the rules of institutions constrain decisions but where and how they are being made in relation to each other. However, this mapping of the system does not provide techniques to understand the political and economic interests shaping the resulting power structures and allocations of responsibility. Chapter 6 suggests that these approaches are complimentary and could be further linked in future work to extend the debates around decision-making within institutional settings with the conceptual elements of risk-based designs including responsibility, use of information, framing of blame. The application in this thesis is however limited in scope and therefore instead identifies potential applications for future studies.

2.6 DRINKING WATER SECURITY AS A RISK-BASED APPROACH

Water security responses framed as both opportunities and a danger

Water security is recognized as a major social and ecological challenge by both research and policy communities, frequently cited as one of the defining global challenges of the 21st century (Grey et al., 2013; Hope, Hansen, Mutembwa, & Schlessingen, 2012; Mason & Calow, 2012).

Water security as a defining agenda, or what Gerlak et al. (2018) describe as a conceptual scaffolding, emerged in the 1990s to provide a framework to organize concerns emerging from environmental, economic, political, and social perspectives. The concept is relatively new to a crowded field of security studies, following from what Mason and Calow (2012) identify as longer-established bodies of discourse around food, energy, human, and national security. A recent set of review articles show however that the concept is not consistently defined or applied; specifically Gerlak et al. (2018) show the variation between place-based case studies and emphasis on thematic sub-attributes. This body of scholarship, framed by Cook and Bakker (2012), are siloed by disciplinary perspectives and methodological assessment tools leaving opportunities to advance multi-modal approaches, specifically in relation to drinking water services. The roots of water security analysis can be traced to several decades of policy and research into water resource management practices as a response to various natural hazards and uncertainties, including what White (1988) identified as the history of water resource sector risk assessment approaches which take into account social structures and decision-making processes.

There is a wider epistemological divergence between risk-based approaches within the water security literature. This difference, explicitly framed by Zeitoun et al (2016), suggests similar

delineations as the realist versus constructivist perspectives on risk; one views controlling risk by quantifying uncertainty as compared to the integrative social, political, and multi-levelled issues shaping decisions and behaviour. This dichotomy is related to the ontological debates in risk theory, summarized in the previous section, which lead to pluralist views of risk. This opens different ways of seeing and interpreting shared normative goals and leads to the multiple perspectives calling for adaptive approaches which, until recently, lacked common definitions between sectors and risk logics.

The policy and research of the global water sector loosely respond to two global political initiatives: the first was the International Decade of Drinking Water Supply and Sanitation which consolidated research around a global provision-based strategy for drinking water services. This was complimented but differentiated by the approaches surrounding Integrated Water Resource Management (IWRM) which emerged after the International Conference on Water and the Environment in 1992 which consolidated a focus on mitigating exposure, vulnerability, and hazards (Conca, 2015). The two major strands of water security focus reflect Beck's view of the two risk mentalities: one focused on provision of goods and the other of management risks.

This has produced a wide body of literature around the intersecting dimensions of water security, water governance, and integrated water resource management. This thesis cannot feasibly review each strand—see Bakker and Morinville (2013) for a more extensive review— instead the thesis discusses the broad contours of this framing lens and sub-themes. This includes the analytic axis between consumptive and productive needs and service provision versus resource management. This framing of water security further eludes to Beck's views of shifting blame

allocated between nature and decisions, scale of exposure which transcends administrative borders into ecosystem scales.

This body of literature further debates a range of thematic areas grouped together under the broad categories of water resource management across variability of flood and droughts for consumptive and productive uses; water quality thresholds and public health responses defining safety; financial and institutional sustainability and affordability of service delivery models; social risks of inequity of access, gender, and cooperative versus competitive use. Finally, there is a wide body of literature discussing analytic methods distinguishing what Garrick and Hall (2014, p. 618) summarize as hazards (phenomena causing damage or harm), exposure (objects and degree facing potential danger or harm), and vulnerability (susceptibility to loss).

This thesis follows the Sadoff and Grey (2007, p. 548) definition of water security for the explicit reason that it extends previous definitions of water security into a duality of risk logics. Reframing previous descriptions, specifically the Global Water Partnership's (2000) which framed water security as a positive logic of providing access to every person through sustainable use, I use Grey and Sadoff's definition of water security as the "availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments, and economies" (Grey & Sadoff, 2007, p. 548). This distinguishes water as one which can be framed as both a productive and a destructive force, a resource to be distributed and a danger to be mitigated.

The specific dichotomy of risk logics was directly applied to the drinking water security debate by Bradley and Bartram (2013). However, a wider body of literature exists discussing risk-based

approaches to drinking water security, including some of the earliest non-explicit discussions focusing on reducing water pollution and urban water supply reliability. Specific risk-based approaches have been applied to domestic drinking water including but not limited to Hope and Rouse (2013) focusing on financial, institutional, and operational risks and Howard et al (2010) identifying specific climate and health vulnerabilities. Overall, water security is grounded in a risk-based framework but current debates reflect the tensions identified by O'Malley (1996) between Knight's (1921) view of uncertainty as a driver of profit and Beck's (1992) view of risk as an increasingly uncontrollable danger to society and institutions.

History of rural drinking water services as a provision-based mentality: handpump technology and community management models

The approaches to rural drinking water service delivery in low-income countries, particularly across African and South Asian contexts, has been defined for decades by the governance techniques attached to the thinking of the late 1960s and actions taken in the 1970s and early 1980s. Although not explicitly risk-based or originating from specific drinking water security frameworks, the progression reflects the evolution of risk logics. By the end of the 1960s, several influential policy-oriented studies emerged linking the rural water to the health sector, outcomes which caused upheavals in the conventional development practices of the time and further differentiated the performance of service approaches in both urban and rural areas (Pineo & Subrahmanyam, 1975). Further academic studies delineated the separate needs and opportunities in rural communities which provided some of the most detailed analysis of rural water demand, including micro-scale descriptions of different use behaviours. The influential work by White, Bradley and White in *Drawers of Water* proposed a taxonomy to classify water

related health risks separated by waterborne, water-washed, water-based, and water-related categories (Bartram & Hunter, 2015; White, Bradley, & White, 1972). This corresponded to a recognition of lagging poverty alleviation goals (Black, 1998) and links to rural drinking water sector performance. As discussed in Chapter 4, the response and shifts in commitments are linked to wider global geopolitical shifts of international development agenda, flows of global finance, and changes in domestic politics.

During this period in the late 1960s and early 1970s, the World Health Organization (WHO) and United Nations International Children's Fund (UNICEF) advanced national surveys and studies of rural water concerns to elevate potential contributions from the international development agendas (WHO, 1971). This caught the attention of a small group of experts in the World Bank who saw low-cost technologies as an opportunity to reframe the development approaches to rural water service delivery (Falkenmark, 1980; Kalbermatten et al., 1980; Saunders & Warford, 1976). Their efforts culminated in the 1977 Mar Del Plata conference which solidified the political commitments to establish the International Decade of Water Supply and Sanitation and define global normative development objectives (Schouten & Moriarty, 2003). This period, where poverty reduction was the main policy driver and decentralization of public mandate the dominant approach to reforming governance, established the provision-based model targeted at increasing access measurable through binary terms of improved or non-improved infrastructure, an approach which defined the next three decades of rural drinking water policy.

By rendering ongoing problems visible to policy-action spaces the World Bank's Policy and Research Division in the Water Supply and Urban Development Department was able to drive efforts to reframe interventions around assessments of cost-benefit analysis, specifically seeking

cost-effective approaches through ‘appropriate technology’ including lower-cost and more reliable infrastructure for rural development settings (Frink & Fannon, 1974; Kalbermatten et al., 1980; Saunders & Warford, 1976). This resulted with the global focus on handpumps, spanning from Sub-Saharan Africa to South and South-East Asia (Arlosoroff et al., 1987; Black, 1990). This was a critical infrastructure-led pathway to achieve population coverage targets, and one, as we see in later chapters in relation to Bangladesh, dramatically changed the type and allocation of risks.

During the following three decades, the number of people lacking access to improved drinking water access decreased significantly. Global estimates suggest that the population lacking improved infrastructure access declined from 1.85 billion rural inhabitants in 1980 to an estimated 676 million in 2015 (Bartram et al., 2014; WHO/UNICEF, 2017). This was a major accomplishment for countries and the global development agenda, particularly salient when considering that the rural population increased by an estimated billion people during that period (World Bank, 2018c). Achieving this reflects billions of dollars of investment across rural areas and a still unquantified number of new water points, each requiring management structures for operations and maintenance.

This leads to the second major contribution from this initial period of global attention on rural drinking water policies which established a service model framed around principles of rural community participation in the context of the devolving role of central government agencies and shifting responsibility away from public sector actors. These aligned with broader shifts in rural development approaches discussed by Chambers (1994) in relation to empowerment of rural communities in the decision-making process, and later summarized by Ribot et al (2006) in

relation to forest management. These show a formal policy shift away from top-down structures towards rural participatory approaches and autonomous local-level decision-making, although often overlapping with municipal and federal government agencies.

This led to the promotion of community-managed systems, under what Arlosoroff et al (1987) outline as the Village Level Operation and Management of Maintenance or community management model where ownership and management responsibility are transferred to self-organized collectives after capital cost and installation by public sector actors. The series of late 1970s and 1980s flagship World Bank reports considered the costs and benefits of services including identifying potential revenues from user's willingness to invest in improved services, benefits from improved health and time-saving convenience, and potential incentives around different ownership models (Briscoe & Ferranti, 1988; Churchill et al., 1987; Saunders & Warford, 1976). Briscoe and Ferranti (1988) specifically discuss Bangladesh and India as examples of countries where the Government role transitioned responsibility towards private contractors for installation and user collectives under community management schemes for management. Community management became the leading service model design for implementing and managing rural water infrastructure systems in developing countries when critiques, initially including Cairncross (1987) and Carter (1993) were followed by a series of articles in the 2000s by Khwaja (2001), Schouten and Moriarty (2003), and Harvey (2008) questioning issues of local politics, trust, and accountability. The key findings from this period of policy, technology, and monitoring innovation from 1970s until the late 1990s had lasting impacts on the sector, including the transfer of decision-making to communities, increasing reliance on non-state financing, and reallocating maintenance responsibilities away from the state agencies towards

self-managed systems and new national scale monitoring platforms and indicators. This process was not linear in transition, with competing ideas and critiques slowly shifting discourse and governance models, however the broad contours show the evolution away from public mandates and central government as the service provider towards models of private sector and collective or individual service management.

Self-supply models, performance-based enterprise models, and adaptive governance

The institutional evolution of drinking water service approaches paralleled broader shifts in the dominant neoliberal approaches to governance seeking to devolve state services and promote entrepreneurship by the early 2000s. While this transition was most prominent in the urban sector, as argued by Bakker (2014), this thesis explores how the process was also occurring in the rural sector, building momentum. The reliance on government provision and community management models since the 1980s were increasingly identified as unable to ensure reliable, safe, and affordable services, sparking discussions for the need to further redesign the institutional model and, implicitly, the allocation of responsibility (Carter, Tyrrel, & Howsam, 1997; Harold Lockwood & Smits, 2011; Schouten & Moriarty, 2003). This extends with what Lockwood et al (2017) categorize as the key service delivery models: community-based management; direct local government provision; public utility provision; private sector provision; privately supported self-supply.

The pursuit of decentralization under principles of subsidiarity, or realigning decision-making to the most efficient disaggregated level of institutions, enabled the expansion of Village Level

Operation and Maintenance models in low-income contexts where the state apparatuses increasingly reallocated risk responsibility to a range of non-state and self-organizing actors across the non-for-profit, hybrid public-private, and for-profit enterprise models (Arlosoroff et al., 1987). These were however, largely outside the formalized or regulated rule-making system.

The most advanced regulatory frameworks for small drinking water systems emerges from the European context where an estimated 65 million residents of the EU in 2010, or 13percent% of the total population, rely on infrastructure supplying less than 1,000 cubic meters per day or serving less than 5,000 persons (EU, 2014). The status of these systems was largely unknown, and unaccounted for in national planning, as of 2009. The Drinking Water Directive, which standardized specific chemical, microbial and indicator parametric values for monitoring water quality across member states, revealed the large gap in identifying or monitoring the small supplies (Hulsmann & Smeets, 2011). There are still exemptions for monitoring small systems, but the directive now mandates a duty to register all water supplies, often through local regulatory or municipal health authorities. These rules still largely focus on services supplying over 20 to 50 people, a distinction in the United States of America where systems under 20 people are classified outside the public mandate and therefore not required to comply with federal standards or be monitored, despite these systems covering an estimated 13percent of the population according to a 2015 study (Dieter et al., 2018). Building from these monitoring requirements linked to water safety plans, a recent study by Gunnarsdottir et al (2020) argue that small water systems have higher risks for pathogens and E-Coli in treated water than larger systems. These examples, while limited in the discussion of self-supply instead focused on small-scale providers above 20 to 50 users, does provide a framework for risk-based management

through regulatory and administrative monitoring systems which formally assign responsibility for risk assessments.

As discussed more extensively in Chapters 5, 6, and 7, the rural service provision sector in both high and low resource contexts have increased the policy attention and quantification of alternative service models to public provision. Hope (2015) questions the effectiveness and demand for community management systems in the context of Kenya while Gero et al (2014) provide a review categorizing alternative micro and small enterprise models, largely in the context of Asia.

Within this realignment of attention on alternative service delivery models, a growing body of literature is emerging around self-supply systems, or privately financed and managed infrastructure with the number of users under 20. This literature includes analysis of both unintentional and informal growth in multiple geographic contexts, as well as recent government-led initiatives to actively enable self-supply models (Butterworth, Sutton, & Mekonta, 2013; J. Grönwall, 2016; Munkonge & Harvey, 2009; Sutton, 2009). Efforts have been made to estimate the scale of self-supply in urban contexts by Grönwall (2018; 2010) but have not been equally replicated in the rural context. The Water Point Data Exchange, summarized by Foster et al (2019), provides the best insights into the scale of rural handpumps in 47 countries from voluntarily reported data, but focuses on functionality, not defining features of management structures. The literature and analysis of alternative and increasingly private and individual, rural infrastructure and water services is increasingly rapidly, but still having major gaps in both understanding rate, scale, type of change and the institutional dimensions.

The multiple decades of innovating service approaches in rural contexts has resulted in what Koehler et al (2018) describe as pluralist risk-management institutional design: multiple archetypal management cultures which exist simultaneously, structuring social relationships, and thus, reflecting overlapping risks-response mechanisms. This creates challenges managing risks, negotiated between what Koehler et al (2018) describes as overlapping rule-making and decision-making authorities including the market, administrative bureaucracies, and community spheres. This is further reflected with a growing body of literature examining the intersection of social enterprises sitting between the government, community, and private sector and the for-profit, not-for-profit divide.

The evolution of the rural drinking water sector policies and rules are orientated around the public sector provision of infrastructure, not private sector involvement. There are many gaps in the literature and documentation of effectiveness and enabling environments required for rural enterprise models to deliver on the goals, specifically the recently adapted to the safety and reliability targets set by the SDGs. There is an emerging recognition in academic papers for the potential of these blended finance and performance-based models (McNicholl et al., 2019; Moriarty et al., 2013; Opryszko et al., 2009) including a growing policy focus by RWSN (Healy, 2019), the World Bank (Ndaw, 2016), World Water Council (Money, 2018), and an urban focus from the Asian Development Bank (ADB, 2015). Progress advancing these models have previously been undermined by various uncertainties in local markets and consumer behaviour, including the institutional, operational, and financial risks as described by Hope and Rouse (2013) and framed around water resource governance limitations as outlined in Bangladesh by the World Bank(2018a). The recent working paper by McNicholl et al (2019) provide detailed examples of

five rural private enterprises which, in the context of Africa, have adapted their approach to manage multiple risks while still leveraging demand and willingness-to-pay, however the companies have still not reached full cost-recovery for rural services.

This addresses a later focus of the thesis in Chapters 5 and 7, which discusses the significant gap in literature and policy recognizing the scale and potential unintended consequences of small scale rural private enterprises and specifically of self-supply systems. Despite the global efforts to rapidly increase access to rural drinking water services, there has been limited to no explicit formal legal or policy recognition around the growing role of private self-supply systems in multiple geographic contexts, across both high-and low-income countries. Further, the rural sector has further devolved responsibility of public services to community and municipal authorities with limited focus on analysing the optimal structure and role for multi-levelled monitoring and regulatory functions. While scholarship, both specific to drinking water and wider institutional theory, increasingly recognizes the plurality of risk management structures (Koehler et al., 2018; Zeitoun et al., 2016) this thesis suggests more analysis is needed to understand the transition processes reallocating risks, how they reshape the allocations between collective and individual decisionmakers, and the specific implications for rural drinking water service systems. The lack of formal regulatory or policy oversight despite concerns for water quality safety, is a core focus of the later chapters of this thesis.

MDG to SDG targets: the domains of rural drinking water risk

Water security frameworks have been extended explicitly into the drinking water sector with increased focus on managing uncertainties of service delivery. There is a significant body of literature identifying and debating the specific sub-thematic concerns and problems of monitoring drinking water security (Bain, Wright, Christenson, & Bartram, 2014; Bartram, Brocklehurst, Bradley, Muller, & Evans, 2018; Bartram et al., 2014; Bradley & Bartram, 2013; Cronk, Slaymaker, & Bartram, 2015; Dickson, Schuster-Wallace, & Newton, 2016; Howard et al., 2010; Kayser, Moriarty, Fonseca, & Bartram, 2013).

SDG 6.1 consolidates multiple variables defined as part of achieving drinking water security through a set of politically negotiated global normative goals. The indicators are limited by the politics and technical evaluations defining what is feasible. As discussed in Chapter 5, indicators under the MDGs focused on providing national estimates of population access to improved infrastructure. The SDGs target expand those to include safety of water quality, affordability for users, climate and demand resilient supplies, reliable infrastructure functionality, and equity for all. However, many of the SDG target do not yet have clear data collection and indicator calculation protocols to standardize across countries. By parsing the language around SDG 6.1, shown in Table 3 below, this section briefly describes the academic literature driving the evolution of those targets. Chapter 5, 6, and 7 further explore the global indicators and information systems in the context of Bangladesh.

Table 3 Summary of SDG 6.1 target and risk domains

SDG 6.1 Target Language	Normative Interpretation	Global Measurement Indicator	Existing/ Planned Data Sources in Bangladesh	Potential Future Data Sources
Universal	Implies all exposure and settings including households, schools, health facilities, workplaces and public facilities and across urban and rural contexts. (Bain et al., 2014; Cronk et al., 2015; Hutchings et al., 2015)	Population using safely managed water services; connection of facilities	Household Surveys and Census data (MICS)	Geospatial Mapping; Administrative Data including education or health MIS systems
And Equitable	Implies progressive reduction and elimination of inequalities between population sub-groups including gender, geographic location, socio-economic groups, and individuals (Wijesekera, Gordon, & Cavill, 2018)	On/Off Premises; gender and age responsible for water collection; wealth quintile	Household Surveys and Census data (MICS)	Geospatial Mapping; Crowdsourcing or citizen reporting; Administrative Data
Access	Implies sustained access to improved water and infrastructure that is reliably and sufficiently available close to home (Carter & Ross, 2016; Foster et al., 2019; Howard, Calow, Macdonald, & Bartram, 2016; Kayser et al., 2013; Lester & Rhiney, 2018; Walters & Javernick-Will, 2015)	Improved water sources; on/off Premises; Available when needed; functional infrastructure.	Household Surveys; DPHE infrastructure inventories of public water points.	Geospatial Mapping; Smart-sensor systems; Crowdsourcing; Facility data; Administrative Data
To Safe	Water, at point of delivery, that is free from pathogens and elevated levels of toxic chemicals at all times. (Alfredo, Seidel, Ghosh, & Roberson, 2017; Bartram et al., 2014; Fuller, Goldstick, Bartram, & Eisenberg, 2016; Howard & Bartram, 2005; Howard et al., 2016; Slaymaker & Johnston, 2016)	Free from faecal and priority chemical contamination	MICS	Administrative data from health facilities; Administrative data from regulators and public water points; Public or private sector water utilities; citizen science
And affordable	Payment for services does not present a barrier to access or prevent people from meeting basic human needs (Fonseca et al., 2010; Hutton, 2012)	TBD	TBD	Administrative data; Public or private sector water utilities; household surveys
Drinking Water	Water used for drinking, cooking, food preparation and personal hygiene (Bradley & Bartram, 2013; Carrard, Foster, & Willetts, 2019; Feitelson & Chenoweth, 2002; Smits, van Koppen, Moriarty, & Butterworth, 2010; Thompson & Cairncross, 2002)	Main source of drinking water	Household Surveys	Water Diaries
For all	Suitable for use by men, women, girls, and boys of all ages including people living with disabilities. (Grant, Huggett, Willets, & Wilbur, 2017; Seager, 2015)	TBD	Household Surveys	Geospatial Mapping; Crowdsourcing or citizen reporting; Administrative Data

2.7 RURAL DRINKING WATER SERVICES IN BANGLADESH: SAFETY, INFORMATION, AND SELF-SUPPLY INFRASTRUCTURE

The academic literature and debates around multiple features of drinking water in Bangladesh is robust and extensive, covered across disciplines and thematic interests. Long considered an innovation hub for development practice with favourable government policies enabling experimental design and research, there is a rich body of scholarly material and publications. The global recognition around innovative microfinance models from Grameen, and later BRAC as well as the decades of cholera and diarrheal disease research from icddr,b, are just several examples where development projects have resulted with a rich body of scientific research. This section is intentionally brief as the content and history is discussed extensively in Chapters 4, 5, and 6. However, those chapters do not provide a detailed macro view of the temporal and thematic change, or the framing of infrastructure, information, and policies in place.



Figure 5 Summary of academic articles by subject cluster and year. Each point represents an article (n=2144). Source Author.

Thematic and temporal attention

The timing, frequency, and disciplinary coverage of academic journal articles reveals the clusters of techno-scientific attention and a considerable increase in total annual publications in the past two decades, perhaps resulting from the growth in total number scientific journals and the evolution of global publishers switching to digital submission processes. The review of academic literature using keyword searches shows that the content of Bangladeshi scientific publications since the 1970s has been consistently focused on issues of cholera and diarrheal disease, as seen in Figure 5. The discovery of arsenic resulted with significant surge of scholarship in mid-2000s. Further, there has been a wave in the past 10 years, after initial surge in arsenic-related coverage, where articles discuss multiple parameters of drinking water safety or overarching drinking water security, perhaps a reflection of multi-modal risk discourse. Finally, the explicit focus on institutional design, governance, affordability, access, and hygiene remains the least explicit

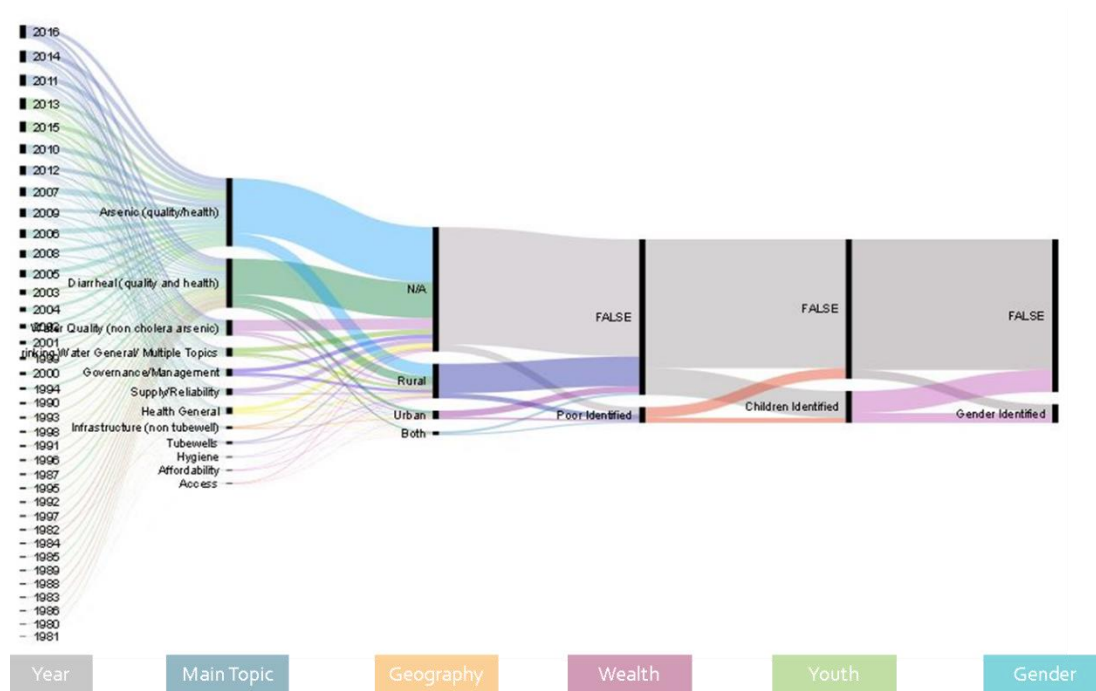


Figure 6 Summary of academic literature by year, main topic, and identification of vulnerable subgroups. Source Author.

focus, however many of these issues may be embedded as secondary discussions within these articles.

A further assessment of the literature, shown in Figure 6, shows an alluvial chart between year published, key word, and specific identification of geography, gender, youth, and poverty in the title or abstract. False refers to no data or reference. The length of the black lines reflects the distribution of the coded articles. The review shows very few articles differentiate vulnerability of sub-group as their core research focus, a distinction relevant to Beck's analysis of risk versus class-based systems. Rural areas were identified in the abstract and titles more frequently than urban, while children –no unifying definition of age—were identified more often than gender or wealth. The main body of the article text, and related data sets, might provide further differentiation on these variables, however from a constructed narrative perspective they were not widely emphasized in the literature. Further analysis is in Chapter 6.

Complexity of Bangladesh's rural drinking water services: a multi-use, multi-source, multi-risk system

The 45-year transition away from ponds and surface water to tubewells, and piped systems, lead to only a small fraction of the rural population connected to public and formally regulated drinking water infrastructure. The rural drinking water sources, points of withdrawal and the specific technologies used to access resources, summarized in Figure 7, is discussed primarily in relation to the water quality risk or geophysical perspectives as a response to cholera and arsenic. Several studies have shown the complexity of household level water use behaviours in single period studies of use decisions across multiple water infrastructure and sources for differentiated

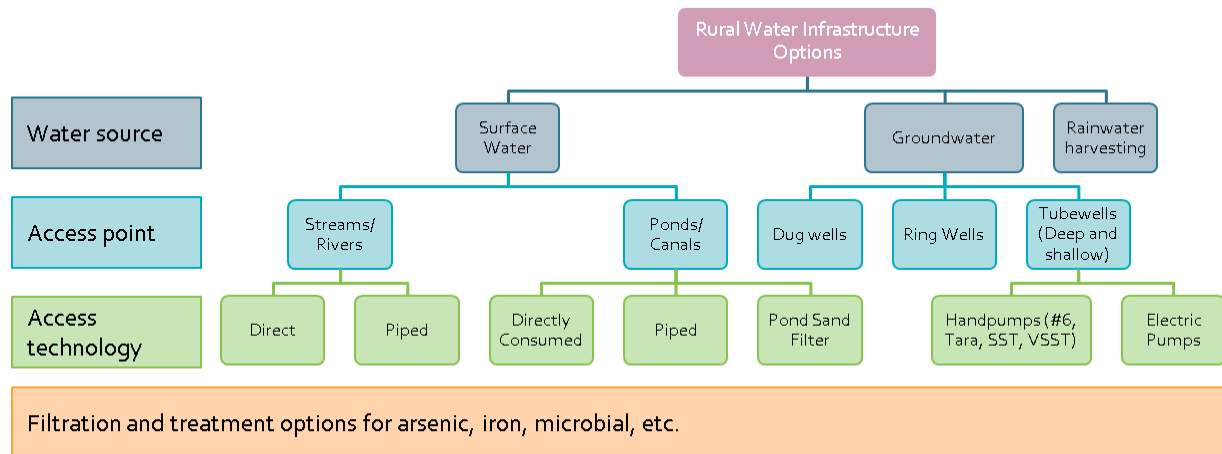


Figure 7 Summary of rural infrastructure options in Bangladesh. Modified from DPHE and Promising Progress (World Bank 2018).

uses and needs such as washing, bathing, cleaning, cooking, or drinking but do not relate this back to management structures (Ahmed, 1998; Fontein, Webster, & Trawick, 2010; S Hanchett et al., 2014; M. U. Khan, Mosley, Chakraborty, & Sarder, 1981; van Geen et al., 2014). These do not however provide longitudinal perspectives of changing use patterns and dependencies, leaving gaps in understanding policy outcomes and infrastructure preferences.

At the time of independence in 1972, rural Bangladeshi communities were at the early stages of transitioning away from dependency on surface water, specifically man-made ponds, ditches, tanks, and canals, towards government-provided tubewells for domestic water uses (Black, 1990; M. U. Khan et al., 1981). The pond systems were managed under an informal governance model of local elders and landowners determining rules around use and access, a largely undocumented structure but one who's power dynamics were replicated in the transition to community management of tubewells (Afroz, Cramb, & Grunbuhel, 2016; Alam et al., 2017; Carrel, Emch, Streatfield, & Yunus, 2009; S Hanchett et al., 2014). In this context, *Samaj*, or the social structure of local power based on lineage and religion governed by social norms, moral principles, and

informal rules enabled a large landowners and influential community members to maintain what Afroz (2016) argues is a patron-client system. A wider body of discussions exist around the political economies of decentralization and role of party politics and local informal leadership, briefly discussed outside of the drinking water sector by Lewis and Hossain (2019). The informal system of rules, while acknowledged, is insufficiently discussed in previous studies on rural drinking water and a gap in the literature.

Concerns of cholera-related mortality dominated the public narratives around drinking water in the 1970s and were used to describe the relationship between water supply and health outcomes, as discussed in Chapter 5. Research in the late 1970s suggested that the reduction of cholera cases was not solely a result of switching to improved infrastructure as Briscoe(1978) surmised from analysis of tubewells across multiple studies from the icddr,^b Matlab Cholera Research Laboratory. The national policy priority to reduce disease burdens linked to the high under-five mortality rates encouraged the government to pursue large-scale public tubewell provisioning programs designed to demonstrate provision of services for rural areas.

Discovery and public recognition of naturally occurring arsenic in the shallow aquifer system disrupted the trajectory of public policy and technology in the early 1990s. By 2000, the use of handpumps in rural areas as a main source of drinking water has become ubiquitous as shown by van Geen et al (2003) blanket infrastructure inventories and national household surveys. Despite the growing private market dominance of private tubewell providers, the government and development partners pursued a rural drinking water sector strategy and arsenic mitigation policy based on provision of safe alternative infrastructure, initially through dug wells and pond sand filters, and later under technical arguments that deep tubewells are classified as a safe

alternative to the shallow tubewells (DPHE, 2002; 1998a, 2004b)³. The selection of these alternative infrastructure options was based on the perceived feasibility, national politics of service delivery, and later technical assessment of the lowest risk options. The TaraDev was introduced in response to observed, and anticipated future, declines in the aquifer tables requiring deeper suction pump systems (DPHE, 2015a). Additional technologies were piloted, including pond sand filters, rain harvesting, and a range of direct filtering technologies but none have gained wide scale adoption in private markets outside of NGO and government programs. Individual and small-scale water point infrastructure therefore remains the dominant access technology in rural areas. Piped water reaches two percent of rural populations as of 2014 according to national surveys (World Bank, 2018a, p. 25). By 2016, the government reported an inventory of the 136 piped water systems installed in small and medium towns across Bangladesh, with upwards of 180 more systems in the planning phases (DPHE, 2016b), a clear policy priority. This major infrastructure investment further defines the public strategy; however, most of these larger piped systems were not seen as affordable for rural areas (WSP & LGD, 2009). Khan and Yang (2014), through a discussion of willingness-to-pay for arsenic safe drinking water, summarize the landscape of actors, stakeholder perspectives on arsenic mitigation actions, and challenges to sustaining multi-source, multi-user systems. As with other arsenic mitigation projects, the analysis didn't differentiate the role of private sector individual household systems within institutional design, instead focusing on technology options.

³ This reflects a distinction of drilling depth of the tubewell classifying shallow tubewells less than 30meter/100ft deep and deep tubewells more than 150meter/490 ft (DPHE, 2015a). The No.6 hand pump technologies could, for the majority of sites, be used for both deep and shallow tubewells due to the high-water table at roughly 6m across the delta (Hossain et al., 2015). There are continued debates around safety and reliability of these definitions, however they continue to be critical definitions for public policy.

Drinking water institutions contingent on state building narratives

The process of rendering risks visible has played an important role in the national identity, establishing state legitimacy and reinforcing multiple government's credibility within global development agendas linked to foreign aid distributions. The history of risk politics in Bangladesh reflect what Ghani and Lockhart (2008) described as the double compact of state-citizen and state-international expectations: provision of services and goods to rural populations while delivering development-sector innovations to sustain foreign aid flows (N. Hossain, 2017). The notable development successes, including a fourfold increase in per capita income since independence and significant achievements across the Millennium Development Goals, occurred in the context of bureaucratic patron-clientelism, weak state regulatory capacity, and ongoing political instability (Hassan, 2013). This juxtaposition has created the paradox characterized by the media and academics including Caldwell et al (2003) as a development agenda achieving nearly national coverage of improved infrastructure access and reduced mortality rates while unable to control the uncertainty resulting from arsenic.

The formal government documents consistently emphasize the state's central role in facilitating citizens access to basic levels of water and sanitation services. The Department of Public Health and Engineering (DPHE) was established in 1954 with a responsibility to provide drinking water access and has consistently been the central governments primary agency with responsibility in the rural drinking water sector. However, the responsibility for fiscal, maintenance, and safety steadily shifted away from the central government towards regional and municipal authorities, and private collectives. This process of transferring operation and maintenance responsibility began in the 1980s as the fabrication of cast iron handpumps shifted from government factories

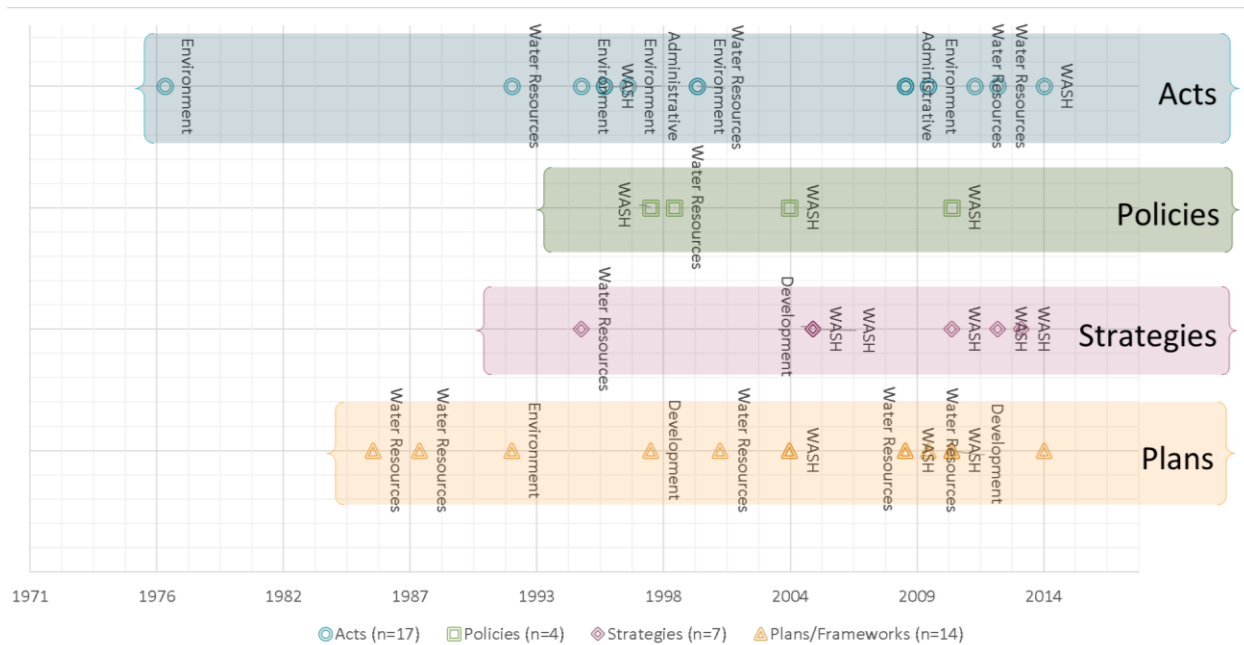


Figure 8 Summary of national formal policy and planning frameworks, 1980-2016

to private companies and the number of water points increased beyond the capacity of DPHE regional field engineers to maintain (Black, 1990). As a result, DPHE began to contract private sector mechanics to install new tubewells and allocate maintenance responsibility to self-organized collectives of ten or more users to shift the cost-sharing responsibility for public infrastructure.

The temporal chart of formal government acts, strategies, policies, and plans—summarized in Figure 8—revealed the recent progress of formal rules: the codification of responsibility of the state for rural drinking water services was established with a focus on provision and specific for the most vulnerable; devolving mandate for infrastructure management from government-to-community; no explicit formal recognition of private self-supply despite water safety concerns; introduction of water quality standards for services; and no allocation of regulatory authority or enforcement.

This process of devolution was codified with the 1998 National Policy for Safe Water and Sanitation (GoB, 1998a) which formally allocated cost-sharing approaches and official transfer of the ongoing rural public waterpoint service management responsibilities away from DPHE engineers and onto self-organised user groups, most often informal private collectives. The 2004 Water Supply and Sanitation Sector Development Framework (GoB, 2004c) set a strategy to devolve further decision-making responsibilities away from the central government and onto local municipal governments and regional water committees, a formal role which was structurally authorized in the 2009 Local Government Acts. These acts reallocated power to local elected councils to decide how and where to distribute new water point installations, although as argued by Sultana (2009), these replicated previous local power dynamics and undermined the equity of access, as further suggested in field studies by van Geen et al (2016). The 2004 Sector Development Framework (GoB, 2004c) identified that while local water and sanitations were created, they were not active, elected members were largely passive, and the ward-level committees needed greater capacity development.

The response to the arsenic contamination included an Arsenic Mitigation Policy (GoB, 2004b) and an Implementation Plan for Arsenic Mitigation in Bangladesh (GoB, 2004a). The policy prioritized surface water over groundwater, but also reflected the debate between technocrats and politicians, with dug wells, filtration systems and rainwater capturing tanks being mentioned with no discussion of deep tubewells, the infrastructure preference which emerged and is now the dominant response. The policy set targets for monitoring of water quality and diagnosis of arsenicosis patients. The policy identified the dominance of private water points, yet the policies and implementation plan do not differentiate responses for monitoring, provision outside local

Inventory of Official National Data Related to Drinking Water in Bangladesh

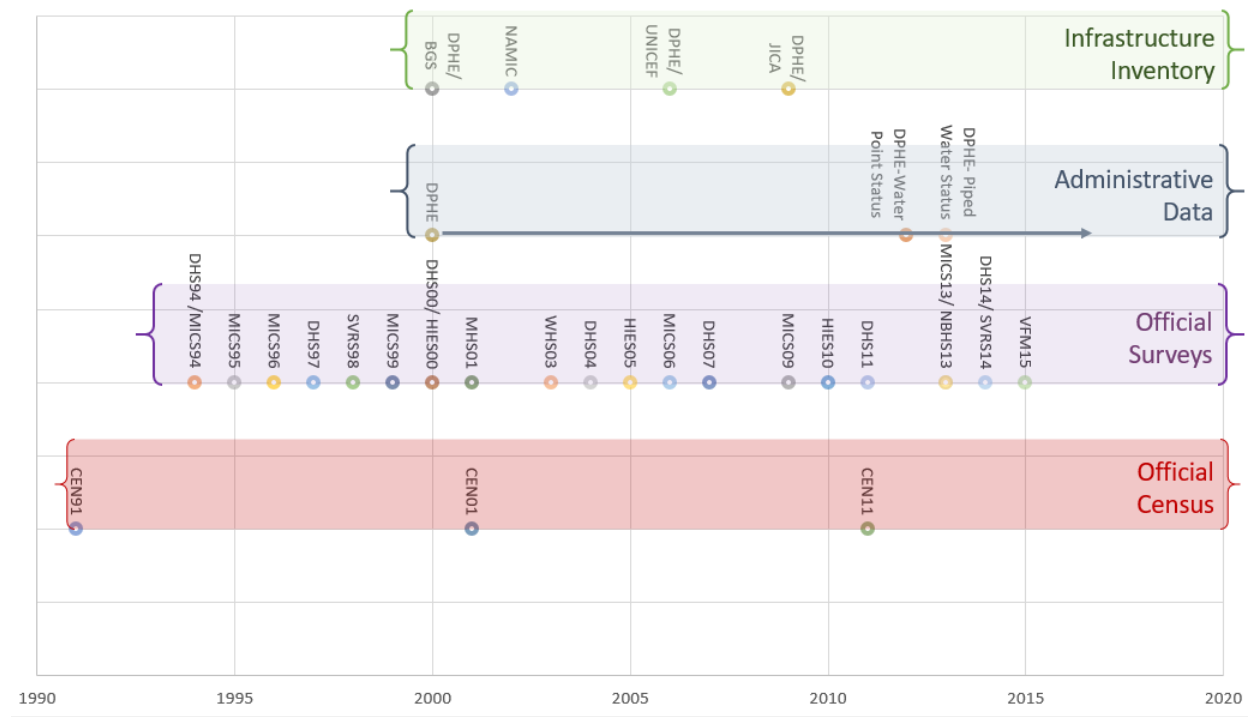


Figure 9 Summary of official national-scale drinking water monitoring systems

government provision, or specific regulatory responses. The private sector remained separate from the public response, despite the acknowledged challenges stemming from private self-supply.

The evolution of policies, strategies, and sector plans reflect a focus on provision of public water infrastructure in rural areas with no explicit discussion or focus on private rural actors. With a discussion of transferral of responsibility to small collectives of water point users, the policies remain focused on publicly provided water points, not privately installed systems. As recently as the 2011 Sector Development Plan (GoB, 2011), the main recognition remain focused on small-scale hardware market and service operators, not private individual actors.

Public sector water point provision was further standardized in response to the arsenic crisis in the mid-2000s, however information remained a key gap. To move beyond diagnosis of the problem and towards one that supported individual decisions, the government undertook one of the world's most comprehensive water quality screening efforts at the time and tested over five million tubewells serving an estimated 67 million people from 2002-2006 (Johnston & Sarker, 2007; van Geen et al., 2006). This resulted with information for users by labelling wells red for unsafe arsenic levels, and green for safe levels. It also produced a national database for government, academic and civil society that guided design of major arsenic mitigation programs. After this national mapping exercise, uncertainty began to grow again around newly installed water points. After the 2004 National Policy for Arsenic Mitigation (GoB, 2004b) made explicit policy for testing water point water quality at time of installation for all new publicly funded water points, the 2009 National Vetting Guidelines for Water Supply and Sanitation Sub-Sector policy (GoB, 2009b) further standardized this process and set of procedures. Despite several actors providing information services and national monitoring summarized in Figure 9, there are still major gaps in frequency, coverage, and integration of individual water point testing and national monitoring systems, specifically the privately installed infrastructure. None of the policies made provisions or requirements for testing private water points or ongoing testing after installation.

The process of decentralization resulted with a range of overlapping mandates and incomplete transitions. While not widely discussed in the academic literature, policy texts identified a specific challenge emerged between overlapping roles of the national agencies where DPHE and LGED both maintained budgetary allocation functions and infrastructure provision programs in the

drinking water sector, despite the sector-specific mandate and history of DPHE programs. This fostered ambiguity of roles in relation to regulatory authority and responsibility to oversee private sector actors. A clear framework of water quality safety thresholds had been established under the 1997 Environmental Conservation Rules. Three different government agencies assumed responsibilities for monitoring and enforcing different dimensions of this mandate: DPHE established the Zonal Laboratories for drinking water related parameters including arsenic, manganese, and E-coli; DoE set up monitoring systems for surface water and environmental health parameters including monitoring industrial and agrochemical pollutants; and Bangladesh Standards and Testing Institute had a mandate to enforce materials, commodities, and operational rules for industry and commerce. This enabled the accidental evolution of a fragmented monitoring system, a structure found in many governance systems. The mandate related to drinking water quality testing was clarified in 2011 Sector Development Plan (GoB, 2011) and prioritized monitoring five priority parameters for new public water points. These systems arguably still fall short on connecting multiple water quality and safety risks under a common and coordinated water monitoring system, including beyond public water systems.

The review of formal documents, and related gaps in academic literature, shows that to date, policy debates have primarily focused on establishing institutional arrangements supporting provision of rural drinking water services through the public sector services but have neglected to clearly establish regulatory authorities, or enforcement capacity for the individual and private enterprises. Qualitative interviews with government officials and the text-based institutional analysis revealed that there is no government agency with a clear mandate to regulate drinking water services. The 1996 WASA Act provided limited regulatory controls over groundwater

abstraction in the Dhaka, Khulna, and Chittagong cities. Water resources (quantity) management was allocated to the Bangladesh Water Development Board (BWDB) but originates out of a focus on flood control not drinking water supply management. The 1992 Water Resource Planning Act assigned Water Resources Planning Organization (WARPO) to develop water resources and was given the responsibility for regulating surface and ground water abstraction in the 2015 Water Act. This Act was the most comprehensive set of formal rules to advance coordination between sub-sectors around abstraction and use of water resources while assigning value to commercial uses and setting up authority for oversight. It enabled WARPO to oversee the Integrated Water Resources Committees at Pourshava, Union, and District levels who are tasked with monitoring water resources and issuing clearance certificates for water resource use and development projects (GoB, 2013, 2015b). This specified oversight of new drinking water projects and an initial framework for exerting control over the abstraction and drilling of new wells; it did not however consider household water point uses and small scale tubewells because of the designation as preferential use to ensure domestic drinking water. The importance of this act is over long-term water resource management but left an incomplete system that relied on municipal committees often lacking technical expertise and independence from the political process. Future work is needed to understand the dynamics of these 15 member committees, most whose members are from municipal governments and communities.

There is no clearly allocated regulatory authority over private rural drinking water services and safety. The rules around water quality and safety for the sector are drawn from the 1995 Environmental Conservation Act and 1997 Environmental Conservation Rules which defined water quality thresholds for human and environmental use. This act empowers the Department

of Environment to restrict and fine industrial and agricultural polluters but does not directly intercede to drinking water service providers. The historic role of DPHE to provide services and ongoing network of civil engineers across the country, positions the agency to perform certain oversight roles but it lacks a regulatory mandate over private sector actors.

This gap in regulatory responsibility is further emphasize by the omission in government policy documents to explicitly debate the scale of private self-supply occurring in the rural sector, instead focusing on improving performance of public infrastructure for urban areas and arsenic mitigation technologies (GoB, 1998a, 2011, 2014). While academic and advocacy papers identify the link between tubewells and private use, including Van Geen et al (2002), Sultana (2012), Atkins (2006), and Hanchett (2002), the extent to which the individual ownership of tubewells, a reflection of private sector growth, drives risks has not been explicitly identified or prioritized in formal policy documents regulatory reviews, or monitoring systems. These findings link to wider finding that policy remains focused on public sector responsibility with limited recognition or management of self-supply and private sector enablers in these rural contexts.

2.8 RESEARCH GAPS AND CHAPTER OBJECTIVES

Building from the literature review and the research questions identified in the introduction, the core chapters are organized around several sub-questions which address gaps cutting across theory, methods, and empirical in existing literature. Their objectives, and associated gaps they seek to address, are summarized in Figure 10 below and discussed in this section.

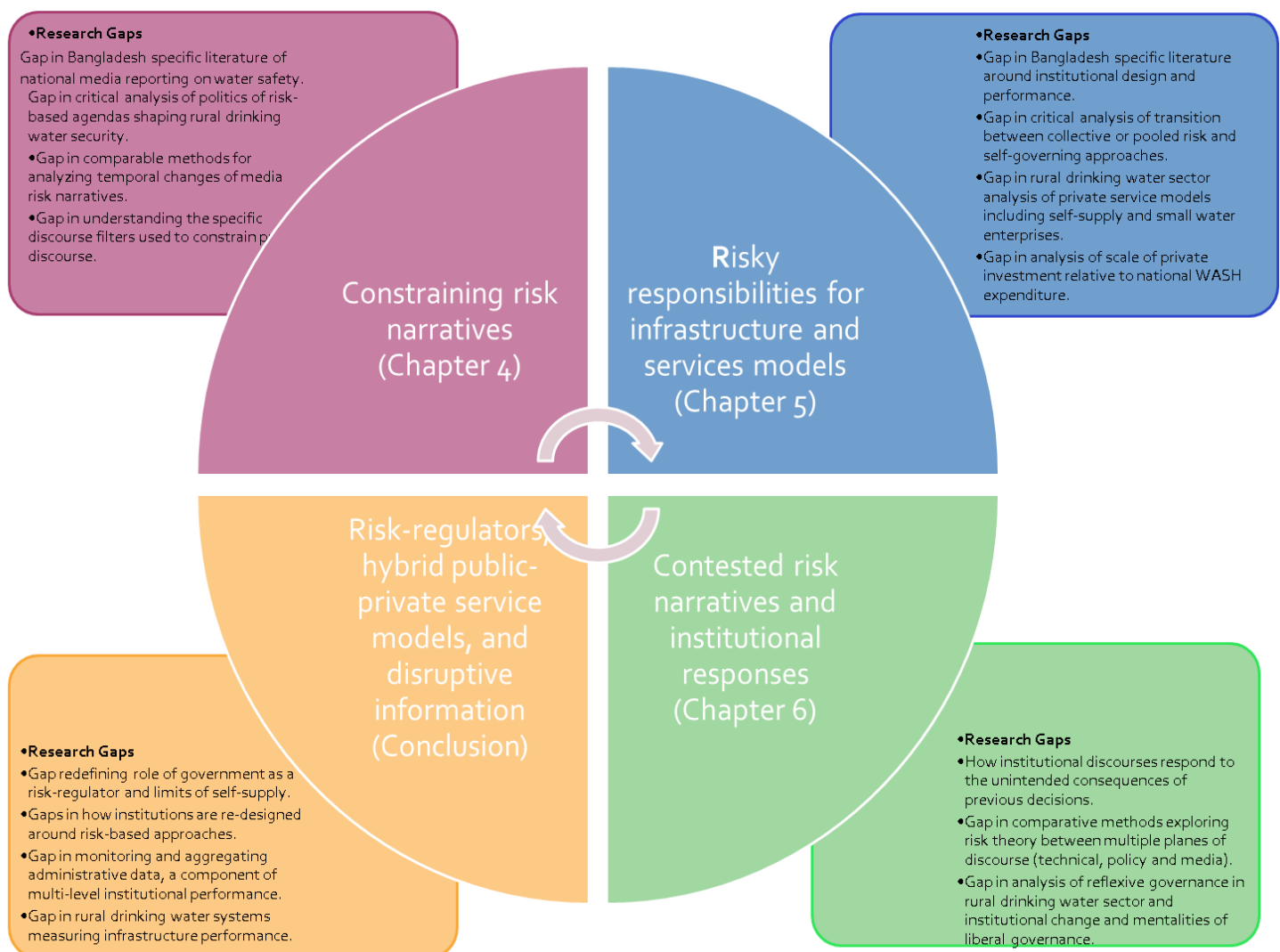


Figure 10 Summary of chapters, sub-research questions, and gaps and opportunities

To explore how are drinking water risks rendered visible in Bangladesh and how national newspapers have debated these narratives in relation to transforming national development agendas (Chapter 4)

Drawing on a multi-decadal inventory of every published article discussing drinking water in the Ittefaq Newspaper, and a second three-year inventory comparing 29 Bangladeshi newspapers' coverage of WASH related topics, a set of risk discourse filters are developed to analyse the socio-political process rendering risk visible. This interdisciplinary perspective seeks to understand how risk narratives are constructed and thus create boundaries to mitigate public concern, reinforce national development agendas, and legitimize structural changes of dominant institutions.

This chapter addresses questions raised by Beck's (2009) later work around the process of social and political construction of risk which elude everyday perception and implicate the power relationships defining the public narratives. Beck (2009, p. 298) specifically reframes the question, not as how non-experiential risks are made socially experiential, but instead how manufactured uncertainties are rendered understandable and therefore shape institutional design and action. Beck's own writings were never unified to answer these questions. Instead he identified a range of social and technical phenomena which can now be used to link risk theories with discourse analysis to advance debates that risks are socio-technical constructions constrained by political processes. The chapter explores the evolution of Beck's perspectives on the role of media as part of the process of self-confrontation or reflexive modernization, a largely unexplored pillar of Beck's scholarship.

The analysis addresses identified gaps in comparative risk discourse analysis approaches to enable cross-text, multi-decadal analysis across risk types and geographies, as discussed by

multiple media studies scholars including Hajer and Versteeg (2005), Bakir (2010), and Kristiansen (2017). The objective of this chapter is to merge the core phenomena of Beck's *Risk Society* (1992) with discourse analysis theories using methods established in agenda-setting and political-economy of media approaches employed in *Manufacturing Consent* by Herman and Chomsky (1988). Herman and Chomsky proposed discourse filters to interpret how dominant political and economic interests embedded across institutions construct or constrain social narratives. This approach is merged with the grammar of risk and applied to the Bangladeshi media.

The media inventory analysis, when applied to the context of Bangladesh, engages the country-specific literature and historical framing of the risk politics related to drinking water security. At the beginning of this thesis process, there were relatively few academic texts debating the historical process of institutional change in drinking water sector in Bangladesh, with the most extensive examples stemming from the urban water provision markets and grey literature produced largely by NGOs in relation to community management models. In 2018, two studies emerged; one identifying governance transitions in the urban drinking water sector using media to interpret historical stages by Yasmin et al (2018), and a second by Hossain (2018b) which framed the post-independence evolution of state-to-citizen contracts with rural communities as a response to risk narratives. These studies provide wider temporal insights but limited attention directly to the rural sector. They further provided limited critical analysis of how public risk narratives have interpreted different water security concerns (cholera to arsenic to industrial pollution), shifts in infrastructure markets, and changes in the formal national laws and policies. It raises questions around which issues were problematized and which were filtered out.

To investigate how public and private sector investment is driving rural drinking water infrastructure growth and how management responsibility has been allocated between pooled-risk strategies and individual self-governing models. (Chapter 5)

This chapter extends the findings from Chapter 4 that the constructed narratives have constrained the problematization around privatization and self-supply in the rural drinking water sector in Bangladesh. The chapter considers the tension identified in modern governance approaches seen through the assignment challenges of allocating risk responsibility across multi-level decision systems, including international, national, sub-national, local, and individual. The distribution of responsibility is widely seen as a tension between pooled, or collective, risk management structures versus self-governed models of individual decisions. Using an audit of rural drinking water infrastructure and analysis of household survey data, this chapter interprets the changing decision-making structures by charting the allocation of financial and operational responsibility to manage individual and multi-user infrastructure systems, how information addresses uncertainty of water safety, and the rules constraining user choices.

This notion of where risk-management responsibility is allocated is particularly relevant in the rural drinking water sector in Bangladesh, which, since independence, has seen a major transition in water sources and infrastructure in response to water safety concerns identified in Chapter 4. Scholarship in Bangladesh since the mid-1990s has alluded to the growing role of the private sector but largely only quantifies public water points (Ravenscroft et al., 2014). Some studies provide estimates that the majority of rural tubewell infrastructure is privately funded, but these studies lack rigorous disaggregated analysis (Johnston & Sarker, 2007; van Geen et al., 2003).

Without national infrastructure inventories, including both public and private systems, academic papers and government policies rely on previous figures to estimate national coverage and use patterns, and do not have nuanced understanding of how the scale of tubewells being installed privately changes use and dependency ratios (people-per-water point). These figures are central to modelling vulnerability and exposure to poor water quality, or potential impact of abstraction on aquifers. As seen in Buchmann et al (Buchmann, Field, Glennerster, & Hussam, 2019), technical risk assessments continue to rely on data of tubewell density from over a decade ago to estimate health consequences for arsenic versus microbial concerns and shape national policy.

On a global scale, there is a growing body of literature advocating self-supply approaches as pathways to achieving national development targets for the sector (Moriarty et al., 2013; Opryszko et al., 2009; Sutton, 2017); however, these approaches remain driven by a development goals focused on provision of access with limited attention on the potential unintended consequences. In the context of Bangladesh, this framing of self-governed water points raises questions over responsibility and authority to govern decisions on private property that result in exposure to arsenic or impact the groundwater availability, introducing a common pool resource management challenge. This thesis seeks to engage this growing body of literature advocating blended finance and self-supply approaches as pathways to achieving national development targets. The chapter provides a rigorous empirical review of the infrastructure growth driven by private finance in the rural market of Bangladesh, the proportion of infrastructure under private individual and private multi-family, versus public water systems, and the rules shaping decisions about use in the face of high uncertainty of water quality safety.

To understand how the risk narratives, constructed, contested, and criticized across policy, media, and techno-scientific planes of discourse, shape risk responsibility and define self-reflexive governance mentalities. (Chapter 6)

The risk discourse filters, proposed in Chapter 4, are expanded around the question of how the Bangladeshi risk narratives confront the unintended consequences of previous development agendas. The risk discourse analysis method is extended to investigate how multiple bodies of text, including academic, media, and policy documents interact to construct, constrain, and confront previous decisions within the risk narratives. This analysis leads to wider discussions around how to chart institutional change over time using the core grammar of risk in relation to decision-making and action scenarios. Building on the findings from Chapter 4 which identified three periods of drinking water risk narratives in Bangladesh, this chapter specifically analyses the risk-response mechanisms related to the ability for self-reflexive criticism which are linked to the allocation of responsibility within the wider design of the rules and action-scenarios. This chapter addresses gaps in critical discourse analysis methods by connecting multiple fragments of discourse, which were previously analysed independently (Fairclough, 1995a; Jäger, 2001; van Dijk, 1993; R Wodak, 2006) and expands risk narrative analysis beyond media studies to also include academic and policy texts (Bakir, 2010; Kristiansen, 2017; Mullen & Klaehn, 2010b).

Following observations from risk theorists on the politics of risk knowledge described above, the chapter addresses gaps in Beck writings articulating the process of institutional change as contingent upon knowledge formation through the construction, contestation, and reflexive or self-confrontational criticism intertwined across the public risk narratives. This chapter contributes to efforts to link risk theory with discourse analysis and institutional design making use of methods deconstructing the grammar of risk. Through this discussion, the chapter

questions how rural drinking water institutions perform in response to multiple risk narratives, how risk-governance models adapt, and why the individualization of risk responsibility has not been problematized in Bangladesh's public narratives.

In Beck's (2006b, 2009, 2011, 2016) final set of writings, he argued that globally imagined risk communities resulting from the unintended consequences of past decisions are becoming uncontrollable and leading to the failure of previous allocations of risk responsibility. This transition leads to what he and others, including Rayner (2007), argue is the rise of risk politics and retreat of the state from previous collective risk responsibilities models. This argument links to a wider body of literature (Bakker, 2002; Girdwood, 2007; Sultana, 2015), specifically in relation to urban water schemes, arguing that the increasingly diffuse neo-liberal models of institutional power structures are promoting the devolution, marketization, and privatization of individual responsibility without addressing new types of risk for decision-making systems.

Significant gaps remain in understanding this process of change in relation to rural drinking water services in fragile and low-income states. This chapter engages a series of debates in risk-governance literature, identified by Beck (2011), Dean (2016), and Matten (2004), surrounding the critique of institutional design and performance in relation to the allocation of decision-making responsibility during the transition process from governance by provision of services to one of risk mitigation of the unintended consequences of human decisions (Beck, 1995, 2006b, 2007; Dean, 1999a; Matten, 2004; Rayner, 2007). This process, which plays out across contested knowledge formation of risk narratives, has limited explanation of how society links power and responsibility in governance structures (Mythen, 2005). This chapter expands literature around institutional design of reflexive governance in the context of Bangladesh.

3 METHODOLOGY

3.1 METHODS

In this section I briefly situate the following research chapters under a pragmatic approach which seeks to bridge the critical theory with transformative theories of power and responsibility. This provides an interdisciplinary research methodology designed to explore several fields of inquiry around drinking water security and the overlapping boundaries of sociology of risk, discourse theory applied to agenda-setting methods, and frame the internal action-scenario through a risk-based approach as part of the institutional analysis.

This chapter briefly describes the mixed methods approaches used to explore these phenomena of risk theory through a field survey using questions derived from rules-in-use framework of institutional theory and archival text research using methods from the overlapping boundaries of discourse theory and media studies. This section further describes the field site context, material identified in archival records, and protocols used to collect and analyse the empirical data. The data collection, supported by several affiliated REACH Programme partners, is summarized in this section and detailed in each chapter due to the journal paper format requirements.

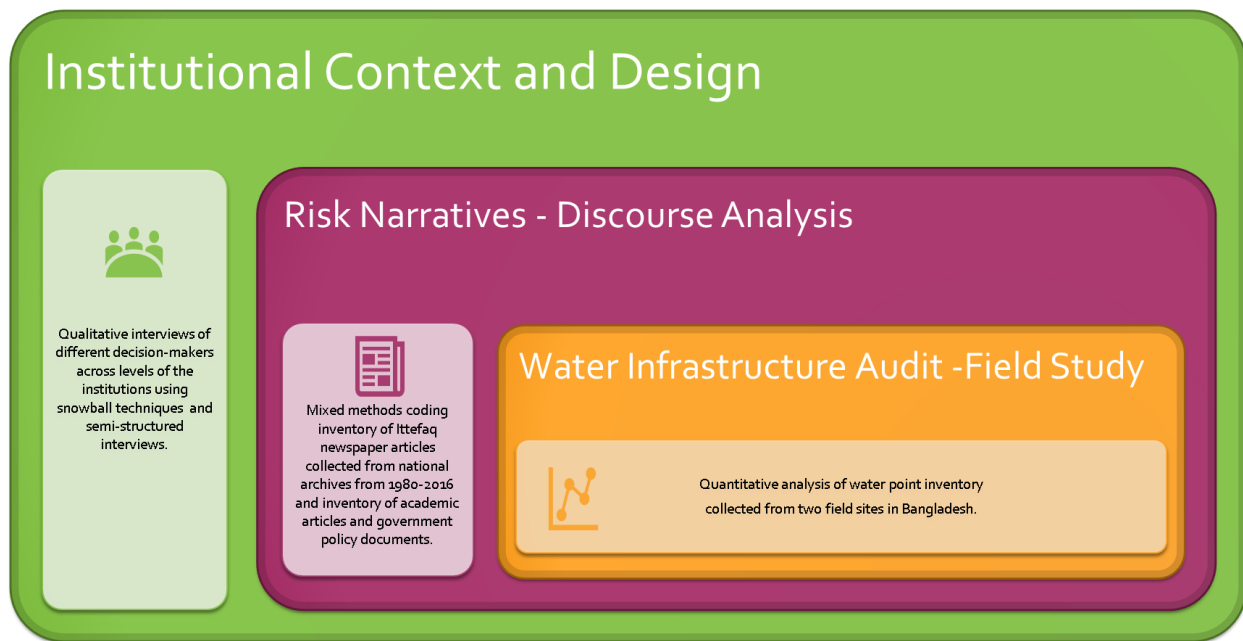


Figure 11 Mixed method research design.

In response to the research gaps, action-based problem definition, and theoretical framework, the mixed methods is designed to employ several research techniques and procedures in order to collect and interpret multiple information sources. Summarized in Figure 11, the survey tools include qualitative semi-structured interview methods and discourse analysis tools for coding inventories of media, academic, and government texts. Further, a localized field study mapped the physical infrastructure and conducted structured interviews with water point managers in ten villages and was later replicated in a second region of Bangladesh.

Research for this dissertation was conducted in two stages, generating several complementary yet distinct datasets. Each component used separate methods for data collection but were interpreted under the overlapping critical theories to create an interdisciplinary approach. As described in detail in the submitted papers, each method seeks to address gaps identified in the literature review and support best practices.

This includes the following methods and data sources, summarized in Table 4 and discussed in greater detail below:

Component	Theory	Method	Tool	Data Source
Institutional Context and Design	Institutional Analysis and Governance (Bushouse, 2011; Gain and Schwab, 2012; McGinnis, 2011; E Ostrom, 2010b; Pahl-Wostl, 2009)	Chain referral sampling (snowball sample)	Semi-Structured Questionnaire	- Informal interviews n=65
Risk Narratives	Discourse and risk theory (Bakir, 2010; Beck, 1992; Fairclough, 1995b; Herman and Chomsky, 1988)	- Agenda setting and Manufactured Consent of Media -Policy text analysis - Total population sampling (1980-2016)	Risk discourse filters coding of identified text	- Ittefaq newspaper articles n=3,211, - Academic articles n=2,151 - Government policy documents n=45
Infrastructure Audit	Infrastructure growth, information systems, governance models, including population modelling using mean-crowding (Beck, 2013; Garrick, 2018; Lloyd, 1967; Luhmann, 1990; O'Malley, 2000; Rayner, 2007)	- Water point mapping - Purposive sampling of 10 villages	Structured questionnaire and spatial mapping	- Tubewell spatial mapping and interview of water point manager or owner n=3,734
Financial and Policy Analysis	Institution Analysis of risk-response (Hope and Rouse, 2013; Mythen, 2005)	- Financial analysis and modelling growth - Total population sampling -Policy text analysis	Historic Price Data Analysis	- Government project documents n=67 - Matlab household interviews n=2792

Table 4 Summary of mixed methods components

Research design

The concept of risk has been debated across disciplines with increased prominence since the 1960s. The ontological claims are increasingly aligned to define risk as constructed knowledge attempting to anticipate the future, however there are a widening plurality of epistemological approaches to understanding how we render concerns knowable and visible. Water resources are a tangible, or real, consumable goods, yet as Lupton (1999a) discussed, water safety risks must be rendered visible through techniques of setting quality thresholds, testing for contamination, interpreting the salience of concern to different actors, and evaluating end user perception and actions in order to exist as a problem or danger. In this thesis, the question is not if 'risks' are real or not, instead I ask how they are constructed, or rendered visible, through a socio-political and technical negotiation process, and thus which ones are acted upon within the constraints of the existing institutional design.

The thesis recognizes the plurality of epistemological approaches to understanding risk, as summarized by Althaus (2005), emphasized by Zeitoun et al (2016) in relation to water security literature, and extended by Brown et al (2012) in relation to global health interventions. The research study is designed to extend interdisciplinary approaches in sustainability studies of social-ecological systems which argue that there are multiple strategies and ways of knowing any context, and that reflexive learning depends on that critical understanding (Miller et al., 2008; Mitchell, Cordell, & Fam, 2015). The thesis therefore explores the process and contestation of what Hajer and Versteeg (2005) describes as the existence of multiple, socially constructed realities mediated through knowledge exchange.

Within this plurality of ways of interpreting risk, institutions, and discourse, as discussed in the previous chapter, the thesis narrows the definitional focus of risk around Luhmann's view that risks are "the possibility of future damage, exceeding all reasonable costs that are attributed to decisions" (Luhmann, 1990, p. 225) differentiated from the tangible experienced damage and hazards and Beck's (1992) focus on the unintended consequences of these decisions. The thesis further applies definitions of discourse under the broad lens of critical theory, which is summarized by Hajer and Versteeg (2005, p. 175) as "an ensemble of ideas, concepts, and categories through which meaning is given to social and physical phenomena." This perspective enables the use of both quantitative techno-scientific calculative approaches and socio-cultural and political rationalities, or ways of thinking about a problem, both as pathways to manage populations (O'Malley, 1996). This definition of risk based around decision-making processes, is further extended to follow North's (1990) view that institutions are designed to reduce uncertainty by providing structure, both formal and informal, as constraints to human decisions and interaction. This manifests through what V. Ostrom (1961) first described as a polycentric decision-making system or a network of overlapping competing and cooperative centres of responsibility and different scales of governing authority (Andersson & Ostrom, 2008; Heikkila, Villamayor-Tomas, & Garrick, 2018; E. Ostrom, 2010a).

Finally, both sociology of Beck's (1994) reflexive modernity and observations derived from studies of polycentric institutional designs summarized by Ostrom's (2010c), focus on learning, adaptation, trust, and cooperation. Ostrom (2010a) summarizes years of a group of scholars work developing the institutional analysis and development (IAD) framework to identify the building blocks of human interaction, including rules-in-use and action situations.

The research design further seeks a pragmatic approach driven by a core problem, or the goal of achieving and maintaining universal drinking water security based on a new and replicable institutional model informed by new flows of information and negotiated knowledge. This enables a pluralist approach by building from critical theory, exploring the politically reflexive relationship between power, knowledge, and discourse while also contrasting with the quantitative analysis of past decisions of users to install tubewells. Critical theory sees knowledge as mediated through power relations that are social and historically constituted (Lindlof & Taylor, 2011). Departing from classical critical theory which is based in production and consumption of capitalism, this thesis uses Beck's reflexive modernism theories and role of risk and self-produced dangers. Discourse theory has been used to link these bodies of thinking through "governmentality" and applied case studies (Dean, 1999a; Foucault, 1991; Huxley, 2016; Rose et al., 2006; Tesfaye Gemechu, 2018). Scrutiny of cultural institutions including media, science and industry is embedded within this approach. The critical theory analysis of risk narratives provides a perspective on the historical and cultural contexts and to relativize the empirical findings.

The interdisciplinary research framework seeks to merge several bodies of literature and analytic approaches around two large longitudinal inventories and multiple secondary information sources: one inventory from archival newspaper records and a second from field surveys mapping drinking water infrastructure and management practices. The large data sets, to be released in separate methods and supplementary information papers, were designed to generate value beyond the boundaries of this thesis and thus may offer researchers further insights into both related and tangential questions.

Research components and data sources

The data collection represents three different data sources, each using different protocols to compile. The first study protocol produced a comprehensive inventory of national newspaper articles while the second aggregated peer-reviewed academic journal articles. These datasets provided the core material for two chapters. The third chapter relied on a field survey to document the every tubewell in a defined region and code user risk-response dynamics. This represents over ten months of continuous data collection and six trips to Bangladesh for field visits and team meetings.

Semi-structured and qualitative interviews

A series of semi-structured interviews with representatives of multiple government and civil society were conducted at the beginning of the thesis in 2015 and 2016 to understand institutional change from the perspective of individuals within organizational units and how information was being used across multi-level decision-making processes. Over 65 individuals were identified using snowball techniques and chain referrals, aided by the UNICEF country teams and icddr,b staff—see the Appendix for the full list of interviews. The semi-structured interviews were held with representatives of organizations that maintain responsibilities in the drinking water sector, including government policy makers, non-profit aid organizations, water utilities, and municipal water managers. A set of largely semi-structured questions were prepared to guide the interviews and ensure a limited comparative analysis—see the Appendix for the questionnaire. They included questions on the formal responsibilities and mandate over drinking water services, organizational history and current structure when appropriate, collection of data and use of information within decision-making processes, and relationship to other actors in the

sector. This resulted with the identification and collection of primary and secondary documents, specifically the DPHE policy documents. The results were used to inform the design of the risk discourse filters and water infrastructure audit. The results were not analysed systematically in the following chapters, instead used to help formulate research questions and analysis.

Media inventory data collection

The media sector in Bangladesh, long dominated by the newspaper culture, had only a handful of publishers until the 1990s when the sector went through a rapid growth of new daily publications, as well as increasing radio and television penetration with new audiences, and most recently the dominance of internet blog forums. This created a highly competitive market with over 300 newspapers across the political spectrum publishing daily, most in Bangla with a range of geographic coverage and circulation (Shoesmith, 2013). Most of these papers are only available in hard copy. There was no known archive for previous television content, which only began broadcasting in the 1990s. This limited the data collection, due to both the temporally intermittent publications which reduced the number of continually published newspapers and hard copies only available in the national archives which limited analysis tools and increased time required.

The media inventory was designed to generate the first complete multi-decade inventory of drinking-water specific articles—detailed in Chapter 4 and expanded in Chapter 6. This single-source newspaper inventory for this study, limited to one newspaper title due to time and budget limitations, was selected after a wider assessment of news coverage from 29 main newspapers, and assessment of their coverage of WASH topics over three years between 2014 and 2016, as seen in Table 5. The data collection methods sought to build a robust inventory of every

Name of Newspaper	Published from	Language of press release	Online version (Published from)		
			Bengali	English	ePaper
Daily Prothom Alo	1998	Bengali	2007 link: http://www.prothom-alo.com/	2014 link: http://en.prothom-alo.com/	2009 link: http://epaper.prothom-alo.com/
Daily Ittefaq	1953	Bengali	2014 http://www.ittfaq.com.bd/	Available but Not sure from when http://www.clickittfaq.com/	2012 link: http://epaper.ittfaq.com.bd/
Daily Star	1991	English		2010 link: http://www.thedailystar.net/	2010 link: http://epaper.thedailystar.net/index.php?opt=view&page=1&date=2016-12-20
Financial Express	1993	English		2007 link: http://www.thefinancialexpress-bd.com/	1997 link: https://epaper.thefinancialexpress-bd.com/
Bangladesh Observer	1949 *	English	Not Available		

Table 5 Comparison of the five major newspapers

newspaper article published between independence in 1971 and 2016. This time period was identified specifically to extend observations from Mahmud (2013) around the role of newspapers during the post-independence era, and from Hossain (2018b) who suggested that the failure of state action in response to storm and flood damage to drinking water systems pre-1972 was as a sub-narrative in the independence movement after being shaped by media coverage.

Selecting which newspaper to inventory was done through a careful cross-comparison of multiple major newspapers. The selection criteria included:

- 1) A newspaper or journal which had consistently published daily editions since 1980.
- 2) A newspaper that was available in the national archives.
- 3) A newspaper that provided reporting at a national scale.
- 4) A newspaper that had high professional standards and no explicit editorial bias, although inherent to the study every newspaper will have specific agendas, both political and financial influencing the published articles.

The Ittefaq was selected for this multidecadal inventory after a review of the 29 largest newspapers' coverage of drinking water topics from 2014-2016, and assessment of the major newspaper's historic coverage. Only 4 newspapers were consistently published through the 1980s after the government set tight censorship rules (Mahmud, 2013). The Ittefaq newspaper was selected to be the source for this inventory due to its historic importance, continuously published source of articles, and estimated circulation as one of the most read newspapers over multiple decades, although no longer the most widely circulated in the past decade.

Once the Ittefaq was selected, a protocol was developed to identify, code, and analyse the newspaper articles building from the methods defined by Herman and Chomsky (1988) in their *Manufacturing Consent* analysis, extended by Entman's (1993, 1996) agenda-setting methods and discussed by Anderson (2006) and Bakir (2010) in the context of risk and media. A trained research assistant, with native fluency in Bengali, reviewed each day's newspaper between 1980 and 2016 using the archives in the Government of Bangladesh's Central Shahbag Public Library, the National Archives, and the Central Library of Dhaka University. Her review identified 3,211 articles where specific references were made to "water" with variations on "drink*", "domestic", "cholera", "diarrhoea" and "arsenic". Each of these articles were then coded using a structured questionnaire, programmed into the ONA software and entered on a tablet device. All articles were coded for basic information including a translated English-language title, date of article, section of newspaper, and page number. Each identified article was next coded for key words in article text differentiated by the articles overall main subject and the title key word. Finally, the first section also recorded the any geographical references in the article, specifically if it is a

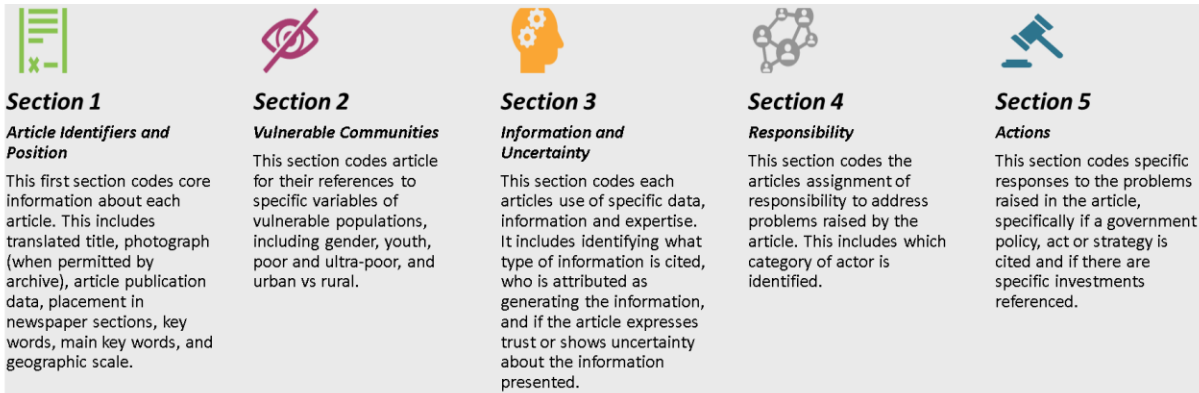


Figure 12 Summary of media inventory coded data.

national, regional, or local story and if a specific administrative Division is referenced in relation to the story. The full coding form is provided in the Appendix.

A randomized subset of 46% of the articles were selected and coded for the following areas—summarized in Figure 12—including the identification of the Government of Bangladesh’s (2005, 2011) defined vulnerable groups including children, women, and poor; if the article cited specific data, information or experts; if responsibility for the problem is clearly assigned; and if specific responses have been taken.

Intracoding was conducted at three points of the study with 84% reliability and intercoding at the beginning of the study to ensure reliability. The coder was provided extensive training and had daily supervision from myself and a program officer based at UNICEF in Dhaka. The data entry showed to be less reliable in sections 4 and 5, and thus the analysis excluded these sections but identify them as important approaches for future studies. The total data entry took 160 person-days and was limited by the archives rules on accessing newspapers, not allowing photography, and being non-digital, which thus excluded automated text analysis.

Peer-reviewed technical document inventory

A second inventory compiled an inventory of 2,151 indexed peer-reviewed technical journal paper which explicitly referenced “Bangladesh” and “drinking water” key words. These were identified through a systematic content search of multiple online digital archives including SCOPUS, OVID, and Web of Science. This search builds from previous papers which have done systematic literature reviews in the water sector, including Cook and Baker (2012) and Gerlak et al.(2018) and a focus on development discourse in academic journals by Madrueno and Tezanos (2018). These studies all use a key word search protocol for as follows:

Step 1: Title-Abstract-Keyword (Bangladesh) AND (water)

Step 2: Add keywords including (drink*); (potable); (domestic);

Step 3: Repeat step one and add key word search with (cholera); (diarrhoea); (arsenic).

Once identified, the articles were filtered to eliminate the following: (1) duplicate articles; (2) articles where Bangladesh was referenced by not the main geographic scope; (2) articles where drinking water was a minor comment or mis-identified including works but not related to the topic of drinking water.

The article titles and abstracts were coded using a similar framework as the media but adapted and limited to include main subject key word; title key word; geographic scale; identification of defined vulnerable groups; and geographic scale. Additional coding was attempted on project funding or project-specific context, including icddr,b, Matlab observatory, and HEALS in Araihaazar. However, the use of multiple data bases meant funding details were only available for a small percentage of the articles.

Legal and policy document inventory

The thesis considers a range of legal, policy, strategy, and planning documents formally endorsed by the Government of Bangladesh. Many of these documents were not immediately available online and thus collected through meetings with government officials and other colleagues. All documents were provided in English. Summarized in Chapter 2.7, and discussed in Chapter 6, they represent over 45 official documents addressing the legal acts, policies, strategies, and planning documents. They all address “drinking water” topics in some context or manner, although not always as main subject.

A further sub-study was conducted in partnership with DPHE to trace the historic costs of installing tubewells and handpumps—described in detail in Chapter 5. This required a research assistant to go to the DPHE offices over a three-month period to access their hard copy project document archives, specifically the Project Proforma and Development Project Proposals (DPP). Each project document contained a budget with expected costs and a report on actual project expenditure. As documents were located and reviewed, most were in Bangla not English, the following information was extracted: month/year of the document; year of planned cost; timeline for project; total project budget; infrastructure type; planned number; total investment; actual cost. This provided the information to calculate expected and actual unit cost of a variety of infrastructure types, however Chapter 6 only discusses deep and shallow tubewells with handpumps. These documents often had limited description of the units being costed and therefore we are unable to clearly determine why there is some cost variation, although assume it is either differences in hydro-geologic conditions where drilling is the most expensive element.

Water infrastructure audit

The Water Infrastructure Audit was designed to map every water point in a geographically defined area linked to a questionnaire implemented with each water point manager or owner to understand a range of risks and decision-related structures. The questionnaire—included in the Appendix—builds on a range of previous studies and questionnaires, both ensuring alignment to global best-practices, academic advances, and Bangladesh-specific protocols. The questions were grouped and sequenced in thematic sections around parameters of water security including functionality, reliability, water quality, and affordability. The questionnaire specifically extends previous studies to include nuanced questions differentiating management, ownership, and responsibilities; financial investments in capital expenditure versus operation and maintenance; and water safety knowledge and decisions.

The Water Audit questionnaire were grouped and sequenced into six thematic sections after obtaining consent including: (1) basic identifiers and physical observations; (2) history and current use; (3) management responsibilities; (4) water quality and safety perceptions; (5) investment and affordability; (6) functionality, reliability and maintenance.

The questionnaire was designed to build on previously standardized instruments. The introduction and basic information section is built around the National Water Point Mapping coding system for public water points designed by DPHE (DPHE, 2014b) and the 2003/2008 arsenic water point mapping for Matlab (Alam et al., 2017; M. Hossain et al., 2015). The sections on current use and installation, management structures and financial investments were adapted from governance literature and previous assessments of operations and management (Carter & Ross, 2016; Foster, 2013; Kabir & Howard, 2007; Kayser et al., 2013; Koehler et al., 2015; Pahl-

Wostl, Lebel, Knieper, & Nikitina, 2012). The water quality and safety perceptions further adapted questions from previous surveys in Bangladesh (Madajewicz et al., 2007; van Geen et al., 2014). Additional questions were added on source and extent of investment, allocation of responsibility differentiated by ownership, management, and funder. Additional information was collected on investment into capital costs and operational expenditures using a framework and definitions provided by the life-cycle costing approach (Fonseca et al., 2010). The framing of the questionnaire is structured around the risk domains and institutional responsibility discussed by Hope and Rouse (2013).

The questionnaire was structured using pre-set close-ended choice questions and integer questions. Most questions were structured as Yes/No/Do Not Know/No Response or a pre-set list of select one or select multiple options. Every choice option included “other,” which if selected would prompt a follow up question with text entry to specify. Extensive field testing and refining of choice options was undertaken, in both the design and piloting stage of the survey.

The survey questionnaire was administered in an electronic form developed in ONA (<https://ona.io/>), a Mobile Survey Platform that provides a hosted server for uploading, editing, viewing and submitting forms. The questionnaire was first programmed in English using XLS Forms and then translated to Bengali for field testing. The ONA Collect provided automated functionality for inbuilt logics and constraints within the questionnaire. Finalized forms were submitted to the cloud data storage every evening with mobile SIM card in the tablets. ONA software allowed immediate spatial, tabular and graphical visualization. The tablets provided minimum of 5meter GPS accuracy, therefore not requiring separate GPS devices. Each water point interview took an average of 25 minutes to cover all sections.

For the purposes of this study, only water points used for domestic drinking water purposes in the households or public facilities were surveyed. Tubewells used solely for agricultural and irrigation purposes were excluded due to limited time and scope of research objectives. Tubewells in all public facilities including schools, health centres, markets, factories and private enterprises were included but sorted out of the final analysis.

Abandoned tubewells, defined as water points no longer being used and with no plans to rehabilitate, were mapped but no questionnaire of owners was conducted. Abandoned water points were differentiated from non-functional tubewells which were defined as water points with no or minimal water flow but who's owners intended to repair.

The enumerators identified all tubewells including both hand pump and electric pumps systems. Piped water systems with more than 10 points of access or connections were not included. Water points that had one point of access, but more than 10 differentiated users were all included.

Matlab study site

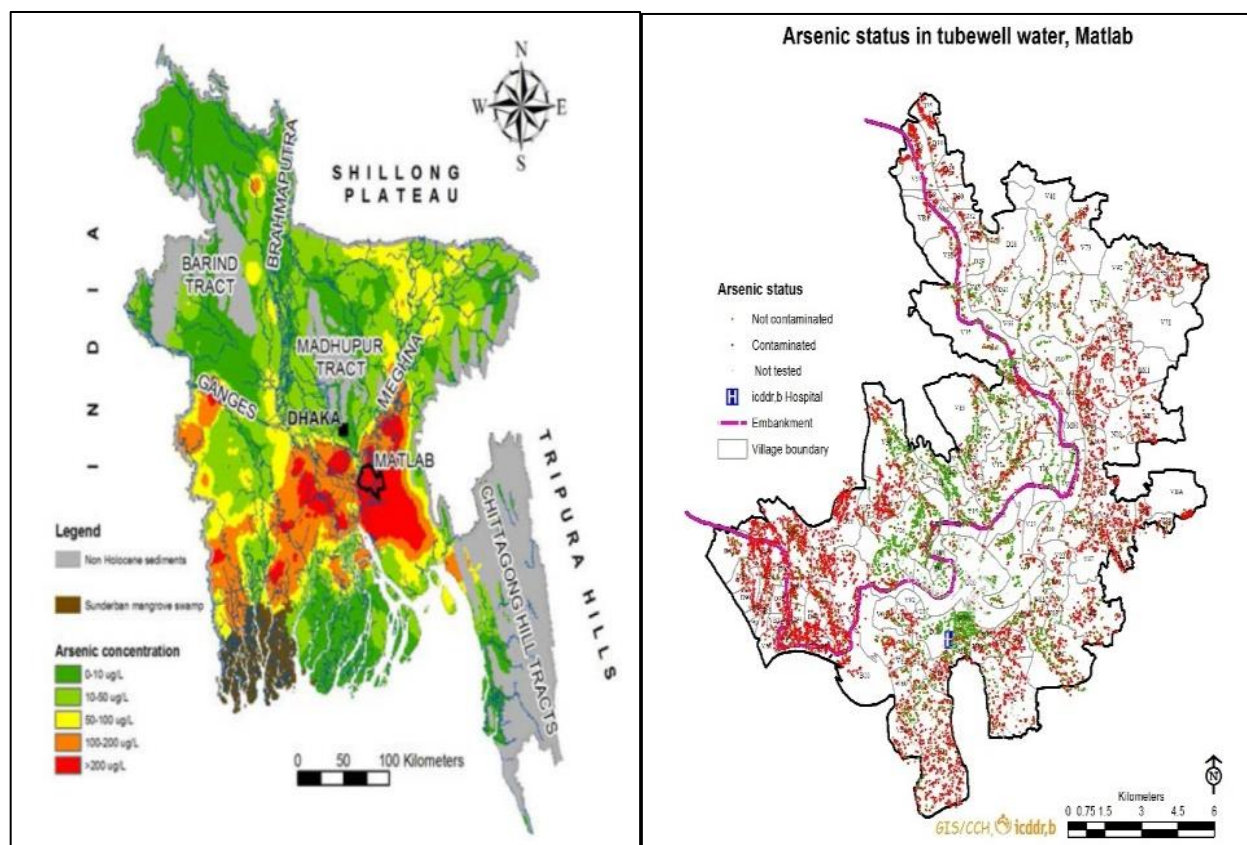
Drinking water provision in Matlab is defined by several dominant water infrastructure options and varying household use decisions across a complex set of multi-source, multi-use behaviours. Located roughly 50 km south-east from Dhaka, although 100km when driving, the study area is outside the Dhaka's metropolitan and industrial areas of direct market influence. The area is across the Meghna river and primarily rural and agrarian, representing three administrative Upazilas or sub-districts with the majority in Matlab Dakshin (South) and Matlab Uttar (North) of Chandpur district with a third area in Daudkandi Upazila in Comilla district. The Chandpur region

of Bangladesh is characterized with by the convergence of multiple concerns around decades of uncertain water quality, flooding, and continues to be one of the fifteen regions with the highest rates of poverty (GoB, 2015a).

The icddr,b operates a geographically bound demographic surveillance, research, and practice program in this area that advances understanding around, but does not specifically focus on, multi-dimensions of the water security nexus, including the health outcomes related to cholera, arsenic, and flood risks. The site was initially established in 1963 as a field diarrhoea hospital and research clinic to test cholera vaccines and diarrheal disease treatments, and by 1966 quickly evolved into what has become the world's longest running health and demographic surveillance site—for a full discussion of icddr,b and the research history see Alam et al (2017). This provides a unique study area due to the multiple decades of monitored change through the population-wide data which has been continuously collected—a summary of the data obtained for this study is in Table 6. The information system monitors the region's demographic change, efficacy of public health interventions, household-level socio-economic characteristics and is linked to bio-physical, hydrological and geospatial data. Each of these data sets are linked together through a family and individual registry system, enabling integrated analysis of previous studies results at various scales.

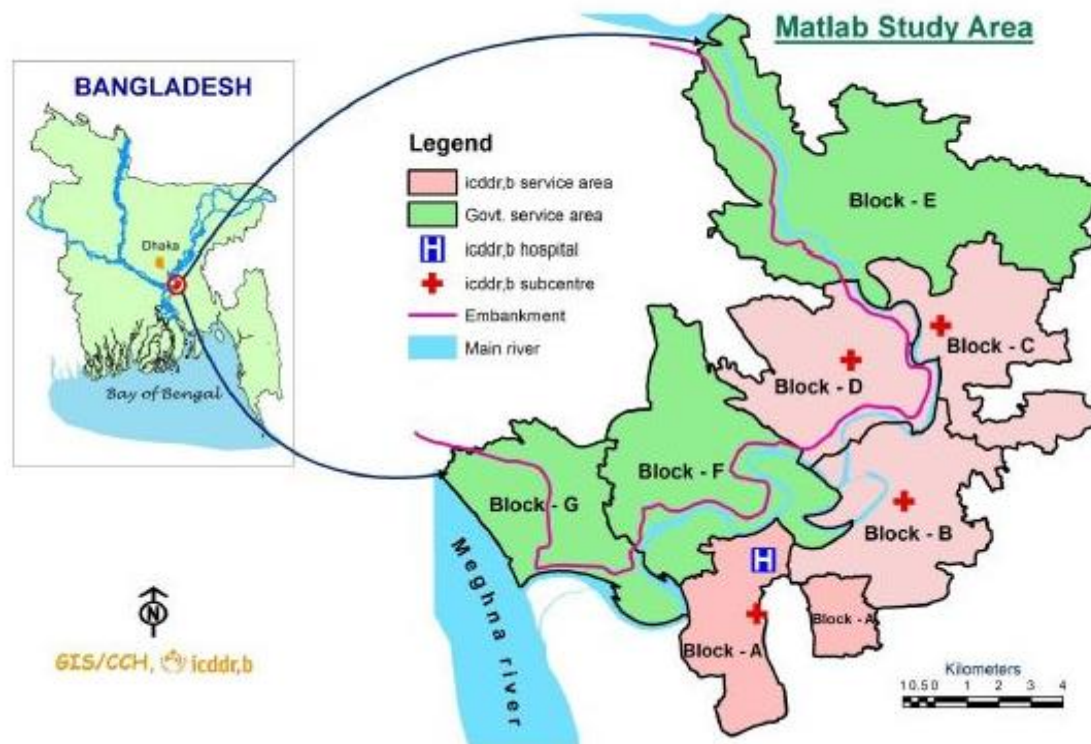
Table 6 Secondary data collected from icddr,b

Type	Questionnaire	Variables	Frequency	Years	Villages
HDSS	Death Registration	CID, location (Reporting Village, village name, village code, town, union, serial No, Upazila), place of death, date, gender, type of death (natural, unnatural)	All Events	1982 (July)-2014	47 Villages
HDSS	In/Out Migration Registration	CID, location (Reporting Village, village name, village code, town, union, serial No, Upazila), date, group type (individual, partial, whole HH), religion, dob, gender, marital status, education, occupation, cause of movement, new household?	All Events	1982 (July)-2014	47 Villages
HDSS	Internal Movement Registration	CID, location (Reporting Village, village name, village code, town, union, serial No, Upazila), date, village arriving to, marital status, cause of split/movement	All Events	1982 (July)-2014	47 Villages
HDSS	Bari GIS location	Spatial Data on location of Bari's used for enumeration	Once	2014	47 Villages
HDSS	Tubewell Location and Arsenic Status	Excel on 2003-2006 inventory of tubewell location, age, and arsenic status.	Once	2006	47 Villages
HDSS	Socio-Economic Survey (1982)	CID; Items owned (13); No. of cows owned (14); No of boats owned (15); total land owned (16); Main sources of water including drinking, cooking, bathing, washing (17); Structure of largest room (18); Dwelling structure.	Once	1982	47 Villages
HDSS	Socio-Economic Survey (1996)	CID (H2); Bari no (H1); HH size (H4); Remittances (H5); HH Possessions (H6); Land ownership (H7); land rented (H8/H9); Built structure (H10-H12); Sanitation (H13-H15); Drinking water source (H16); Cooking water source (H17); Washing water source (H18); Bathing water source (H19); loan (H25-H27); Income women (H28); Date of interview	Once	1996	47 Villages
HDSS	Socio-Economic Survey (2005)	Bari code; CID; land information (S.1); Source of income and wellbeing (S.2 & S.3 & S.7); Built structures (S.4-S.6); Sanitation (S.8); Drinking water (S.9); date of interview	Once	2005	47 Villages
HDSS	Socio-Economic Survey (2014)	Bari code; CID; land information (S.1); Source of income and wellbeing (S.2-S.5 & S.7-S.8); Built structures (S.6); Sanitation (S.9); Drinking water (S.10); Energy (S.11-S.12) NGO (S.13); Insurance (S.14); Info Centre (S.15); Bank Account (S.16); date of interview	Once	2014	47 Villages



Map 2 Matlab arsenic risk maps including water point blanket samples. Source icddr,b 2016

This research site, formed in response to the concerns and research into the waterborne spread of cholera, was later used to study the high rates of arsenic contamination. This site was in part selected due to the comprehensive arsenic testing for all water points in 2003 which mapped spatial extent of the tubewell contamination—seen in Map 2 (Jakariya, Vahter, et al., 2007). This blanket inventory generated a baseline of every tubewell as a reference, however only captured data on geocoordinates, age, depth and arsenic level in one sample. The wide spread and rapid increase of installing shallow tubewells resulted with an estimated 12,532 handpumps across 47 of the icddr,b defined villages (M. Hossain et al., 2015), a ratio of 16 people per tubewell in the 10 villages in 2005.



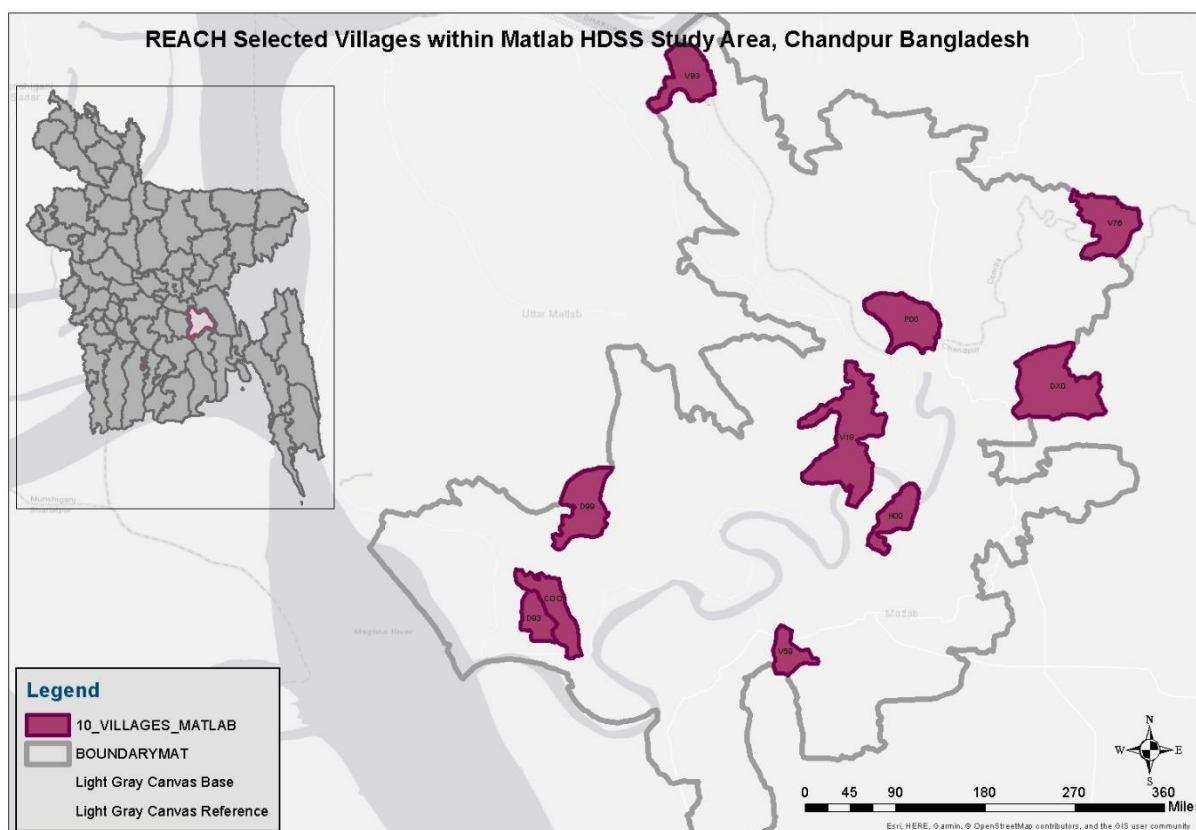
Map 3 Enumeration blocks of 142 villages in Matlab enumeration area. Source: icddr,b 2016

The Health and Demographic Surveillance System (HDSS) now covers a population of 230,185 as of 2014 that live in two distinct geographies divided on either side by the Dhonagoda River, a tributary of the Meghna river (Haider et al., 2016). The site was further divided into two regions based on provision of government and icddr,b health services, a distinction used in other studies but not this one. This site provides decades of continued focus on the dominant issues defining national drinking water quality problems and insecurity.

The study population is dispersed across 142 enumerator areas divided into seven blocks differentiated by health service provider, as seen in the Map 3. The enumeration units roughly aligned to the lowest level of administrative unit of the village ward or Mouza, a unit being officially mapped at the time of this study (GoB, 2015a). Within these wards are baris or clusters of built structures and households often linked through patrilineal relations and who use a

common courtyard, although these familial lines may be changing in the recent decade (Nahar, 2007). In 1988 as part of the Bangladesh Flood Action Plan and under the Meghna-Dhonagoda Irrigation Project (MDIP), which sought to address chronic concerns of extreme flooding and water management to increase agricultural productivity, an embankment was built along the northern banks of the Dhonagoda tributary. This differentiated the north and south of the study area based on the zone protected from flooding and a southern zone with no flood protection infrastructure (Carrel et al., 2009). Although this was constructed outside the icddr,b study focus, the embankment provided a clear division of the study population and a range of studies on the impact on health outcomes, although was not explicitly discussed by icddr,b annual reports until the 2014 Socio-Economic Survey report (Carrel et al., 2009; Myaux, Ali, Chakraborty, & de Francisco, 1997; *The demographic, health, and nutrition impact of the Meghna-Dhonagoda embankment*, 1992). This spatial distinction was used to design the sample selection as described below.

Under the purview of the REACH Programme, we collected secondary data from icddr,b for one third of the villages. The selection of these 47 villages was driven by the study by Manandhar which employed machine learning techniques for risk-prediction models and water security outcomes from the complex, heterogeneous data set provided by icddr,b. These villages were randomly selected under criteria to ensure a balanced sample of villages in and out of the embankment and representing a mixed of improved and unimproved drinking water sources.



Map 4 Ten villages selected for the Water Audit data collection

Within the overall 47 villages, the water audit study purposively selected ten villages to conduct the infrastructure inventory, limited due to budget and time constraints. The ten selected villages, displayed in Map 4, represents 25,617 people in 6,036 households as of the 2016 icddr,b demographic data (Haq et al., 2018). The villages were purposively identified based on two criteria, summarized in Table 6. Half of the villages were located inside the flood projection embankment, and a sample of villages representing a heterogenous mix of main drinking water source across infrastructure type and arsenic/no arsenic. This ensured the water infrastructure audit covered areas with deep tubewells, shallow tubewells painted green as arsenic safe, shallow tubewells painted red as arsenic contaminated, and areas with piped water or surface water reliance.

Table 7. Criteria highlighted in blue were used for selecting 10 villages for the household survey.

Village Code	Village Name	No. of Baris (HDSS, 2017)	No. of households (HDSS, 2017)	Population (SES, 2014)	Sources of drinking water (SES, 2014)								
					Deep tubewells	Shallow tubewells			Piped water	Rainwater	Pond	River	Ditch/ canal
						Green	Red	Not tested					
H00	Lamchari	55	284	1230	46 (16%)	70 (25%)	57 (20%)	32 (11%)	0 (0%)	0 (0%)	43 (15%)	49 (17%)	0 (0%)
V59	Doshpara	185	607	2364	0 (0%)	445 (80%)	16 (2.9%)	36 (6.5%)	74 (13.3%)	2 (0.4%)	1 (0.2%)	0 (0%)	1 (0.2%)
DX0	Barogaon	71	816	3461	22 (3%)	53 (7%)	468 (59%)	38 (5%)	324 (41%)	3 (0%)	1 (0.1%)	0 (0%)	2 (0.3%)
P00	Titerkandi	76	480	2011	2 (0.4%)	387 (84%)	9 (2%)	29 (6%)	0 (0%)	1 (0.2%)	0 (0%)	44 (9.5%)	0 (0%)
V18	Torkey	271	946	3998	56 (6.1%)	676 (73.1%)	132 (14.3%)	93 (10.1%)	8 (0.9%)	28 (3%)	5 (0.5%)	9 (1%)	0 (0%)
VB3	Rayerkandi	119	695	2919	585 (88.9%)	35 (5.3%)	2 (0.3%)	0 (0%)	2 (0.3%)	10 (1.5%)	0 (0%)	47 (7.1%)	0 (0%)
V76	Chosoi	51	407	1735	114 (29%)	43 (10.9%)	60 (15.3%)	257 (65.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
D99	Mandertali	148	487	2035	42 (9%)	196 (42%)	183 (39%)	52 (11%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
D93	Maizkandi	134	338	1318	290 (90%)	4 (1.2%)	77 (24%)	62 (19.3%)	0 (0%)	209 (65%)	253 (79%)	3 (0.9%)	26 (8.1%)
C00	Sarderkandi	332	976	3857	13 (1.4%)	218 (23.6%)	295 (32%)	417 (45.2%)	0 (0%)	0 (0%)	1 (0.1%)	0 (0%)	0 (0%)

The Matlab work was designed, coordinated, and supervised by the authors from Oxford and icddr,b and coordinated by a trained project officer located in Dhaka and a long-time study coordinator located in Matlab. The field survey data was collected by ten female enumerators who were hired directly from each of the villages and trained over the course of a ten-day period, including piloting data collection and reviewing their entry reliability.

Mobile network enabled tablets were programmed using ONA software to enable enumerators to locate and map every water point infrastructure in defined villages and complete a questionnaire in an integrated survey tool, immediately visualized online. Enumerators went to every icddr,b bari, or enumeration area within the ten villages to visually inspect for tubewells and ask residents to identify all water points which are in use, non-functional, or abandoned, including ones located inside four walls of a built structure. These final numbers were compared with the 2003 icddr,b water point inventory and 2014 SES survey results to ensure wall-to-wall inventory. Once identified, the enumerators interviewed the water point owners or managers. The data was cleaned each day, using automated logic checks and manual review to ensure reliability of entry. All respondents were over 18 years of age and provided oral consent to be interviewed about their tubewell infrastructure beyond identification of location.

Khulna Study Site

The second field study was conducted by a separate field team under the same REACH Programme grant and deployed the same blanket sampling strategy as Matlab. However, this site used a shortened version of the questionnaire. The site is located 160km south-west of Matlab in an embankment, or polder system, covering five unions across Dumuria and Batiaghata Upazilas (sub-districts), with 58,000 inhabitants living in 17,000 households. The overall

environmental risks are similar to Matlab area, however there is different emphasis on the increasing salinization and less supply reliability of the aquifer. Although arsenic is present in the region it is reported with far lower frequencies than at Matlab (Abedin, Habiba, & Shaw, 2012; Sarker, Van Camp, Islam, Ahmed, & Walraevens, 2018). The Khulna water audit was conducted in the south and central regions of the polder, covering 34,639 people and identified 2,805 tubewells and 19 pond sand filters. The data provides contrasting insights to Matlab through different hydro-climatic context in south western coastal zone and decision-responses to high levels of saline intrusion. The full results and analysis can be found in the article by Hoque et al (2019).

3.2 ANALYTIC APPROACHES

This thesis follows a sequential analysis approach to extract results and interpret meanings across each dataset. This employs two major analytic tools: discourse analysis in the two chapters and financial and spatial change modelling in the third. They are all interpreted using risk theory frameworks to isolate the features influencing institutional design and change.

Two of the chapters analyse this data by applying the proposed risk-discourse filters to deconstruct the socio-political and techno-scientific narratives using risk theories and historical policy context. The analysis tracks the temporal changes in the discursive content and the spatial emphasis on specific risk factors shaping institutional responses, extending analysis to how specific risk narratives disrupt governance mentalities and contest the dominant interests of national development and media agendas. Chapter 4 relies on the media inventory to determine the landscape of risk narratives and examine how Herman and Chomsky's (1988) structural

factors, and later Entman's (1993) agenda-setting and framing techniques are used in the context of risk narratives and drinking water security. Chapter 6 merges the media inventory with the academic journal paper inventory and provides more explicit framing in relation to the government policies and strategies and contested knowledge formation. This applies the same risk-discourse filters and expands wider theories of discourse and power, identifying techniques emerging from both linguistic interpretive studies of language-in-use and the sociological perspective of social constructivists building from Foucault's lectures on Governmentality (Dean, 1999a; Fairclough, 1995b; Hajer & Versteeg, 2005; Rose et al., 2006; Ruth Wodak, 2009).

Chapter 5 builds from empirical analysis tools used by ecologists and geographers to model the spatial and demographic change of specific populations, in this case non-living entities of tubewells. The findings from Matlab are first analysed using Lloyd's (1967) mean crowding metrics to interpret growth rates in public, collective and private systems across different infrastructure types, including depth of tubewells and type of pumps. This interpretative method provides insights into density-dependent processes and patterns of behaviour leading into aggregated clusters at the bari scale. These findings are further considered in relation to potential drivers of the growth, including risk-response to water quality concerns, change in price of infrastructure and finally welfare changes. The growth rates in Matlab are further compared to the results from Khulna and Narayanganj districts to estimate potential national scale growth. They are modelled using national census data to accurately portray regional variation and environmental conditions impacting water infrastructure types. The scale of growth is converted into financial scale of public and private investments using data collected from local market surveys and historic project documents provided by the Government under the WASH life-cycle

frameworks (Fonseca et al., 2011; Foster & Hope, 2016; Hutton, 2013). These results are further interpreted in relation to national sector expenditure, differentiating public expenditure as reported by DPHE (2016a) and GLAAS (2017) from private household expenditure estimated from the Water Audits. These findings are interpreted using a reflexive risk framework to understand how responsibility is allocated within existing polycentric institutional designs.

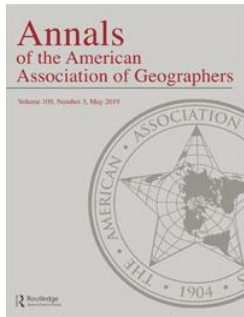
3.3 ETHICS

Prior to commencing any data collection, the thesis went through three ethics review processes. Research approvals were obtained from University of Oxford's Central University Research Ethics Committee, the icddr,b internal Research Review Protocol, and the icddr,b external Ethics Review Protocol which included government representatives.

Before commencing the Water Audit, all selected participants were informed about the purpose of the study, the nature of information sought, the degree of commitment required, and any possible risks and benefits associated with their participation. Written copies of these information were given to the respondents, who either gave verbal consent or signed the consent form. Participants were free to withdraw at any stage of the questionnaire no explanation required. In the Matlab Water Audit, 80 individuals declined to participate. The study involves collection of identifier codes linked to a separate data base, maintained by icddr,b, with personal identifiers. The research team has never had access to this second data base and uses anonymized codes for each water point.

The final data set will remain complete anonymized but made available through Oxford's online data repositories and REACH project archives. The newspaper inventory files have no human subject data and will be published through a journal methods paper and University repositories.

4 CONSTRAINING RISK NARRATIVES: A MULTIDECADAL MEDIA ANALYSIS OF DRINKING WATER INSECURITY IN BANGLADESH



Annals of the American Association of Geographers

**Title: Constraining Risk Narratives:
A Multidecadal Media Analysis of Drinking Water Insecurity in Bangladesh**

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Note:

This chapter is presented as published.

ABSTRACT

Sustainable development agendas in Bangladesh are frequently framed in the media as being constrained by water insecurity and the decision-making challenges posed by multiple risks of both natural and human origins. This article suggests, however, that the reverse also occurs: The boundaries of risk narratives constructed by the media serve to mitigate public concerns, reinforce national development agendas, and legitimize structural changes of the dominant institutions. These relationships are explored through a set of risk-discourse filters which merge content analysis approaches with the defining phenomena of risk society theory. Advancing an inventory of 3,211 drinking water specific articles published by the *Ittefaq* newspaper between 1980 and 2016, the analysis identifies three temporal clusters of discursive behaviors and content focus which contribute an historic perspective of how Bengali newspapers construct, define, and react to multiple water safety crises, specifically cholera and arsenic. The risk discourse filters suggest that the media's problematization of drinking water remains aligned to nation-building processes and the political narratives of development successes defined by international targets. The results map the discursive distribution of concerns across geographies and risk positions, extending interpretations of how and where blame is allocated. The inventory reveals an identifiable temporal and content pattern of inclusion and exclusion of topics and draws links to the overall institutional dynamics of political and economic change.

INTRODUCTION

In Bangladesh, the national narrative around sustainable development is often distinguished by the collective challenges to manage water variability, maintain service reliability, and reduce safety uncertainties (“Beating the bugs: How Bangladesh vanquished diarrhoea,” 2018; Black, 1990; Paprocki, 2018; van Geen, 2008). Global forums of scientific discourse frequently characterize Bangladesh as one of the world’s most water-insecure nations, a portrayal emerging from a complex confluence of both environmental hazards and unintended consequences of anthropogenic actions (Smith et al., 2000; Sultana, 2012; van Geen, 2008). At the same time, domestic forums of public policy seek to portray Bangladesh as a successful nationalist project, with the state protecting population from environmental dangers and enabling ongoing innovation in development approaches relevant to national and global interests (Faaland & Parkinson, 1976; N. Hossain, 2017). These narratives represent a tension between the competing voices contributing to the construction and interpretation of publicly debated drinking water risks. It also raises the question, however, of how the public narratives incorporate and mediate the contestation of different spheres of Bangladeshi and international institutions, interests, and information systems.

Bangladesh is located in one of the most densely populated and engineered deltaic plains in the world, a complex physical environment of rivers and man-made canals situated in the foothills of the Himalayas. Academic studies characterize the country by the high levels of climatic variability due to the annual monsoon cycles from the Bay of Bengal (NIPOORT, 2013). Scientists and experts often contextualize their research as a response to the severity and estimated scale of the depicted environmental crises, from some of the comparatively high global maternal and infant

mortality rates in the 1970s related to cholera outbreaks to the public acknowledgement of arsenic contamination in the 1990s (Black, 1990; Smith et al., 2000). The discovery of naturally occurring arsenic in the shallow aquifer levels attracted international attention to the uncertainty around who is at-risk, a scale estimated to be in the tens-of-millions and defined by the specific threshold levels applied (Johnston & Sarker, 2007). The extensive technocratic focus emerged from what Hossain(2017) argued is the global role of Bangladesh as an aid laboratory of national experimental policy, one that is characterized as repeatedly achieving multiple development and innovation successes.

International newspapers have provided an external voice to legitimize and disseminate these technical concerns. The widely cited 1998 *New York Times* article's description of arsenic contamination shocked the world with its severe portrayal of the situation by stating: "Bangladesh is in the midst of what some experts say could be the biggest mass poisoning in history" (Bearak, 1998). Prior national independence in 1971, water resources were characterized as a source of prosperity and fertility, an element of the romanticized national cultural identity labeled *Sonar Bengal*, or Golden Bangladesh (S Hanchett et al., 2014; N. Hossain, 2017). Hossain argues the national narrative around water security was re-framed after independence as a controllable danger, one which the new state pledged to manage. This reframing connects to what Black(1990) argues is the state's dual commitment to rural constituents and international aid structures seeking to solve a problem, specifically to reduce infant mortality blamed on cholera epidemics and unsafe water systems. The positive and negative framing suggests a divergence of how water is problematized between overlapping national development narratives, one advancing a positive social and political interpretation of

water as critical to the nation's social and political development, and the other issuing techno-scientific warnings of increasing exposure to harm and future dangers.

Within the continuum of theories on the nature and definition of risk, this article explores theories how risks are negotiated through individual and collective processes reconciling definitions, reproducing awareness, disseminating a specific portrayal of past decisions, and constructing future dangers (Beck, 1992, 2009; Luhmann, 1990; Lupton, 1999b). Beck defines risks as potentially catastrophic, manufactured uncertainties which are socially constructed, socio-technically contested, and socio-politically criticized across institutional and discursive dynamics (Beck, 1992; Cottle, 1998). This view is predicated on the argument that the concerns, specifically drinking water in this article, are a neutral concept until a group or population attach technical, political, cultural filters to denote 'good' and 'bad' attributes, or decisions (Douglas, 1992; Ewald, 1991). This rendering process necessitates mechanisms to make risks imaginable as they are not experienced (Beck, 1992, p. 28). This occurs across multiple discourse fragments, bodies of texts, and from multiple discursive planes, or institutional locations from which the discourse happens (Ruth Wodak, 2001).

Despite a broad consensus around the discursive role in manufacturing risk, communication studies scholars have identified gaps in the methodological toolkits and definitional frameworks for comparable analysis. Specifically, Bakir (2010) identified the need for comparable macro-view longitudinal studies across multiple socio-spatial contexts to interrogate the historic evolution and construction processes. Further, Kristiansen(2017) documented that recent scholarship varies in their definitional understandings rendering empirical methods incomparable, limiting analysis across spatial contexts and concerns.

This article therefore seeks to understand not only how, but also why, the media renders certain risks visible and knowable. This builds from Beck's risk theories to design a replicable approach for future multi-context comparisons using nuanced risk-discourse filters to identify the factors influencing the construction and constraints of the public narrative. To do this, the article attempts to understand how Bangladesh's drinking water narratives evolved within newspapers texts and how discursive tools were deployed to delineate, categorize and exert control over this formation process. This has implications for the allocation of risk responsibility across multiple actors and shaping expectations for collective and private actions to mitigate uncertainty and insecurity.

MANUFACTURING RISK: A MERGED FRAMEWORK

The following sections propose a framework which merges two broad areas of academic inquiry: the features defined within Beck's (1992) theories of risk society, and the discursive filters employed within communication studies, specifically by Herman and Chomsky (1988).

Table 8: Interpretation of newspaper inventory using risk discourse filters by period of the narrative.

Risk Society Components		Periods of narrative		
		1980-1992 Constructing a risk-response paradigm	1993-2005 Deconstructing previous approaches: Uncertainty of concern and response	2006-2016 Reconstructing a controllable but more complex risk
Production and construction of risks	-Selection of topics and frequency of key words in articles: inclusion and exclusion. (Herman & Chomsky, 1988, p. 132) -Problem Framing (Entman, 1993; Nisbet & Mooney, 2007) -Key events and structure of news reports (Kristiansen, 2017; van Dijk, 1988)	Coverage aligned to national development goals with greatest focus on tubewell infrastructure functionality and health risks related to cholera and diarrhea.	Coverage shifts to urgency and uncertainty to arsenic contamination but doesn't replace diarrhea; focus on TW functionality diminish with increased discussion of other physical infrastructure options.	Coverage increases in complexity and heterogeneity of article topics. Some alignment to national plans for piped systems but no dominant topic.
Allocation of blame	-Positionality of an article and frequency (Herman & Chomsky, 1988, p. 38) -Newsworthy and Salience (Entman, 1993; Lippmann, 1922) -Identification of responsibility.	Front page focus on cholera and diarrhea 1983-92; Responsibility tubewell maintenance and repair assigned to government agencies and engineers.	Letters and editorials spike requesting safe water but no frontpage coverage; Arsenic blame attributed to nature. Government assumes responsibility to reduce uncertainty of exposure.	Country section articles dominant with diminished frontpage coverage. International comparisons increase to diminish unique severity.
Risk positions and distribution of concerns	-Use of language (Herman & Chomsky, 1988, p. 43) - Direct/indirect attribution (Boykoff & Boykoff, 2007; Entman, 2007; Kristiansen, 2017).	No focus on distribution of goods such as improved access. Children identified in cholera related articles but limited.	Arsenic distribution portrayed as universal and not delineated spatially or socially while government policies specifically identify vulnerable groups.	Minimal media attention to achievement of development goals or findings of government arsenic data collection.
Filtering of Information and legitimization	-Legitimation and filtering information (Herman & Chomsky, 1988, p. 118 and 125) - Identifying authority and building trust; -Salience, biases, and citations of information sources (Boykoff & Boykoff, 2007; Entman, 2007)	Articles rely heavily on unattributed sources, followed by government experts to legitimate risk. Characteristics are easily imagined and tangible i.e. number of broken TW or mortality rates	Arsenic risk defined by scientific, often international experts; Reporting focuses on contamination of specific wells; increased citation of government sources, fewer unattributed.	Decrease in total number of citations. small increase in attributed citations to NGO officials and academic sources for arsenic stories.
Risk severity and priority	- Calculability vs uncertainty of risk - Relative severity and use of comparisons - Editorials and subjective tone	Titles specify topic through past events and situational identifiers including specific data. Limited interpretation or intensification. Mortality emphasized.	Titles shift towards indirect identifiers, fewer data points, and 'Crisis' terminology emphasized for arsenic. Emphasis shift to number of cases.	Increasing use of general or nonspecific language in titles regarding water quality such as "Water problem in urban area."
Maintaining control and extent of reflexivity	- Sustaining crises or reporting fatigue(Kristiansen, 2017) - Allocation of responsibility (Herman and Chomsky 1988, 43) -Staging and remedy (Entman, 1993)	Articles emphasized collective response and successes such as health services. Concept of 'diarrhea' less severe than cholera. Articles identify responsibility for public services to repair TWs.	Arsenic risk uncontrollable, loss of technocratic control until "nature" blamed. Uncertainty sustains dialogue.	Increased data available but not widely debated in articles, sustaining uncertainty while diverting coverage away from arsenic.

Media and discursive analysis framework

Building from critical discourse analysis approaches which provide tools to locate discourse within the broader socio-cultural context, this study narrows in on methods used by communication and media studies scholars to understand how various themes are located within multiple discourse fragments, ranging from formal government policies to techno-scientific papers to print news to audio-visual content to new online social media. These inventory and article coding tools enable comparative analysis of how the public agenda setting processes respond to or are shaped by institutional priorities (Entman, 1993; Painter, Kristiansen, & Schäfer, 2018). Media studies have focused on what Bakir (2010) described as four key approaches: events, framing, newsworthy, and biases. This article seeks to expand these content analysis methods into a systematic framework to delineate the context, formation, and contestation of the dominant narratives.

Herman and Chomsky (1988) used critical discourse analysis techniques in the 1980s to generate a critique of media performance. Building on Lippmann's (1922) influential observations that media discourse is used as a tool to manufacture various forms of social and public consent, Herman and Chomsky argue that the media serves a specific societal purpose of "inculcating and defending the economic, social and political agenda of privileged groups that dominate the domestic society and the state" (1988, p. 298). Their critique in the late 1980s, known as the "Propaganda Model", provided a sharp contrast to the prevailing American liberal-pluralists view of media as guardians of "public interests and watchdog on the exercise of power" (Mullen, 2010). This article acknowledges the relevance of this work for broader political critiques but

seeks a different application of their work, focused instead on how the structural elements are utilized to construct risk narratives in a very different institutional context of Bangladesh.

Herman and Chomsky based their work on the assumption that the mass media serves as a “system for communicating messages and symbols to the general populace...that inculcates individuals with values, beliefs and codes of behaviors that will integrate them into the institutional structures of the larger society”(1988, p. 1). To that end, their model proposes five main strategies and practices of the mass media: ownership structures, financial revenue sources, bias towards dominant sources of information, flak or negative push back, and use of fear as a control mechanism (Mullen, 2010).

This article builds from the range of structural and discursive tools used to analyze the media. They include the frequency and selection of topics; the length and detail provided to a story; the position and framing of articles within the overall presentation of news; the use of external citations to legitimate concerns; role of experts to filter information; the emphasis and tone to build trust or moderate interest in a topic; and the articles discursive allocation of responsibility and interpretation of action (Herman & Chomsky, 1988, p. 298). This further explores the alignment between components of risk theory and media analysis tools. The alignment of these approaches is summarized later in Table 8 and used to define the coding methods for the newspaper inventory.

Defining components of risk society

This article's analysis is situated within the process which Beck (1992) described as a dynamic competition of rationalities between the organs of public life. Beck, along with other scholars, has argued that public media discourse has historically been a dominant voice defining and propagating risks perceptions (Anderson, 2006; Beck, 2006a; Cottle, 1998; Dean, 1999a). Beck argued that the risk definition process has the power to influence the macro-evolution of modernization, as well as socio-economic and political development (Beck, 1992, p. 56). Beck further explains the rationality of the techno-scientific approach, which quantifies uncertainty using probabilistic estimates, as a form of future-making that results in controllable and distributable forms of risk imaginaries. Although quantified in language of probabilistic hazards, vulnerabilities and exposures, he argues that most risks remain invisible in the public consciousness until negotiated within a process of collective knowledge production and public legitimization (Beck, 1992, p. 71).

Beck's theories were criticized for not providing empirical or replicable methods explaining the risk formation process within public discourse (Cottle, 1998; Gabe Mythen, 2005). A series of recent articles have sought to address an element of this gap by merging media studies methods with multiple risk theories, although largely focusing on the thematic topic of global climate change and nuclear power (Adger, Benjaminsen, Brown, & Svarstad, 2001; Painter et al., 2018). Several papers, specifically Cottle(2014) and Anderson(2006) extend Beck's analytic framework to deconstruct the discursive process of risk production, while others like McEvoy and Wilders (2012) offer empirical studies. Although these papers offer important interpretive analysis, they have not generated replicable tools for longitudinal assessments.

Building from previous papers' application of Beck's risk features to the construction of public narratives, this article identifies the following core features from Beck's theories to be integrated into discourse analysis frameworks (Beck, 1992, 1995, 2006a, 2013) :

- the production and controllability of uncertainties;
- the winners and losers of which topics are identified and debated within risk narratives;
- the definition of safety thresholds and process to secure social acceptability;
- the technical representation and calculability of risks;
- the dependence on experts for legitimization;
- the distributions of "goods" and "bads";
- the allocation of blame and responsibility;
- the recognition or self-confrontation of unintended, or latent side-effects of technological and social innovations.

While this article uses Beck's original work as its foundational structure, there are several limitations, summarized by Mythen (2007, p. 799), to address. This article does not assume uniformity of risk experiences or behavioral responses when using the term *public*, and it does not seek to explain individual or collective actions. Instead, the article seeks to understand the strategies used by the media to select and organize the central ideas problematizing drinking water concerns (Dean, 1999a; Entman, 1993; Nisbet & Mooney, 2007). The second acknowledges the limitations of Beck's primary focus on the "icons of destruction," including nuclear war, climate change, genetic manipulation, and environmental ecosystem collapses. Following from Allan (1999), however, this article extends the application beyond Beck's originally defined catastrophic risks into the drinking water sector. By doing this, the article argues the growing utility of social theory for interpreting the politics mediating knowledge production and rendering awareness of "new risks" informed by science, negotiated culturally, and filtered through changing national and international political economies.

MEDIA INVENTORY

Media context in Bangladesh

Following independence from Pakistan in 1971, the media industry maintained an important role in national development and state legitimization (Mahmud, 2013; vom Busch & Carthew, 2008). For nearly twenty years after independence the media remained under direct, and indirect, forms of government control, which include censorship of content, monopoly over information, control of revenue, and restricting printing press supplies. By the early 1990s, a political consensus between major parties removed these direct controls to enable more freedoms of press and entry of new publishers and titles into the media market (Mahmud, 2013, p. 40). These changes reflect incentives of political parties to direct campaign messages and market opportunities to expand readership through the growing educated middle-class urban population.

The shifts in the political patronage and increased readership encouraged private investment in media sector. The printed newspaper industry grew from the four government-approved papers in the mid-1970s to over 300 daily newspapers in the late 1990s. By the mid-2000s there were over 1800 newspapers and periodicals published in the country, 90percent of which were also in Bengali (vom Busch & Carthew, 2008, p. 11). The daily print newspapers were competing with a rapidly growing media market of television, radio, and internet. Despite these changes, newspapers remain politically influential medium for public discourse, continuing to advance national debates and business priorities (Chowdhury, 2017).

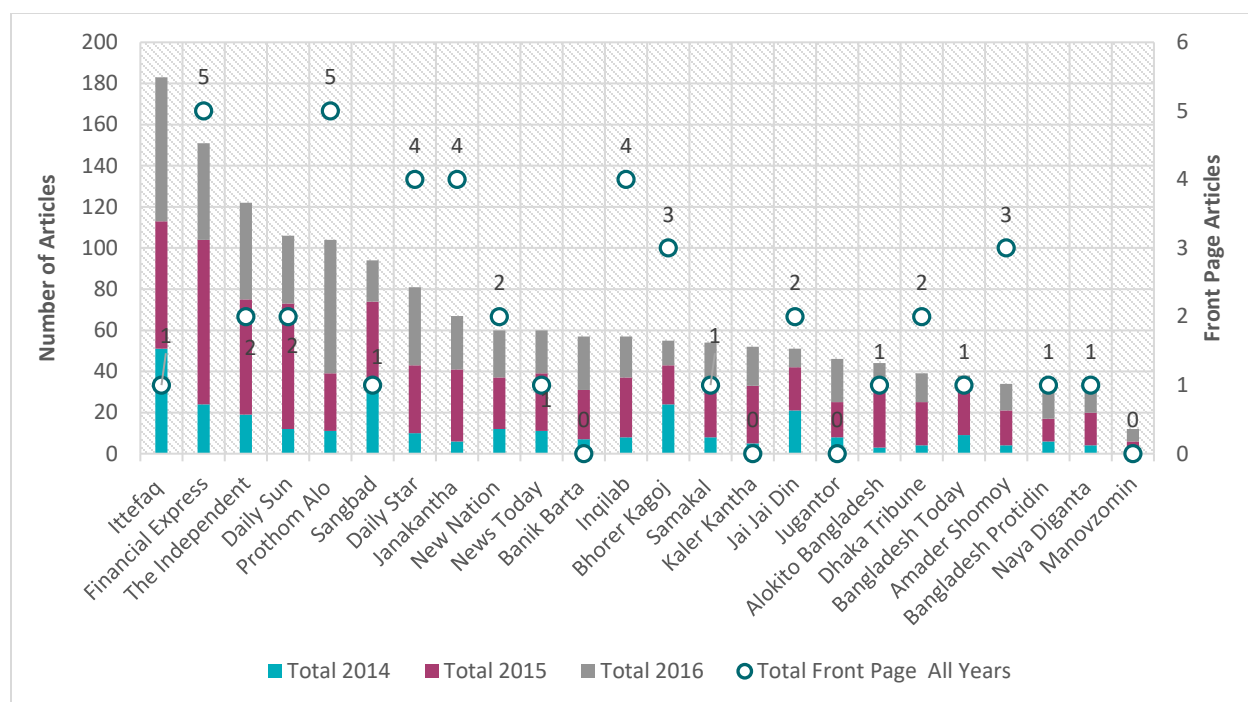


Figure 13: Summary of 29 national Bangladeshi newspapers WASH coverage from 2014-2016. Data provided by UNICEF-Bangladesh.

The heterogeneity of newspapers brought differences in coverage and thematic focus of reporting on drinking water themes. As seen in Figure 13, the United Nations Children’s Fund (UNICEF) provided their daily media inventory, which offered a pre-filtered inventory of twenty-nine newspapers reporting on water, sanitation and hygiene (WASH) between 2014 and 2016. This inventory was compiled by E-Media, a consulting firm in Dhaka, using a daily keyword search to identify all articles pertaining to domestic/drinking water, sanitation, and hygiene. As this was compiled by an outside firm without the researcher’s involvement, the results provide a snapshot of the trends and key issues in the daily news cycle but are not useful for detailed analysis. This UNICEF data guides the selection of which newspaper to inventory for this study.

The media clips show an uneven distribution of articles published by different newspapers, suggesting divergent interests and editorial priorities across the major Bangladeshi newspapers. In aggregate, the *Ittefaq*(total:183) published the largest number of WASH-related articles, followed by the Financial Express(total:151) and the Independent(total:122). Two of these papers are English-language publications, implying a specific target audience of business, international, and educated readers. In comparison, the Prothom Alo newspaper, identified as having the largest circulation as of 2011 (Mahmud, 2013, p. 45), reported 104 WASH-related articles. The UNICEF media inventory suggests that WASH topics are not covered equally across newspaper titles, neither in total number of articles published per year or amount of frontpage stories. The range of coverage contextualizes later analysis and acknowledges the limits of the *Ittefaq* as just one perspective within the broader social discourse.

Newspaper selection

The *Ittefaq* newspaper was selected for further analysis due to its prominent role as one of the oldest, continually published, and politically relevant Bangla-language news sources in Bangladesh (Chowdhury, 2017). The paper had a reported circulation of 135,350 daily readers in 2011 (Mahmud, 2013, p. 45). It remains a privately-owned newspaper, first published in 1952 by a prominent and founding member of the Awami League, one of the main Bangladeshi political parties. The paper served as a prominent voice in opposition to Pakistani rule, demanding regional autonomy which led to the 1971 attack by Pakistani military on the newspaper's headquarters in Dhaka. As a result, the newspaper became a symbol for the nationalist movement, a sentiment which remains a defining feature of the newspaper today (Chowdhury,

2017). As a daily newspaper it remains an influential source of news and editorials, partly aided by its historic symbolism and continued perception of political neutrality relative to other papers.

Inventory methods

The methods for this article seek to build a longitudinal inventory of newspaper articles to track the evolution of a specific discourse fragment using a content analysis framework described in the previous section and summarized in Table 8.

Every hard-copy edition published between 1980 and 2016 was reviewed to identify every article containing references to “drinking water” or water and specific health outcomes of water insecurity including “cholera,” “diarrhea,” and “arsenic” in the title, by-line or text. Bengali drinking water-related vocabulary inventory was provided by Hanchett et al (2014) and included, but was not limited to, the Bangla words: *khobar pani* or drinking water; *panir sorboraho* or water supply; *dushito pani* or polluted water; *pani bishuddho* or clear water; and *panir songkot* or water crisis.

The data entry was structured using pre-set choice and integer questions, and then administered in an electronic form using the mobile data entry platform ONA for uploading, editing, and viewing submitted forms. In addition to a literature review on coding design, the form was reviewed by Bangladeshi and international domain experts.

After identifying articles discussing drinking water in the daily newspapers, the coder entered key information including title, date published, position in the newspaper, specific geographic identifiers at divisional scale, and keywords. Each article was coded using a pre-defined list of

keywords, with a text options for any unusual or atypical “other” key words. The thematic keywords, 30 in total, which are fully listed in Table 9, were clustered in thematic categories: physical infrastructure, water quality, functionality and reliability, management and administration, environment and climate, and health outcomes. After reading the article and photographing the text, when permitted by the library, the first reviewer, a research assistant from University of Dhaka, selected all key words (AKW) referenced within the text. This was followed by the same reviewer selecting the main key word (MKW) based on their assessment of the primary subject of the total article text, across both the title and the story body. The English translations of the title were coded based on the primary subject of the title text (TKW) by a separate reviewer who was unfamiliar with the full text of the article.

A subset of the identified *Ittefaq* articles, 1,507 of 3,211 (46percent of the total), were randomly selected from a list of each month’s identified articles for further coding using discrete questions. The additional coding included the following categories: specific reference to vulnerable groups including women, children and the “poor”; citations to information and data; citations of expert opinion or knowledge; article text directly assigning responsibility to specific actors to address the problem; and text assigning or reporting actions taken in response to problem or topic.

The archival research was conducted between mid-January and October 2017 by a graduate student at the University of Dhaka who was trained on the coding methods. Archival work represented over 160 person-days in the public libraries, translation, and data cleaning. Intercoder reliability was tested after three weeks by a second trained native Bengali-speaking staff member, and a further random sample after three months. The intracoder reliability was tested at two points, after three weeks and a random sample at the end of the study, showing

84percent reliability of main key words. All title translations were checked by main researcher for English-language coherency.

Data limitations

The process of cataloging the *Ittefaq* articles presented several challenges, the costliest being the absence of digital archives and restrictions on the number hard-copy editions that could be accessed each week. Although originally intended to begin in 1971, the costs and time restricted the inventory to the years 1980-2016.

There are four other key limitations of this project. One, the restrictions placed by the libraries to photograph or return to articles inhibited further critical discourse analysis of visual symbolism and semantic structures in the full article text. Two, the scope of this initial project limited our ability to undertake comparative analysis with other thematic water topics such as agricultural and natural disasters, or with other modalities of the Bangladeshi media such as internet blogs, social media, television or radio. This limits our conclusions to printed media represented by the *Ittefaq*, one of the only continuous published text. Three, the research team did not have access to newspaper staff to explore their perspectives on editorial decisions and intentionality behind observed results. Finally, we acknowledge that this content analysis represents one newspaper's publishing decisions and should not be used to interpret readers internalization or behavioral responses to the represented risks. These limitations do not jeopardize the findings and scope of the analysis; instead they provide opportunities for future studies.

RESULTS

This following section discusses the empirical results of thirty-six years of the *Ittefaq* reporting, which identified 3,211 articles focused on drinking water-related topics. The temporal and content findings are summarized in previous Table 9.

Table 9: Summary of inventory findings by thematic cluster using main key word (MKW).

Drinking water discursive themes and keywords	Key findings	Content Trends in Three Temporal Clusters		
		1980 to 1992 Controlling concerns	1993 to 2005 Mitigating uncertainty	2006 to 2016 Interpreting complexity
Health: Cholera, Diarrhea, Legionnaires', Typhoid, Jaundice, arsenic poisoning	Diarrhea, not cholera, continuously reported main topic. Limited comparative coverage of arsenic poisoning.	Cholera dominant topic until 1987. Replaced by diarrhea stories. A spike in reporting in mid-1980s. Period with largest number of health stories Average: 40 MKW per year	Diarrhea decreased in 1990s. Overshadowed by arsenic poisoning from 1999 to 2001. Health decreases in proportion to other topics Average: 24 MKW per year	Arsenic poisoning decreases and diarrhea re-emerges as most frequent health topic. Change in seasonality of reported diarrhea. Average: 13 MKW per year
Water Quality: E-Coli, Arsenic, Salinity, Iron, Heavy Metals, Water Quality General	Arsenic dominant topic. Other parameters relatively low coverage. Post-2005 titles use general water quality descriptors	Limited number of articles reference WQ in main subject or title. Microbial not discussed in late 1980s and early 1990s after cholera/diarrhea outbreak. Average: 5MKW per year	Arsenic contamination first reported in 1993. Uncertainty drives reporting and is significantly larger than any other parameter. Average: 20MKW per year	Large number of non-specified or general titles. Increase in salinity articles. Limited reference to toxicity and other environmental pollution. Average: 14MKW per year
Infrastructure: Tubewells (Deep and Shallow), Piped, Pond, Surface, Rain Harvesting, Pond Sand Filters	Majority of article texts discuss infrastructure but rarely as main subject. Tubewell dominant until 2008 when pipes overtake.	Tubewell most frequent key word. Surface water surpasses piped water discussions until 1999, except after cholera outbreak in 1987-1990. Average: 2.4MKW per year	Spike in tubewell and piped water systems focus in 2000 respond to arsenic. Alternative rainwater harvesting, and pond sand filters first appear. Average: 2.7MKW per year	Piped systems briefly surpass tubewells in frequency from 2008-2012. Increase in surface water and rain topics after 2013. Average: 1.7MKW per year
Access: Access to Improved Infrastructure, Affordability	Half articles located in letter section requesting service connections.	Spike in late 1980s after cholera and diarrhea outbreak. Many specific requests for constructing new tubewells. Average: 8 MKW per year	Spike in 1994 and again in 1998-2000. Frequently included in requests for arsenic free shallow and deep tubewells. Average: 9 MKW per year	Focus on gaps in coverage and safe water systems more generally. Less direct links to infrastructure types. Average: 6 MKW per year
Functionality: Infrastructure Functionality, Supply Reliability, Efficiency	Most frequent and consistent topic but declining after 1991; mostly reported in country section	Most frequent topic in 1980 to 1984. Focus on government role to repair malfunctioning tubewells. Average: 28 MKW per year	Decline in coverage after government transition. Average: 23 MKW per year	Focus shifts from functionality to reliability of supply. Average: 13MKW per year.
Administration/Management: Politics, Budget, Public Communication	Steady but small increase articles across years with max of 16 articles per year. Large gaps in years covered.	Intermittent coverage. Centralized distribution of services with articles focusing on corruption referenced, but not mismanagement. Budget discussed until 1989. Average: 4 MKW per year	Limited coverage until arsenic crisis. Directed comments towards WASA management after 1999. Highest during arsenic crisis. Average: 6 MKW per year	Increased in coverage and consistency of articles after 2008. Political parties and disputes increasingly covered. Average: 6 MKW per year
Environment: Flood, Drought, Climate Change	Least frequent topic and limited connection to impacts	Flooding damage driving projects to provide new infrastructure. Average: 6 MKW per year	Drought articles more closely linked with uncertainty of water supply. Average: 8 MKW per year	Increased number of articles on drought outside of dry season. Average: 5 MKW per year

Production of concerns and declining coverage

The temporal distribution of the annual and thematic content, shown in Figure 14, provides a multi-year perspective around the construction of drinking water concerns in the *Ittefaq*. The annual number of articles shows that drinking water topics have been continually reported as newsworthy in Bangladesh, meaning a long-term problematization within the public agenda. Within the year-to-year reporting two spikes of increased coverage occurred during the 1985 to 1988 cholera outbreak and the height of the arsenic crisis in 2000 to 2004. Although a limited portion of the total news cycle, drinking water topics have been sustained for decades within the public discourse, contrasting other studies which identify risk-reporting as contingent upon specific events, such as nuclear accidents or natural disasters (Anderson, 2006; Kristiansen, 2017).

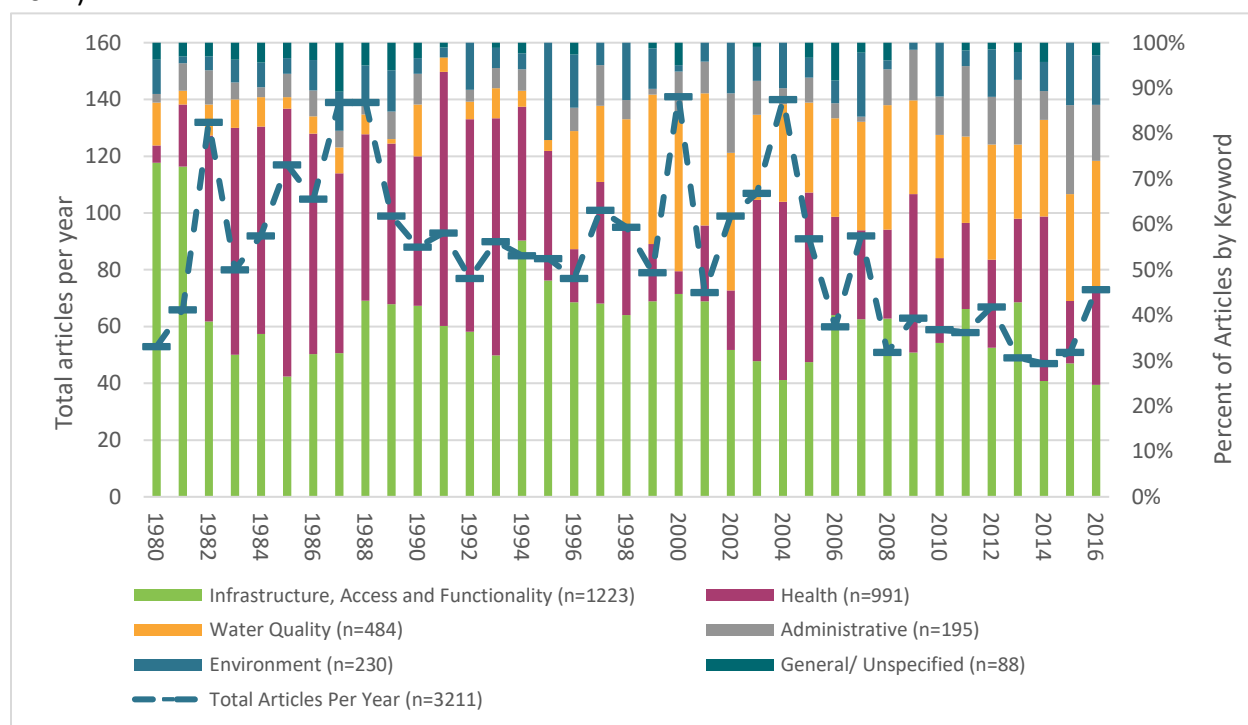


Figure 14: Summary of the annual variation of the total number of articles and proportion by thematic coverage in the *Ittefaq*, 1980 to 2016.

The inventory also reveals that the annual average number of articles declined after a decade of the arsenic discussion. The average number decreased from ninety-seven articles per year between 1980 and 2005 to sixty-three per year from 2006 to 2016, a nearly 40 percent drop. This decline could be explained through a lens of competing risk narratives, including the late 2000s food crisis. However, the timing suggests reporting fatigue, occurring immediately after a period of extensive policy, research and public debate around arsenic. This proportional decline contrasts the increased policy prominence given to drinking water goals in the same period including release of multiple government policies after 2005 and the global attention by reporting achievement of the Millennium Development Goal (MDG) target on access to improved drinking water sources.

Constraining concerns around infrastructure and cholera

Beyond annual trends, the discourse analysis filters assess how topics are problematized through selection, frequency and prominence across article titles, subject and text. The *Ittefaq* inventory revealed an identifiable pattern of inclusion and exclusion of specific themes, summarized in Table 9. The most frequent main subjects over the thirty-six years, appearing in 52percent of the articles, emphasized diarrhea-related concerns (cholera and diarrhea) and infrastructure sustainability (functionality and reliability). These two topics specifically dominated reporting on drinking water topics between 1980 and 1993, appearing as the main subject in over 70percent of the articles, and 40percent of articles 1993-2016. These two topics reflect what scholars identify as the government's dual priorities: 1) maintaining state legitimacy by providing reliable drinking water infrastructure and 2) gaining international recognition through health system

achievements, reducing mortality rates by controlling diarrheal diseases (Hassan, 2013; N. Hossain, 2017).

Drinking water infrastructure gained significance during the independence movement when the newly formed government committed to ensure the functionality of handpumps, a political bargain to increase legitimacy with rural populations (N. Hossain, 2018b). The Department of Public Health and Engineering (DPHE), supported by international agencies, implemented the programs to increase the ratio of tubewells from 400 people per handpump in 1972 to a target of 135 in 1990 (Black, 1990, p. 19). The Bangladeshi government pursued this state-driven water service provision model for nearly two decades after independence (Black, 1990), controlling the production and distribution channels for handpump hardware and providing maintenance services for all public water points through the 1980s. This established a further political interest around provision of rural water services. Despite the increasingly prominence in national policy, tubewells appeared as the main subject in 1.3percent of the articles but were referenced in over 45percent of the article texts. A quarter of the articles in the 1980s focused on place-specific concerns of tubewell functionality, frequently using the same structure in the title: “X number of tubewells are dysfunctional in Y location: scarcity of drinking water.” This presented a controllable concern where the government could respond to specific geographies.

After two decades of tubewell investment programs, the number of functionality articles declined from an average of 21percent of total articles per year from 1980-1992 to 14 percent between 1993-2005. The largest drop occurred in the years surrounding the political transition from the Ershad government into competitive party politics in 1991, arguably reflecting end of the post-independence state commitments ensuring tubewell functionality and shift in

institutional structure (GoB, 1998b). Leading into this shift, the international development agencies increasingly placed pressure on the government to demonstrate aid effectiveness (Rizvi, 1991). The frequency of stories on dysfunctional handpumps contradicted technical national tubewell surveys which reported over 90percent of public tubewells operational (UNICEF, 1993). The declined media reporting on functionality and shift to supply reliability reflects a reallocation of concern to nature. This change in blame occurred in the context of reallocations of responsibility away from the central government for service provision for tubewells and into one around multi-user piped systems.

The media coverage in the late 1980s also began excluding explicit references to cholera and replacing them with diarrhea terminology. Cholera was reported on extensively in the early and mid-1980s, reflecting the ongoing policy and scientific attention from previous decades. However, explicit references to cholera sharply declined after 1984, becoming entirely absent by 1990 with only a few exceptions in the 2000s. By 1989, the *Ittefaq* editorial page explained the shift in vernacular by attributing it to the government: “The same old topic of diarrhea and cholera needs to be discussed here again because the authorities are not willing to accept that these deaths are caused by cholera. They use the term diarrhea. But whatever the name of the disease, a death is a death whether it is caused by diarrhea or cholera” (“Diarrhea and cholera,” 1989). This editorial comment implies intentional government intervention over terminology influencing the way reporting frames concerns for ongoing outbreaks, partially controlled in national epidemiological surveillance systems which did not differentiate the causes (Siddique et al., 1992).

The change in terminology reflects a change in the concern around allocation of blame and framing severity. Article titles discussing cholera often explicitly referenced the number of reported deaths compared to diarrhea reporting after 1989 which largely focused attention on the number of reported cases and spatial extent of the outbreak, not mortalities. For both tubewells and waterborne diseases, the *Ittefaq* reporting reduced the salience for target audiences (Entman, 2007). The timing of exclusions aligns with changes in national and international political agendas, reinforcing Herman and Chomsky's argument that media places politically-motivated discursive constraints on the problematization and representation of concerns.

Positioning arsenic uncertainty and mitigation

Within these macroscale thematic trends, the distribution of where articles are placed within the newspaper sections further constrains the prominence, priority, and emphasis on severity of specific content. Building on what Lippman (1922) identifies as the editorial decisions of selecting which stories are most newsworthy, Herman and Chomsky (1988) use the positionality of articles to explore the constructed importance of specific topics. As seen in Figure 15, the frontpage articles, representing 14percent of the total inventoried articles, were highest in the 1980s, a period when the state had direct and indirect controls over the media industry and the government-led solutions to cholera remained central to national development agendas. However, the number of frontpage articles began to decline after the political transition in 1992.

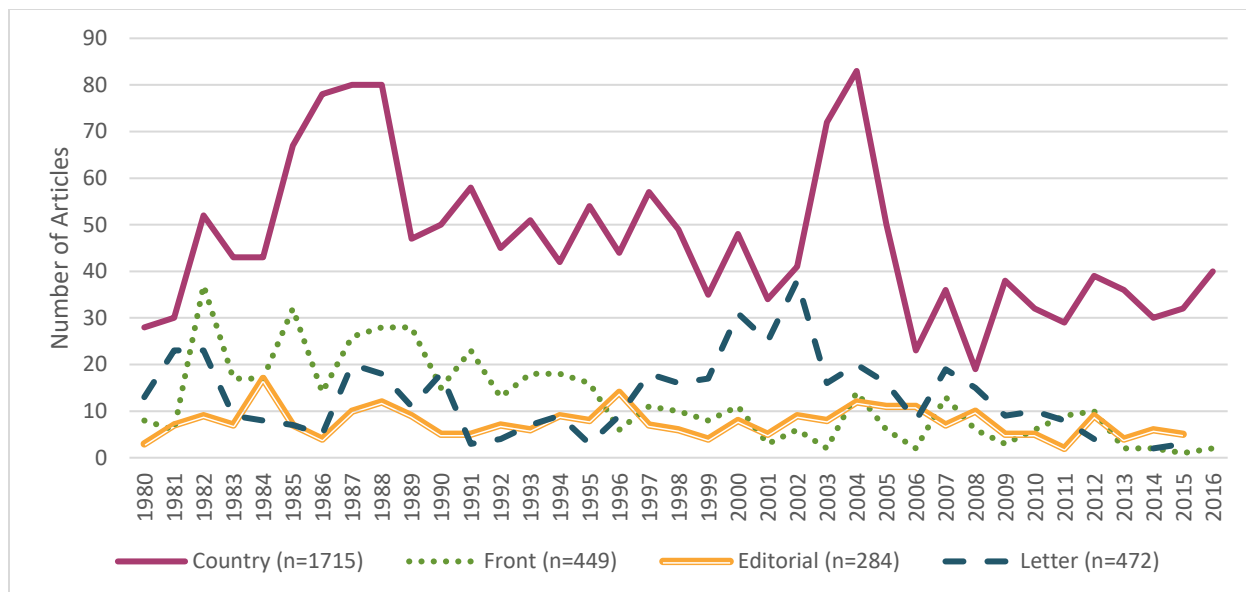


Figure 15 Annual variation in the positionality of articles across four main sections of the *Ittefaq*, 1980 to 2016.

This declining front-page prominence contradicts the technocratic portrayals of the severity of the arsenic contamination. The first public recognition of arsenic in aquifers appeared in the *Ittefaq* article in 1993, a decade after concerns were initially identified in public health circles in West Bengal (“Risk of arsenic pollution in tube well water of 13 boundary side areas,” 1993; Smith et al., 2000). The coverage of arsenic stories occurred after 1995 in the “country” or national news section, not on the front pages. Although articles described arsenic as a “national panic” (“Arsenic panic in whole country,” 1996) and coverage represented an increasingly significant percentage of articles between 1996 and 2006, only a relatively limited number were frontpage articles (20MKW, or 7 percent of total arsenic articles). During the 1980s and 1990s, frontpage coverage of diarrhea and cholera (185MKW, or 21percent of total cholera/diarrhea articles) and functionality and reliability (79MKW, or 10percent of total stories) was much higher as a portion of drinking water related articles and in number of stories. This suggests a specific discursive approach avoiding emphasis on arsenic, a problem with initially uncertain

causes, poorly measured, chronic largely unseen impacts, and no immediate actionable responses.

Multiple scholars have argued arsenic threatened the narrative of development successes of previous tubewell access narratives (Caldwell et al., 2003; Sultana, 2012). It was not until after the national arsenic testing campaigns in 1999 and 2002-2005 that the techno-political development community aligned around specific mitigation approaches, codified in the 2004 Arsenic Mitigation Plan (GoB, 2004b). However, instead of increasing to interpret and interrogate these findings and national awareness campaigns (Pfaff, Schoenfeld Walker, Ahmed, & van Geen, 2017), the media coverage declined. Media discussion of infrastructure alternatives, such as deep tubewells and piped water, increased slightly after 2005, but not at the rate reflecting the urgency advocated by technical evaluations.

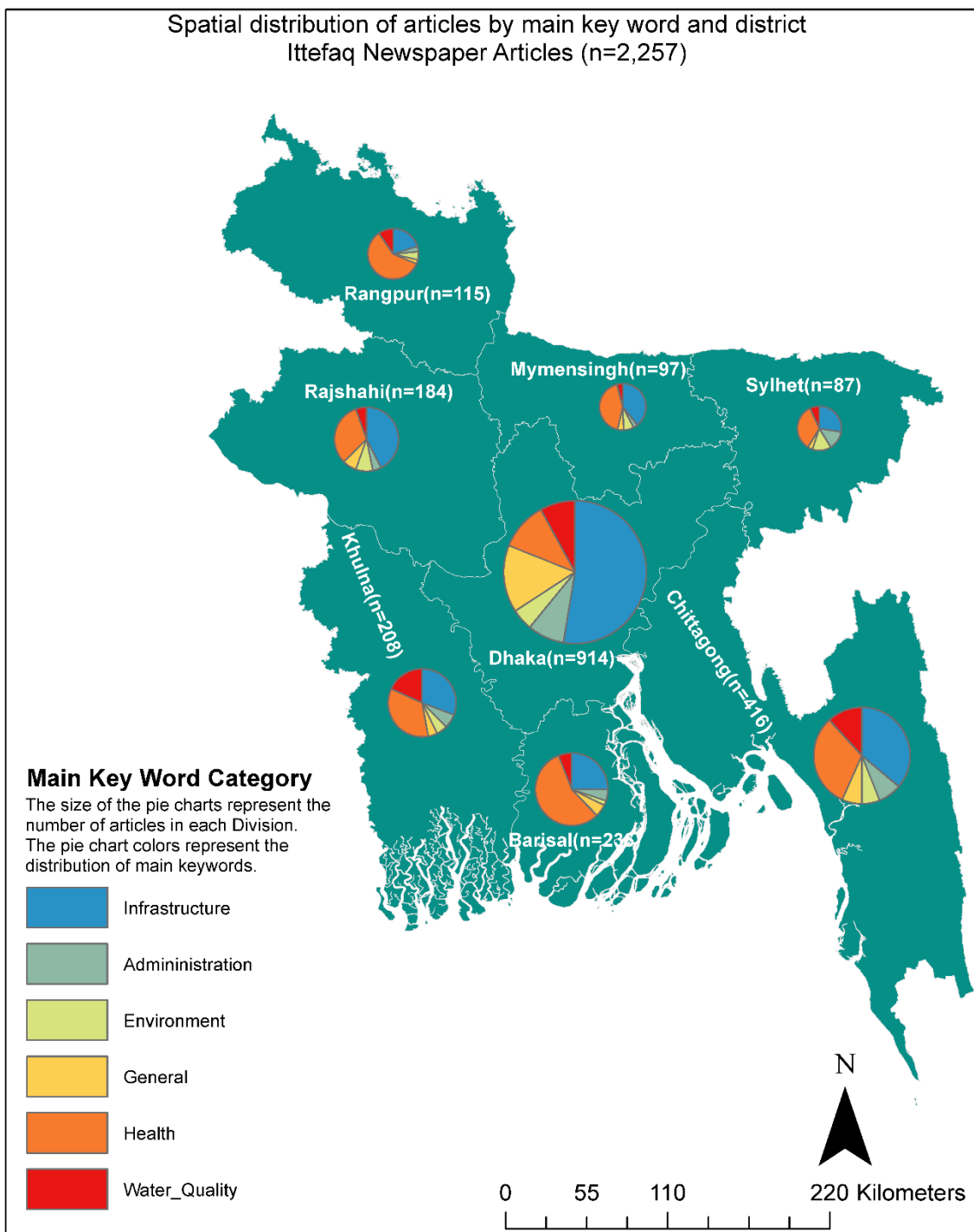
The absence on the front pages of the *Ittefaq* were replaced by articles in the letters section. Starting in 1996 when arsenic articles began being reported more frequently, the number of letters per year surpassed that of the other sections, except “country,” as seen in Figure 15. Qualitative analysis of these articles suggest that they provide a vehicle for citizens to direct concerns to the government entities that manage water services. A quarter of letters explicitly directed requests to the Government’s Water Supply and Sewage Authority (WASA) (106 articles). The main subject of over half the letters addressed issues of infrastructure, including requests for access, repairs, and supply reliability. In contrast to the frontpage and country sections, diarrhea and cholera represented the main subject of 2percent while arsenic appeared in 8percent and unspecified water quality concerns in 12percent. This shifted the direction of

discourse expanded the previous linear flows of the media being a risk definer to enable risk consumers to influence the construction and focus of concerns.

Distribution of social and spatial risk positions

One of Beck's central arguments is that catastrophic hazards have transformed society into an egalitarian distribution of risk, beyond previous models of hierarchical class-based distribution of goods (Beck, 2013). Several scholars challenge this view, including Curran (2013), who argues that wealth differentials related to class continue to shape risk distribution and life-chances. The *Ittefaq* article inventory largely reinforced Beck's view of undifferentiated social risk, rarely allocating concerns to specific vulnerable populations or reports unequal impacts.

This reporting pattern diverges from the dominant agendas of global development goals. Government policy documents and international agencies explicitly prioritize vulnerable subgroups, defined as the "ultra-poor," women, and children (GoB, 2015a; Sultana, 2012). Within the *Ittefaq* articles, "poor" communities were explicitly identified in 3.5percent of the 1,506 coded articles, of which more than half discussed tubewell functionality and reliability before 2005. Specific references to gender appeared in 2 percent of the 1,506 articles, with over three-quarters of those articles discussing diarrhea and related health treatments. References to children were found in 7.5percent of the 1,506 articles, with nearly a third published between 1985 and 1988 related to the diarrhea and cholera outbreak. The disconnect between policy emphasis in government publications not reflected in media articles suggests the politics of risk allocation at national levels, not that of exposure or international agendas.



Map 5 Number of drinking water articles explicitly referencing specific districts and the thematic distribution in the Ittefaq, 1980 to 2016. Size of pie chart represents number of articles.

In contrast to social categorization, the spatial distribution of stories, seen in Map 5, reveals more articles were discursively located within urban Dhaka than other region. Among the articles which specifically identified an administrative division (n=2,257), Dhaka appears in 40 percent while the divisions of Sylhet and Mymensingh appear in fewer than 5 percent. This geographic focus suggests that events were selected through the lens of what is newsworthy to the readership, primarily urban circulation (Mahmud, 2013), despite over 65 percent of the population classified as rural in 2016. This spatial pattern is further explained by information biases resulting from more consistent measurement of urban piped water schemes and significant gaps in rural monitoring. The place-specific media coverage was often maligned with technical assessments of exposure, such as low number of articles covering high arsenic risk areas in the Sylhet division or arsenicosis cases disproportionately represented in Dhaka compared to contamination (WHO/UNICEF, 2017, p. 42). The spatial distribution of risk positions appears to be based on media reporting biases, not techno-scientific quantifications of concerns.

Legitimizing the narrative

Beck (2006b) argued that national risk imaginaries require the sensory organs of science to render their existence visible and reduce the boundaries of uncertainty. Media studies offer approaches to critically evaluate how the press engage expertise to define, legitimize, or cast doubt on specific concerns (Nisbet & Mooney, 2007). The *Ittefaq* articles reinforce Beck's view of a contingent relationship, with nearly two thirds of articles (n=934 out of 1,506) explicitly citing data, statistics, study results, or experts within the story text. Almost half (49 percent) of those

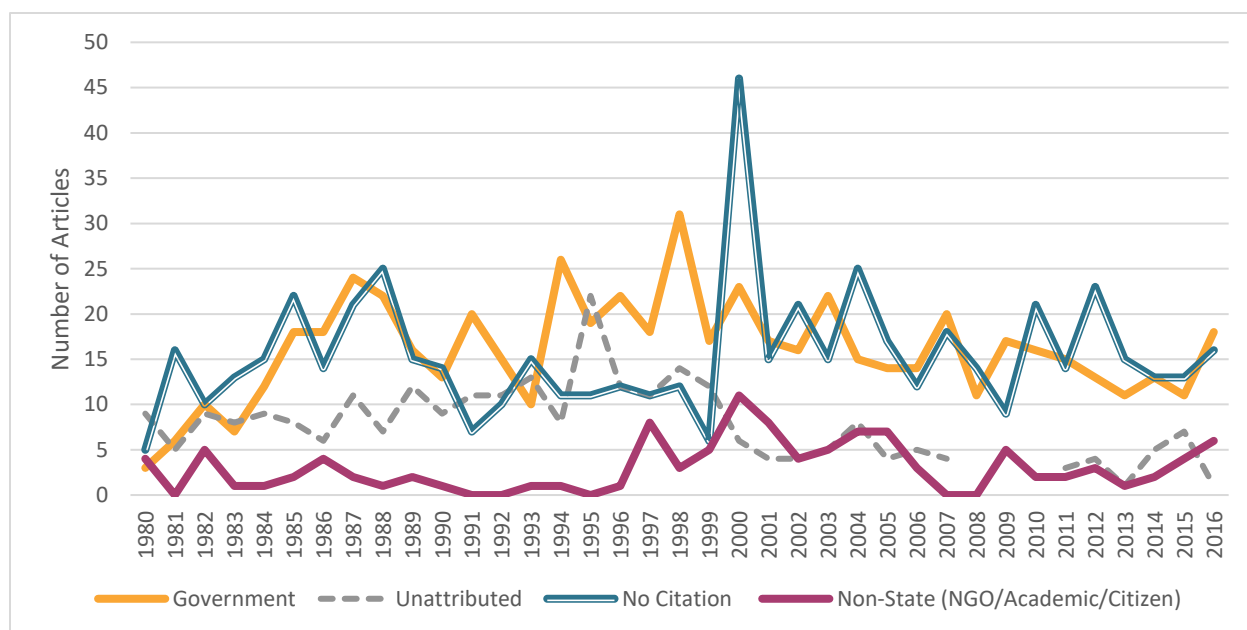


Figure 16 Comparison of the source of information cited within articles in the Ittefaq, 1980 to 2016.

main keywords focused on infrastructure access, functionality or reliability, two thirds of which appeared before 1997, prior to the arsenic crisis.

Reliance on external information for validation varied between topics: arsenic articles were heavily dependent, with 90 percent including citations; climate, flood and drought articles had 63 percent with citations. These topics contrasted with a lower proportion of cholera and diarrhea articles, 18 percent, having citations. While the initial coding method for this article was not nuanced enough to differentiate tone or context of these citations, the results suggest that specific topics were more reliant on expertise to interpret the uncertainty.

The power to define problems is further reflected by who the article cites to legitimize a concern. As seen in Figure 16, over 60 percent of the article citations identify the source as Government sources, suggesting the state controlled the flow of information. A further 28 percent of article citations were unattributed, such as “a source” or “an expert,” although declining sharply in the mid-1990s after the opening of press freedoms and replaced by unattributed article. The

remaining citations (12 percent) were attributed directly to NGO and academic sources. Although articles provided limited direct connection to NGOs, the large percentage of unattributed citations reflects a possible approach to maintain national ownership of the narrative and authority with the government. Initial qualitative evidence suggests that many studies and data are produced with the involvement of international agencies but published and accredited to Government agencies, thereby reinforcing authority of the government and concealing the influence of non-state actors in the media. Further study is required but these findings suggest that the media reinforces the dominant power structures by filtering of sources of information.

Allocating of blame and responsibility: water quality versus health within an agenda-setting discourse

Controlling the risk narratives becomes increasingly political as the causation, or blame for, the concerns shifted from nature to society. Beck (1992) describes this transition as the reflexive consequences of human decisions and technology. The *Ittefaq* inventory suggests this self-confrontation did not occur: articles discussing water quality safety were reported on less than half as frequently as health-related stories, as seen in Figure 17. Despite the extensive coverage of diarrhea and cholera, issues of microbial contamination, including sewage contamination and bacteria such as E-coli and *Vibrio cholerae*, appeared in significantly fewer articles: 5percent of the articles referenced microbial topics in the body of the story text; fewer than 1percent of the articles focused on microbial concerns as the story's main subject. Further, ambiguous or multi-parameter water quality articles were more frequent than microbiological stories, specifically increasing after 2005. While this is likely a result of measurement bias with health outcomes

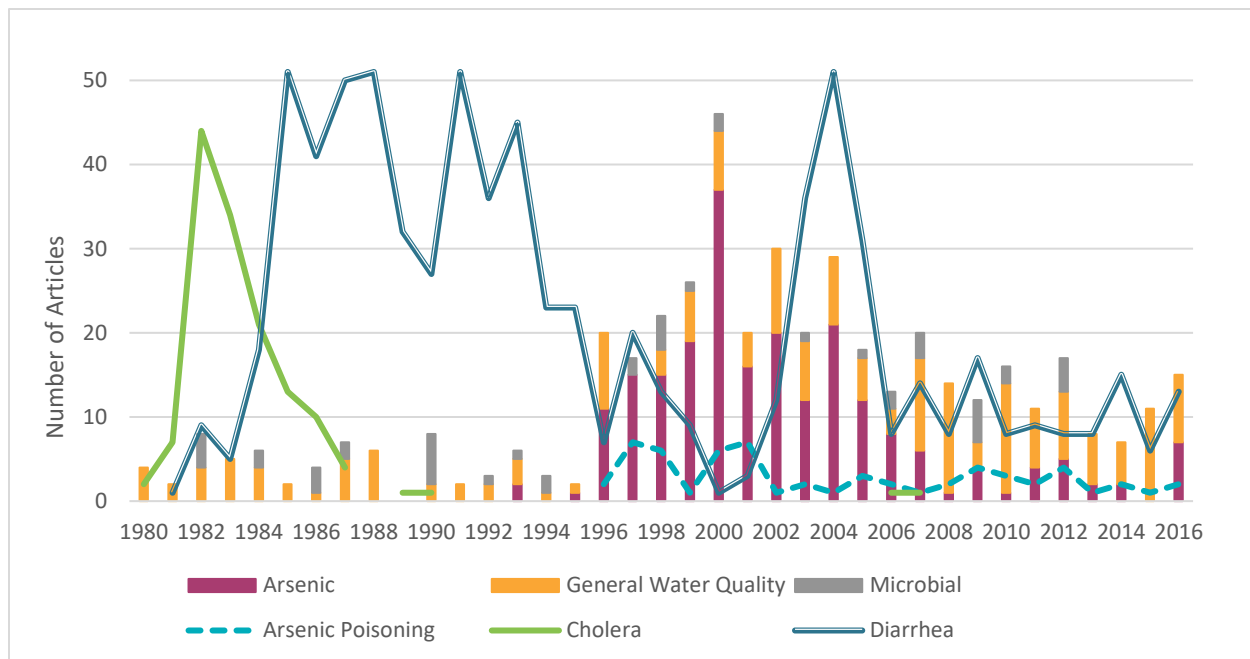


Figure 17 Comparison of the annual variation of coverage of water quality and health specific articles by main key word in the Ittefaq, 1980 to 2016

more regularly tracked than water quality data, the titles of the water quality articles are structured around ongoing problem identification with blame and responsibility attributed, often explicitly, at public agencies: “Unhygienic WASA water: conflicts between authorities for water” (“Unhygienic WASA water: Conflicts between authorities,” 1984). This information structure contrasts the reporting approaches on diarrhea and cholera which focus on past events, discussed above. The difference appears to be largely in the temporality and allocation of responsibility, with water quality reporting, not including arsenic, directly implicating the need for collective or public action.

This imbalance of reporting on water quality was reversed by the discovery of arsenic contamination, deconstructing the previous risk narratives focused on the ability to manage and control the problem. The uncertainty of source and spatial distribution were reported twice as frequently as articles discussing the health outcomes of arsenicosis: the inverse pattern of

diarrhea/cholera to microbial contaminants. This suggests different politics of blame and attention, with titles not directly allocating responsibility. Cholera and diarrhea are reported around the acute symptoms, high certainty of cause and immediate tangibility of danger with clear infrastructure and health treatments options. Arsenic in contrast was debated in a process of reconciling the uncertainty of cause of contamination, and impact of chronic exposure with often invisible symptoms and limited treatment options. One was represented in reporting as past risks which are controllable while the other focused on unknowns in the future. The varying coverage of water quality factors in newspaper articles constructs different narratives around the causality and controllability of risks, and thus responsibility to act: one perpetuating the previous development narrative of ability to manage human-caused risks while the other shifted blame to nature while solutions were not immediately actionable.

DISCUSSION

This section interprets the multi-decadal media content analysis in relation to the politics of the national development agendas. As summarized in Table 8 and Table 9, the empirical results reveal three broad temporal clusters of drinking water narratives identified through risk-discourse filters and content patterns.

Constructing risk narratives: 1971-1992

The first period of drinking water narratives in Bangladesh extends from post-independence in 1971 until the public identification of arsenic in 1993, however the *Ittefaq* inventory starts in 1980 due to archival limitations. This period is characterized by several interlinked concerns

underpinning the elite consensus on national development strategies: reducing infant and maternal mortality rates, preventing cholera outbreaks, and increasing tubewell infrastructure access (Hassan, 2013). The *Ittefaq* reporting constructed a narrative around these topics by problematizing cholera and diarrhea cases and public service delivery of infrastructure functionality. These concerns reflect international development targets which structured development aid based on national measurement of indicators which were publicly monitored. The construction of these risk narratives by the media, predominantly citing government authorities as sources of information, reinforced the central state's legitimacy and aligned to the agreed responsibility structures by framing the issues as controllable problems.

The political and institutional reforms of the late 1980s are reflected in the specific content and discourse shifts of the *Ittefaq*. While macro indicators, such as infant and maternal mortality, continued to improve, major cholera outbreaks and non-functioning tubewell infrastructure undermined the narrative of cost-effective development interventions. Simultaneously, pressure was mounting on the Ershad government from international agencies to demonstrate program effectiveness and justify continued flows of foreign aid, funding critical to the state authority through a patronage system (Rizvi, 1991). The national press, remaining under the government's direct and indirect controls during this period, reinforced the state's interests by shifting content production, specifically explicitly identifying cholera in articles and gradually shifting from functionality of tubewells to supply reliability problems. This represents a change in salience of waterborne concerns by replacing reporting on the number of cholera-related deaths with stories describing diarrhea as number of cases being treated.

The media behavior in this period suggests that while risk priorities reflected broader international targets of improved access and reduced mortality, the narrative was constructed to advance national state interests. The control over information distribution and definitions of what is measured further limited public contestation of risk severity. These risk-discourse filters reveal the constrained ability and interest of the media to extend the problematization, counter state priorities, or interpret techno-scientific assessments.

Deconstructing the narrative: 1993-2005

The second period is characterized by the disruption of a controllable narrative by the public acknowledgement of arsenic in 1993. The announcement aligns with the introduction of competitive party politics, national elections, decentralization of service responsibility, and increasing press freedoms reliant on new non-state revenue sources. The period is defined by the socio-technical negotiation to deconstruct previous narratives of tubewell infrastructure and groundwater safety, interpret the uncertainty of spatial risk distributions, and render arsenic into a manageable concern. These uncertainties challenged previous political arrangements and corresponding narratives focused on distribution of infrastructure and health services.

Whereas global drinking water goals increasingly emphasized on-premise infrastructure systems, decades of tubewell growth created a paradox for media and policymakers as the scope and scale of arsenic increased concerns of potential exposure. This threatened previous development agendas, including attainment of the Millennium Development Goal target based on definitions of improved infrastructure access. The discourse filters reflected this tension: the media rarely emphasized arsenic concerns on the front page despite many articles in the national news

section, diminishing the salience and contrasting previous cholera reporting. This resulted with a contrasting construction of arsenic severity: a crisis in description but not in priority allocated through discourse filters.

Further, reporters continued to predominantly cite government sources despite major international aid agencies and academic investments trying to grapple with the cause, uncertainty of spatial distribution, and mitigation options to the arsenic contamination. The discourse filters suggest that in the early 2000s more articles had no information or experts cited than articles with government officials, suggesting a temporary aversion to allocate responsibility in the face of uncertainty. Without an immediate solution and high uncertainty, this suggests a discursive approach to interpret the new risk without undermining the national ownership of previous development successes.

Reconstructing a controllable narrative: 2006-2016

The most recent period from 2006-2016 is characterized by the divergence of media and policy emphasis on drinking water and re-alignment of content problematization around new multidimensional development targets. With greater freedoms of press and new advertising incentives, the direct link of media and state interests eroded from previous decades. This period shows a sharp decline in total number of drinking water related articles. While decline might reflect these shifting media incentives or other priority concerns however it clearly contrasts the public sector attention allocated to drinking water in a range of new policies and renewed international commitments. This could also suggest a widening gap between national politics and

international development narratives with *Ittefaq* focused on domestic audiences. If true, this implies drinking water remained on both agendas but was diminished in domestic agendas.

Despite the decline in media attention, both bodies of text problematized a more heterogeneous set of concerns, particularly water safety and quality, supply system reliability, and sustainable management of multiple infrastructure types. This content shift mirrors the evolution of Sustainable Development Goals definitions of drinking water security entering national narratives. The decline of arsenic coverage after 2005 contrasted academic and civil society concerns of increasing exposure suggests limited media interpretation of risk severity. This period suggests the narrative was reconstructed to interpret complexity of water safety reinforcing a model where blame is allocated to nature when outside of immediately controllable problem-solution paradigms.

Implications of risk discourse filters and a constrained national narrative

There is a large body of academic literature on arsenic and cholera research spanning decades in Bangladesh quantifying exposure, vulnerability, and responses; however, there is limited inquiry around how the media's discursive filters interpret and position these concerns. The empirical results suggest that key concerns are represented differently between the *Ittefaq* and technical literature, a known occurrence in climate-related discourse analysis but one which has not been interpreted in the context of drinking water security (Boykoff & Boykoff, 2007). The contrast is most evident in the problematization of cholera and arsenic: despite ongoing identification of exposure by technocratic studies the media, under government influence, excluded cholera from public discourse and delayed public recognition of arsenic for a decade after initial discovery. This

avoided directly challenging the development narratives of achieving near universal access to improved drinking water infrastructure. This further implies that the *Ittefaq* did not perform the function of a conduit of development communication aimed at behavior change such as well-switching promoted by NGOs. The result limited public self-confrontation around the side-effects of infrastructure decisions and provision-based models.

The findings advance what Bakir (2010, p. 13) identified as gaps in longitudinal, historical, contextual and interpretive methodologies to trace risk narratives at macrolevels. The analysis of *Ittefaq* newspaper uncovers how various levels of the development institutions and governance transitions exert direct and indirect influences over the construction of drinking water security narratives to shape the political meanings. These findings reinforce Herman and Chomsky's (1988) view that media is influenced by dominant interests, which in this context is the dual pressures of national and international development agendas. Although the state's role appears to be dominant in shaping the media's narrative, the indirect influence of NGOs and international organizations requires further consideration in future work and coding. The significant number of unattributed expert quotes suggests discursive positioning of other actors disguising their role and influence, instead reinforcing the Government's authority and responsibility.

The results further identify the importance of discursive allocation of blame and risk responsibility in shaping the political interests to control the overall narrative. Future work has been identified to expand the theoretical and pragmatic implications for risk-response dynamics across multiple texts, and the political meanings for state authority and management instruments. The initial assessment suggests a limited political willingness for what Beck (2006b) describes as reflexive governance, or the avoidance to prioritize and reframe concerns if they

implicate failures or unintended consequences of previous policy decisions. In the case of Bangladesh, this questions the successful government tubewell campaigns and recent growth private markets. This reinforces Beck's view of the contingent relationship between risk representations and politics of national identities: reflexive risk threatens narratives of state control over development power relations. The identified risk-discourse filters contextualize why certain risks are problematized while others are reframed or prioritized differently, including the reframing of previous concerns into opportunities. These findings reinforce the notion that risks narratives are political in construction and meaning.

CONCLUSION

The previous institutional approaches to managing drinking water security in Bangladesh were challenged by the uncertainty of arsenic distributions and redefinition of cause-effect relationships between nature and society. An empirical and longitudinal analysis of one of the oldest continually published newspapers in Bangladesh provides unique insights into the declining frequency and prominence of attention placed on drinking water security. The results show some unexpected divergences between technical, political, and media narratives. First, newspaper coverage of drinking water declined at the same time as completion of national programs for arsenic mitigation and the recognition of the country's early achievement of MDG drinking water targets; second, the media explicitly excluded "cholera" in article texts to shift salience of the concern from mortality to treatability; third, the articles used risk reporting to reinforce state legitimacy by citing government sources and information, diminishing the prominence and role of NGO and civil society voices; and finally, the descriptive depiction of

arsenic as a crisis was not reflected on the newspaper's front pages, constraining the portrayal of severity and exposure. These discursive behaviors reflect the dominant construction of problems as controllable through technical and health solutions. Beck's theories help explain why arsenic challenged this previous narrative through the high uncertainty of distribution, contested allocation of blame, and lack of immediate mitigation options which wouldn't undermine previous achievements of tube well infrastructure provision.

This analysis provides further insights into the institutional transitions across the three identified temporal periods in Bangladesh, revealing a contested narrative between technocratic estimates of exposure and the socio-political discursive process to render risks visible. The application of risk-discourse filters advances several broader findings: the production and framing of drinking water security is linked to political and economic development agendas; the discursive practices used by the media reinforce the state's authority and control over the definition process; and the media's distribution of social and spatial concerns diverges from technical estimates of exposure and stated public policy priorities. These specific media approaches are significant for how blame and responsibility are allocated within wider governance transitions. The results extend Beck's framing of risk politics by identifying the limitations of the current institutional designs to engage in the discursive process of self-confrontation around reflexive risks, a perspective increasingly important for achieving drinking water security.

5 RISKY RESPONSIBILITIES FOR RURAL DRINKING WATER INSTITUTIONS: THE CASE FOR REGULATING SELF-SUPPLY IN BANGLADESH



Global Environmental Change

Title: Risky responsibilities for rural drinking water institutions: the case for regulating self-supply in Bangladesh

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Key Words: Bangladesh, water security, risk, institutions, infrastructure, sustainable development

Note:

This chapter is presented as submitted for review.

ABSTRACT

The drinking water sector is underperforming according to the 2017 Sustainable Development Goal indicators which estimate over a quarter of the world's population lacking safe and reliable services. The previous national policy narratives focused on provision of improved infrastructure are being redefined by challenges to manage multiple risks, including variability of supply and quality. By analyzing information, infrastructure, and institutional systems in the context of the rural drinking water sector of Bangladesh, we argue there is an overlooked problem of where responsibilities for service provision and risk-management are being allocated, specifically the shift away from the public sector and collective structures into unregulated private markets and self-supply systems.

We apply machine learning techniques and crowding metrics to show the rate and scale of growth of self-supply systems. Between 2012 and 2017, for every publicly funded rural water point installed by the Government of Bangladesh, an estimated 45 unregulated tubewells were installed privately. Household tubewell investments therefore could represent over a third of the annual national water and sanitation sector budget. Despite well-known concerns for groundwater safety, the exponential growth of private self-supply systems remains unnoticed in national monitoring platforms. The results suggest an opportunity for the public sector to leverage private investment towards emerging consumer preferences of in-premises systems and pooled risk. Rural drinking water institutions are however at risk of failing to address the core challenges defined by SDG 6.1 without new information systems, reallocating institutional responsibility towards governments as risk-regulators, and leveraging private capital flows.

INTRODUCTION

The challenge of achieving and sustaining safely managed rural drinking water systems in national development agendas has evolved under a widening set of problem definitions encoded by the global Sustainable Development Goal 6.1, measured through new data flows and delivered through multiple service models. Although the day-to-day experience of users has not changed, the expanding indicators redefine the gaps in global institutional performance from 844 million people in need of improved infrastructure access to over 2.1 billion lacking safe reliable drinking water services (WHO/UNICEF, 2017). The SDGs targets reflect how global policy drivers are moving beyond a model defined by provision of goods, specifically improved infrastructure access targets, to one that also includes managing the distribution of risks, a key distinction in water security literature (Bradley & Bartram, 2013). This raises questions whether the dominant institutional models for rural drinking water services are designed to cope and adapt to the new uncertainties of water quality, supply variability, infrastructure functionality, and in many cases confront the unintended consequences of reallocation of risk responsibilities.

Global and national monitoring systems are constantly evolving with enhanced tools and methods to identify how risk is distributed across geographies, vulnerable populations, and to evaluate sector performance. Nonetheless these monitoring systems provide limited insights into how decision authority and responsibility for the consequences are allocated within institutions. The growing policy and academic debate around the role of private investment and public-private service providers is largely focused on multi-user systems within the context of urban utilities (Bakker, 2013). The increase in self-supply systems through private investment however remains largely absent from national monitoring systems, public discourse, and policy planning

documents. A body of recent academic research around self-supply and private financial flows however suggest that these individual systems are increasing in many regions of the world but are seldom, or only recently, formally recognized within national planning frameworks (Butterworth et al., 2013; H Lockwood et al., 2017; Sutton, 2017). Private and individual service approaches pose new challenges to the rural drinking water sector's institutional design with risk responsibilities managed outside the formal mechanisms of government oversight or risk-pooling instruments such as multi-user infrastructure or insurance. New approaches are therefore sought to interpret how the distribution of public and private investment shape institutional performance to achieve the expanded sector sustainability goals. These goals include water safety, maintenance, affordability, and ensuring equal access.

We explore the implications of long-term failure of rural drinking water institutions to measure, problematize, and adapt to the new allocations of private risk responsibilities emerging from self-supply markets, specifically when those outpace the scale of public provision systems. Bangladesh provides a unique context to explore this process. There is a significant body of literature quantifying exposure, vulnerability and discussing hazards related to water quality and supply in Bangladesh, but a more limited analysis of how institutions adapted to these risks. We therefore examine the infrastructure, information, and institutional transitions in rural drinking water services critical for this risk management. The empirical study compares the rate and scale of growth of tubewell infrastructure across different regions of Bangladesh; how these new water points are managed; and in which ways private financing redistributes decision-making responsibility away from public collectives towards private individuals. Data from three drinking water infrastructure audits located in different regions of Bangladesh are compared to identify

scale and rate of tubewell installations: one of the studies is contrasted with household socio-economic surveys to differentiate risk narratives. After projecting the growth rates to a national scale model, we interpret the consequences of private finance shaping the risk management approaches. The results argue for a shift in governance mentalities away from provision of goods to one of risk-mitigation through regulatory approaches.

Limits of institutional designs

The rural drinking water sector, like many other sectors, is at an inflection point in the framing of social and political risk logics. The transition is from one focused on what sociologist Ulrich Beck describes as the distribution of 'goods' such as income, social services, health, and infrastructure to one increasingly focused on the distribution and prevention of 'bads', i.e. harmful risks(Beck, 1992, 2013). He describes this inflection point as a shift from a positive logic of acquisition to one which also includes a negative logic of disposition(Beck, 1992, p. 26). His theories emerge from a framing of catastrophic hazards including climate change, nuclear annihilation and ecosystem collapse. Since he argues these hazards are not delineated spatially, temporarily, or socially they therefore redefine the distributions of dangers beyond previous class-based allocations. These, he argues, require sensory systems of science and interpretation of media to render them visible.

This framework originates in part from one of Beck's core theories of reflexive risks: that the pursuit of acquiring these 'goods' has created harmful, unpredictable, and unintended side effects, or 'boomerang effects,' on routine economic, social, and techno-scientific processes and decisions (Beck, 1992, p. 35). This framework partially extends from Luhmann's definition of risk as the possibility of future damage attributed to a decision, or "the prospect of post-decisional

regret (Luhmann, 1990, p. 225).” Reflexivity, or as Lash describes it, as a break from the previous linear processes of modernization by self-monitoring and confronting results of past decisions, has threatened the increasingly diffuse neo-liberal model of institutional power structures which are promoting decentralization, marketization, and privatization of responsibility (Bakker, 2002; Beck, 2013; Lash, 2003; Gabe Mythen, 2005). Implicit within Beck’s argument of broad social transitions to reflexive risk society, is the politics of institutions realigning to manage the unknowable, incalculable risks. Rayner argued even more explicitly that the rise of risk politics has caused the “state to retreat from many responsibilities and prerogatives that it took for granted in the mid-20th century, ceding them to the private sector and to civil society in the form of non-governmental organizations (Rayner, 2007, p. 166).” Matten (2004) further observes that scientific uncertainty, unclear allocation of responsibilities, and short political timeframes lead to the failure of classical political actors to manage risks. This article argues that the limits of institutional design are amplified in rural drinking water sector by overlooking the realignment of responsibility and authority from public sector and private collectives pooling risk, to private interests and individuals.

The dominant institutional models for rural drinking water services have thus been shaped by positive logics of acquisition of services, not framing the multiple risks as overlapping concerns to mitigate or manage distribution. These models have been shaped by subsidiarity approaches to governance under assumptions of ongoing involvement in multiple forms of public service provision. Subsidiarity has shaped legal, policy, and administrative governance reforms by transforming how and where institutions assign responsibility for decisions and who is involved with the action-situation (Garrick et al., 2018; E. Ostrom, 2010b). These transitions of

responsibility follow a rough sequence starting from a centralized state responsibility for drinking water provision to decentralized regional administrative units; reallocation of authority from government to municipal level operation and maintenance systems, often structured around community management models (Harvey & Reed, 2007; Hope, 2015); enabling professionalized public-private service delivery approaches (Moriarty et al., 2013); to fully private self-supply (Sutton, 2017). This sequence more broadly reflects a redistribution of decision making responsibility away from a centralized state into multiple levels of a polycentric system (E. Ostrom, 2010b), facilitating what Koehler et al (2018) argue are increasingly pluralist arrangements to manage risks. Lockwood et al (2017) categorize these service delivery models into five groups: community based; direct local government provisioning; public utility; private sector; and self-supply. In the case of rural settings, the most recent transfer of responsibility and accountability to the non-government actors, most often private individuals and familial collectives, have not been formalized or reconciled with collective risk-sharing mechanisms. These organizational structures manage risks differently. However, the global policy driven by the Millennium Development Goals (MDGs) often standardizes best practice approaches and unintentionally reinforce service models focused on increasing access, not managing the multiple risks and uncertainties of the sector.

Quantifying scale of self-supply and private investment

Self-supply, or privately financed and managed systems often with limited number of users, are not a new phenomenon for rural areas. Recent work based on household surveys by Grönwall et al (2010, p. 14) estimate that 269 million urban residents across 43 countries rely on self-supply,

while country-specific studies in Lebanon (Korfali & Jurdi, 2007) and Madagascar (MacCarthy, Annis, & Mihelcic, 2013) suggest even greater scales of uncounted private systems. Efforts to formalize and leverage self-supply are emerging in many countries, including Zambia (Sutton, 2004), Ethiopia's Self-supply Acceleration Programme (Butterworth et al., 2013), Zimbabwe's Upgraded Family Well Programme (Olschewsk A., 2016), and widely adopted rain water harvesting in Thailand and Vanuatu (Foster & Willetts, 2018; Saladin, 2016). These recent policy initiatives reframe self-supply as an opportunity to expand access beyond limitations of government public provision models.

In many countries however, including those with advanced regulatory systems, self-supply also produces new challenges. There is no formal recognition of individual private water systems and limited regulatory oversight of small-scale infrastructure systems. The clearest example of self-supply challenges emerge from the United States where an estimated 42.5 million individuals, or roughly 13 percent of the total population, rely on private self-supply from groundwater sources for drinking water (Dieter et al., 2018). These systems are not subject to federal regulatory oversight which defines drinking water systems with less than twenty users as outside public mandates and thus do not require compliance with federal water quality standards (Flanagan & Zheng, 2018). In other country contexts, particularly Eastern European countries, the only direct oversight to rural water systems classified as private is through permitting of drillers and construction standards (Olschewsk A., 2016). The European Union passed the Drinking Water Directive which mandates water quality testing and alignment with water safety plans introduced a framework in 2014 to address gaps between urban and small systems, although it does not specify self-supply infrastructure with under 50 users (Hulsmann & Smeets, 2011). While self-

supply is increasingly prominent policy option in many country contexts there is a lack of regulatory oversight which leaves millions of households at risk of exposure to unsafe water. In the absence of regulation of either drillers and or infrastructure owners, abstraction of water resources goes unregistered and unmonitored.

These gaps remain largely invisible in national measurements of institutional performance. The current SDG 6.1 monitoring systems, in Bangladesh as with many other country contexts, are not designed to track these private systems and infrastructure performance. Recent policy work discussed within the Rural Water and Sanitation Network (RWSN) continues to use household survey data and user-to-infrastructure ratios to estimate scale of infrastructure (RWSN, 2019), rarely acknowledging the limitations of the data. With household's as the primary unit of analysis, the indicators are not designed to reflect how risks are managed, instead focusing on provision aspects such as main infrastructure type and proximity to dwelling.

Recognizing some of these gaps, the World Health Organization (WHO) and country statistical offices produce the Global Analysis and Assessment of Sanitation and Drinking-water (GLAAS) which offer the only globally comparative estimates of annual national aggregate expenditures across the WASH sector (GLAAS, 2017). The results, summarized for 2010 through 2016 in Figure 18, shows a significant variation in the share of the total national WASH expenditure provided by households. The differentiation of sector finance provides a proxy indicator for institutional design and role of private sector in managing water sources but is limited by lack of differentiation across water, sanitation and hygiene and capital versus operational expenses.

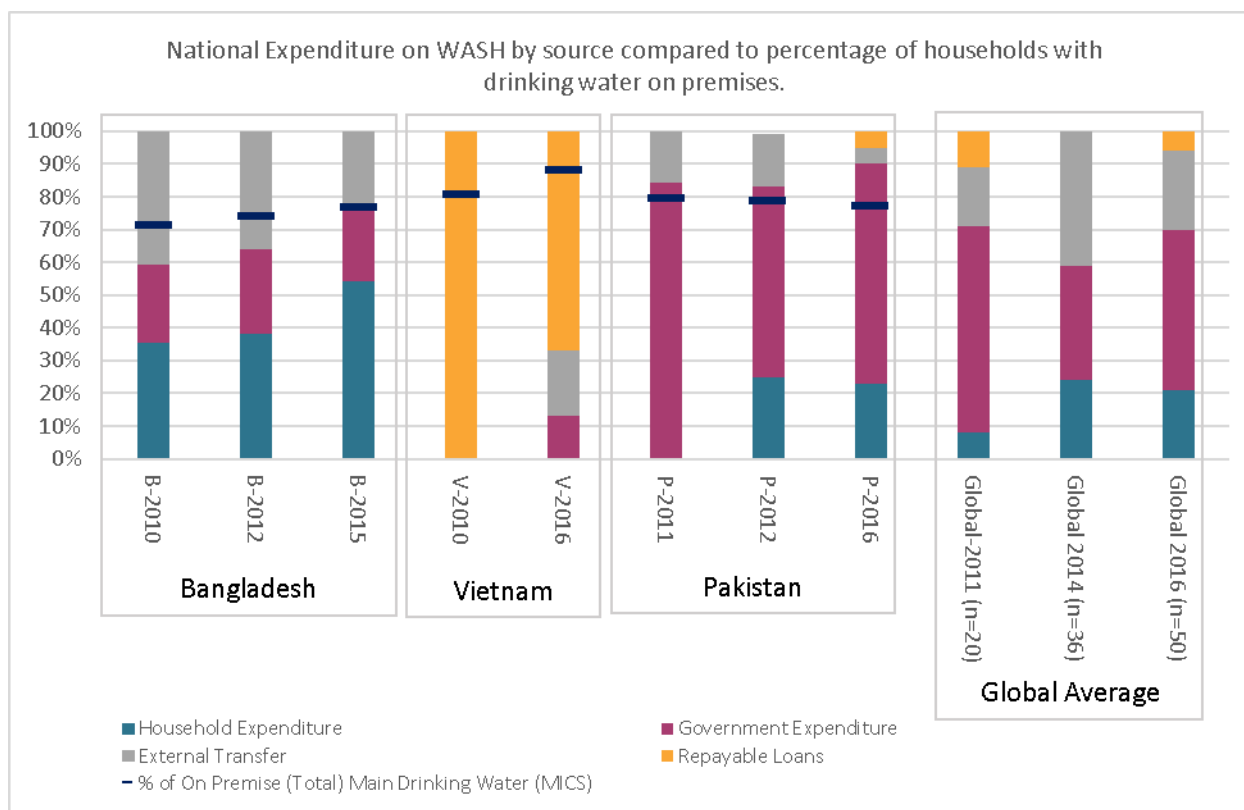


Figure 18 Proportion of reported financing sources compared percent of on-premise drinking water points. Data: GLAAS 2017, GLAAS 2014 and GLAAS 2010 and MICS 2017

Bangladesh context and the institutional allocation of responsibility

Bangladesh provides a context to explore the transformation of rural drinking water services in response to a set of distinct risk narratives. The country has been frequently portrayed as one of the most complex social-ecological systems for institutions to deliver safe water for the 160 million people, of which 105 million are considered rural (Hoque et al., 2019; World Bank, 2018c). This portrayal emerges from the confluence of both environmental hazards and the unintended consequences of institutional and infrastructure choices (P. Atkins & Dunn, 2007; Sultana, 2012). Bangladesh's physical topography combines with the annual monsoon cycles to create significant intra-annual variation of water resources, from flooding events to growing water variability during the dry season. Growing demand for groundwater resources and reduced recharge has increased concerns of drawdown of aquifers, particularly during the dry season (DPHE, 2015a).

Ensuring drinking water safety has been an enduring public policy challenge in Bangladesh since before independence, driven by government promises to citizens for infrastructure access and global policy targets of reducing mortality rates linked exposure to waterborne diseases.

The transitions in infrastructure, governance, and risk narratives are clustered into three temporal periods by Yasmin et al (2018) for urban context and Fischer (2019) in the rural. The first period stretching roughly from 1972 until 1992 reflects a period defined by concerns around cholera and diarrhea contamination with a response to shift household water sources from ponds and surface water to groundwater abstraction through tubewells. Between 1972 and 1985, the government and development partners installed an estimated 408,000 public shallow tubewells and 15,000 public deep tubewells (Black, 1990). As part of a global initiative to improve handpump technology efficiencies, Battelle Laboratories designed a modified No.6 handpump, an innovation with long-term implications for Bangladesh (Black, 1990; Frink & Fannon, 1974). The technological innovation of the lower-cost and more durable cast-iron handpumps enabled domestic private companies to acquire greater shares of the local supply chains, initially financed by demand from the irrigation sector. These technological advances and domestic supply chains put in place the enabling conditions for the now ubiquitous private handpump market.

The shift towards handpump infrastructure facilitated institutional shifts starting in the late 1970s as the central state decentralized service provision responsibility to upazila (sub-district or country level), reallocated infrastructure allocation decisions to Union Parishads (the lowest administrative units for local government), and by the late 1980s reassigned operational and maintenance duties to the private self-assembled collectives of users. Infrastructure installed through the Government's Department of Public Health and Engineering (DPHE) required

collectives of ten or more individuals to apply and declare it would be maintained by the group. The publicly provided water points by DPHE engineers go through a formal tender process defined by a set of installation requirements, and as of 2012, are also required to have independent water quality testing at time of installation (DPHE, 2015b). However, the growing scale of the informal private sector of local well drillers, or *mistri*, who installed shallow tubewells (STW), defined as less than 30 meters deep (100 feet), without sophisticated drilling equipment, had no regulatory or licensing oversight. By the mid-1980s, functionality of tubewells declined as a prominent concern in the media (A. Fischer, 2019). This corresponded with the private market increasing availability of spare parts reduced government supply delays. The rapid growth of private manufactures arguably enabled the informal shift towards “self-help” or consumer control model of maintenance (Black, 1990). Although not formally regulated, this period saw the transition from community managed ponds and surface water into state provided and collectively managed tubewells.

The formal government and media recognition of arsenic contamination in ground water systems in 1993 marks the beginning of the second major phase continuing until roughly 2005 at the close of the World Bank funded Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP), which included the National Arsenic Mitigation Information Centre (NAMIC). This phase is characterized by initiatives to again shift household’s main drinking water source towards newly defined arsenic-safe infrastructure. The chronic nature of arsenic pathogenesis and uncertainty of contamination, different from the previous acute and immediately visible characteristics of diarrheal diseases, particularly cholera, challenged the previous period’s discursive narrative of rural water sector progress enabled by the wide adoption of handpumps in shallow tubewells

(Caldwell et al., 2003). This new water safety concern represents what Beck(2009) categorizes as manufactured uncertainties beyond the scope of previous calculable and experienced risks. This interpretation, observed by Atkins (2007), partially extends Beck's original framing of risks by acknowledging the uncertainty of the arsenic contamination's spatial distribution as contingent upon experts and scientific testing to render the concern visible. The techno-political debate focused on causality, and where to allocate blame for the contamination (Smedley & Kinniburgh, 2002; Smith et al., 2000; van Geen et al., 2002). The policy response focused on technology alternatives to mitigate exposure (Jamil et al., 2019; Kabir & Howard, 2007; Sultana, 2013; van Geen, 2008). While arsenic dominated drinking water security debates, less attention was directed at the institutional implications of growing private markets driving increased household reliance on the shallow tubewell infrastructure.

The third period, starting after the major investment into NAMIC and blanket monitoring of tubewells ended in 2006, suggests a greater attention on water quality and supply reliability but continues to focus on state provision of public water points defined as safe under national water quality thresholds (DPHE, 2015a; A. Fischer, 2019; van Geen et al., 2016). Unlike the public water points, private systems do not require drilling permits, registration, or certification of safety. Policy documents, starting with the 1998 National Policy for Safe Water Supply and Sanitation (GoB, 1998a) and followed by consecutive policy documents including the National Arsenic Mitigation Plan (GoB, 2004b) do not specify rules for private self-supply infrastructure. The Government's Sector strategies in both 2004 and in 2011 (GoB, 2004c, 2011), focusing instead on how to leverage private finance for larger multi-user piped networks. Despite the major shift of households away from surface water over the past three decades, only a small fraction of the

population had access to formally regulated piped schemes. The Government's DPHE estimated in 2017 national averages of 88 people-per-public operating water point(2017a) compared to UNICEF (1993) estimates in 1992 placing the average at 92 people-per-public operating water point, neither included piped schemes. The significant focus on the 'safe' drinking water technology and environmental drivers of risks are useful but do not explain the institutional service delivery model, risk-management structures, or the transition towards private market models for tubewells. The result is that the literature has arguably overlooked the conditions leading to increasing market privatization infrastructure, limitations of public service delivery, and implicit allocation of risk management responsibility to households and individuals.

Tubewell growth rates have not been consistently or systematically measured over time, specifically when differentiating public versus privately funded and managed infrastructure. Estimates of national tubewell infrastructure can be traced back to the 1972 when they were predominately public water points, as discussed in Black (1990, p. 44). The 1993 UNICEF and DPHE water point status report focused on public infrastructure growth without differentiating scale of private infrastructure (UNICEF, 1993). After the 1990s, population-to-infrastructure ratio estimates were replaced by approximated aggregate number of water points. The national arsenic mitigation projects produced two of the most widely cited estimates of national tubewell infrastructure: the first in the policy findings of the 2000 BGS/DPHE national study, which estimated between 6 and 11 million tubewells, 50percent of which were suggested to be private (BGS, 2001, p. 2). The second was an outcome of the early 2000s Bangladesh National Arsenic Mitigation and Water Supply Project (BAMWSP) and related National Arsenic Mitigation Information Center (NAMIC) which tested and labeled nearly 5 million public and private water

points for arsenic contamination in the majority of the country, later estimating national stock at 8.6million tubewells (Johnston & Sarker, 2007, p. 1890). Additional studies reinforced estimates for the updated figures published in the early 2010s placing national infrastructure between 10million and 11.5million public and private tubewells (BBS, 2010). These estimates were recently updated by Jamil et al (2019) to approach 18 million around 2013. Informal and unpublished numbers from government experts estimated total tubewell infrastructure is around 15million as of 2018 (Informal interview). This creates a context of significant uncertainty of water safety for private water points and newly installed tubewells.

METHODOLOGY

Study Design

This study is designed to triangulate infrastructure growth rates and investment decisions between two study sites representing regions of the country with different risk profiles. The resulting field data is designed to be further compared with an inventory of public investment costs collected from government project archives (see section 2.3 below). The empirical contributions of this paper are based on data collected through Water Infrastructure Audits, or blanket inventories designed to map every infrastructure point in a defined geographic area and collect related information from the owners or managers of those points. This approach provides bari scale data on the scale of infrastructure, source of investment, and assumed responsibility for the system. By mapping every physical water point the study avoids double counting water points when co-owned or shared by two or more households in the same bari, an area defined as spatially clustered residential housing generally linked by related families, a problem identified

in earlier studies (George et al., 2012; S Hanchett et al., 2014). These results produce comparable estimates on scale, rate, and source of growth from different geographic and socio-economic zones of Bangladesh.

Several analytical tools are applied to provide interdisciplinary understanding of the results. First, Gaussian Process (Rasmussen, 2004), a Bayesian machine learning approach, was used to model the growth trend of tubewells. The Gaussian Process approach, which provides probabilistic predictions based on uncertain data, was chosen because it is suitable to incorporate the uncertainty of the reported age and costs. Second, mean-crowding metrics were used to model growth patterns at the village and bari scale across three periods. This method, borrowed from ecologists, was originally devised by Lloyd (1967) to reveal the patchiness of micro-scale distribution and competition experienced by an individual within a defined population. Mean crowding metrics measures the density from the perspective of the individual entity in a replicable and defined area. This is applied to Matlab inventory to capture the tubewell density per bari. Mean crowding values around or below one implies randomly dispersed tubewells with less than one tubewell-per-bari while higher values imply densely clustered units, i.e. crowding within the baris. This metric provides a quantitative way to understand average density-dependencies of users-to-infrastructure at large spatial scales which often disguise nonrandom spatial distributions and obscure inequities in access, patterns of investment, and risk exposure (Wade, Fitzpatrick, & Lively, 2018).

Study Sites and Methods

The two water audit studies were undertaken consecutively, starting with Matlab water infrastructure audit from February until April 2017, followed by the second research site in Khulna from December 2017 until January 2018.

Matlab Study Site

The Matlab work was designed, managed, and supervised by the authors and coordinated by a trained project officer and a field manager based in Matlab. The study population is dispersed across 142 enumerator areas, roughly aligned to the lowest level of administrative unit of the ward. Within these wards, or villages, are baris or clusters of built structures. Detailed information about the history of the study site is available by Alam et al (2017) and within the icddr,b annual reports (Haq et al., 2018). Within the overall 142 villages, this study purposively selected 10 villages to conduct the infrastructure water audit, due to budget and time limitations. The selected villages represent 25,617 people in 6,036 households as of the 2016 icddr,b demographic data (Haq et al., 2018). The villages were identified based on two criteria: 1) half of the villages to be located inside the flood projection embankment and 2) include a heterogeneous sample of villages where the icddr,b 2014 household survey results report varying main drinking water infrastructure (Haider et al., 2016).

The data were collected by 10 female enumerators who were hired directly from each of the 10 villages and trained over the course of a ten-day period, including piloting data collection and reviewing reliability. Mobile network enabled tablet computers were programmed with ONA software (<https://ona.io/>) to enable enumerators to locate and map all water point infrastructure

in defined villages and complete a questionnaire in an integrated survey tool, data immediately displayed online. Enumerators went to every icddr,b defined bari in the villages to visually identify tubewells and asked residents to locate all domestic water points which are in use, nonfunctional, or previously abandoned, including ones located inside four walls of a built structure. Water points used for irrigation were not included in the study. Once identified, the enumerators interviewed the water point owners or managers. The data was cleaned each day, using automated logic checks and manual review to ensure reliability of entry. All respondents were over 18 years of age and provided oral consent to be interviewed about their tubewell infrastructure. The two field data collection studies were granted research ethics permissions from lead university's Central Research Ethics Committee. In addition, the work in Matlab received permission from the Ethical Review Board at icddr,b which includes external evaluators. The Matlab Water Audit comprised of six thematic sections after obtaining consent including: (1) basic identifiers and physical observations; (2) history and current use; (3) management responsibilities; (4) water quality and safety perceptions; (5) investment and affordability; (6) functionality, reliability and maintenance. The questionnaire was designed to build on previously standardized instruments and refined through key informant interviews and field-testing prior to implementation.

Khulna Study Site

The second field study was conducted by a separate field team under the same research grant using the same blanket sampling strategy and a shortened version of the Matlab Water Infrastructure Audit questionnaire. The site is located 160km south-west of Matlab in an

embankment, or polder system, covering five unions across Dumuria and Batiaghata upazilas (sub-districts), with 58,000 inhabitants living in 17,000 households. The Khulna water audit was conducted in the south and central regions of the polder, covering 34,639 people and identified 2,805 tubewells and 19 pond sand filters. The data provides distinct insights from Matlab through different hydro-climatic context in coastal zone and decision-responses to high levels of saline intrusion. The full results and analysis can be found in the article by Hoque et al (2019).

Secondary data

This paper draws from the results of several other studies and historic records from government agencies including a third geographic region in order to triangulate findings with the two water audits. This third site is from the widely published research emerging from nearly two decades of longitudinal data collection in Araihaazar described in articles by Van Geen et al(2014, 2003). The Araihaazar study area is located 51km north of Matlab and provides two blanket surveys of tubewell infrastructure in 2000-2001 and 2012-2013. For full study details see Van Geen et al (2014) and recent analysis by Jamil et al (2019).

The second is the public infrastructure installation cost data extracted from 67 different DPHE Project Proforma documents, providing figures for 150 unique budget items recorded as both initial tender costs and actual reported costs at time of installation. Of the 150 identified cost figures, 29 were costs for shallow tubewells and 36 were for deep tubewells. This analysis uses the initial tender quote aligned to the year provided and averages the cost when multiples project costs were identified in the same year. By 2017, DPHE provided a standardized cost list by infrastructure type, however this did not exist for previous years(DPHE, 2017b).

RESULTS

The results provide insights into three components of rural tubewell infrastructure, information, and management including: a) the rate and pattern of growth, differentiated by data source, tubewell depth, pumping technology, and funder; b) revised estimates of growth at cross regional and national scales; and c) the historic changes in costs to install tubewells, differentiated between public sector and private market providers, and the potential scale of private sector financial flows a year after the survey.

Differing interpretations of Matlab's drinking water infrastructure growth and transitions

The Matlab household socio-economic household survey data provided by iccdr,^b across five survey years indicates that by 1980, tubewells had overtaken surface water as the reported main drinking water source in the Matlab villages. Sixteen years later, the proportion of households relying on tubewells (both shallow and deep) peaked at 95percent as mirrored by the fall of surface sources to less than 10percent, seen in Figure 19(A). After 1996, other improved infrastructure remained below 20percent of coverage at any point (Haider et al., 2016; Nahar, 2007; Razzaque, Nahar, Sarder, van Ginneken, & Shaikh, 1996).

The 2017 Matlab Water Audit reveals a different trajectory of growth periods. The audit identified a total of 3,830 water points in the 10 villages of which 3,734 were identified as domestic water sources and used for the analysis. Abandoned tubewells, defined as points that owners have no plans to rehabilitate were identified as 8percent of the tubewell (n=295), while non-functional tubewell at time of visit were 1.5percent of the total (n=58). In order to account

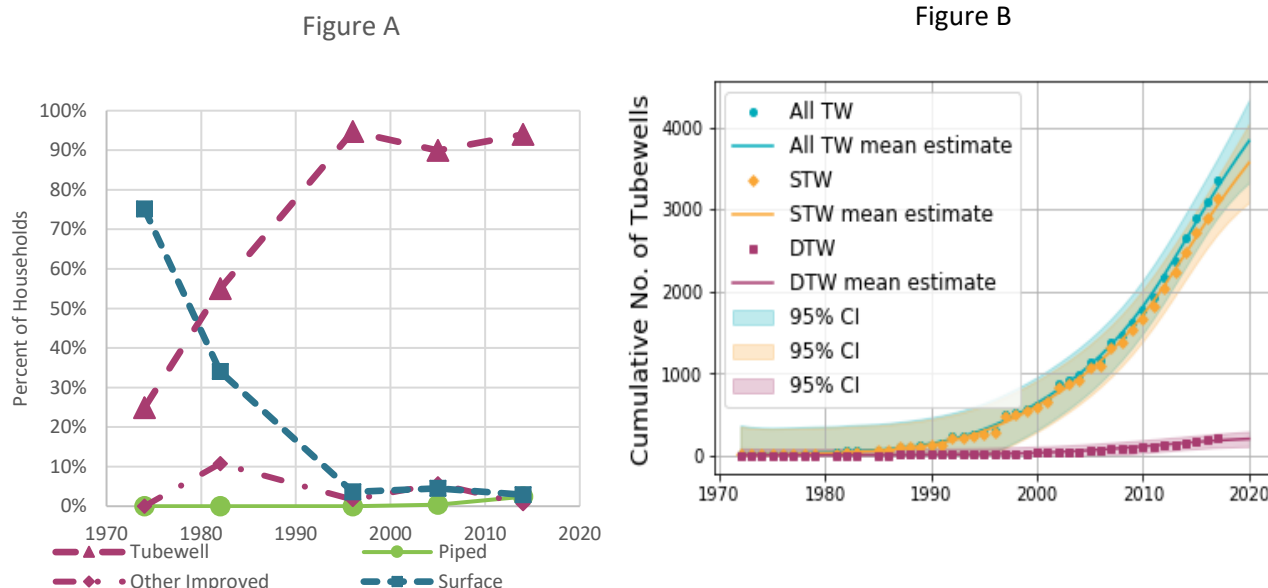


Figure 19 A) Households main source of drinking water from 1974 to 2014 across 142 villages of icddr,b enumeration area. B) shows the growth of tubewell installations by year as reported by owners in 2017 Water Audit for 10 villages. N=3734

for the respondent's recall bias observed in the spike of reported tubewell installations each five years from date of interview, a Gaussian Process (Rasmussen, 2004) was used to model the uncertainty in the data, represented in Figure 19 (B) as upper and lower bounds of the 95percent confidence interval. While the proportion of households using tubewells as main source of drinking water declined temporarily during the height of the arsenic crisis in the early 2000s, the rate of installations continued to grow exponentially. As seen in Figure 19 (B), the majority (60percent) of tubewell growth (n=2,234) occurred after icddr,b's blanket arsenic testing campaign completed in 2005, which labeled tubewells red or green in accordance with the Government of Bangladesh's arsenic safety threshold of 50ppb (Jakariya, von Brömssen, et al., 2007). Further, out of the tubewells installed post-2005, 80percent were reported as used for drinking water. This growth rate suggests changes to the rural drinking water system were not aligned to arsenic concerns and remain unseen when using household survey to interpret risks from water services.

The application of infrastructure inventories extends the macro-perspective of changing access coverage and risks further beyond household statistics. Applying density of households-to-tubewell or users-to-tubewell ratios revealed that the average coverage rates decreased from over 50 households-per-tubewell in 1982 to less than two households-per-tubewell in 2017, seen in Figure 19A. By 2017 the differences in infrastructure coverage between villages, as seen in Figure 20, also diminished significantly, decreasing from a standard deviation of 1.63 in 2005 to 0.38 in 2017. This metric is significant when considering the total population in the study area has grown 10percent since 1996 while the number of households has grown 70percent, reflecting even greater demand for new water points from new houses with smaller average family size. Further, the villages with historically lower coverage reported the largest increases including the two villages P00 and H00 with the greatest change and lowest levels of wellbeing according to icddr,b's 2014 asset index(Haider et al., 2016). These two villages reported less than 1.5percent of the tubewells as publicly funded leaving the vast majority reported as privately financed. These statistics do not identify equity or local politics of access issues. Instead, they do show that the villages with lowest assets according to the 2014 icddr,b socio-economic survey (Haider et al., 2016) saw the greatest gains in coverage rates, driven by private investment.

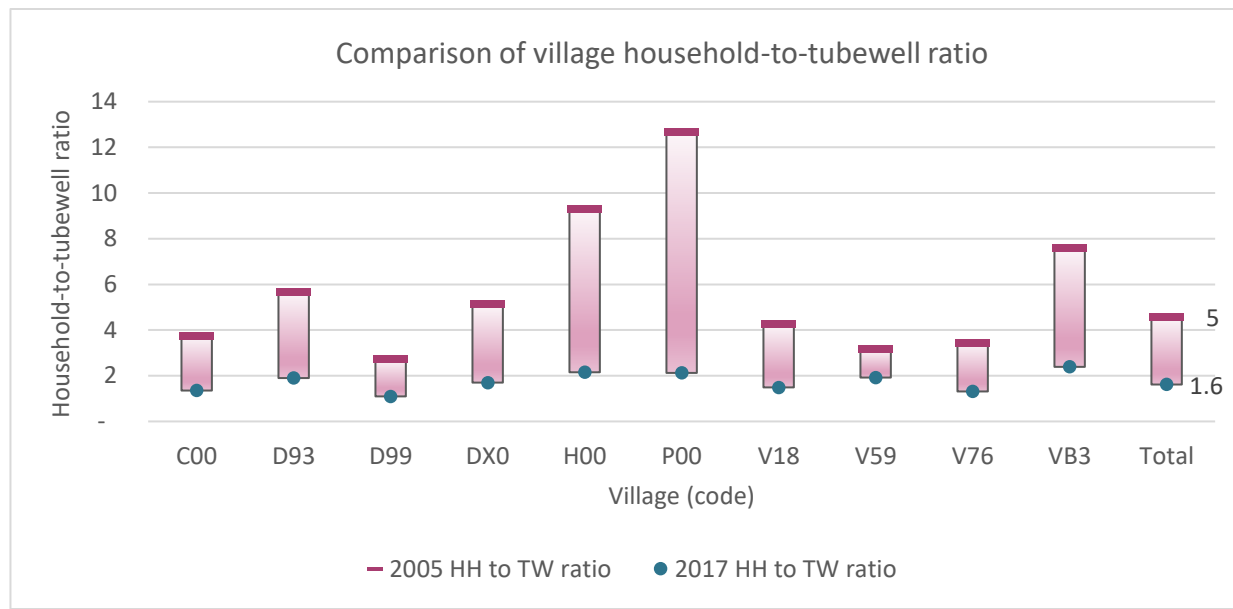


Figure 20 Village-level comparison of household-to-TW ratio, 2005 to 2017

The village ratios obscure the bari-scale growth patterns which are poorly understood in relation to spatial and household dependencies on water points, and the temporal shifts from public multi-user systems and collective multi-user systems to private and self-supply systems. By applying the mean crowding metric to the village of Titerkandi (P00), illustrated in Map 6, it provides an empirical analysis of this transition from shared to individual water points (227 tubewells, 480 households and a population of 2026 people as of 2017). Before 1996 the village reported 7percent of the baris having a tubewell, with each of those having a mean crowding less than one. Despite the very small portion of baris having tubewell infrastructure, the prominence of tubewells as the main drinking water source of households increased from 20percent in 1982 to 56percent in 1996 (Razzaque et al., 1996). By 2005, 70percent of the households reported using tubewells as their main drinking water source (Nahar, 2007) but only 33percent of the baris had tubewell infrastructure. The 2005 mean crowding remained less than one. By 2017, 82percent of the baris reporting having at least one tubewell and the mean crowding rose to four

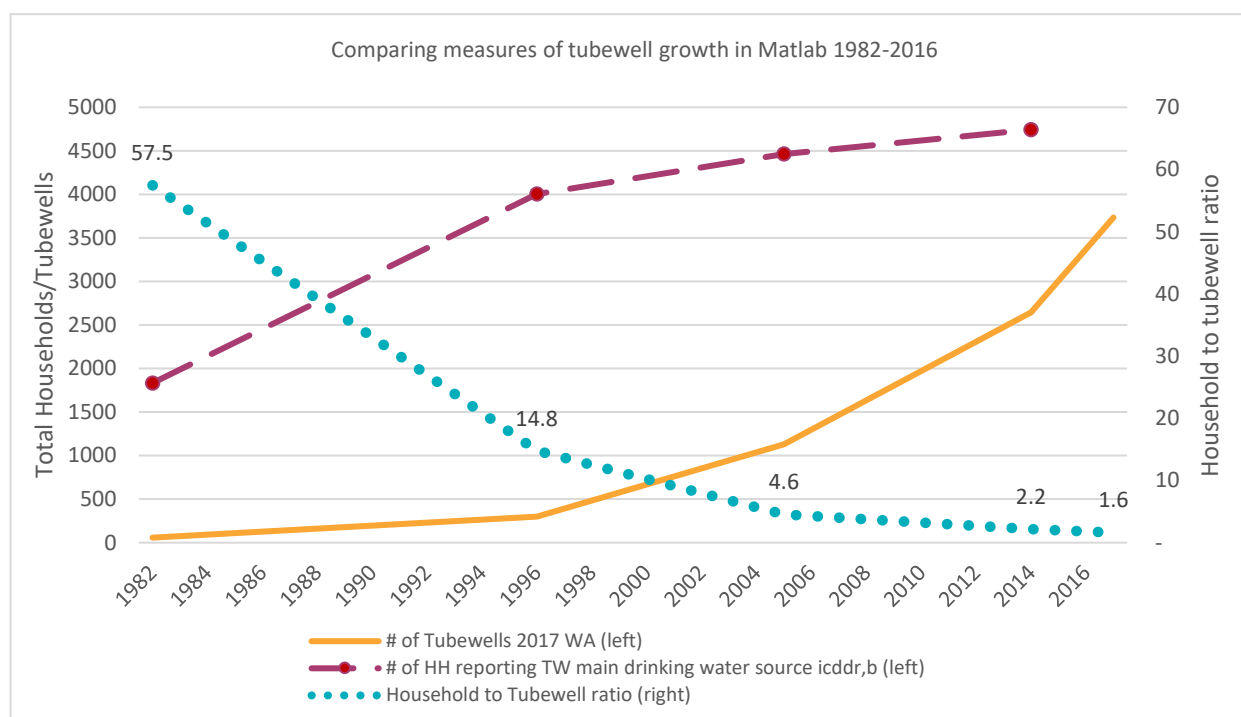


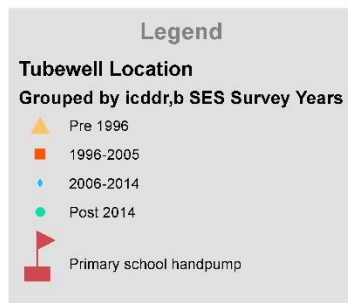
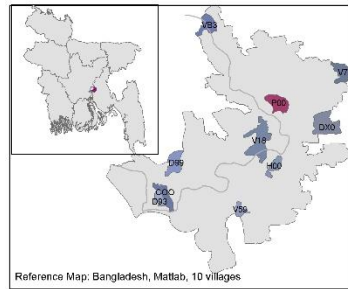
Figure 21 Comparison of tubewell growth from household survey and water audit results 1982-2016.

with only a small increase in households, 74percent, using tubewells as their main drinking water source. This reflects the increased density or crowding of tubewells in each bari.

This progression shows the transition in infrastructure and implies new forms of risk management. Household's main drinking water infrastructure in the 1970s-1990s reflect a period of pooled risk through shared water points under collective or public management models (Ahmed, 1998). By 2005, the reliance on multi-user shared tubewells located in nearby baris diminished and switched to a system of privately managed collective tubewell located within individual baris. Most recently, ownership has shifted to individual water points per household, diminishing reliance on shared tubewells within the same bari. The rates of this change vary between villages, but all show similar institutional transitions.

The converging trajectory of individual tubewells for each household is shown in Figure 21. If the 2015-2016 growth rate of 9percent and number of households are held constant, it suggests that

Tubewell growth in four phases (Village P00)



within the next decade Matlab villages could reach a point of market saturation of one tubewell-per-household. This is reinforced by the water audit findings that 67percent of shallow tubewells were reported as used by a single household compared to 20percent of deep tubewells. When considering use as three or less households, this number increased to 90percent of the shallow tubewells and 30percent of the deep tubewells. This indicates the market has shifted towards private and largely individual self-supply water points.

Beyond the aggregate growth rate and spatial patterns there are two additional trends which are not widely quantified or identified by previous studies but consistent across both Matlab and Khulna sites. The first is the specific role of private financing in this growth trajectory and the

second is changing technology preferences increasingly shifted towards private deep tubewells, electric pumps, and in-premises handpump access.

The increased installation of individual and private water points is linked to changing ownership and management structures. In Matlab, 95percent of the shallow and 72percent of deep tubewells were reported as privately owned and financed. An even greater percentage, 96percent of shallow and 77percent of deep tubewells, were reported as privately managed and maintained. This allocates decision-making responsibility of water safety and repairs to private households.

The second observation is a shift of private investment towards deep tubewells and electric pumps. The Matlab water audit identified 5percent of the tubewells (n=173) reported as deeper than 150meters, of which 90percent were installed after 2005 and two thirds through private funding. Further, one-in-ten tubewells reported using electric pump systems (n=343) instead of No.6 handpumps. There was a more significant shift in household preferences: nearly 60percent of identified No.6 handpumps installed between 2006 and 2017 are located inside a built structure, defined as located within the enclosed four walls. These observed trends suggest the market is in early stages of changing preferences and redefining demand both deeper water sources defined as safer and convenience of service delivery into household structures.

Comparing regional growth trends

Previous blanket inventories provide an opportunity for insight into the regional comparability of the tubewell market growth and variation of risk-responses across different environmental and social-economic contexts. While recognizing that the majority of the population has obtained

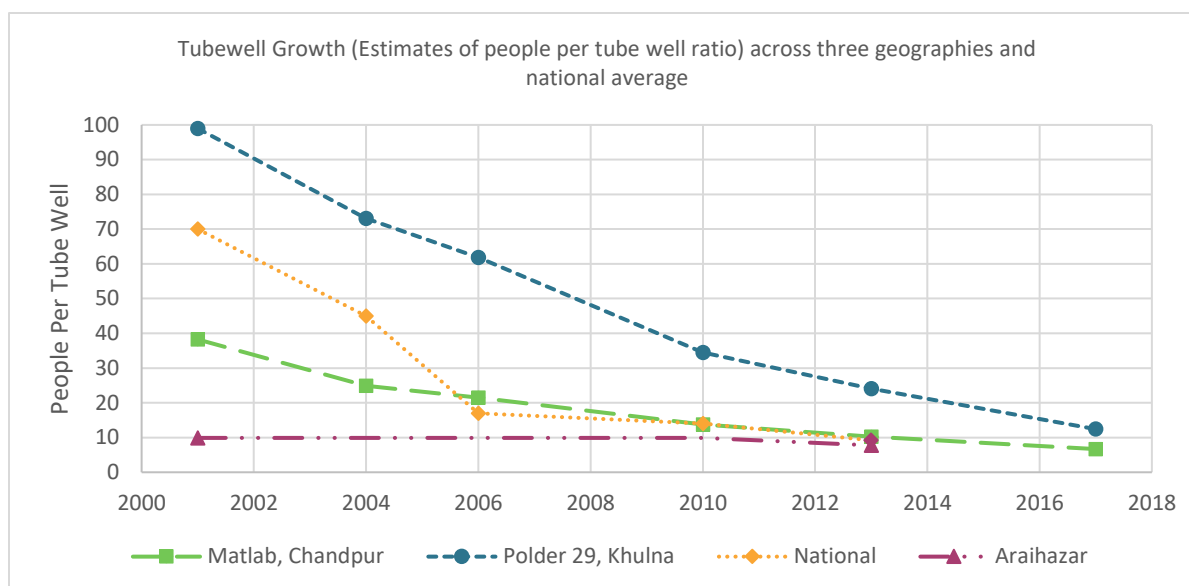


Figure 22 Population-to-tubewell density across three blanket surveys and the national average.

access to improved infrastructure, previous studies identified significant variation of tubewell density between southern coastal areas and other regions of the country (UNICEF, 1993). As seen in Figure 22 ⁴, the gaps between these regions have diminished significantly in the past 17 years. The recent ratios range from 12.4 people-to-tubewell in Khulna in 2017; 6.7 in Matlab in 2017; 7.8 in Araihaazar in 2013 as reported in Jamil et al(2019) and 9.2 nationally using rural population to tubewell estimates(BBS, 2015).

Contrasting risk drivers

The largest scale of growth was observed in the coastal belt. Khulna's Polder 29 study showed both private and public investment despite widespread concerns for saline intrusion into shallow aquifers and the unavailability of suitable deep aquifers (Hoque et al., 2019). Government and UNICEF studies previously identified this region as having a significantly lower tubewell coverage

⁴ Data sources: 2017 Matlab water audit; 2018 Khulna Polder 29 water audit (Hoque et al. 2019); the Araihaazar studies published by Jamil et al (2019) and Van Geen et al (2003; 2014); and Government-published national averages (BBS, 2010; GoB, 1998a).

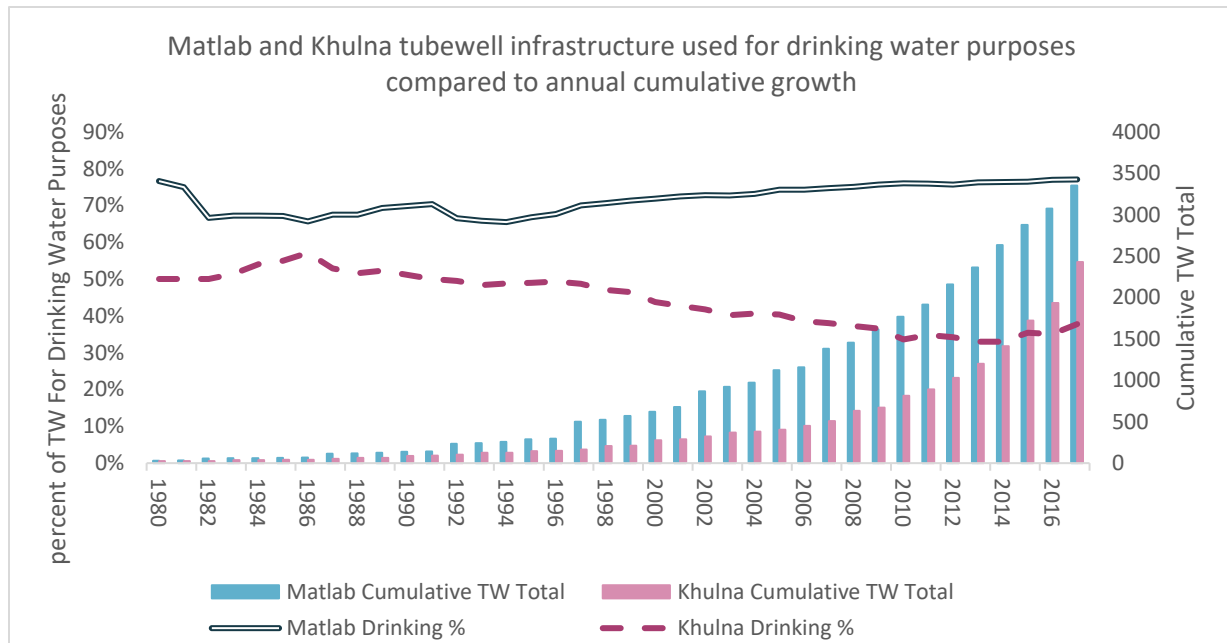


Figure 23 Cumulative tubewell growth and proportion used for drinking across two sites.

than other parts of Bangladesh (UNICEF, 1993). The past decade of tubewell growth in Khulna was fourfold, compared to over double in Matlab. However, the main use varied significantly between regions. As seen in Figure 23⁵ over 70 percent of new tubewells installed in Matlab were reportedly used for drinking water purposes compared to a declining proportion in Khulna, reported around 35 percent in 2017. This reflects a critical difference in the type of groundwater concerns and risk-responses. In Khulna, salinity in ground water drove users towards alternative drinking water sources including pond sand filters, small piped-schemes and informal vendors. Tubewells were used for other domestic purposes including washing, bathing, and cooking. In contrast, Matlab users reported increasingly use of newly installed and privately managed sources despite higher uncertainty of arsenic.

⁵ Cumulative number of tubewell totals should not be compared due to differences in area and population of the study sites.

National growth beyond public provision models

The scale of observed growth in the three sites suggest national estimates are underestimating the total infrastructure stock. This section estimates the national tubewell infrastructure stock using the 2017 population-to-tubewell ratios from Matlab and Polder 29 to determine the high and low scales with estimates of rural tubewell coverage. The upper bounds of potential growth used the ratio of 6.7 people-per-tubewell from Matlab. The lower bound is based on a 12.4 people-per-tubewell ratio from Polder 29 in Khulna in 2017. Using World Bank population estimates, these figures provide an estimated total tubewell infrastructure in the rural areas for 2017 ranging between 8.8 million and 15.8 million tubewells, consistent with Jamil et al (2019) estimates.

Estimating total national tubewell growth in order to align to other studies was more difficult due to the absence of data on public and private tubewells urban areas, an issue identified across multiple other studies. The urban level of households reporting use of tubewells as their main drinking water source in census data dropped from 64percent in the 2001 to 45percent in the 2011 (BBS, 2012). However, this drop isn't directly correlated with the number of tubewells in use or dependency ratios. The World Bank reports that 70% of urban households use tubewells for water (World Bank, 2018a). The 2011 Water Supply and Sanitation Sector Development Plan (WSSSDP) only discusses urban areas covered by WASA areas, 2 city corporations, and 102 Pourshavas (small town municipalities) out of the total 308 Pourshavas. The report provides a count of 172,077 tubewells (GoB, 2011, pp. 26–29). The report does not specify if this includes private tubewells. This estimate represents roughly half the total projected urban population, with an estimated 22.79 million people living in the remaining 206 Pourshavas as of 2011, areas

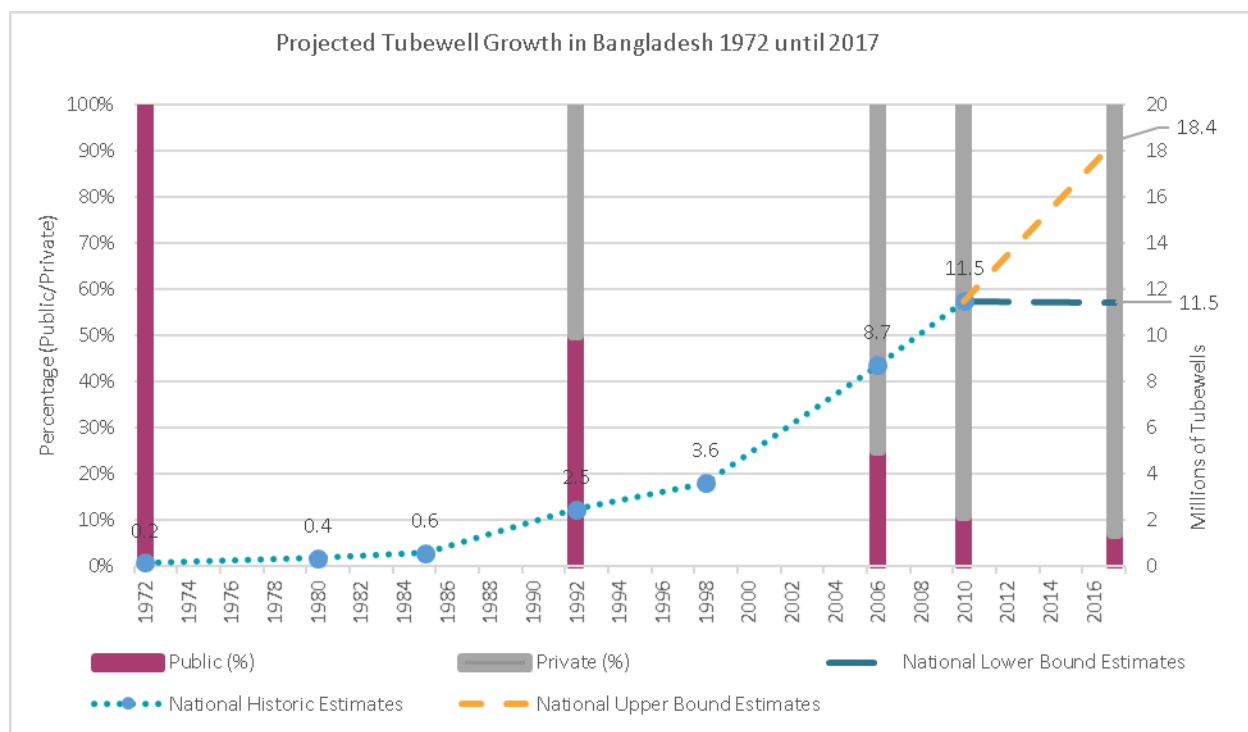


Figure 24 Estimates of national tubewell growth from 1972 until 2016 and distribution of public versus private investment.

where tubewell ownership and dependency is assumed to be higher. The 1998 National Policy for Safe Water Supply and Sanitation (NPSWSS) document sets a target that urban areas have a ratio of 50 people-per-public water point and 5 people-per-private water point (GoB, 2011, p. 18). To estimate total urban tubewells, the national public-to-private ratio from 2010 is applied to the portion of urban population. This results in a total estimate of 2,666,446 tubewells in urban areas, although this is likely an underestimate. When combined with the rural numbers, the projected national number of tubewells is between 11.5 million and 18.4 million tubewells, summarized in Figure 24⁶.

Within the total infrastructure, the ratio of public-to-private has changed significantly since 1972. Starting in 2012, the annual DPHE Circle Wise Water Source Status and Coverage Reports openly

⁶ Data sources: national figures in 1972, 1980 and 1985 from Black (1990, p. 45); 1992 from Caldwell (2003) and UNICEF (1993); 1998 from GoB-DPHE(1998a); 2006 from NAMIC as reported by Johnston and Sarker (2007, p. 1890); 2017 from this study and Jamil et al (2019))

released data on publicly funded rural water infrastructure showing a steady, but lower, growth rate compared to private water points and the district-level spatial distribution of coverage. In 2017, the government reported a national coverage rate of 88 people per public water point, not including urban piped networks (DPHE, 2017a). This represents a total of 1,662,672 water points, of which 91percent are reported as functional, 962,933 were shallow tubewells, 335,538 were deep tubewells, 292,936 were Tara tubewells, 14,593 were shallow shrouded tubewells, while the remaining are split between pond sand filters, ringwells, rain water harvesting systems (DPHE, 2017a). Publicly provided water points are therefore estimated between 8percent and 15percent of the total non-piped infrastructure.

Diverging infrastructure costs

The explicit motivation and market drivers of the newly installed tubewells have not been carefully explored. The 2014 National Strategy for Water and Sanitation Sector sets out a specific strategy to facilitate private sector participation but prioritizes urban sector needs and doesn't identify the potential scale if rural investments are pooled (GoB, 2014). Of the drinking-water-only water points installed between 2006 and 2017 in Matlab, 10percent of the respondents reported the reason for installation as well-switching away from an arsenic contaminated source, 24percent for other water contamination concerns while 94percent reported they installed based on personal preference for a private source. Twelve percent of households identified income increases as a motivating factor while none of the households reported cost reduction or loans.

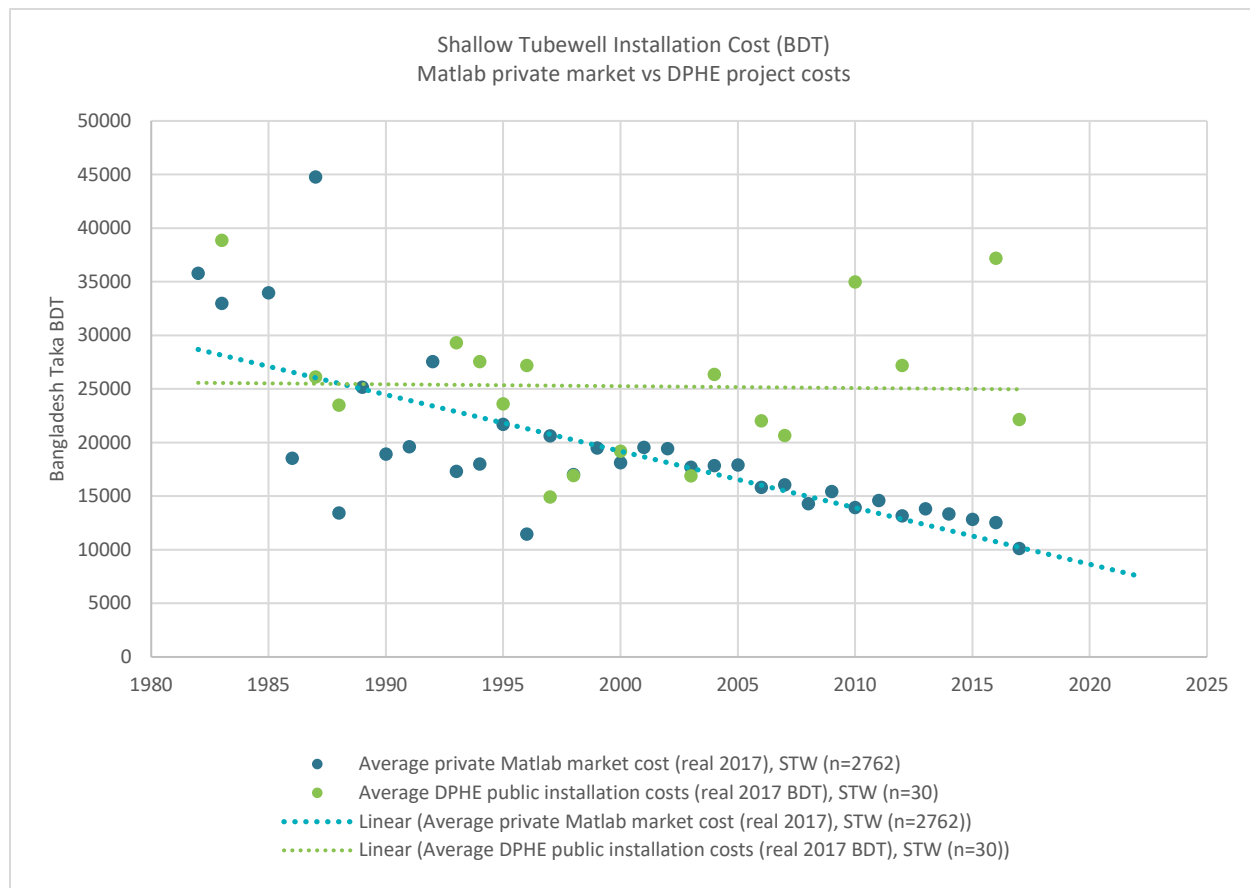


Figure 25 Shallow tubewell cost of installation adjusted using Matlab Water Audit and DPHE project proforma reported costs adjust to real 2017 inflation.

Previous studies offer insights into the costs of installing tubewells in specific years but not how they have changed. Most of these are derived from NGO and Government budgets, not private market vendors (Balasubramanya et al., 2014; Jakariya, von Brömssen, et al., 2007; Jamil et al., 2019; Ravenscroft et al., 2014). Using data from the Matlab water audit and DPHE project proforma documents, Figure 25 constructs a time series of reported public and private costs for installing shallow tubewells since the 1980s, adjusted for inflation using World Bank deflators in Bangladesh Taka (BDT).

While the nominal costs for both private and public installation costs have steadily increased since the 1980s, the costs when adjusted for inflation have halved. The 1982-1987 average

nominal cost of shallow tubewells increased from nearly 5000BDT to three decades later an 2012-2017 average just over 11,000BDT. The real 2017 costs of private market for installing shallow tubewells when adjusted for inflation, shows a decrease for consumers from a 1982-2017 average of 32,500BDT to a 2012-2017 average of just above 12,000BDT. A similar pattern was observed for DPHE deep tubewells with nominal costs of private installers rising from 42,806BDT in 1987 to over 115,000BDT in 2017 compared to real 2017 inflation-adjusted costs dropping from 237,887 to 115,000BDT. This suggests that although the nominal costs are increasing, the real costs perceived by consumers, would feel less expensive in 2017 than in earlier periods due to a slower rate of change relative to other market goods.

Beyond installation capital expenditure, No6 handpumps have annual operation and maintenance costs (OPEX) to factor into annual sector financial flows. The annual OpEx in Matlab show that costs vary by infrastructure age, with older handpumps reported as having higher average annual costs. The annual reported OpEx for both public and private shallow tubewells with handpumps installed in Matlab before 2007 averaged 536BDT per year per handpump (n=793), and an average of 319BDT per year per handpump for those installed after 2007 (n=1167). These rates suggest a small but ongoing annual reoccurring investment by households, but not the scale required for piped schemes.

Private household investment significant contributor to national sector financial flows

Between capital and operational expenses, there is a significant inflow of financial investment from the private sector not clearly accounted for in public planning models. Assuming a continued 9percent growth rate of tubewell infrastructure for rural areas based on Matlab, the projected national growth suggests a potential of between 793,005 to 1,420,307 new water

points could have been installed in 2018, a year after this study. If most of the growth remains shallow tubewells, and the average private market costs remains around 10,000BDT, there is a potential of 7.9billionBDT to 14.2billionBDT of new investments in 2018. Applying the World Bank Global Economic Monitoring database for 2018 exchange rate of 83.5 BDT to 1 USD, this reflects between 95millionUSD and 170millionUSD. Based on these infrastructure stock and age estimates, the annual OpEx investment from rural households is upwards of 6.9billionBDT or 83millionUSD for 2018.

In summary and when including urban figures, estimates of 2018 private household capital investment into tubewell infrastructure is placed in the order of 290millionUSD. This compares to GLAAS data reporting a total of 794millionUSD expenditure in the WASH sector across urban and rural geographies, of which 428MillionUSD was identified as investment by households, 182millionUSD from government budgets, and 184millionUSD from external aid (GLAAS, 2017). Although GLAAS data is three years old, the scale suggests private investment into tubewells could represent 70percent of the total household investment. It further could represent nearly four out of every ten dollars spent in the entire WASH sector.

DISCUSSION

Multiple countries, explored specifically through the case of Bangladesh, are undergoing a largely undetected shift of service delivery models towards privately managed and financed self-supply infrastructure systems installed at rates and scales multiple times larger than public and regulated systems. The empirical findings between 2012 and 2017 in Bangladesh show that for every new publicly funded rural water point installed by the government, an estimated 45 new

tubewells were privately installed. While these overall rates of growth have been identified in previous site-specific studies, the national implications of privatized risk allocations are less explicitly monitored or publicly debated.

Extensive research explores households' risk-response behaviors to increasingly awareness of arsenic. However, the reverse question around what is motivating this investment in new tubewells has not been fully explored: less than a quarter of owners in Matlab, an area with high levels of arsenic contamination and decades of NGO activities focused on cholera treatment and prevention, identified water quality as the motivating reason for installing the water point. Instead changes in socio-cultural preferences are reflected by almost every respondent identifying a personal preference to have an on, or in-premises water source. These changing preferences are perhaps motivated by the average costs of shallow tubewells on the private market, after adjusting to 2017 real terms, feeling nearly three times less expensive than in the early 1980s relative to other goods. Although lower costs were not identified by consumers, perhaps because in nominal terms they have steadily increased, the private market costs to install tubewells relative other market goods would make installations feel more affordable.

This consumer preference has significant policy and financial implications for a sector traditionally lacking significant private capital flows and with perceived limitations of user contributions. Previous studies by Khan et al (2014) show that households are, on average, willing to allocate 5percent of their disposable income to safe tubewells and 20percent to piped water schemes. These previous studies help explain household specific patterns but not the aggregate scale of investment. This article estimates that for 2018 the total national rural private investment into tubewell infrastructure is upwards of 170million USD while the operation and

maintenance costs are estimated at a total of 83million USD per year, increasing with each new tubewell installed. Electric pumps present an opportunity and a challenge: shifting towards small-scale piped networks is more feasible to regulate than the numerous individual water points, however the higher maintenance costs places additional challenges for continued functionality as well as increasing rates of extraction of aquifer resources.

The findings advance an argument that domestic development policy progress, including achieving global MDG targets of improved access, were not driven by the government investment programs launched in the 1970s and 1980s. Instead they have been determined by private sector capital investment, including investment from households from all income and wealth brackets. The role of private investment advancing provision targets conceals the growing risks of the reallocation of responsibilities outside government control or oversight. This transition has not been identified by national monitoring systems; particularly household surveys which for two decades have reported continuous levels of main drinking water sources without identifying major shifts in infrastructure reliance, and thus do not accurately reflect changing risk profiles for unsafe water. While household surveys capture which water source is used as the main drinking water point, it doesn't differentiate regulated from unregulated, private from public, or if it is shared between one or one-hundred other users, factors influencing the safety and reliability of the system. In order to achieve SDG 6.1, the expanded global development targets imply not only infrastructure provision but also an institutional role for risk mitigation and management. This framing challenges the previous politics of national and international development actors primarily focused on access to infrastructure. Shifting to a risk-based approach could require

governments to restrain use of existing services deemed unsafe and establish controls over future decisions.

This growth of private unregulated infrastructure in Bangladesh reflects Rayner's (2007) argument of the 'state retreat' of responsibility. The failure to problematize self-supply, and the unintended consequences of individual decisions, is amplified by arsenic concerns and the increasing consumer demand for on and in-premises access delivered through mechanized pumping of aquifers at a time of growing water supply variability and aquifer decline (DPHE, 2015a). The potential consequences continue to increase as the number of rural household units, each an individual demand point, has outpaced population growth, increasing 43percent between the 2001 to 2011 census(BBS, 2012). This increased demand has major implications for sustainability of aquifers, growth of the market, and for health risks if private tubewells remain untested. As a result, unregulated growth of self-supply challenges sector sustainability with dependence on aquifer systems vulnerable to declining water levels.

The rural drinking water sector in Bangladesh provides critical insights into a need to shift institutional approaches towards risk regulation. The growth of private tubewells, driven in part by lowering costs, went unproblematized long after the concerns for arsenic emerged. As Fischer (2019) argues, the public risk narratives promoted provision of safe infrastructure, namely deep tubewells, not risk-regulation. Ongoing mitigation approaches are based on radius targets for deep tubewells-to-populations and do not account for the significant changes in household preferences for on-premise services, overlooked in reports such as Buchmann et al (2019). Further, water quality testing has not been enforced for the millions of new private systems.

The situation is now one of unregulated infrastructure with individualized responsibility for risk management. Although several policy reports suggest it is not feasible to regulate private shallow tubewells (World Bank, 2018a, p. 22), recent articles by Jamil et al. (2019) argue there are cost-effective approaches to reduce uncertainty through water quality testing and optimizing micro-scale spatial distribution of deep tubewells in relation to arsenic-free shallow tubewells. The application of crowding metrics and spatial optimization offer methods to design distributed infrastructure networks, reinforced with licensed and performance-based service enterprises. The growing demand from households for in-premises piped systems and deep tubewells implies a need for quick action to redesign institutional risk mentalities away from provision only by including a combination of the government as a risk regulator and the government incentivizing households to pool finances and share risks.

CONCLUSION

The Sustainable Development Goal ambition for safely managed drinking water departs substantively from the Millennium Development Goal period where countries like Bangladesh saw their hard-won gains of achieving almost universal access being redefined as gaps in safely and reliably managed services. The normative mandate to deliver safe water quality, supply reliability, affordability, and equitable access requires a significant shift in how institutions allocate responsibilities, monitor performance, and design risk-based governance approaches to evolving service delivery models.

With an annual global financing needs for rural drinking water services estimated at USD37.6 billion per year (Hutton & Varughese, 2016) the SDGs will not be achieved without cost-sharing

arrangements that harness this private investment with public funds. Governments have an opportunity to harness the demand for improved services and infrastructure by leveraging the significant private investments by rural water users. Early evidence from these public-private models is qualified by limited performance without accompanying institutional, regulatory, and financial architecture. While there are opportunities to redirect financial flows toward preferred safer infrastructure options, almost always under collective or pooled-risk structures, they should be accompanied by shifts in risk governance to regulate the less mature markets prior to expansive growth.

The rural drinking water sector is however, not currently designed to manage the associated risks of self-supply and individual decisions on private property. Recent academic studies, not national monitoring systems, have identified not only the growth tubewells but also of small-distributed piped schemes and rain water capture under private enterprise structure models across South and South-East Asian countries (Foster, Shantz, Lala, & Willetts, 2018; Gero et al., 2014). Neglecting to systematically quantify so great a development may appear remarkable however it is not without precedent; in East Africa the doubling rural-per-capita use of hand-carried water, probably due to the shift from groundnut oil tins (Debes) to plastic jerry-cans for carrying the water, was similarly missed until it was measured in a wide-ranging community survey which revealed similar 'plateau effect' relation in the distance-to-source and per-capita water use (White et al., 1972). The global monitoring system is not well equipped to identify the changing risk allocations resulting from growth of private infrastructure and investment, although new information flows from reconciled administrative data, real-time monitoring, and modified household survey methods offer significant opportunities to evolve.

The challenge remains that comparative global and national governance paradigms offer limited insights into how to regulate private and individual actions, a sphere defined as outside the allocated authority of public action and government mandates. It is far more politically palatable to provide a tangible service than to potentially take one away. As Beck (1992, 2009, 2013) argues, uncertainty and unknowns increasingly transcend both political or environmental boundaries, including who is vulnerable to unsafe water or which waterpoint faces groundwater depletion. The core concern of rural drinking water risk-management ties back into the limitations of modern institutions to adapt to reflexive risks and manage the consequences, intended or not, of our previous decisions and allocation of responsibility to self-governance paradigms.

6 REFLEXIVE RISK NARRATIVES AND INSTITUTIONAL RESPONSES: THE EVOLUTION OF RURAL DRINKING WATER SERVICES IN BANGLADESH, 1980-2016



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Title: Reflexive risk narratives and institutional responses: the evolution of rural drinking water services in Bangladesh, 1980-2016

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Note:

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ABSTRACT

Many countries, including Bangladesh, are in a process of downscaling the Sustainable Development Goal 6.1 targets into national rural drinking water policies. This transition implies a need to reconcile dominant institutional models designed around positive risk logics, or ones focused on providing improved infrastructure access, with negative risk logics, or ones designed around preventing or mitigating dangers and formalizing responsibility for safe and reliable water services. Adapting an institution designed to provide predictability of decision-making processes implies a need for wider shifts in the way responsibilities are allocated and how information systems are interpreted across competing texts and interests. This grammar of risk theory is interpreted using discourse analysis methods to understand how risk mentalities influences the distribution of pooled or individual responsibility within institutions. The public risk narratives framing drinking water security concerns are defined by the interplay of multiple texts and socio-political voices however previous studies don't provide methods to interrogate how multiple texts and discourse fragments interact in relation to each other. Moving beyond the analysis of single text, this article explores how risk narratives shape institutions in the context of Bangladesh's rural drinking water services, specifically through the construction, contestation, and process of self-confrontation of past decisions, narratives linked to emerging models of reflexive governance.

Certain dimensions of institutional change are thus explored using a set of risk discourse filters applied to a multi-decadal inventory of media (n=3211), academic (n=2151), and policy (n=45) texts explicitly discussing drinking water in Bangladesh between 1980 and 2016. The risk narratives cluster around three periods which construct, constrain, and confront drinking water as a controllable risk. The negotiated techno-social debate constructed cholera and arsenic as different types of water crises but framed them both as manageable through positive risk logics of providing health or infrastructure access. The narrative analysis suggests that the unintended consequences of past infrastructure provision policies created a political reaction seeking to constrain how risk knowledge is produced and publicly debated. Further, the politics of risk narratives limited the problematization of the exponential growth of self-supply tubewells while enabling the reallocation of responsibility to individual households outside existing government authority. Finally, the absence of self-critical narratives maintained a focus on devolution of power and administrative responsibility to municipalities without expanding that debate to regulation or monitoring of private enterprise and individual tubewells. The risk-discourse framework provides the tools to interpret the implications and politics constraining the institutional transitions towards reflexive governance mentalities able to manage the complexity of the Sustainable Development Goals.

INTRODUCTION

The Sustainable Development Goals (SDGs) related to achieving access to safe, reliable, and affordable drinking water for all reflect an evolution of risk governance approaches away from ones focused on provision of access alone towards ones which also include management of multiple types of services and uncertainties of water quality and reliability. The SDGs, which reflect a politically negotiated international development agendas, embody this distinction through a series of expanded indicators and greater data inputs. These targets are reshaping the understanding of country-level performance in the drinking water sector and international narratives: at a globally aggregated level the distance from achieving drinking water targets shifted from 795million people lacking improved infrastructure access under Millennium Development Goal (MDG) indicators to over 2.19billion lacking safe and reliable drinking water under SDG 6.1 composite indicators (UNICEF et al., 2019). The downscaling process of SDG goals into national policies offers an opportunity to understand how institutions respond to new risk mentalities and offer further insights into a phenomena identified by multiple disciplinary perspectives but which remains insufficiently understood in the context of both risk theory and in relation to adapting governance approaches to achieve safe and reliable drinking water services.

This transition is particularly acute in the country context of Bangladesh where the drinking water institutions are adjusting to address increasingly understood service risks, specifically related to rural geographies where service responsibilities are not clearly allocated defined between public and private sectors. Attention from global water sector technocrats have increasingly focused on modifying service delivery models after identifying the limitations of government public sector

provision (Carter et al., 1993) and community management models (Cairncross, 1987; Hope, 2015) towards privately managed service providers (Bakker, 2002; Moriarty et al., 2013; Sutton, 2017). By changing the priorities and focus of sector targets with new service models, institutional economists identify the need to understand which decisions are being made by whom within a system of overlapping action scenarios, formal and informal rules designed to constrain choices, and as a result how responsibility is allocated between individual and collective risk management structures (F. D. Cleaver & De Koning, 2015; Ericson, 2005; March & Olsen, 1984; E. Ostrom, 2010a). This suggests that as the government's policy agenda and the public narrative around sector-specific risks transform, there is a need to renegotiate the allocation of responsibilities between levels state actors, private market providers, community organizations and individual and collective users.

As a result of the internationally adopted SDGs, many national development agendas are being challenged to recognize and interpret why previous hard won gains of providing greater levels of improved infrastructure access are now seen as potential risks undermining sector performance, how the new paradigms implicate the need for institutional governance and service models transform into risk mitigators to improve safe, reliable, affordable, and equitable services. As a result, this article considers how the national public media, government policies, and technocratic assessments interact to interpret and negotiate these transitions in development agendas and sector approaches.

In order to understand these transitions of how institutions adapt to new risk logics, a macro-transition as framed by Beck's (2006b, 2013, 2016) discussions of world risk society, the article deconstructs public debates across techno-scientific, policy, and media discourses to identify

pressures shaping and constraining public narratives and the phenomena influencing institutional structures of responsibilities and decision scenarios (Beck, 1995; Dean, 1999a; O'Malley, 1996). The historical evolution and discursive interaction of media, policy, and scientific texts provide a method to diagnose and frame the changing representations of drinking water risks. This analysis contributes new insights into how risk discourse filters shape techno-social risk narratives and the challenges of shifting rural water service approaches from provision of access to mitigation of risks under reflexive governance structures.

BANGLADESH CONTEXT OF OVERLAPPING DISCOURSES

Global forums of policy and scientific discourse have characterized Bangladesh as a country with one of the world's more complex contexts to address multiple competing risks facing drinking water security, a portrayal emerging from the confluence of both environmental hazards and the unintended consequences of past infrastructure decisions (Nicholls et al., 2016; Smith et al., 2000; Sultana, 2012). At the same time, domestic forums of public policy and national media portray the country as a successful development project, emphasizing the government's actions to protect the population from environmental dangers and ensuring continued economic growth which has led to a dramatic reduction of extreme poverty (N. Hossain, 2017). This national narrative of economic success has been closely intertwined with management of the wider water resource sector, ranging from managing seasonally variable supplies in order to ensure agricultural productivity to providing drinking water services as part of the social contract made in 1971 at the formation of the new independent government (Faaland & Parkinson, 1976; N. Hossain, 2018b; Sultana, 2007). Therefore, the management of uncertainty and provision of

infrastructure continues to be closely linked to the dual state commitments ensuring national political legitimacy and maintaining international credibility.

During the 45-year period post 1971 independence, rural communities across Bangladesh rapidly transitioned away from pond and surface as the main drinking water source, replaced by a dependence on tubewells, which have become ubiquitous in rural areas. This has led to only a small fraction of the rural population connected to public and formally regulated infrastructure, with piped water systems a priority but still small percentage of the rural connections. The discovery of naturally occurring arsenic in the shallow aquifer system in the early 1990s disrupted this trajectory of public policy, preferred technology, and public risk narrative by rendering water quality of tubewells highly uncertain without testing. Despite these concerns, the growth of tubewells continued at exponential rates, with the vast majority driven by individual household investment as quantified by Jamil et al (2019) and Fischer et al (forthcoming). These two articles show that the extensive national narrative around drinking water risks did not impact the trajectory of the exponential growth of privately managed tubewells. The untested tubewells outside public management created additional uncertainty of arsenic exposure at scales not factored into national risk and exposure models as seen in the recent article by Buchmann (2019) which rely on 2007 estimates, half the number now estimated to be in circulation.

The risk narrative in Bangladesh, constructed across extensive media coverage, Government actions, and techno-scientific analysis, continues to manage potential danger through provision of infrastructure, not mitigation of uncertainty through performance-based service models. The variability of problematization and malleability of how risk is emphasized across sub-national geographies and between historical periods is underscored in recent analysis by Fischer (2019)

who argued that the Bangladeshi media, specifically the national Ittefaq newspaper, constructed three periods of rural drinking water risk narratives, all of which were situated within the constraints of the national and international political economies of development agendas. Likewise, Yasmin et al (2018) identify similar historic transitions in governance approaches in the urban geographies of Bangladesh drawing from analysis of newspaper reporting and policy documents. The history of Bangladesh provides a national context to explore how the progression of framing water security has shifted between positive and negative risk logics and shifted from the MDG to SDG era of global targets.

THE GRAMMAR OF RISK NARRATIVES

The analysis of risk phenomena is operationalized using discourse filters to critically assess the interplay of socio-technical texts. Summarized in Table 11, this article fuses core components of risk theory with methodological approaches analyzing the macro structures of discourse and interpreting the results through risk governance logics. This approach structures the framework around the architectural features defined in *Risk Society* as first articulated by Beck(1992) and uses media analysis tools outlined by Entman's (1993) concepts of agenda-setting filters and by Herman and Chomsky's (1988) *Manufactured Consent* to delineate the socio-political versus technocratic production of a risk narrative. This is linked to how institutions evolve over time by explicitly considering how risk responsibility is allocated between collective and self-governing mentalities through the interpreted risk discourse (Dean, 1999a; Ewald, 1991; Rose et al., 2006) and how the grammar of risk enhances the interpretation of how institutions are designed.

This comparative discursive process explains what Beck originally described as the competition of rationalities: the contestation of risk producers (techno-scientific) and risk consumers (socio-political). Beck's (1992, 2006b) theories of reflexive modernism, defined by global risk society and uncertainty which de-spatializes political identities and necessitates society's self-confrontation of the unintended consequences of their past decisions, is critically engaged in this article in the context of how risk narratives are constructed in relation to how institutions change and reallocate responsibility.

Beck argued that "states alone no longer constitute the arena of collective action... this meta-transformation of the political is becoming reflexive, or self-confronting." (Beck, 2006b, p. 31) Reflexive modernization identifies the dynamic and circular relationship of cause and effect resulting in self-confrontation of the unintended side-effects of decisions and technologies (Beck, 2006b; Luhmann, 1990). This transformation is identified by Beck but requires further analysis of how risk narratives shift from the positive logics of provision, which result with politics constraining the production and distribution of blame and responsibility to narrative which are self-critical and enable reflexive approaches to risk mitigation.

Scholars from other disciplines respond to the gaps left by Beck by proposing the use of discourse analysis tools (Bakir, 2010; Kitzinger, 1999). A substantial body of scholarship was emerging in media studies explores the discursive role in setting public agendas (McCombs, Shaw, & Weaver, 2014), practices to frame and promote particular narratives (Entman, 2007), and theories to explain the process of shaping knowledge, and in turn, social action (Jäger, 2001; Ruth Wodak, 2009). These methods do not directly address risk formation, but they offer methods to explore

Risk Phenomena (Beck, 1992, 1996, 2013)	Media Framing (Entman, 1993, 2007)	Media Filters (Herman & Chomsky, 1988)	Analytic Tools	Institutional Design (Ostrom 2010)
Struggle for control of production and construction of risks	Problem selection	Selection of topics and frequency of key words in articles (p132)	- Keywords/content selection - Repetition of topics - Inclusion/exclusion criteria	Position Rules
Risk priority, representation of uncertainty, and blame	Causal analysis	Positionality of an article (p 38) Length of article (p 40)	- Placement in publication sections - Article length - Relative descriptive severity in text - Representation of uncertainty - Relative comparisons - Allocation of responsibility for causation	Boundary Rules
Distribution of goods and bads and risk logics	Moral concerns	Identification of specific vulnerable groups Direct attention to or from specific groups	- Distribution of goods and bads - Identification of specific geographies or vulnerable sub-groups - Focus on prevention, mitigation or response	Choice Rules
Filtering of information, role of expertise, legitimating thresholds	Problem definition	Legitimation and filtering information (p 118; p125; 157)	- Citation of experts, data and information - Public credibility/ scientific recognition - Determining trust; - Interpreting latent side effects	Information rules
Winners and losers of narrative	Salience	Use of language (p 34;43;118)	- Identification of cause of concern - Portrayal of concern as past event or future risk - Relative severity in text descriptors - Objective or subjective voice - Extent of editorializing story	Payoff Rules
Staging and reflexivity: maintaining control of risk	Priming Staging Remedy	Allocation of responsibility (p43)	- Self-confrontation through blame-responsibility - Assigning action or response in text - Allocation of responsibility to specific actors; - Extent uncertainty is interpreted - Comparison of response to other contexts	Aggregation rules

Table 10 Merged Risk Society with Manufacturing Consent and Agenda Setting Frameworks

how the media shapes narratives and agendas, both representing past events and imagining future concerns.

This paper extends these tools, summarized in Table 10 and proposed by Fischer (2019), to the interplay of media texts and journal articles in relation to formal policy documents. This modified framework provides an empirical assessment of longitudinal narrative construction of specific risk features but needs additional analytic lens to interpret the meanings of the delineated

geographies of risk and historical transitions in problematization. Post-structuralist scholars argue that risk has become a critical form of calculation which orders the conduct of individuals, collectives, and populations by enabling specific discursive subfields and determining forms of measurement (Dean, 1999a; Hajer & Versteeg, 2005; Rose et al., 2006). In this view, governance technologies and institutional approaches reflect ways in which the formation of collective thought frames problems to render them manageable (O'Malley, 1996; Rose et al., 2006). This further uncovers how dominant power structures define and constrain ways of collective thinking, and responsibility to act.

Beck argued institutions are fundamentally changing but did not define these institutions or provide specificity of how and where they are failing. To address this, Table 10 further aligns the grammar of risk to the grammar of institutions. Following Crawford and Ostrom's (1995) grammar of institutions and operationalized through the institutional analysis and development framework (IAD), the components identify and generalize a set of situational variables which influence individual and collective behaviour through physical and material conditions (resource units and systems), community attributes (actors), and rules-in-use (governance system) (Aligica and Boettke, 2011; Garrick et al., 2018; E. Ostrom, 2010a; Polski and E. Ostrom, 1999). These factors create the arena which positions individual and collectives to make decisions within an action-situation as relative to social and ecological variables.

By aligning the components of institutional design to the grammar of risk, the results of the risk narrative analysis can be applied to understandings of how institutions change. This specifically includes how reassigning blame and causality from nature to unintended consequences of our past decisions shapes how actors enter and leave positions; how reallocating responsibility and

authority changes the choice sets and potential decision outcomes; how the universality of risk vulnerability changes the distribution and thus position of actors; how negotiated risk narratives interpret information linked to action; how new unknowns undermine ability to map impact of decisions in aggregation rules; and how the forms of assessing cost-benefits of payoff rules is thrown into disarray with unintended consequences and self-reflexive risks. This framework addresses gaps in risk theory's perspective on how decisions within institutional settings are changing while also expanding earlier institutional theory with a new grammar of risk. This is a formative attempt to merge the two using an extensive inventory of Bangladeshi newspaper, academic and policy texts. We acknowledge that this a framework which requires significant future comparative contexts and data sets to expand applicability beyond Bangladesh. The results, discussed in the following sections, remain valuable for both Bangladesh and deepening the applicability of risk theory to provide insights into institutional design.

METHODS FOR COMPARATIVE RISK DISCOURSE ANALYSIS

The analytic framework is applied to a standardized inventory of articles from both newspaper and academic journals, compiled using a comparable identification and coding rubrics building on the risk discourse filters proposed by A. Fischer(2019). This method built on those techniques by comparing to another non-media inventory. The coding technique is designed around keyword content searches in both digital and physical archives and extended to academic articles using methods from literature reviews used in previous water security literature (Cook & Bakker, 2012; Gerlak et al., 2018), institutional coding (Heikkila & Weible, 2018) and critical discourse analysis (Bakir, 2010; Entman, 2007; Herman & Chomsky, 1988).

Media Inventory

The media inventory data and methods are described in detail in A. Fischer (2019) and summarized here. After reviewing 29 Bengali newspapers' coverage of drinking water topics from 2014-2016, and assessing the major newspaper's coverage patterns since 1971, the *Ittefaq* newspaper was selected to be the source for this inventory due to its historic importance, continuously published articles since 1971 and being one of the most widely read newspapers based on circulation estimates. However, the *Ittefaq* was only available in hardcopy, and therefore required manual identification and coding in library archives by a trained research assistant fluent in Bengali. Every edition of the *Ittefaq* newspaper published from 1980-2016 was accessed and reviewed in the Government of Bangladesh's Central Public Library, the National Archives and the Central Library of Dhaka University. This review identified 3,211 articles which discussed "water" and with variations on "drink*", "domestic", "cholera", "diarrhea" and "arsenic" were coded. Their titles were translated into English in addition to being coded for basic information including date, section of newspaper and page number. Each identified article was coded for key words in text, main subject keyword, title key word and geographic scale using grouped key words listed in the Table 10. Further, a random subset of articles were coded for explicit identification of the Government of Bangladesh's (GoB, 2005, 2011) defined vulnerable groups including children, women, and poor. Further the articles were coded when they cited specific data, information or experts and the source of that information. Finally, articles were coded when explicitly allocating responsibility for the problem or risk to specific actors, including government agencies, international actors, or local private and municipal actors. Intracoding was

conducted at three points of the study with 84% reliability and intercoding at the beginning of the study.

Academic article inventory

The academic articles were identified through a systematic content search of multiple online digital archives using a key word search protocol. This builds on methods documented in previous papers tracking the evolution of research on drinking water security (Cook & Bakker, 2012; Gerlak et al., 2018; Madrueño & Tezanos, 2018). These included Web of Science, Scopus and OVID to seek the widest coverage of disciplinary journals and temporal coverage between 1980 and 2016. All searches include keywords “Bangladesh” AND “water” and with variations on “drink*”, “cholera”, “Diarrhea/diarrhoea” and “arsenic”. After identification, duplications were removed and any article which did not focus on Bangladesh as a primary spatial unit of analysis, such as articles which had cited Bangladesh as a reference to other country studies, were all removed. The total number of articles identified were 2,151. Of these, 134 articles did not provide an abstract, limiting portions of the secondary coding. Once identified, the researcher conducted the same coding scheme as the media inventory for main key keyword, geographic scale, and identification of the Government of Bangladesh’s (GoB, 2005, 2011) defined vulnerable groups, including children, women, and poor based on text in the abstract. The intracoding reliability was tested at the end of coding process.

Limitations of study

There are several key limitations of the compiled data sets which impact the analysis and interpretation of the findings. The first is that due to financial and time constraints required to digitize newspaper archives, the inventory was limited to 1980 instead of starting in 1971 after

independence due to. Second, the academic articles are compiled from multiple journal titles while the newspaper inventory is derived from a single title due to limitations of non-digitized media archives. Therefore, the two data sets are compared for temporal trends as a percentage of the total content not in aggregate number of articles or frequency of reporting on specific topics.

This leaves future work to expand the historic discourse analysis by including multiple newspapers, radio, television and the onset of internet media to compare representations and different publishing biases. Further opportunities exist to expand the academic article inventory beyond globally indexed papers and include more work from the Bangladeshi academy and grey literature, recognizing techno-scientific expertise beyond the international peer-reviewed papers. Further analysis on academic context is possible as we were only able to identify funding sources for 20% of the articles and thus did not include that component in the analysis.

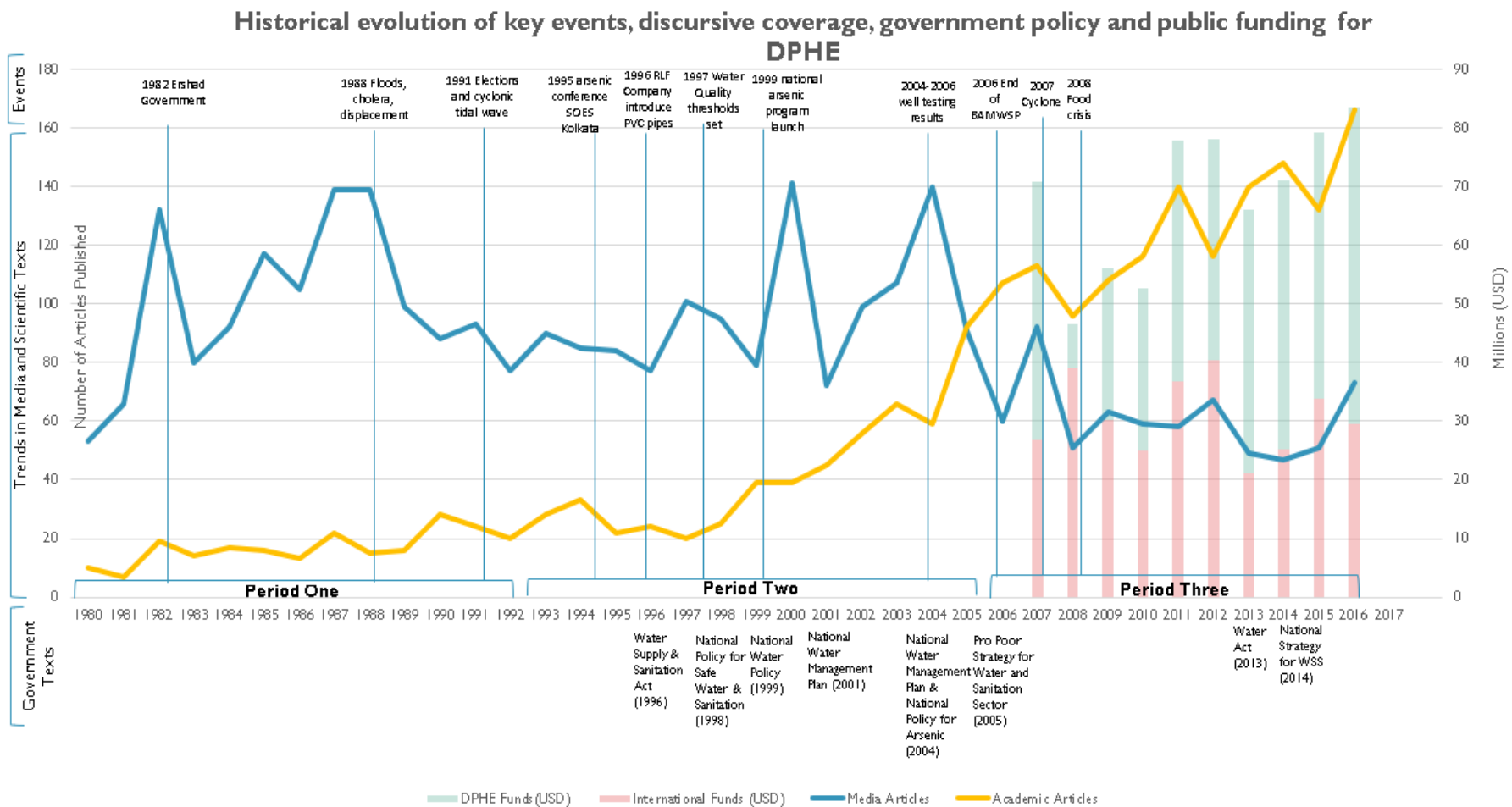


Figure 26 Evolution of media and academic journal articles on drinking water in Bangladesh in context of events, policy decisions, and government spending.

RESULTS

Post-independence institutional and infrastructure approaches to drinking water management

This next section synthesizes the evolution of the rural drinking water sector development in Bangladesh since independence in 1971. This analysis follows the temporal clustering identified by A. Fischer (2019) which categorizes three periods of institutional development and drinking water narratives. These periods are summarized in Figure 26 and include the aggregate results discussed in the next section. The periods include (1) post 1971 independence public provision of rural water infrastructure until the shift to competitive party-based elections in 1991; (2) public recognition of arsenic until the completion of the first phase of national arsenic monitoring programs in 2005; (3) a recent period widening the focus on multiple water quality concerns, supply reliability, and a growing focus on multi-user piped systems. This next section expands these previous studies by contextualizing the periods in relation to national development policies.

The prominence of drinking water concerns within Bangladesh is illustrated by the proportion of academic journal papers specifically discussing Bangladesh and drinking water relative to other Bangladesh and topics. As seen in Figure 27A, the total number of journal papers identified in an online database from 1980 to 2016 search directly discussing India ($n=285,636$) is almost 12 times larger than Bangladesh ($n=24,646$). However, within those country totals, the percentage of drinking water related journal papers is highest for Bangladesh (7% of total) compared to India (2% of total) or Myanmar (1% of total), seen in Figure 27B. This suggests that the relative to other

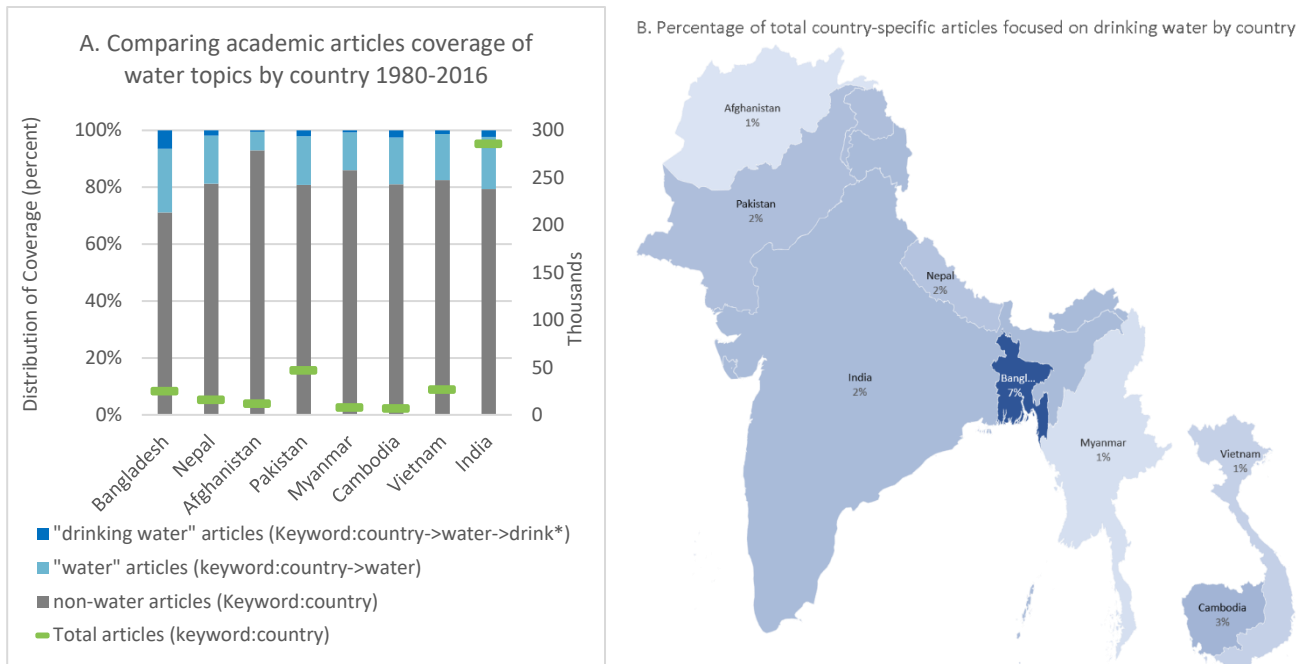


Figure 27 (A) Inventory of total published articles on drinking water by country from 1980-2016. (B) Distribution of drinking water specific articles as percentage of total articles

countries, Bangladesh's technical risk discourse places a greater proportional emphasis on drinking water concerns. Wider issues of resource management and climate change are not explicitly included in this estimate unless explicit references to drinking water. The annual number of these published journal papers continues to increase in Bangladesh, however the growth rate is slowing relative to neighboring countries, suggesting other countries increased focus on the sector. These figures show that the drinking water sector has been a prominent topic in academic texts.

Newspapers reporting on drinking water in Bangladesh do not have as proportionally high drinking water coverage as academic research. Relative to total number of published articles, the Ittefaq Newspaper, one of the oldest and continually published papers, printed an estimated average of 140 articles per day in 2014, 2015 and 2016. Less than 1 percent of those articles were identified to be drinking water related. A comparison of multiple newspapers and their focus on

drinking water shows significant variation in total number of drinking-water related articles between titles: Ittefaq and English-language papers printing a most articles (A. Fischer, 2019). Further comprehensive data on publication and circulation figures are needed to establish the variation of total coverage between multiple Bangladeshi newspapers.

The formation of Bangladesh's institutional design to manage rural drinking water has been influenced by these media and technical discourses. The combined narrative reflects the competing priorities of the post-independence socio-political agreements: social provisioning commitments to the rural populations and efforts to enhance international credibility through development project technical successes. Recent work by N. Hossain (2018b) contends that media coverage in the late 1960s and early 1970s reinforced the Bangladeshi independence movement. The coverage links the emergence of this risk mentality to the burgeoning nationalist Bengali media's efforts to depict the Pakistani authorities as unresponsive to Bengali needs after the 1970 Bhola cyclone which killed an estimated 250,000 people, framing specific actions as insensitive and insufficient (N. Hossain, 2017). N. Hossain (2018b) argues the publication of these newspaper articles helped boost electoral turnout resulting with the election of the nationalist political party, Awami League, and precipitating the declaration of independence by three months later (N. Hossain, 2018b, p. 190). During this period, the media coverage helped shape public expectations of the state and a redefined social contract. The media's use of a risk narrative within this specific politically driven context assigned blame for malfunctioning services to the previous institutions and reallocated responsibility to the new Bengali state under a public service provision model.

The second rural drinking water risk response approach emerged prior to independence with research and state-led projects aimed at addressing the endemic cholera outbreaks. At the time of independence, scientific research and national epidemiological surveillance systems reported some of the world's highest rates of maternal and infant mortality rates, with scholars linking these to the ongoing cholera outbreaks (M. U. Khan et al., 1981; Siddique et al., 1992). Scientific research in the 1960s and 1970s identified concerns that rural, and urban, populations remained heavily dependent on surface water instead of improved drinking water infrastructure classified as safer from microbiological contaminants (Briscoe et al., 1979). In a review of UNICEF and government rural water service projects, Black (1990) argued that the new government was seeking to achieve global development health targets by delivering improved water infrastructure access, mainly tubewells. This risk-response approach underpinned the following three decades of government investment. It further framed rural drinking water risks as controllable through the distribution of 'goods', both medical treatments and physical infrastructure.

The initial service provision model allocated responsibility to the central government under the purview of DPHE to be the distributor of infrastructure and hardware, provider of local maintenance services, and catalyst for technological innovation to improve production and reliability (Black, 1990; N. Hossain, 2018b; A. R. Khan & Hossain, 1989). This reflected the state-led provision of physical capital i.e. public handpumps as part of a broader development agenda established through the Marshall Plan seeking to establish legitimacy of the new government after independence.

For two decades following national independence, the central state-led provision of infrastructure approaches remained dominant until being disrupted by the political upheaval of the early 1990s which led to the re-introduction of competitive party politics and devolution of administrative authority. The growing population and decreasing budgets made it difficult to maintain the centralized service provision model for rural drinking water services while also increasing infrastructure coverage rates (Black, 1990). The devolution of drinking water services and actions started in the late 1980s under Ershad's government and was codified in the 1998 National Water Policy (GoB, 1998b). This policy formally shifted responsibilities away from DPHE, reallocating them to local government institutions, specifically Union committees. This period advanced cost-sharing structures and gave local committees decision authority to distribute subsidized public tubewells to groups of 10 or more private households. The new structure implied a reallocation of some risk responsibility away from public sector into private collectives or communal systems.

This change in the provision and responsibility paralleled a shift in technology and private markets, specifically away from government control over modes of production. Supported by the World Bank and USAID global financing initiative, implemented by UNICEFs, a locally fabricated No. 6 handpump was introduced to the local market in the 1980s, reducing costs and increasing availability by replacing imported parts and using less expensive cast iron composites (Black, 1990). This was followed by introduction of non-rusting polyvinyl chloride (PVC) pipes in 1996 by the local Bengali RFL company. Although growth of this market is initially attributed to demand from the irrigation sector, these technological innovations quickly translated into the domestic sector increasing market availability for private households self-supply (Akteruzzaman, Kondo,

Osanami, & Doi, 1998). By 1992, a national survey estimated 71% of the roughly 2.5 million tubewells were private, a rate that increased to 91% of the projected 11million tubewells by 2006 (BBS/UNICEF, 2009; UNICEF, 1993). Public investment declined relative to the expanding private investment, facilitated by availability of handpumps on local markets.

Rural drinking water service approaches were again disrupted and redefined by the uncertainty of arsenic contamination across many areas. This period was marked by the official recognition of arsenic concerns by the government and media in 1992 and extends through the national testing initiatives of the early 2000s which labeled tubewells with red or green paint to reduce spatial and user uncertainty (Johnston & Sarker, 2007). The results challenged the institutional model focused on provision of goods through infrastructure: groundwater safety became highly uncertain without technical monitoring and verification (Caldwell et al., 2003). The government introduced water quality thresholds in 1997 which established estimates of exposure in the millions, and building on national testing projects, delineated spatial zones of greatest concern (Smith et al., 2000). However, the rate of growth in new tubewells, largely private and shallow continued to increase (van Geen et al., 2014), suggesting the rural water sector was continuing to shift towards private individuals (Fischer forthcoming).

In the most recent phase, 2006-2016, government investment to the drinking water sector continued to expand, as seen in previous Figure 26, in contrast to the declining of media coverage. Many of the DPHE funding project documents were framed in the context of expanding “arsenic safe” infrastructure options, primarily deep tubewells and public multi-user piped systems (Rammelt & Boes, 2005). The government estimated roughly 11million tubewells existed in 2009, 1.3million were identified as publicly funded (GoB, 2011), an increase from the 185,000

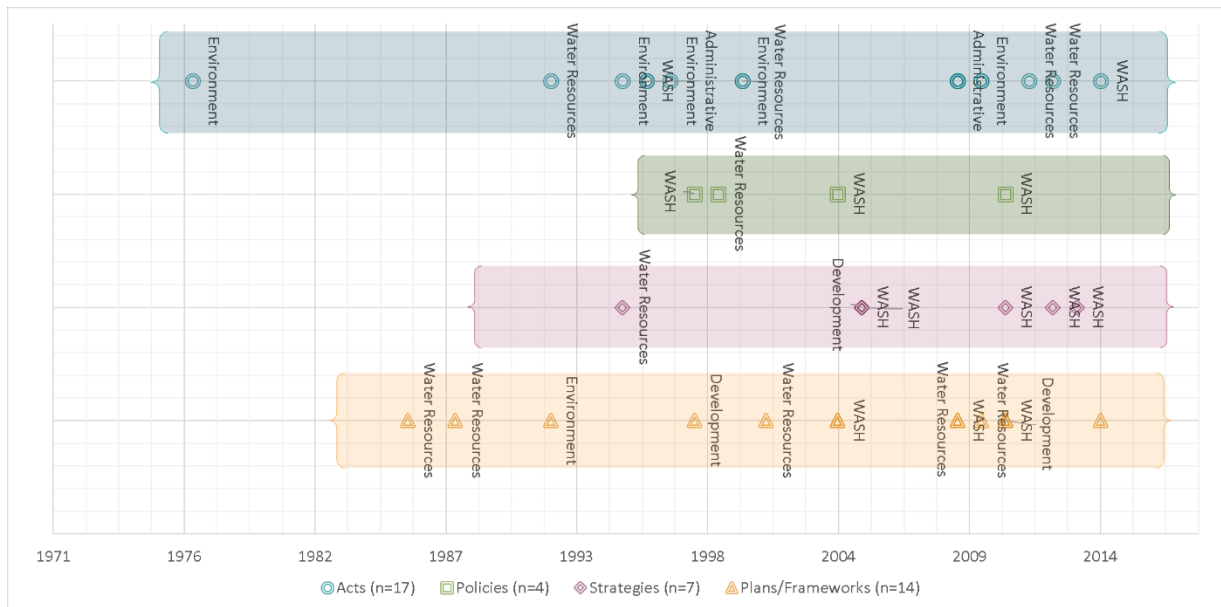


Figure 28 Summary of Government Acts, Policies, Strategies, and Plans in the drinking water sector.

estimated in 1971 (Black, 1990, p. 21). Government policy documents (GoB, 2001, 2011) identified a strategy for the rural water sector to pursue internationally supported models of community-based participation (H Lockwood, 2004) through local government allocation of subsidies for “arsenic safe” infrastructure to private self-organized collectives, predicated on what Sultana (2012) describes as self-regulated co-investment model. This transition of institutional structures transferred responsibility away from publicly managed water points, without identifying rules and structures in response to manage rapidly increasing private systems.

These key periods of formal responsibility are codified in the national acts, policies and strategies, summarized in Figure 26, starting the mid-1990s. The formalization of rules rapidly advanced the process of transferring risk-responsibility away from the central government agencies towards local councils and collective risk-sharing mechanisms of private collectives of user groups. The analysis of policy documents further revealed the distribution of sector authority forming since

the 1980s as an increasing number of formal acts and plans are passed to formalize responsibilities distributed between departments at the national level including water quality standards in the Ministry of Environment, water resource management at the Ministry of Water Resources, and infrastructure planning and financing residing with the Ministry of Local Government, Rural Development and Cooperatives (LGD). The Department of Public Health and Engineering (DPHE), a sub-agencies to the Local Government Division, maintained the role as the focal administrative agency for drinking water services. However, DPHE officials did not have the authority to regulate or enforce water quality or set and monitor extraction rates.

As discussed further below, this raises questions around how media and academic texts reinterpreted the shifting institutional dynamics of service provision in relation to water quality risks and the uneven distribution of public and private responsibility for infrastructure.

<i>Drinking water discursive themes and keywords</i>	Total Title Number (n) M=Media A=Academic	Media (n=3211 articles in Ittefaq)	Academic (n=2151 articles across journals)
<i>Health: Cholera, Diarrhea, Legionnaires', Typhoid, Jaundice, arsenicosis</i>	n(M)= 1025 32% of total(M) n(A)= 930 43% of Total(A)	Diarrhea largest, and continuously reported, main article topic. Limited comparative coverage of arsenic impacts mostly focused on reported cases. Cholera ceases being reported after mid-1980s. Focus on morbidity and mortality.	Majority of academic articles pre1995. Cholera articles spike in 1993/1994 and focus on treatment including ORS and vaccines. Cholera treatment reflects scientific research successes but not reflected in media. Arsenic poisoning focuses on symptoms and impact, not treatment.
<i>Water Quality: E-Coli, Arsenic, Salinity, Iron, Heavy Metals, Water Quality General</i>	n(M)=476 15% of Total(M) n(A)=814 38% of Total (A)	Arsenic dominant topic focused on spatial distribution Many titles use general water quality descriptions. Microbiological contamination was minimal in titles. Heavy metals were not covered in titles of media articles.	Arsenic dominant topic focused on cause and later distribution. Microbiology was second largest followed by heavy metals. Other concerns included manganese and iron appeared in titles of academic articles.
<i>Infrastructure: Tubewells (Deep and Shallow), Piped, Pond/Surface, Rain Harvesting, Pond Filters</i>	n(M)=77 2% of Total(M) n(A)=72 3% of Total (A)	Majority of article text discuss tubewell infrastructure but rarely as main subject. Most articles published before 2007.	Tubewells are not widely covered. Same number of articles covering surface water, piped systems, pond sand filters and rain water harvesting post 2005.
<i>Access: Access to Improved Infrastructure, Affordability</i>	n(M)=118 4% of Total(M) n(A)=23 1% of Total (A)	Half of access-related articles are in letter section requesting service connections. Primarily focused on gaps in coverage and citizen engagement.	Minimal focus as main topic. However larger emphasis and citation in abstracts on the achievement of the Millennium Development Goals.
<i>Functionality: Infrastructure Functionality, Supply Reliability, Efficiency</i>	n(M)=529 16% of Total(M) n(A)=15 1% of Total (A)	Third most frequent topic in article title and consistently reported until 2006 decline, in proportion to other topics; most reported in country section.	Only 2 articles directly focus on functionality and few on supply reliability. Perhaps higher in grey literature from technical but no academic focus except on new innovations in response to arsenic 2000.
<i>Administration and Management Politics, Budget, Public Communication</i>	n(M)=197 6% of Total(M) n(A)=43 2% of Total (A)	Steady but small increase articles across years. Large gaps in years covered. Budget topic for projects and utilities discussed along with increasing coverage of politics.	Limited total number, increasing after 2003 with focus on arsenic response.
<i>Environment: Flood, Drought, Climate Change</i>	n(M)=64 2% of Total(M) n(A)=69 3% of Total (A)	Flood is the most frequent subject in this category with no articles directly discussing climate change in their title.	Climate change is the most frequent while drought is not directly mentioned in any article titles.
<i>Awareness and Communication</i>	n(M)=17 1% of Total(M) n(A)=65 3% of Total (A)	Media did not cover behavior and awareness as a main topic of articles.	Academic articles more specifically explore awareness of water quality and arsenic risk, with linked behavioral responses.
<i>General/ Unspecified</i>	n(M)=708 22% of Total(M) n(A)=120 6% of Total (A)	Media general drinking water most frequent until 2001 with decline. Water quality unspecified increases after 2006.	There is a significant increase in multi-thematic and unspecified titles after 2005.

Table 11 Summary of combined media and academic inventory

Contesting competing voices in the production of risk narratives

The two texts diverged in coverage timing and trends of risk production: the Ittefaq newspaper declined in aggregate reporting after 1980 while techno-scientific articles steadily increased annual totals, as seen previous Figure 26. The newspaper inventory reveals that after 2005 there was a 40% decline in drinking water articles from the previous 25-year average. This occurred during the period when the newspapers' revenue fully shifted away from controls set by the Government into a free-market competitive advertising model, changing reporting incentives and styles, not the drinking water sector.

The decline in media contrasts a period when the government was taking extensive policy and project action to address water safety and insecurity: releasing the results from a national arsenic testing and mitigation project; formalizing multiple water sector specific legal instruments, polices, strategies and plans; and reporting successes of early achievement of global drinking water targets including the Millennium Development Goals on improved access. The declining coverage suggests a break from previous alignment of government and political agendas impacting interpretations of the mass media's representation of risks in both periods. It also implies drinking water security narratives were no longer as prominent relative to other concerns in the media, and thus there is less public confrontation of risk responsibility despite growing formal sector policies.

In contrast, academic discourse maintained a steady and continued increase in the number of publications, with the largest jumps after periods of major international projects and investments in national monitoring systems, specifically arsenic. Academic articles require peer review which

delays publication, creating a process that is largely disconnected from the weekly news cycles and specific events reported in media. While the Ittefaq newspaper publication trends reflect interannual peaks and dips in the number of articles responsive to major drinking water-related events, this inventory suggests an increasing allocation of scientific attention with sustained attention after major events.

The academic coverage reflects increasing concerns allocated to drinking water issues in contrast to decreasing aggregate coverage and declining prominence on Ittefaq's frontpage. The two texts divergent patterns have clear temporal signatures indicating changing financial incentives and political agendas. This creates what Beck described as the competing risk rationalities, one increasingly problematizing drinking water and the other diverting attention to other concerns.

Constructing cholera and diarrheal diseases as a controllable health problem: 1972-1992

Although the two texts appear to have markedly different aggregate trends, there have similar patterns in the narrative's epistemological origins and content focus. Both bodies of text emerge largely from health-focused diagnostics, reflected in the high proportion of articles quantifying the past or potential human impacts as the main foci of the articles. The journal article inventory suggests that the majority (n=933 or 43%) of the techno-scientific papers were published by journals focused on health and medicine, inviting a specific readership and disciplinary response.

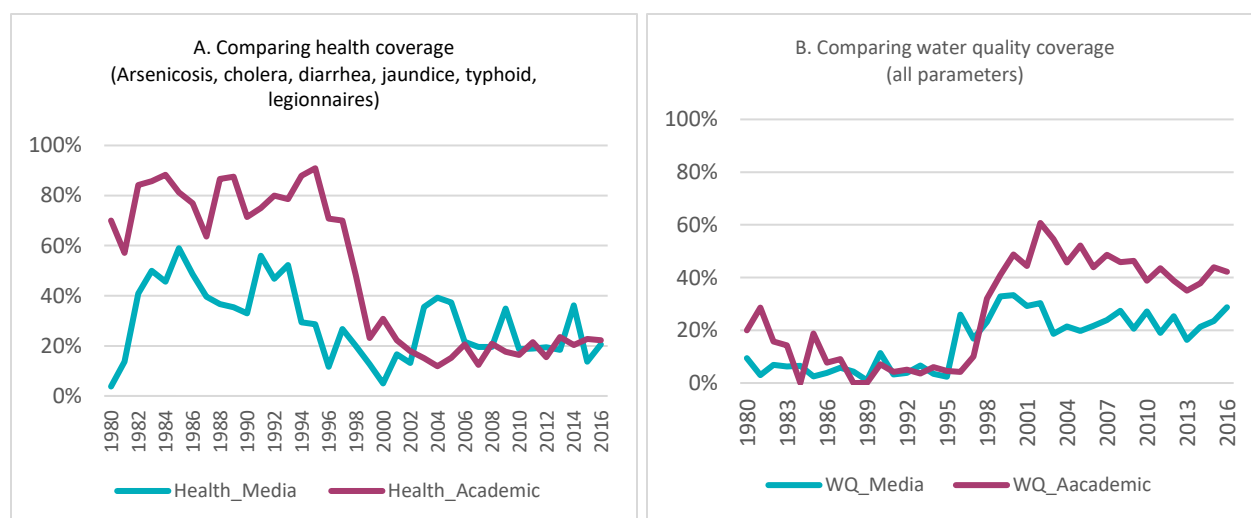
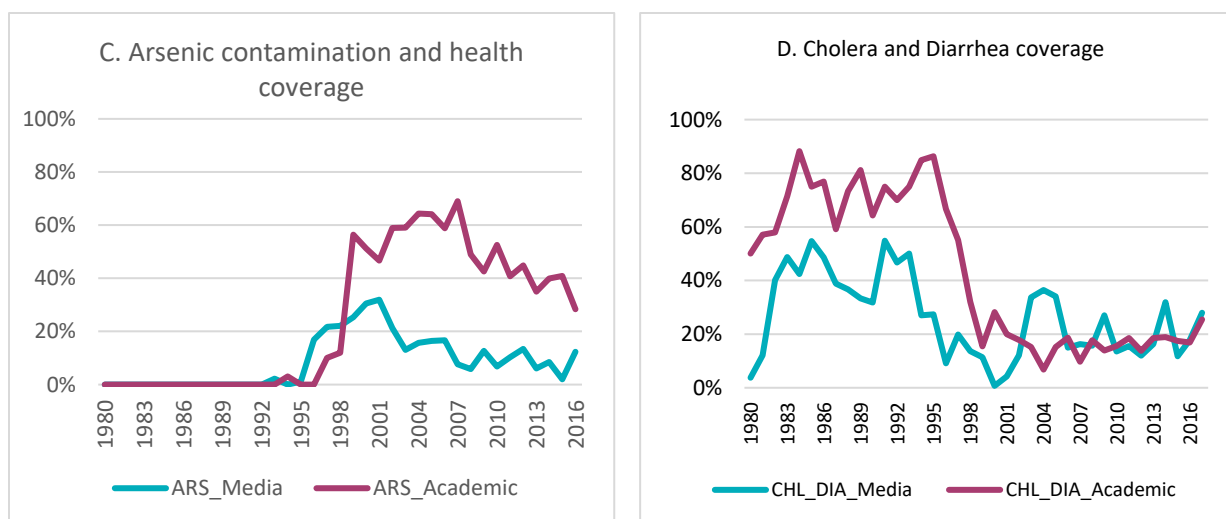


Figure 29 Thematic variation of article coverage of health and water quality topics as percentage of yearly total drinking water articles 1980-2016. Two inventories are not comparable by total number of articles.



From a temporal perspective, academic discourse published over 60% of its' drinking water articles with the main keyword focused on the diagnosis and treatment of the health effects of cholera until 1997 when it dropped to below 20% per year, as seen in Figure 29A, a trend disrupted by the arsenic crisis which reversed focus onto water quality concerns as seen in Figure 29B. This is mirrored by the largest thematic group of Ittefaq articles specifically focused on health topics (n=1025 or 32%). This focus on health reflects Dean's categorization that one of the main risk rationalities depend on the quantification of clinical management and epidemiological risks (Dean, 1999a). This allowed drinking water risks to be discussed through the lens of health literature as controllable through diagnosis and treatment until the late 1990s.

This framing had, however, impacted decades of previous sector approaches. Cholera emerged within national discourse well before the 1971 independence and had become a global development policy priority (Black, 1990). However, the ongoing concerns were not identified by political historians in the same nationalist narrative as flood control, or directly linked to the social contract of state after independence (N. Hossain, 2018b). Instead, cholera prevention, and later treatment, has been identified as a core element of the country's development research agenda successfully producing knowledge exports as a source of international standing. One reflection of this continued technical concerns is found in the sustained investment by the International Centre for Diarrheal Disease Research, Bangladesh (icddr,b) (Alam et al., 2017) which has arguably saved millions of lives in Bangladesh, and more globally, through the health diagnosis and treatment interventions, such as oral rehydration therapy (ORT) and vaccines, and the controlled trials to determine efficiency of risk reduction approaches.

The content of scientific literature around cholera reflects a risk-rationality which focused on techniques to control of outbreaks including research on reducing exposure through transmission, seasonality, and role of drinking water and sanitation infrastructure, specifically surface water, in the 1970s and 1980s (Briscoe et al., 1979; Glass et al., 1982; M. U. Khan et al., 1981); followed a focus on mitigating danger through health treatment options in the mid-1980s and early 1990s (Bhattacharya, 1994; M. A. Islam, Mahalanabis, & Majid, 1994); and preventing problems through strain identification related to vaccines in the mid-1990s (M. S. Islam & Bateman, 1994). This built a controllable narrative driven by technical advances to provide key services, both health treatment and infrastructure. The findings further reinforced political priorities to reduce mortality rates and increase tubewell access rates, two nationally measured figures. The initial cholera risk narrative was thus constructed around a view of controllable concerns, located in a time and space, and remedied through the distribution of tubewells.

By the late 1980s, the *Ittefaq* ceased printing any references to cholera in its articles, replacing them instead with reports of “severe” diarrhea (“Diarrhea and cholera,” 1989). This euphemism shifted attention from a contaminant articles previous framed in terms of mortality rates to a generalized health outcome discussed as treatable cases. After decades of sector interventions which had not eliminated the risk, this suggests an effort to renegotiate a politically controllable narrative. There was almost no coverage in the *Ittefaq* of the microbiology and source of contamination: instead articles focused on number of sick and spatial extent of the outbreaks. The newspaper further published a significant number of stories emphasizing infrastructure access and functionality, which contrasted academic focus on health treatment options in response to cholera outbreaks. The two texts’ discursive attention during the 1980s and early

1990s reflects a wider agenda: reinforcing the Government's services through public investment in infrastructure and the country's role as a hub for innovations in the health sector and rural development.

Constraining arsenic risk and reallocating blame to nature: 1993-2005

The risk management approaches focused on provision of tubewells and public health services was disrupted by the discovery and deep uncertainty of arsenic contamination across broad geographic regions of the deltaic zones. This began in the 1980s but wasn't brought into the sphere of public discourse until 1993, which we mark as the transition point to the second phase of drinking water discourse, aligned with the political transition of the 1992 election. Grey literature, including academic conferences and unpublished technical studies, identified the presence of high levels of arsenic in West Bengal, India as early as 1983 (Garai, Chakraborty, Dey, & Saha, 1984) and suspected cases from Bangladesh in 1987. However it took a further decade for the first peer-reviewed journal article to be published directly identifying arsenic concerns within Bangladesh (Dhar et al., 1997). This was four years after the *Ittefaq* printed their first story calling attention to concerns about border regions, with only a handful of follow-up articles published again until 1996 ("Risk of arsenic pollution in tube well water of 13 boundary side areas," 1993).

The watershed moment for *Ittefaq* coverage began in 1996, arguably triggered by the technical conference at the Kolkata School of Environment Studies, with a significant increase in number of articles, mainly discussing arsenicosis in relation to skin-based observable cases or spatially specific locations tested for contaminated water. The articles specifically characterized the public

reaction as a national crisis (“Arsenic panic in whole country,” 1996). The media faced a challenge to communicate the invisible risk with no specific cure, relying on government test results and experts to legitimate concerns to influence behaviors (Johnston et al., 2014). This period marks a significant shift in discursive attention away from previous cholera concerns towards uncertainty of arsenic, both by increasing aggregate number of articles discussing drinking water quality and re-directing attention from other related topics. The nature of the risk had changed: the acute risks of cholera, one of the quickest diseases to cause symptoms including death was being replaced by portrayals of arsenic as a slow cumulative risk, with limited immediately visible or tangible symptoms and needing outside experts’ abilities to forecast and allocate risks.

Within the initial coverage of arsenic, both texts sought to navigate and interpret the uncertainty around the source and spatial distribution of contamination. The allocation of blame oscillated between consequences of human actions and natural processes of hydro-geologic sediment: Ittefaq initially identified Indian industrial waste followed by concerns of agricultural irrigation over-abstraction ; scholars have argued about both the environmental and socio-technical origins (Bose & De, 2013; “Dangerous arsenic level in tube well water in 8 Zillas,” 1995; Nickson et al., 1998; Sultana, 2012). The uncertainty presented a new imperative for the monitoring systems to shift away from quantifying human health impacts and access to tubewells to one which monitored environmental uncertainty and multiple dimensions of water quality. The technical expert system of diagnosing the arsenic risk was further contingent upon the state’s adoption of water quality safety thresholds which were formally adopted in 1997, defined as 0.05mg/l (Bose & De, 2013; DoE, 1997). Within a short period of 1995 to 2005, the Department of Public Health and Engineering (DPHE) and British Geological Survey (BGS) conducted national studies of

tubewell water quality expanded from regional tests (n=3534) into a national blanket survey of over 5 million water points through the Bangladesh Arsenic Mitigation and Water Supply Project (BAMWSP) (Johnston & Sarker, 2007; Kinniburgh & Smedley, 2001; Smith et al., 2000). The results shifted techno-scientific analysis to directly allocate blame for the contamination of groundwater to natural causes from centuries of sediment runoff from the Himalayas, not the unintended consequences of the proliferating, mostly private, tubewells (Kinniburgh & Smedley, 2001; van Geen et al., 2014). However, the water quality testing was limited to one-time projects and did not convert into a continuous monitoring system for new installations, specifically private ones outside the government's control.

Furthermore, the two texts showed incongruent patterns in their allocation of severity to the arsenic contamination, suggesting what Beck labels winners and losers of risk production. The *Ittefaq* utilizes article placement, specifically on frontpages, to signify and contextualize articles as important within the broader set of national concerns. Drinking water was not a frequent topic on the frontpages of the *Ittefaq* between 1980 and 2016 (14% of the total identified articles were on the frontpage). Cholera and diarrhea were the most frequent topic, 44% of those frontpage articles. Arsenic contamination and arsenicosis consisted of 4.75% of the frontpage articles, despite being labeled a national crisis. This reflects a different conceptualization of severity, what Entman (2007) described as salience, and reflects how the two topics featured within the broader political agenda.

Arsenic rarely provided the same event-based reporting as cholera outbreaks and treatment. Academic articles often framed the relevance around the scale of potential risk facing citizens in Bangladesh, referencing the scale of population potentially exposed to arsenic or comparing the

magnitude as higher than in any other country (P. Atkins & Dunn, 2007). However, the difficulty to quantify arsenicosis related-health impacts left academic studies estimating the proportional hazards of exposures and impacts based on specific studies, such as Health Effects of Arsenic Longitudinal Study (HEALS), not the same vital statistics or administrative data as previously used for diarrhea and cholera (Argos et al., 2010). This was further reflected in Ittefaq's spatial allocation of articles, a majority of diarrhea/cholera articles focused on Dhaka while arsenic was more evenly distributed across Divisions. The nature of academic analysis thus varied significantly from newspapers seeking tangible and immediate events for stories. While Ittefaq is only one source of news in Bangladesh, the minimal coverage on the frontpages of the Ittefaq suggest that arsenic was harder to explain, with no immediate collective agreement on scale, impact, solution, or even preferred response, compared with cholera which had immediate measurable impacts and clear outbreak control procedures.

Arsenic therefore presented a different challenge to the socio-political and economic development agenda compared to cholera and diarrhea which were portrayed as controllable through physical infrastructure, behavioral decisions around hygiene, and health treatment. The Government of Bangladesh had committed itself to achieving global development targets aimed at increasing access to improved drinking water infrastructure, defined in a way which included all tubewells(BBS, 2015). The arsenic crisis presented a situation where the previous service provision approaches were no longer reliable as safe. The 2004 national Arsenic Mitigation Implementation Plan set a priority to develop surface water over groundwater and was premised on a collective model of shared safe water systems and allocation of responsibility to the Local Government Institutions(GoB, 2004b). This change in cause-effect relationships of previous eras

were disrupted by arsenic uncertainty, challenging the established social, economic and political order underlying the state's risk management approaches. This suggests concerns were shifting away from a service model focused on the distribution of infrastructure access into what Beck argues is one managing the distribution of "bads" or risk mitigation. This shift in risk construction was reflected in academic texts, but not as explicitly in the *Ittefaq* articles which remained focused on infrastructure reliability and blaming arsenic on natural causes.

Confronting rural drinking water insecurity and the challenge of reconstructing risk narratives: 2006-2016

After the major investments in arsenic mitigation and analysis in the early 2000s, the media's coverage suddenly declined in frequency and the nature of coverage shifted to a more complex portrayal of water quality concerns, definitions, and measurement targets. This period is marked by the formalization of water quality monitoring protocols which required testing of newly installed rural water points across multiple parameters. This responsibility was allocated to regional DPHE engineers to conduct the testing of public water points and a random sample of private systems (DPHE, 2005, p. 25). Mirroring this shift in policy focus to water quality, as seen in Figure 30E, both texts proportional coverage of unspecified and multidimensional water quality topics spiked after 2006. Academic texts allocated a greater percentage of analysis to microbial-specific contamination in the 1980s during the height of cholera responses (Figure 30F) and increasingly discussed heavy metals and pollution in the 2000s (Figure 30G). Although these remain a limited percentage of the total articles compared to arsenic, it does reflect a shift in attention and main concerns which parallel shifts in policy focuses toward piped systems relying

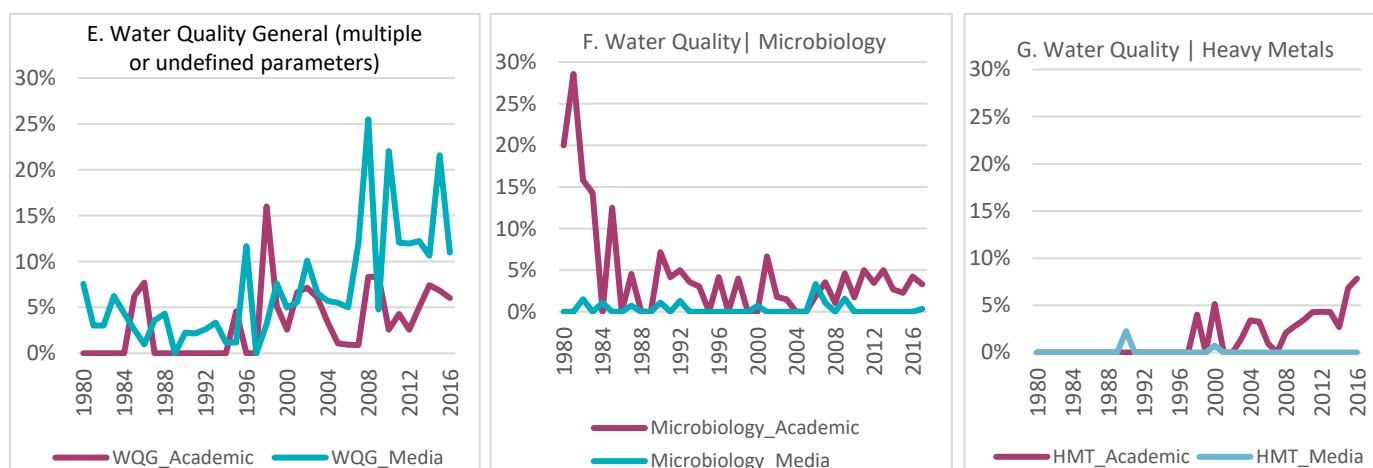


Figure 30 Coverage of water quality topics (main key word) as percentage of total year's drinking water articles. M=Media (n=3211); A=Academic (n=2151).

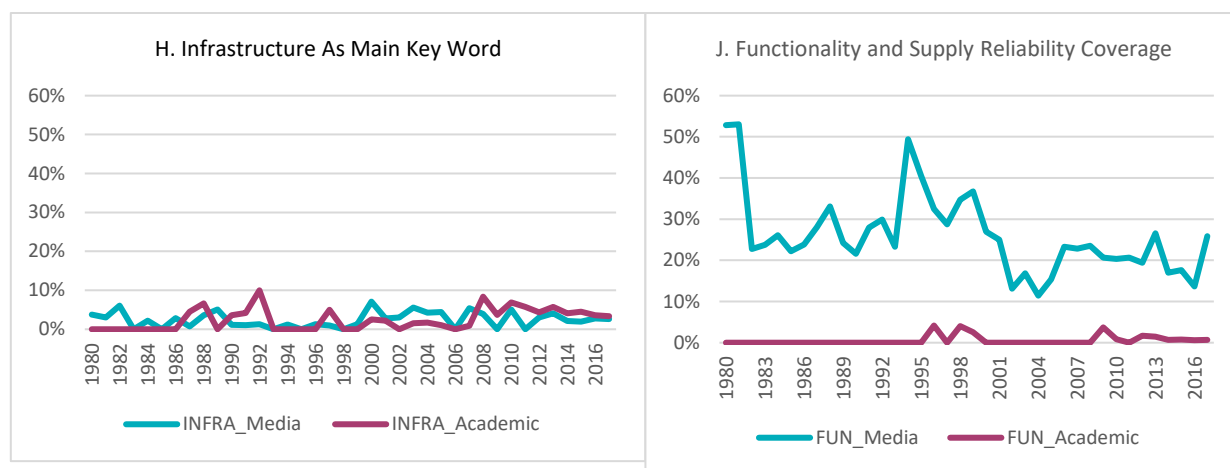


Figure 31 Coverage of infrastructure and functionality specific topics (main key word) as percentage of total year's drinking water articles, 1980-2016. Media n=3,211. Academic n=2,151..

on surface water, suggesting that after diarrheal diseases were de-problematized, research moved to newly tractable problems (Motaleb, Ahamed, Hossain, & Yniguez, 2014).

While arsenic disrupted previous rural water sector approaches focused on tubewells, the coverage of heavy metals and chemicals contaminants problematized new risks around safety of piped water schemes by identifying unintended consequences of economic development and industrial production as pollutant sources for surface water. However, while arsenic was frequently discussed in both texts, heavy metals was non-existent in the media and limited in academic texts. Further, neither texts problematized infrastructure type as the main concern, rather the media emphasized functionality and supply reliability in relation to infrastructure, seen in Figure 31H. Technical literature may be better represented outside of peer-reviewed journals. However, this suggests a divergence between the texts in relation to interpretation of what Beck(2006b) describes as reflexive risk problematization, specifically linking the cause and effect of water safety to unintended consequences of national development successes and response decisions to manage the new concerns.

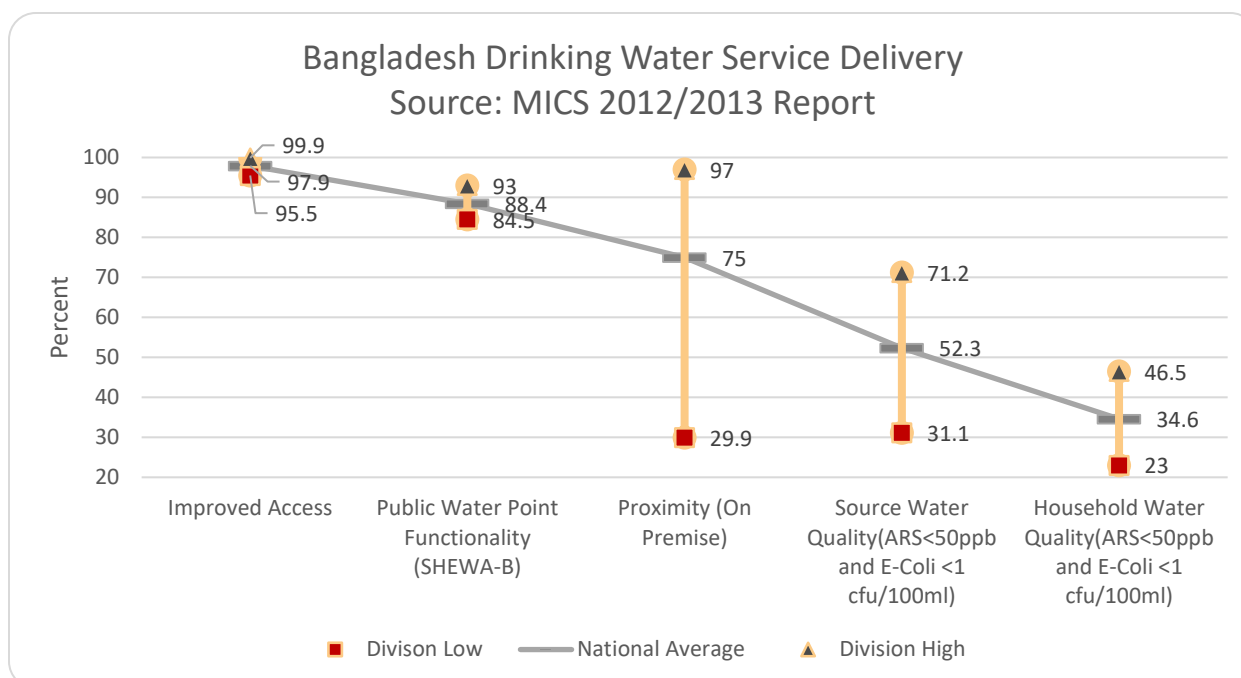


Figure 32 Proportion of households meeting criteria for safe water services as high and low across Division's averages.
Source: (BBS, 2015; UNICEF, 2014)

This period of discourse occurred while global water security definitions and monitoring capability expanded beyond the dichotomous categorization of infrastructure-bound targets of the Millennium Development Goals into the sequence-based targets aimed at safely managed service provision of the Sustainable Development Goals (Bartram et al., 2014; Bradley & Bartram, 2013; Wescoat, Fletcher, & Novellino, 2016). This global definitional transition occurred in parallel to the introduction of new water quality measurements initially piloted in Bangladesh's national household surveys, specifically the 2008 Multi-Indicator Cluster Survey (MICS). The 2012/2013 survey round standardized this approach, again a demonstration of Bangladesh's contributions to global development methods.

The results however, shown in Figure 32, redefined progress across the multiple targets and suggest performance of water sector services declines as evolved targets are measured at wider scales and technically defined thresholds applied (BBS, 2015). Improved access, with its specific

definition of infrastructure types, shows national results of nearly 100% of the population meeting the goal, a reflection of decades of government and media focus on these issues. Functionality and reliability, which was a major focus of the media and policy in the 1980s, is not systematically measured, however a one-time national assessment of public water points reports comparatively high performance relative to other indicators. Proximity to water source targets as modifications to the access ratio measurements reported a national average of 75% of respondents, compared to 62% average for South Asia(WHO/UNICEF, 2017). Water quality, measured in two parameters below, shows the lowest performance on average. This transparent reporting of national survey data reflects which measurements are rendered visible in public forums thus interpreted into risk narratives. While articles did not explicitly cite these data, there is an observed pattern that increasing coverage of both academic and media articles discussing water safety and multi-parameter quality occurred in the same temporal period as expanded national reporting. As Wescoat et al (2016) point out in India, these national monitoring platforms are not yet practical tools for decision-making across governance systems. However, the release of multi-parameter water quality data as part of national surveys linked to global development targets, corresponds to a shift in media and scientific narratives. This suggests that both national policies and international targets coalesced attention on water safety parameters, reflected in the media's coverage.

During this period, government-funded projects continued to allocate resources to expand the network of “safe” infrastructure options, specifically piped schemes and subsidized deep tubewells. However, private investment in individual water points continued to increase at exponential rates, suggested by through the declining ratio of people to tubewells shown by

Fischer et al (Forthcoming). By 2015, DPHE narrowed their testing responsibility to publicly installed water points, leaving private points water safety testing responsibility at discretion of individual owners (DPHE, 2015b). Future research is needed to identify how these testing protocols and results influence public discourse and translate into rural awareness, however initial perspective suggests that as more information became available, the aggregate media coverage and prioritization declined.

Component		1972-1992	1993-2005	2006-2016
Risk construction	Political economy of mass media	Government control and national agenda	Party politics and ideology	Market competition
	Focus of mass media	Tangible past events i.e. number of sick, malfunctions	Uncertain futures i.e. arsenic exposure	Unexpected stories and interpreting complexity
	Techno-scientific focus	Diagnosis of transmission and cause (cholera and diarrhea prevention and treatment)	Diagnosis of origins and distribution of bads (Arsenic contamination and exposure, limited treatment)	Reflexive solutions (safe infrastructure technology and vaccines)
	Resulting problematization (Type of risk)	Controllable: Spatially and temporarily defined	Uncontrollable: Spatially and temporarily uncertain	Reflexive: Anthropogenic with infrastructure solutions
	Allocation of blame	Society	Nature	Nature-society
	Discursive allocation of responsibility	Central state	Local government and private collectives	Polycentric government and individuals
Risk Response	Institutional design	Centralized	Decentralized	Hybrid and market-based
	Rural water supply infrastructure	Shift from unprotected surface water to public tubewells	Collective tubewells, Government shift to deep	Private tubewells and arsenic-safe public systems
	Management Approaches	Provision of goods (Health services and tubewells)	Prevention of bads (Arsenic mitigation)	Provision of goods (Arsenic “safe” infrastructure)
	Administration and regulation	Top-down command and control with regional DPHE engineers	Top-down finance, decentralized responsibility, and formalized water safety thresholds	Regulated public-private piped and collective systems. Unregulated private self-supply
	Subject of national drinking water sector measurement	Human health (mortality) and infrastructure access (tubewell ratio to population)	Human health; improved infrastructure access and proximity; and arsenic contamination	Multiple risks of safely managed services including water quality and reliability
	International development agenda	International Drinking Water and Sanitation Decade (Handpump technology)	Millennium Development Goals (Improved access)	Sustainable Development Goals (ensure availability and sustainable management of safe water and sanitation for all)

Table 12 Evolution of drinking water risk-response dynamics in Bangladesh

DISCUSSION

The uncomfortable transition from public to private responsibility: an overlooked result of devolution and challenge of self-confronting regulation

The interplay of two bodies of texts in relation to formal government policies reveals how the public risk narrative related to drinking water in Bangladesh was constructed, contested, and confronting over nearly five decades. The results found how the narrative constrained where blame was allocated, how the positive risk logic focused on provision of goods as a form of risk mitigation and control over the emphasized dangers was politically convenient, and where responsibility is allocated in relation to constructed narratives. These are all factors linked to how institutions evolve. The inventories were interpreted using risk discourse filters in relation to formal government policy texts to uncover how institutional risk logics remained aligned around the provision of public water infrastructure and health treatment as the preferred response to cholera, arsenic, and water supply variability, not service performance or risk prevention.

The analysis identified and aligned these transitions within the wider political economy of development, summarized in Table 12. The socio-technical drinking water risk narratives remained clustered around the three chronological periods previously identified by A. Fischer (2019). The risk discourse filters suggested that the construction, deconstruction and reconstruction of risk narratives aligned to the social contracts made by the Bengali state post-independence to ensure rural drinking water security and maintain the rural-elite political bargains through continued service provision (N. Hossain, 2018b). By deconstructing the relationship of two key discourse fragments, both technical and social narratives advanced this positive risk logic of provision of services and institutional responsibility allocated to the state.

We show that the post-independence drinking water security narrative framed the core concern around cholera and diarrheal disease as a manageable and treatable danger. The newly independent Bengali government responded with the promise of widely available and continually functioning public tubewells, leading to the exponential rate of growth later characterized as a national development success and attributed to government actions (Fischer et al Forthcoming). This narrative was sustained through both academic studies of cholera mitigation options through oral rehydration and health services and media's coverage of central government efforts to distribute physical goods, i.e. tubewells and urban piped water schemes. The attention constructed drinking water problems as the responsibility of a top-down government structure.

The 1970s and 1980s risk narrative, framed as controllable, was disrupted by the public acknowledgement of arsenic in aquifers in the early 1990s. The media played a role in interpreting the complexity of uncertainty but had limited voice contesting the previous allocation of responsibility which had been slowly decentralized to municipalities and from public to private collectives in the late 1980s and early 1990s. The uncertainty of blame and exposure challenged the narrative of controllable drinking water dangers and drove academic research to classify new types of safe infrastructure. This effort linked into the Government's blanket water point testing in the early 2000s to help reduce household and technical uncertainty (Johnston & Sarker, 2007). Despite the completion of public sector studies and academic research identifying the uncertainty and high probabilities of exposures to arsenic in shallow tubewells, government service provision of 'safe' public water points continued under the same service model in rural areas while the privately installed water points in rural areas continued to grow exponentially (Balasubramanya et al., 2014). The governance approaches remained, or were reconstructed,

around the previous risk-response paradigms as controllable through the provision of infrastructure defined as safe.

The final period of discourse, post-arsenic crisis and during the transition from MDG into SDG global development targets, reconstructed a narrative which recognized the complexity of nature-society interactions but had limited discursive self-confrontation about the unintended consequences of previous development policies, specifically tubewells linked to arsenic exposure. The national risk narratives after 2006 provided minimal recognition of private markets which already outpaced public provisioning and were evolving beyond the states direct control. The risk discourse filters suggest that neither body of text directed extensive attention to what had become the dominant service model in the rural drinking water sector: self-supply of tubewells, or self-organized individuals and households privately financing and managing water points outside of state allocated responsibility. This limited the responsibility for collective oversight or action to prevent or mitigate water quality or reliability challenges. If allocation of blame had been problematized differently, it would challenge the institutional apparatus to recognize the need to regulate private self-supply systems in addition to public multi-user systems. Shifting to regulate the water quality of private infrastructure would disrupt the previous allocations of responsibility with the potential to restructure government involvement with rural constituents away from providing a service to taking them away.

A self-confronting risk narrative would challenge the decades of positive risk logic of provision of goods and imply a needed institutional shift towards a model managing the consequences of past decisions, what Beck (2006b) argues as reflexive regulation. The application of the risk discourse filters to multiple bodies of text identify the institutional risk-management logics: preferencing

concerns with actionable solutions, creating risk logics focused on distribution of access, and maintaining control of the narrative by limiting the self-confrontation of blame, in the case of arsenic to nature, thus avoiding difficult socio-political debates around extent of responsibility. This left responsibility allocated to the Government for public water points and failed to problematize the rapid growth of unregulated private and individual water points in rural areas where water quality concerns remain significant.

The longitudinal analysis delineated where and how the two texts diverged around which concerns were problematized in relation to service provision. The media focused on topics of functionality and reliability of public infrastructure where responsibility was explicitly allocated under the government mandates to maintain public tubewells in the 1980s and later piped water schemes in urban areas. While several government reports provide estimates of the prolific rate of private tubewell growth, neither media nor academic discourse explicitly problematized the institutional dimensions of growing private self-supply. Formal public policy texts, including the 1998 National Water Policy and the 2013 Water Act, focused on facilitating public-private partnerships related to financing of larger-scale piped water systems or formalizing the decentralization of service delivery to local government institutions and transferring maintenance responsibility of rural water points, specifically deep tubewells, to private collectives (GoB, 1998b, 2011, 2013). Scientific studies estimated the scope of people exposed to arsenic without direct problematization of growth rates of private unregulated markets of tubewells. Both the texts focused the problematization of concerns around the allocation of blame to nature and the media focused risk-response narratives around manageable aspects of

public infrastructure safety and reliability, thus avoiding complexity of self-confrontation of blame which would lead to intrusion around private property and individual decisions.

While the nature of risk has changed in Bangladesh, the portrayal and risk-response logic has remained largely consistent, suggesting minimal changes to the institutional design. This article argues that the risk-response dynamics, embodied in discursive practices, did not achieve what Beck defined as the process of self-confrontation leading to reflexive governance (Beck, 2006b). The government's commitment to the Sustainable Development Goals, particularly safely-managed drinking water for all (SDG6.1), presents a renewed political opportunity to redefine risk geographies through new monitoring technologies, definitional targets, and institutional designs focused on service models to prevent risks, not only mitigate them. However, without a major impulse towards reflexive risk narratives and adaptive governance that regulates both public and private action, water insecurity will likely continue, particularly for the rural poor.

CONCLUSION

This article argues there is a renewed utility of risk-discourse filters to provide critical insights into the construction, contestation, and reflexive confrontation of public risk narratives and past policy decisions shaping drinking water security. The ability of these narratives to contest and criticize the unintended consequences of past decisions is an increasingly central component of the politics affecting reflexive risk-response mechanisms and reshaping formal and informal institutions. The merged methods for longitudinal and cross-text analysis deconstruct the socio-technical process generating risk narratives through both public media and scientific discourses. The results uncovered three historic periods of discursive trends shaping the evolution of

Bangladesh's risk-response politics. The periods are directly linked to the dominant interests of national and international development agendas. These agendas constrained coverage of cholera and placed blame for arsenic on nature avoiding discussions of responsibility. There are specific policy implications for how the texts allocated blame and avoided self-confrontation around collective and individual decisions to continue installing shallow tubewells without public or government control.

This article demonstrates how the SDG targets on rural drinking water targets, rendered visible by standardized international monitoring systems, challenge previous risk-responses narratives which legitimated provision-based risk management models. The SDG 6.1 implies performance will be defined institutions capable of managing the unintended and uncertain consequences resulting from multiple decision-making levels, specifically related to water safety, affordability, functionality of infrastructure, and reliability of supply management. The governance approaches in Bangladesh remain entrenched in the previous risk management logic focused on service provision of improved infrastructure. This has implications for the exponentially growing number of self-supply systems where risks are assumed by private individuals located beyond the current state risk-response mandates. The risk-discourse filters suggest that this is protracted by the historic interests of a post-independence political bargain placing the government as a service provider to reinforce political legitimacy and techno-scientific literature focused on infrastructure solutions, not institutional ones. The media constructed a public risk narrative portraying private tubewell infrastructure as a prominent success, not a problem, reinforcing this dynamic.

This article specifically advances methods to analyze reflexive risk theories by mapping the interaction and evolution of techno-social narratives using discourse filters focused on production, prioritization, distribution of concerns and allocation risk-response mechanisms. The findings suggest that while scientific journals articles define thresholds of concern, they primarily target actionable research constrained by socially defined problems and thus do not define the public risk narrative priorities. In contrast, the media constructs the portrayal of risk-response dynamics within the context of the changing political interests and development agenda priorities. The comparative empirical analysis provides a modified approach to assess the formation and implications for the rural water sector's institutional responsibility, critical to new approaches towards national and global development targets.

7 CONCLUSION

7.1 SUMMARY OF FINDINGS

The previous chapters advance an argument that private household investment into self-supply and small multi-user systems will continue to drive changes in the rural drinking water sector in Bangladesh, and globally. The exponential growth of tubewells in Bangladesh is a conspicuous case: rural private investment outpaces public provision at a rate of at least 45 unregulated tubewells to one public water point. This growth of this infrastructure reflects several decades of successful government policies responding to public demand for state-led, and later market-driven, risk-responses to widespread cholera and diarrheal diseases.

Unfortunately, with each new unregulated privately installed tubewell, there is an unintentional increase in drinking water insecurity through the increased uncertainty of safety and reliability. The empirical work of this thesis estimates that there are at least twelve million new water points with unknown and unregulated water quality and reliability, and a further five million tubewells which were tested in 2005 but where user's memory now appears unreliable. Continued information deficiencies and asymmetries between experts, media, and water consumers leaves water quality of these new water points, specifically related to arsenic contamination, uncertain. The analysis identifies how the institutional framework has evolved into a system of self-management, where responsibility for testing water quality and managing the risks of private water points were informally assigned to individual households without any regulatory or pooled risk management.

The limited problematization of self-governed water points is exacerbated by a public narrative which frames arsenic as a salient public concern yet does not engage in reflexive self-

confrontation to diagnose the cause or suggest a remedy. This reflects both the politics of a continued governance mentality focused on provision of services and the informal allocation of risk-management responsibility outside government control and beyond collective risk pooling structures.

With global rural drinking water approaches increasingly advocating self-supply and self-governing systems outside state oversight authority, this thesis suggests that the success of the United Nations' SDG 6.1 is contingent upon risk governance mentalities shifting beyond provision of access to one of risk management and regulation. This implies a need to critically assess how decision-making responsibilities are allocated across polycentric institutions. Analysis of the risk narrative in Bangladesh suggests that to do this requires social, political, and technical discourses to engage in reflexive debates, confronting the consequences of past collective and individual decisions. The narrative from Bangladesh did not reveal attempts to redistribute, or rebalance, the unevenly distributed roles and responsibilities between government, market, community, and individual actors in order to manage the multiple water-related risks.

This redistribution of risk responsibility could include a transformed role for the central and local governments, away from infrastructure provision alone and into one as a facilitator of private enterprises and market-driven innovations. If balanced with authority and enforcement capacity to act as a risk-regulator, a responsibility which is not currently formally allocated in law or advocated in the national public risk debates, a multi-levelled reflexive-risk governance approach could allow a more adaptive institutional design and respond to multiple domains of risks. This approach offers opportunities for future research to debate collective risk techniques beyond insurance-based models and command-and-control models of centralized state regulation to

ones engaging cooperative and reflexive regulation through distributed responsibilities. These reflexive processes rely on a risk narrative capable of self-criticism and a politics centred around risk management, utilizing regulatory approaches linked to dynamic monitoring systems.

In this remaining conclusion, I briefly reinterpret the overarching core contributions by expanding on linkages between chapters and with the wider paradigm of sustainable development and water security framed in the intro and literature gaps. The thesis has focused on the three themes of socio-political construction of risk narratives, risk governance paradigms, and institutional design of responsibility. The intentions are not to repeat the findings from the chapters but synthesize the contributions into major themes related to both theoretical and empirical contributions. Within this analysis, I also identify the limitations of the study and reflect on the application of risk frameworks to drinking water security and institutional analysis. The final sections provide brief summaries of future planned or possible research to build from these presented findings. The dissertation concludes by outlining the pragmatic observations and contributions of the thesis towards development policy and rural drinking water services in Bangladesh.

7.2 REFLECTIONS ON CONTRIBUTIONS TO THEORY, METHODOLOGIES, AND EMPIRICAL STUDIES

Global academic debates over the past 50 years have identified concerns that the nature of global risks is moving beyond the control of technocratic governance systems, posing new geographies of uncertainty, universalizing vulnerability, and forcing socio-political self-confrontation due to the unintended consequences of our past decisions. In the previous chapters, I suggest there is a need to conceptualize the future of drinking water sector policies as contingent upon self-reflexive governance approaches across multiple risk management levels. These changes are currently framed as threats to domestic political and economic interests which have historically pursued provision-based governance techniques reinforced and legitimated by the previous global MDG targets.

This thesis extends Allan's (1999) interpretation of Beck's (1992) original *Risk Society* thesis, that, in the specific context of drinking water resources, social theory is an essential lens, but does not provide a sufficient diagnostic framework to explain how polycentric institutions have evolved or what is required to manage water insecurity. By synthesizing the grammar of risk and aligning it to the decision-making processes embedded within institutions, the thesis shows how rural drinking water institutions in Bangladesh have transformed in response to shifting risk-narratives and changing technologies of governance, including infrastructure and information. The discussion in each chapter also identifies ways in which the challenges to address drinking water insecurity in Bangladesh are no longer technical but institutional, a departure from the existing focus of academic and media texts and discourse.

The analysis presented in Chapters 4 and 6 adapted discourse analysis methods by merging them with the core phenomena identified in risk theory to explore how the socio-technical and political processes allocate formal and informal responsibilities to different actors and how they constrain interpretations of information impacting the predictability of decisions within the system. The findings suggest the rural drinking water sector performance, differentiated from urban spheres, continues to be constrained by a dominant focus on provision of infrastructure. In the case of Bangladesh, these approaches resulted with an informal institutional reallocation of responsibility to private individuals, largely through self-supply systems and small unregulated enterprises. This redistribution of responsibility didn't change the actors in the system or levels of decision-making. Instead it shifted risk management responsibility from collective decisions to individual decisions reducing the polycentricity of the system and overlapping interdependencies. By shifting decisions to the lowest level of decision-making, the goal of subsidiarity, it has now limited retroactive intervention options which would require intervening on private property or taking away existing services, neither of which are politically palatable. These results suggest how risk theory, when interpreted through risk discourse filters, is a useful approach to understand how institutional responsibilities are allocated and offers nuanced analysis of how decision-making systems are changing.

These risk narratives provide the core analytic lens of the thesis. The results of the discourse analysis suggest that despite shifts in global normative frameworks of drinking water security addressing multi-modal risks, the national development strategies and plans have not adjusted, and continue to use previous information systems to legitimate policy priorities. The national media narrative, mapped in Chapter 4, maintains focus on controlling the emergent problems

through health treatment and infrastructure mitigation while failing to address the institutional challenges of unconstrained, and largely individual decision-making. The risk narratives did not explicitly link the arsenic crisis to the cause and effect of past decisions, instead assigning blame to natural causes. Chapter 6 identified those outcomes as constrained by political interests which are threatened by the consequences of acknowledging the latent side-effects which might necessitate the redistribution of responsibility.

After deconstructing the risk narrative over 36 years, the thesis uses an empirical water infrastructure audit presented in Chapter 5 to question the efficacy of national policy responses focused on public water point provision by extending previous scholarship differentiating the consequences of management responsibility, not infrastructure types, for water safety, functionality, and supply reliability. The previously opaque transition of rural service responsibility became visible through the growth rate of privatizing rural household tubewells. This revealed a national rural sector development strategy which, although publicly focusing on government provision of safe water points, informally relied on self-supply and small enterprises to achieve the MDG target of near universal improved infrastructure access. This hybrid approach of public-private service models appears to be unintentional, not explicitly outlined in government policy and strategy documents and poorly documented in media articles and academic analysis.

The thesis chapters therefore seek to contribute to the following four key areas linked with these wider debates while acknowledging the study limitations:

Deconstructing risk narratives across media, academic, and government discourses provides an interpretive tool for how the institutional risk-responses are constrained within the manufactured boundaries of public debate: a multi-text empirical inventory delineates three techno-social and political periods of drinking water insecurity in Bangladesh

This thesis addresses methodological gaps identified in risk discourse analysis studies and empirical limitations of previous risk theorists. It is explored through a proposed set of risk discourse filters which seek to contribute interdisciplinary methods applied to a multi-text inventory with the following results:

- a) enabled a standardized method to compare the temporal construction of risk narratives across multiple discursive planes of texts and applicable to different sectors, risk domains, and geographic scales for future studies;
- b) expanded critique of how societal knowledge structures are formed in relation to the contestation of technocratic and media narratives, political economies of development agendas, and why certain risks end up being managed while others are not;
- c) mapped three historic periods of risk narratives in relation to politics of national development agendas and changing governance mentalities.

This framework was applied to a multidecadal inventory of one newspaper, a global index of academic articles, and an inventory of official government policy documents. Although the results found issue-specific discrepancies between the media and scientific content framing of drinking water security issues, the multiple texts presented a similar focus on national government agencies as the duty bearer for 'safe' service delivery, a narrative reinforced by the United Nations beholden to member-state power structures.

The thesis standardized a method and framework to enable comparable analysis of competing discourses. This extends beyond previous scholarship by applying the same risk discourse filter framework to multiple planes of text, using the comparison to interrogate the wider process of knowledge formation and understand how and why certain risks get problematized while others do not. This cross-discourse approach identifies the role and limits to disruptive information within the system, critiquing not only who produces and controls the process of sharing, but how information becomes normalized within the broader narrative over time, as seen with the reporting tubewell functionality issues in the 1980s and spatial extent of arsenic contamination in the 2000s.

The newspaper analysis for this study could not deploy automated text analysis software due to historic records being limited to hard-copy archives, but these advanced analysis techniques offer ways to enhance the precision and depth of analytic tools in future studies. The risk discourse filters were designed to provide opportunities for future applications to digital texts with more nuanced analysis of the process of contested narratives across a wider range of text sources. Future studies can deploy additional linguistic analysis tools to identify how and where blame is assigned and why responsibility is allocated in response to problem definition processes. Further techniques could explore coding techniques used by Heikkila and Weible (2018) to more explicitly differentiate information providers from consumers, levels of decision-making, and blame for decision-outcomes.

The coding done for the Ittefaq was insufficient for several aspects of institutional design including nuances of authority, rules-in-use, and blame for specific actors entering and leaving decision positions. Further text analysis is needed to explore this process, specifically the rules of

how information is cited and interpreted in relation to blame and responsibility. This includes specific interpretation of news articles in the 1980s and 1990s which, in qualitative interviews, were alleged to have copied information directly from NGO press releases reflecting the broader observation of limited attribution of information outside of government authority.

The text analysis focused on texts located primarily in the realm of formal rules, with a focus on government policies, strategies, and acts. There was limited attention on assessing informal dimensions of institutions, including individual-level decision-making and local informal power structures with the *Samaj* (local elders) and religious institutions. The wider theoretical framing and grammar of risk can be applied to these informal systems but would require a different corpus of texts and modified, although not new, coding framework. Immediate future text fragments to analyse include social media, blogs which are influential and popular in Bangladesh, and transcribed interviews with water point owners and managers.

The risk discourse filters revealed the limits of institutional change and reinforced the critiques set out by Beck of the political limitations of reflexive modernisation. This process of manufacturing a narrative extends the findings from Herman and Chomsky (1988) which argued the media, intertwined with dominant political and economic interests, construct specific concerns while shaping the allocation of blame, especially if the alternative could threaten existing social and political arrangements. Chapter 4 argues that the constructed narrative of drinking water security was used in a way to reinforce post-independence state legitimacy to both domestic constituents and commitments to international donors, reinforcing previous scholars arguments of double contracts (Ghani & Lockhart, 2008; Hassan, 2013) and most recently reinforce narratives of political transitions away from foreign aid dependent models

towards national control. The inventory identified this through the often-sudden diminishing media coverage of issues including cholera, public tubewell functionality, to arsenic contamination after 2005. This exertion of direct control over a risk narrative reflects the centralized power of the Government in the 1980s but also willingness to redefine the problem.

The use of narrative analysis expands previous scholarship around how and when institutions changed in Bangladesh. The inventory results mapped temporal patterns of drinking water concerns across the bodies of texts which aligned with three periods of risk responses. These findings further substantiate the urban water sector governance transitions identified by Yasmin et al (2018) and extends the interpretation of political economy of state services to rural communities and aid dependencies discussed by Hossain (2018b). The discourse filters show how the media was often at odds with the technocratic interpretation of risk severity yet aligned around allocation of responsibility, reinforcing the techno-policy focus on health and infrastructure solutions. In the context of Bangladesh, this constructed narrative constrained the ability for the institutions to adapt, specifically by not problematizing the shifting responsibility away from the government and collective structures and dependency on private systems.

The thesis argues this contributed to the failure of the institutions to problematize, and thus manage, the uncertainty between the central government, individual decisions, and market service enterprises. The discourse analysis of what Herman and Chomsky argue is manufactured consent, in this context manufactured risk narratives, reveals how power-knowledge relations extend beyond the political arithmetic and technocratic governance of numbers as observed by Rose (1991) into a process of socio-technical contestation, specifically in relation to the allocation of blame and responsibility.

Market growth of informal small enterprises installing privately financed self-supply infrastructure systems is transforming the rural water service sector: multi-site empirical results from water audit re-define assumptions of household demand for 'on' and 'in'-premises infrastructure in Bangladesh.

The thesis argues that private finance drove the attainment of Bangladesh's rural drinking water sector goals under the MDGs but, in that process, has unintentionally reallocated responsibility to non-state actors and away from collectivized risk systems. This extends previous empirical findings through blanket water audit inventories mapping infrastructure growth and differentiating private investment from public water points. This resulted with the following contributions:

- a) Revealed the ongoing exponential growth rate of private shallow tubewells with villages approaching similar scales of coverage despite previous differences in socio-economic status, and rapidly diminishing geographic differences;
- b) Posited that the exponential growth might be related to the historic tubewell costs changing at a slower rate than inflation of wider basket of consumer goods;
- c) Estimated that the private investment, which when aggregated, changes previous assumptions around scale of sector funding opportunities, specifically when relative to public-sector investments;
- d) Identified how the design of existing monitoring systems measuring provision of services alone is inadequate for the SDG 6.1 targets, specifically understanding performance and providing information to manage decisions emerging from self-supply systems;
- e) challenged assumptions on household demand by showing widespread socio-cultural demand for in-premises infrastructure and growing investment into deep tubewells and small distributed piped schemes through electric pumps.

The empirical results from the water infrastructure audit in Chandpur and Khulna provided a further perspective on the shift of rural infrastructure reliance away from publicly provided and collectively managed systems into privately installed and self-governed ones. The results suggest that for every new public water point installed between 2012 and 2017, there were 45 unregulated private tubewells installed through private market suppliers. Although there is further work possible to replicate these inventories in other hydro-geologic and socio-economic regions of the country to expand the sample coverage, the comparison to other secondary data sets reinforced these findings. Previous market assessments, both qualitative interviews and unpublished studies by UNICEF, show that no alternative water distribution technology has gained significant private market share, including minimal uptake of rainwater harvesting and filtering technologies. Other arsenic mitigation technologies, including pond sand filters, continue to be primarily provided by community groups and NGOs, not through the open private market. Additional robust market studies are needed to understand why alternative technologies have not entered or compete with the handpump market, specifically in response to the multiple water quality crises.

The Water Audit identified a further change in consumer preferences from tubewells on-premises to decisions to install new infrastructure in-premises, a distinction not identified in monitoring platforms but significant for sector financing and future demand. In the context of Matlab, the majority of the tubewells installed in the past decade were placed inside a four-walled structure, either within their primary residence or inside an enclosed WASH-specific out building. This 'on' and 'in'-premises demand signifies new socio-cultural patterns, increased financial investment levels, and qualitative interviews suggest generational preferences. This

includes an argument that investment is increasing towards a tipping point where electric pumps will be widely available market options.

Further observations extend beyond previous studies by identifying a sharp increase in the past ten years of privately financed and installed deep tubewells and electric pumps linked to small piped distribution schemes. While these remain a small portion of overall investment, it signifies the early stages of adoption and market changes, one which offers multiple opportunities explored further in the next section. This spatial data can be linked in future analysis with icddr,b's multidecadal household socio-economic surveys to provide population-wide insights and advance modelling infrastructure options for potential alternative enterprise and infrastructure models.

The globally standardized, nationally reported, and publicly available national access indicators have driven national successful policy goals in Bangladesh but concealed sector changes critical to ensuring safe and reliable water services as defined by SDG 6.1. This focus is compounded by the continued reliance on MDG-era indicators focused on provision of services to report sector progress as recently as the 2018 Government of Bangladesh national SDG report⁷ (GoB, 2018). The measurement tools and data collection methods reinforcing improved access figures have driven national WASH policy for two decades but increasingly provide limited insights into the multiple risks categories defined in wider drinking water security literature and framed in the SDG 6.1 targets. Without diminishing the global importance and impact of these standardized and nationally comparable survey tools which first emerged in the late 1960s and 1970s, the

⁷ Agency-specific draft reports shared during the write up phase of this thesis suggest that this might be shifting, however at the time of writing this chapter, the strategy and policy documents had not been published.

empirical results of the study reveal an overlooked and largely unmeasured component of rural water systems: how risk-management responsibility relates to water security. Chapter 5 and 6 discuss how households surveys overlook the source of finance driving infrastructure growth, who formally or informally assumes risk-responsibility for water supply safety, dependency ratios of users-to-infrastructure, who has access to public water points, and who assumes and performs management and maintenance responsibility.

There is an extensive and well documented body of literature focusing on measurement gaps in the rural water sector around infrastructure functionality and water quality, however there is more limited attention on understanding risks stemming from distribution of decision-making within allowable choice sets defined by the overall institutional design. The recent global policy focus on leveraging new data collection technologies, characterized as the SDG Data Revolution (Sachs, Badiie, Giovannini, & Chen, 2015) was launched at the start of this thesis to push international agencies, governments, local communities, and technology innovators to incorporate new data sources into the formal statistical reports. This has seen new ambitions in the Joint Monitoring Programme (JMP) (Slaymaker & Johnston, 2016) largely focus on water quality, functionality, and to a smaller degree affordability. This thesis suggests there are opportunities for data systems like the WHO GLAAS Government surveys to incorporate data and analysis of the past and present institutional design and performance, including value in understanding the temporal dynamics between types of infrastructure access, population-to-infrastructure dependency ratios, and the proportion of the population relying on different service models as indicators of risks based on who is allocated management responsibility.

Where and how public risk narratives allocate blame and responsibility uncovers the unintentional retreat of government authority: connecting risk theory and institutional design to critique unregulated or self-governed service models including self-supply

The questions raised throughout the previous chapters suggest that public risk narratives, rendered visible through the contestation of socio-technical discourses, do not differentiate responsibility across multi-levelled institutions. This thesis argues that the core concepts of risk theory, specifically the foundational phenomena of Beck's (1992) *Risk Society*, enable new ways to theorize and map institutional design including the following:

- a) Argued that risk discourse filters provide insights into institutional design frameworks;
- b) Aligned the grammar of risk with the contestation of public risk narratives which produce, and reproduce, the formal and informal process allocating blame and responsibility across the multiple levels of decision-making through a set of risk-based rules-in-use;
- c) Analysis of how newspapers in Bangladesh employed agenda-setting techniques to reinforce dominant political and economic interests by not problematizing management of self-supply, instead enabling a neoliberal governance model of self-governed risk;
- d) Identified how the politics of national development agendas limit reflexive-governance responses to the unintended consequences of past policy and technology decisions.

These methods—discussed in Chapter 2—link decision-making processes identified in risk theory to understanding of how institutions are designed to shape decisions. This theoretical linkage provides a framework to map the meta-level evolution of the service delivery and governance approaches around the rural drinking water sector. They also show how processes of institutional change are limited by the way risks are conceptualized and debated across interacting bodies of texts over time.

The discursive analysis specifically focused on how responsibility is assigned as a culmination of multiple components of the risk narratives. The results from Bangladesh's Ittefaq newspaper and inventory of academic journal articles shows a public discourse which rarely explicitly identified or debated the reallocation of responsibility from the public sector to individuals, or label tubewells as self-supply infrastructure. Instead, the concerns of water quality and supply variability in policy debates of rural service models remain disconnected from the institutional structure. The small percentage of newspaper articles where responsibility was explicitly allocated focused on formal state responsibilities towards urban utilities (WASA), mostly in Dhaka, and public schools and health facilities.

This thesis challenges the existing narrative by arguing there is an overlooked problem due to the reliance on self-supply infrastructure. Although the density of tubewell infrastructure is unique in Bangladesh, there is ample evidence of the similar growth of household and self-supply systems in Africa (Sutton, 2017), small water enterprises and self-supply in other South and South-East Asia countries (Barnwal et al., 2017; Foster et al., 2018; Gero et al., 2014; Salter, 2003), and significant private and individual systems in Eastern Europe and North America (Dieter et al., 2018). The European Union under the Drinking Water Directive and 2014 risk-based approach to managing small and self-supply systems have supported member states close the gap on monitoring and registering these systems. These systems exist outside of government regulation, systematic monitoring, and insurance-based models to pool the risks. A provision-based service and governance model has enabled responsibility to be passed to the end users compared to a risk-based service model which creates a broader ecosystem of distributed responsibility and

necessitates adaptive systems to respond to multiple risk types. This reallocation impacts multiple institutional levels, both the formal and informal mechanisms of the action situation.

These informal and unintentional shifts in responsibility have changed the design of service delivery models in the rural drinking water sector and reflect the diminishing role of formal pooled-risks structures specifically as state authority is replaced by market-based and self-governing enterprises. These results argue that private finance has shaped the capacity and willingness for institutional responses, expanding the empirical and methodological approaches to what Beck (2011) and Rayner (2007) argue are institutional limitations to manage reflexive modernization. The use of risk discourse analysis advances previous scholarship by risk scholars, by applying modified methods to empirically delineate the transitions in public narratives and allocation of responsibility within institutional decision-making structures with specific observations of the struggle between national governments and the reallocation of power to supra-national agendas and private markets.

The carefully quantified scale and rate of growth of private tubewells draws further attention to the limits of government authority over private property and questions who is responsible for past individual decisions. The analysis identifies gaps in the institution's formal rules, in this case the level of regulatory intervention and standardization of private drilling and hardware markets and limited availability of information on water quality to empower individual decisions. The DPHE maintained a clear mandate to provide public services but not exert regulatory authority over private actors or enterprises. Government policy and legal texts do not allocate regulatory authority over rural services.

Future work is required to define reflexive regulatory frameworks and further deconstruct the process of integrating oversight into the current context of no direct intervention or authority over private property. The thesis identifies this as a core political challenge in Bangladesh requiring switch in both risk narratives and governance mentalities. The thesis also identifies a global gap in governance models for rural small-scale drinking water systems, as seen through the limitations of the models to intervene in private property, although there are encouraging examples emerging from the European in the past five years. These studies offer empirically grounding for alternative market-based approaches which, if linked with risk-based regulatory governance, could advance progress towards SDG 6.1.

This study therefore extends Beck's core and most recent argument that nation-states are unable to manage new forms of risk (Beck, 2007, 2015, 2016). The discourse analysis and field work suggest that part of this challenge emerges from the redistribution of responsibility away from collective models of risk-pooling mechanisms towards allocations of blame placed on self-governing individuals which encourages risk taking without clear consequences for unintentional outcomes. This is perhaps not a failure of the nation-states but one of neoliberal governance models. The lack of discursive challenges to neo-liberal allocations of responsibility in the media, policy and academic texts in Bangladesh suggest in that context, there is a failure of institutions but not the ones identified by Beck. This thesis suggests Beck (2013) was correct to reframe the governance mentality away from distribution of goods to ones of mitigation of bads, which could be achieved in the case of Bangladesh through regulation. By analysing the distribution of responsibility in rural Bangladesh, we see how polycentric structures are transforming towards more monocentric decision-systems, and blame is not being clearly allocated.

Sustainable Development Goals have created a politically inconvenient problem by changing the paradigm from acquisition of goods to a logic of mitigating risks.

This thesis questions how to manage rural drinking water systems under dual governance mentalities viewing risk as both an opportunity and danger, two approaches which have different implications for self-governing mechanisms versus collective risk pooling techniques. This question implicates a wider politically inconvenient problem in the process of downscaling the post-2015 agenda from global goals to national policy: the rapid growth of private sector water service provision, specifically self-supply, has enabled multiple successes but inadvertently reallocated risk responsibility to individuals in the absence of other risk-pooling mechanisms such as insurance, regulation, or information. The thesis argues this finding through the following ways:

- a) The shift from the MDG to SDG agendas reflects a core change in the global risk mentalities away from one focused on provision of service to one embedded in managing the distribution of risks and unintended consequences of our choices;
- b) The privately funded growth of infrastructure has enabled governments to claim political credit for development agenda successes but now face unintended political and social barriers to adapt to declining drinking water safety and increasing common-pool conflicts over variable water supply reliability;
- c) In order to problematize self-supply tubewell infrastructure and self-governing enterprise models, it requires a political will and risk narrative to confront unintended consequences of past decisions and shift power dynamics by holding service providers accountable;

- d) There are no global models for regulating small-scale rural water services on private property.

By implying a need for a post-installation intervention to reduce uncertainty of water quality and manage common-pool resources, this creates a politically inconvenient scenario for government actors pursuing SDG 6.1 targets. The risk-based framing of the SDGs challenges the domestic politics of emerging-market states seeking to establish state authority and advanced democratic institutions under neoliberal economic models where state intervention is seen as constraining personal freedoms and impinging on property rights. The SDGs therefore implies a shift in the role of government from a provider of services and access to one which sets constraints on individual choices and decisions. This reflects what Beck (1996, 2009) identified as part of the clumsy shift in the political economies and dominant institutions from positive to negative risk logics. This creates a core politically inconvenient dilemma for domestic development agendas and politics, what Beck identified as the definitional struggle of who produces and consumes risk narratives and the ramifications of the unintended consequences of past decisions where everyone, and yet no one, is held responsible.

To enable these institutional changes, the transition depends in part on redefining the risk management responsibilities in the dominant neoliberal governance models. This identifies a tension expressed across the thesis between view of risk as a danger as framed by Beck (2016) and addressed through models of classical and social liberalism against those who treat risk as an opportunity, as initially framed by Knight (1921) and expanding into models of neoliberalism where uncertainty and self-governing drives economic growth (O'Malley, 2004). These paradigms and tensions appear in broader water security literature summarized by Grey and

Sadoff (2007) but are not reconciled in drinking water specific literature as discussed by Bradley and Bartram (2013). The way risk narratives characterize the value and role of risk have significant implications for the limits of governance techniques and where responsibility in multi-level institutions are allocated. This has implications for how institutions are redesigned in response to the SDGs and how public risk narratives adapt to reflexive governance techniques through construction, contestation, and self-criticism.

These shifts have gone largely unseen by decades of previous international target-based systems. The application of risk-narratives revealed how the historic process of institutional design in perspective of the broader sector approaches to rural drinking water models and dominant global governance paradigms. Starting in the 1970s and 1980s, rural drinking water development approaches reflected classical liberalism where risk management was allocated to the state who assured provision of services. In the context of Bangladesh, this was seen in the mandate of DPHE to manufacture, distribute, and maintain handpumps starting in the late 1960s through the 1980s. This overlapped with a period where paradigms of social liberalism refocused risk management toward collective and pooled structures, insurance as a technique in Western markets and community management in the context of rural development models. In Bangladesh, this was seen through the transfer of maintenance and repair responsibility from the Government to community organized committees in the late 1980s and 1990s. The recent global debates on blended finance models and private ownership and service delivery reflects shifts towards neoliberal risk models of self-governing enterprises, as seen in the case of self-supply tubewells in Bangladesh and small service providers in South-East Asia. This thesis shows that these mentalities often existing in overlapping ways, what Koehler et al (2018) argues as

pluralistic risk responses. The raises further questions of how reflexive governance techniques are adopted across pluralistic, and polycentric, institutions.

7.3 FUTURE RESEARCH QUESTIONS AND DIRECTIONS

The findings and contributions summarized above have the potential for wider contributions to development practice, institutional design, and understanding the role of risk in modern governance and society. The next section expands these future lines of research which emerged from the dissertation's findings.

How can the scale of private investment in Bangladesh be leveraged towards models of blended finance and collective risk management mechanisms to achieve multiple SDGs targets?

This thesis quantified how private finance played a significant, yet largely unrecognized, role in advancing progress towards achieving MDG sectors goals of improved access but falls short in effectively addressing the challenges of risk-based SDGs targets. Future research is situated within global debates around how to finance the implementation of the SDGs, with the explicit focus on the role of pooled public and private investment as part of national-level planning. This approach was addressed in the 2015 Third Conference on Financing for Development and summarized across sectors by Schmidt-Traub and Sachs (2015). The debate identified questions, and gaps in policy estimates at multiple levels, around the total financing needs for specific sectors. However, a narrow focus on overseas aid efficiency since the early 2000s has left the total private sector expenditure largely unknown and unaggregated at global scales. This remains a significant data gap for national and international resource allocation planning processes. And further undermines the ability for Governments to enact policies and administrative mechanisms designed at leveraging resources in relation to public sector expenditure.

This dissertation identified an opportunity for researchers and policymakers to support standardized methods for initiatives such as the UN-Water GLAAS surveys which increasingly provide comprehensive public and private country-level WASH sector budget estimates. Although the current data offers limited disaggregation by sub-sector, geographic scale, or by actor, it does provide the only comparable window into national public and private budgets as previous efforts have focused primarily on overseas aid flows and bilateral expenditures,

including as OECD development finance data and academic centres such as AID Data. There have been some efforts to track national budgets, but mostly at country-level initiatives, not standardized global systems and thus of limited comparative value. As discussed below, a major advance in the next decade could come from aggregating administrative data to provide these national estimates of infrastructure coverage, use, investment, and water quality as aligned with water safety plans., something already being experimented with in countries like India.

The rural drinking water sector funding needs to achieve SDG 6.1 at a global scale was most recently estimated between 10 billion USD and 16.4 billion USD per year by Hutton and Varughese (2016), a subset of the total WASH sector estimated at 114 billion USD per year. There have been several costing exercises in Bangladesh in the mid-2000s to estimate costs for MDG sector delivery (GoB, 2009a), arsenic mitigation costs (N. I. Khan et al., 2014), and the 2011 Water and Sanitation Sector Development Plan (GoB, 2011). The 2011 Government plan called for investment of 142,622 billion BDT (1.9 billion USD in 2011) over 15 years, or roughly 120 million USD per year for rural water sector supply. That is less than half what this dissertation estimates in Chapter 5 are the 2018 levels of private household investments. The empirical findings suggest that the estimated 2018 level of household investment into tubewells alone could represent upwards of one third of the annual total WASH sector expenditure in Bangladesh and nearly 70 percent of the reported household investment which includes tariffs and capital investments. This presents a major opportunity to leverage private finance towards national sector plans.

The case of Bangladesh and the reported figures in the 2017 GLAAS country data suggest that it is unlikely the aggregate level of private sector investment is being accurately estimated or utilized in sector strategies. While total private investment remains largely underestimated,

global attention is focused on advancing new service models to address the risk-based concerns, including Money (2018) who argues for blended finance approaches and McNicholl et al (2019) who identify the potential for data-driven performance-based models. The growing calls for leveraging public-private funding suggests that (a) future analysis, both policy and academic, is required to assess the existing and potential scale of private investment in relation to total national sector funding needs; (b) there is a need for further action-based research to align willingness-to-pay assumptions with changing households preferences as seen with demand for electric pumps and deep tubewells; (c) and introduce smart monitoring systems across the multi-source, multi-use sources linked with service delivery and accountability.

The dissertation supports these perspectives that there are opportunities to expand mechanisms incentivizing blended finance strategies, specifically ones building out of the “bottom-of-the-pyramid” approaches which Hammond et al (2008) argue constitutes a underutilized aggregate purchasing power for market-based business models. This deviates from some blended finance approaches which focuses on private equity and larger institutional investors, not individuals.

A second dimension of future research is required to focus on designing alternative institutional and service delivery models which more effectively and directly leverage household investment. In contrast to rural approaches, global policy makers and investors have specifically pursued public-private finance models for urban services, as documented by Bakker (2002, 2014) and McIntosh (2010a). In the past five years, emerging research has refocused rural drinking water sector approaches around the potential for blended finance models, paired with performance-based service models and small water enterprises, framed by Moriarty et al (2013) but expanded and explored by Hope (2015), Koehler et al (2015), McNicholl et al. (2019), and Gero et al. (2014).

These innovations in service delivery models, which utilize smart-monitoring technologies to ensure transparent performance of providers, have so far not been explored in the context of Bangladesh at any scale, individual water points, service clusters, or small-town regions.

To design these potential service models, the water audit data and local-level analysis can be extended beyond the mean-crowding analysis—discussed in Chapter 5—to further identify how the Bari as a socio-spatial unit can become a serviceable unit for drinking water enterprises. Additional analysis is required to determine the proximity of built structures in relation to water points but offers an opportunity to determine feasibility to pool this finance across the bari units, and if collective investment at that scale, could be leveraged for alternative sustainable service models. The unique data collected from icddr,^b offers opportunities to apply spatial optimization modelling and econometric modelling by combining socio-economic variables, infrastructure audit results, demographic data, built structure or settlement spatial locations, and administrative data to understand alternative spatially defined service delivery models.

The second specific opportunity is to provide further insights into the domestic supply market and consumer demand specifically for electric pumps and other non-handpump technologies. The analysis on regulating services, discussed in the next section, is partially linked to the current market structure and understanding the potential strategies to gradually introduce government oversight and authority, through the pathways of least political resistance. This must consider regulatory incentives which are not currently in place to fulfil monitoring protocols or enforce standards.

By identifying the previously unmeasured scale of household investment, the results imply new local and municipal service models are feasible if pursued under appropriate conditions. This is a key area for future research to trial alternative service delivery models linked to changing infrastructure and socio-cultural demand for services on and in premises. The results implicate national-scale planning, both specific to the drinking water sector but also to wider debates around financing the SDGs.

How can risk narratives and institutional structures reconcile the unintended consequences of self-governing decision-making models with pooled risk-responsibility, particularly the regulation of self-supply infrastructure on private property?

The discursive formation of risk mentalities—described in Chapter 4—and formal and informal allocation of responsibility within dominant governance models—described in Chapter 6—are argued to be core components of institutions defining the boundaries of decision-making through corresponding rules and techniques of power. Further analysis is possible including:

- (a) extend narrative frameworks by introducing process tracing techniques to specific articles, events, or policies to provide an empirical perspective on the differing contexts and impacts;
- (b) refine risk discourse filter analysis through additional cross-country comparisons to identify patterns in constructing narratives and institutional reactions;
- (c) advance theoretical work more explicitly linking institutional theory with risk phenomena through questions of decisions and action;
- (d) define techniques of reflexive risk regulation models in the context of rural settings and transitions from informal to formal rule-based systems to address the limits set by neo-liberal risk governance models.
- (e) Chart the complexity of decision points across polycentric systems with attention to implicit versus explicit allocations of responsibility for risk management, or formal and informal rules.

This thesis has argued that the existing institutions are ill equipped to manage the context of water quality uncertainty, supply variability, changing household preferences for increased water consumption, lack of accountability in service models, and increasing allocation of responsibility

to individuals in a context of a largely informal market system. The drinking water security goals, as with most of the SDGs, assume an explicit role of the formal government as a risk-regulator to set rules, ensure information flows, and mitigate and manage risks emerging from past decisions. The ability to redesign national state-based approaches around the implications of reflexive risks is a defining component of the long-term performance and success of the SDGs. However, the thesis shows how this transition process is being shaped by the political responses, and resistance, to regulatory and adaptive techniques of power. Institutions are designed to reduce uncertainty of decision making and reduce transaction costs for information and enforcement of behaviour between actors (Garrick, McCann, & Pannell, 2013; North, 1990; Williamson, 1993), however the shift in governance paradigms of where responsibility is allocated, and power to enforce, have diminished pooled risk models in exchange for self-governing approaches. The media inventory, academic articles, and formal government documents collected in this study allows further research into the role and interconnection of specific events impacting the broader narrative.

The application of the risk discourse filters, linked to the institutional structures, are limited to the context of Bangladesh. Additional work is proposed to expand this analysis and framework in other social-environmental and political contexts. This specifically includes the potential to expand the analysis to the context of Kenya and South East Asia. This would develop further links with the recent work by Koehler et al (2018) which focuses on the dynamic relationship of risks, values, and institutions. Further opportunities exist to build on technical advances coding formal governance rules, as discussed by Heikilla et al (2018). These coding techniques enable more

sophisticated charting of institutional complexity and could build from this thesis advances linking multiple bodies of text.

Finally, the thesis only began to draw explicit linkages between the design of responsibility across polycentric institutions with the risk management paradigms and techniques used under different philosophies of liberal governance. The uncontrollable, uncertain, and unintended phenomena identified in the theory of *World Risk Society* (Beck, 1996) provide the argumentative basis that institutions are failing to respond, yet these texts provide limited interrogation of how or where institutions are limited. Further analysis is required to define the mechanisms of reflexive risk governance, and the reconciliation of risk allocation mentalities. Future work should return to the wider body of literature addressing the conceptual risks domains identified by Hope and Rouse (2013) including information systems, institutional arrangements, operational systems, and financial structure. Within these areas are a wide range of approaches, largely debated in the boundaries of specific disciplines including legal structures, public policy, and administrative techniques, many of which are summarized by Saleth and Dinar(2005) and applied to the Bangladesh's water resource sector by Gain (2012). Further research is required to structure specific recommendations for regulatory approaches in this context of self-supply and uncertainty.

7.4 LIMITATIONS OF RESEARCHING INSTITUTIONAL CHANGE

As discussed throughout the chapters and the previous sections conclusion, it is valuable to explicitly summarize the limitations of the research approach, methods, available data, and case study. This study was conducted with the full participation of the Government of Bangladesh, UNICEF, and the REACH observatory team which provided unique perspectives and opportunities to observe and contribute to policy debates shaping the process of downscaling new global development goals into national programs. This role however, placed me as an actor within the system and no longer an entirely objective observer. It further generated implicit expectations to produce constructive results which could contribute to wider policy debates, shaping how some of the questions are framed.

Further, when conducting field studies in Matlab—the findings reported in chapter 5—I relied on icddr,b for support ranging from hiring enumerators, identifying interviewees for qualitative interviews, and using their data to select the sample locations and manage field operations. The icddr,b organisation has been active in Matlab for almost 60 years which places them as an entrenched actor in the community, including sensitizing communities to numerous research studies and as major economic job provider, possibly distorting some of the region's markets. This was recognized as a limitation but also a call for future research replicating methods and analysis in other geographic contexts in Bangladesh, as done initially with Polder 29 in Khulna.

The historic text analysis relied on content coding of archival newspapers, academic, and government texts. This required access and permissions as most of the historic texts were not digitized, readily available to the public, or collated in a single archive. The multidecadal

inventory, the basis of analysis in both Chapters 4 and 6, was limited to one newspaper due to time required to code thousands of articles and because it was one of the only newspapers which published continually since 1972. Cross newspaper analysis, summarized in Chapter 4, helped contextualize and identify potential biases from a single publisher, but further cross text comparisons were not feasible in the time of this thesis. This places limits on understanding contested media narratives, which we know is distinct in Bangladesh due to the role media played in party politics in the 1990s and from other country contexts including the work on political narratives in United States by Entman (2010). Further, these texts were only available in hardcopy in the national archives which required eight months of a trained RA to identify and code the articles. Photos of articles were prohibited by the archive which limited the ability to explore automated software analysis and detailed review of article text beyond a purposive subsample of 50 articles.

The use of Bangla-language paper archival records created inevitable challenges for the study. The first and most critical is that my interpretation of the articles content was dependent on translated articles. There is a wide body of anthropological and linguistic literature which correctly identifies the limits of non-native speakers understanding nuance of vocabulary and sub-text, or what Hajer and Versteeg (2005) describe as language-in-use. Many of the reviewed methods articles which apply discourse analysis fail to identify language constraints or language of their data-sets, including the two recent papers on Bangladesh from Yasmin et al (2018) and Hossain(2018a). This could lead to misinterpretation of articles in qualitative reviews. I tried to adapt to this by using standardized, and widely recognized, content analysis tools with a careful process of intercoding and intracoding cross-checking from a second and third fluent Bangla

speakers at UNICEF and U. Dhaka. The online publishing of Ittefaq newspaper articles in English over the past 4 years provided me with a body of texts to review to understand narrative style but this did not address the core limits.

The research in chapter 6 was further unable to produce a systematic collection of NGO and non-peer reviewed grey literature on drinking water sector projects including technical studies and policy review or commentary experts. This was partially addressed by compiling 45 formal government policy documents and review of 65 DPHE project documents. However, the cholera and arsenic crises occurred before the internet was widely available in Bangladesh and organizations had a culture of posting materials online, limiting the public availability of historic policy documents for comparative analysis, specifically across the multiple actors involved in the sector. While certain documents were obtained through site visits and qualitative interviews, they did not provide a basis for systematic and comparative analysis. This is a gap which could be addressed in future studies.

Finally, the core narrative and content analysis were designed for multi-geographies and multi-sector applications, not specifically for the case of Bangladesh. They were, however, only applied to the context of Bangladesh for this thesis. The findings are thus limited to the one country and one sector, and therefore do not claim to be representative for other country contexts. The thesis therefore recognizes the need to expand the application to other country contexts to test the risk-filter framework and interpret the country-specific unique historical evolution of politics and media. This presents opportunities for future work to determine strength and weaknesses of the framework in other domains, sectors, historic contexts, and geographies.

7.5 RECOMMENDATIONS FOR POLICY AND PRACTICE

The thesis concludes by putting forward several ideas for consideration, and additional analysis, for policy and practice in the context of Bangladesh. Each is linked to the avenues for future research discussed in section 7.2 and recognizes they require further consideration and debate. However, each one stems from observations and analysis provided in the previous chapters or from the data analysis. They are summarized here and will be expanded upon in white papers or policy briefs shortly after submission of the dissertation.

Redistribute risk-management authority across multiple actors by establishing regulatory responsibilities in the rural drinking water sector

The thesis has highlighted the limitations of how and where responsibility for decisions are allocated in the multi-level and overlapping institutional designs and reactions to shifting risk narratives. The findings have highlighted the current institutional approach to self-governing approaches in Bangladesh which sit outside of pooled and regulated risk structures. The review of government policy documents in relation to media and academic texts, summarized in Figure 26 in Chapter 6, shows the increase of the formal legal and policy interventions into the water sector after the recognition of the scale of arsenic exposure in the mid-1990s. The review of these government acts and policies identifies the progression of specific acts, policies, and strategies enabling the decentralization of drinking water service provision and fragmented responsibilities between public and private sectors, water resources managers and public service agencies, and between national and local levels of government. This further relies on the transnational system of health expertise to set standards, led by the WHO and debated across global expert forums.

The thesis suggests the following approaches to be considered in the upcoming national Water Sector Policy review process in Bangladesh and in future policy analysis:

- a) Explore the feasibility and comparative contexts which require a formal license-based system for all rural enterprises providing well-drilling services and vending hardware. Building on the national construction standards, this could include a permitting system for new abstraction which is currently mandated and managed by WARPO for irrigation; require the reporting of water quality to certify certain safety thresholds at time of installation; define and implement Water Safety Plans beyond small towns to include rural private and collective single user and multi-user systems, including water quality testing after installation at specific defined intervals; and establish an administrative reporting system to register new private and public water points within a district or national database. This will be specifically important for the expansion of deep tubewells and electric pumps which have more immediate impacts on common pool resources. Shallow aquifers are replenished annually, largely during the monsoon season, but are subject to declining rainfall and river flows. Deep confined aquifer dynamics are not as well understood but with increasing indications of over abstraction, discussed in more detail by Knappett et al (2016) around greater Dhaka area and Ravenscroft et al (2018) for multiple deep aquifers in the Bengal Basin, and DPHE planning studies (DPHE, 2015a). This requires costing to understand delivery to determine feasibility and trade-offs as well as consideration of the politics of corruption and the challenge of disrupting existing service providers.

- b) Set national standards for abstraction technologies. This study has shown user uncertainty around depth of tubewells, specifically deep tubewells, which are installed to provide “safer” water. Without extensive testing of individual water points, deep tubewells are presumed to be safe alternatives to shallow tubewells, specifically for mitigate arsenic. However, as seen in Chapter 5, water point managers provided conflicting information to the depth and identification of over 25percent of the potentially ‘deep’ points. If managers and users are uncertain over depth, perhaps misidentifying shallow tubewells for deep one, this diminishes the effectiveness of users relying on them for ‘safe’ alternatives. The government could mandate handpump hardware manufacturers to produce unique shaped handles or bodies to signify and differentiate the publicly provided water points from #6 handpumps widely used on shallow tubewells, as was done in the 1980s when DPHE manufactured their own models.

The study has also found that the national arsenic testing campaign from 2001-2005 labelled tubewells with red or green paint which is now faded or fading. Handpump manufacturers continue to sell new handpumps painted red and green, unrelated to the previous labelling campaign. This confused the Matlab study enumerators, all of whom are women from the villages, and left a number of household’s uncertain if their water points had been tested and confirmed as contaminated. Without a new testing campaign and more permanent labels, such as metal placards as suggested by van Geen et al (2014), depth acts as the least uncertain option for safe water in an overall context of high uncertainty. This again raises the broader point around the need to reduce uncertainty of water quality through standards which are reinforced by testing and public reporting to ensure information is available across multiple

decision-making levels. This reflects a broader opportunity for public narratives to debate water quality standards, rates of testing, and interpret public reporting.

- c) Building on the future research suggestions for further analysis of feasibility of alternative service models and pump technologies serving bari clusters, the Government could begin to review the enabling environment to formally license and incentivize small water enterprises with micro-scale systems, not only the current focus on medium scale piped schemes for small towns (GoB, 2011; World Bank, 2018a). This could further redirect public funding from deep tubewells into blended finance models with small private enterprises serving 100 or less households, or a specific threshold, aligned with monitoring and performance metrics. This would provide a distinct shift away from previous rural public water point models.

As documented by Hoque et al (2019) in the Khulna Polder 29 system, there is a growing number of private small to medium scale enterprise models, in addition to community management models, linked to a range of infrastructure types: from small scale electric pumps to reverse osmosis filtration to trucking and transporting of potable drinking water. Several policy documents have discussed regulatory needs for the urban water sector in Bangladesh (ADB, 2015) focusing on regulating tariffs and World Bank analysis with recommendations for small town piped water schemes (World Bank, 2018a), now a major Government-funded initiative. However, these overlook the exponential growth of private tubewells and increasing demand for micro-grid piped water systems enabled through electric pumps entering the market. As discussed in the next section, the government has an opportunity to be ahead of the technology uptake curve by enforcing current permitting schemes for new abstraction and introducing water quality and safety standards to ensure

comprehensive risk-management structures. Lessons can be drawn from other South-Asian countries including Vietnam, Cambodia, and Indonesia where small and medium private piped enterprises are setup and regulated (Gero et al., 2014).

- d) Finally, formally allocate an independent body to provide regulatory oversight of the drinking water sector. There is no current clear regulator, this thesis argues against the finding of the 2009 Asian Development Bank report suggesting Bangladesh's administrative and political system isn't ready for a regulatory body, instead utility level oversight bodies (ADB, 2015). existing roles are embedded within agencies with historic mandates and interests. There are examples of independent price and safety regulators from countries including Australia, which might provide initial models in addition to the European Union's Drinking Water Directive which offers specific frameworks for nation states. However, the findings of this thesis argue that with an existing extent of the distributed decision-making system, nearly at the individual household level, there are core challenges to design adaptive regulatory systems at that scale and to ensure clear feedback loops. Further research is required to understand how to minimize transaction costs and overcome some of the challenges of continued corruption which are currently linked to screening problems and inaccurate monitoring systems.

The shift in risk narratives and shift away from a public expectation of provision to one of risk mitigation is a key component in this process. This requires a wider acceptance of the shift into a formal rule-based system accompanied by both incentives through subsidies but also sanctions. Formal and informal rules and decision-processes do not change at the same rate. Therefore, further work understanding informal power and rules constraining individual and

household water users is important as a factor into future regulatory approaches. There is minimal literature about this in relation to Bangladesh rural drinking water sector, as seen with only two identified articles discussing the transition of local *Samaj* and *Mistri* between the era of ponds and the recent decades of dominant tubewells.

Reduce information asymmetry in order to open more sustainable service models, financial structures, and safe water outcomes.

Much of this thesis has been focused on the question of contested knowledge and the application of information across different institutional levels of decision-making. The Post-2015 global development agenda policy debates diverge from previous eras of development through a framing on the role of the 'Data Revolution for SDGs' in advancing real-time and disaggregated monitoring of the SDGs (Sachs et al., 2015). The global initiative offers additional funding incentives for countries to pilot and experiment with new monitoring approaches and technologies. Chapter 5 explored how reliance on national monitoring of improved access enabled a narrative of sector stability while overlooking the exponential growth of private tubewells which increased uncertainty of exposure to arsenic through shifting local use patterns. The analysis in Chapter 2 and 6 further suggests there is a division between the global policy perspective around the complexity of the SDG indicators on safe and reliable drinking water and the adaptive willingness of the official Government statistics system to expand beyond the previous MDG targets, especially if the new indicators threaten narratives of past successes.

As of the 2016, the internal GoB planning documents outlining monitoring strategies for SDG 6.1 remained focused on measurement of improved access under the previous MDGs targets. At the time of this chapter, the most recent GoB "SDG Bangladesh Progress Report 2018" reported that the national indicators of improved access figures hadn't changed since MDG era, ensuring continuity of water sector performance (GoB, 2018). The design of this information system, which limited the scope and ambition of official national reporting, misses an opportunity to advance country-level leadership in relation to the High-Level Panel on Water and global policy debates.

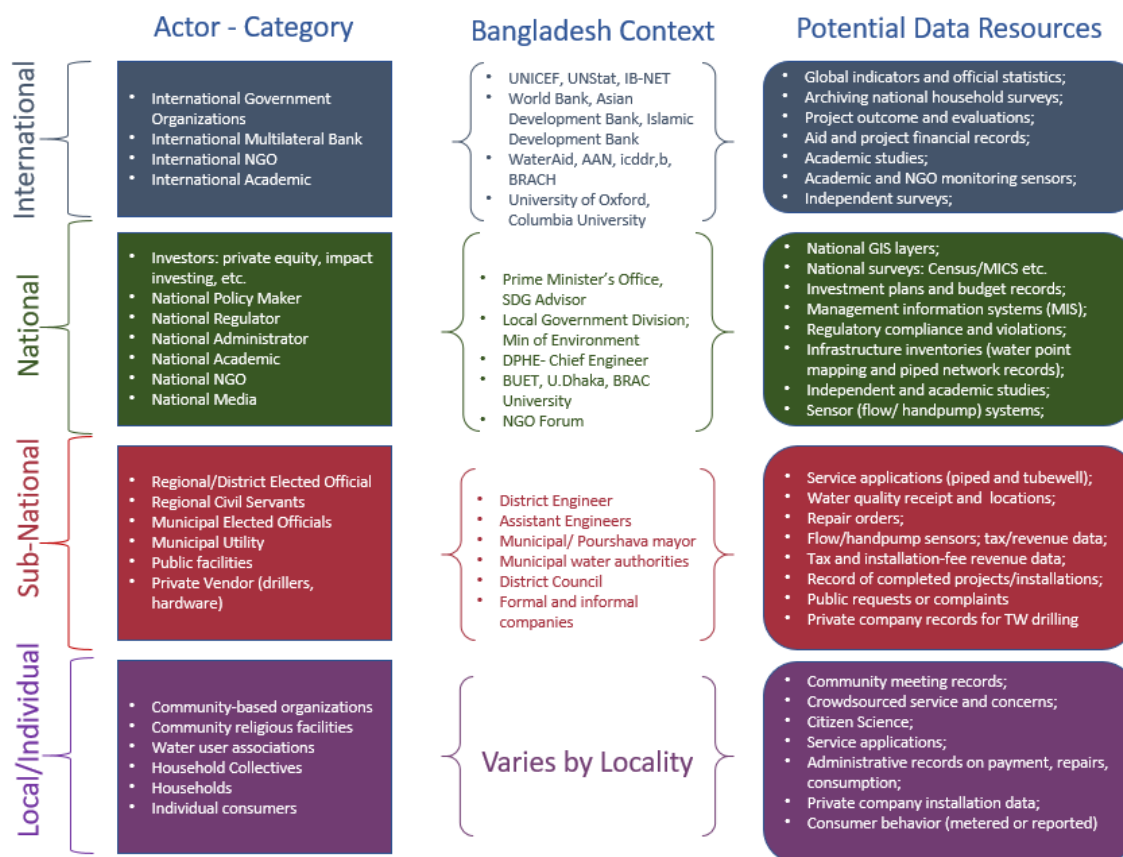


Figure 33 Summary of data produced by different institutional levels and actors.

The use of MDG indicators further fails to recognize previous innovations emerging from Bangladesh from the 2012-2013 MICS data collection which included testing household water quality and the efforts to design and launch the DPHE Management Information System (MIS) which tracks new public infrastructure including tubewells and piped schemes(BBS, 2015; DPHE, 2014a). It also fails to reflect an ambition to integrate other data sources, including administrative data which has become a core pillar in European Union Directives on ensuring water safety for small supply systems(EU, 2014) and is being piloted in multiple countries by UN Water and the JMP. As shown in Figure 33, there are data opportunities across the multiple actors and institutional levels in Bangladesh which could be leveraged towards SDG monitoring (A. Fischer, 2017). The Government of Bangladesh is positioned to be a global leader in this space but, as

suggested in Chapter 6, would need to adaptive governance and monitoring approaches while willingly engaging the resulting reflexive narratives.

The thesis suggests the following approaches to be considered to encourage technological data-collection innovations for rural drinking water sector while also redesigning national and international monitoring indicators away from provision targets to include indicators valuable for decision-making needs.

- a) The global policy attention, specifically when framed through the lens of risk-based approaches to development, has challenged the use of blanket target-based information systems as enabling unintended outcomes and redirecting policy attention away from the decision-needs of service delivery, as shown in Chapter 5, and seen through further examples in the education sector arguing universal primary school access targets undermined the other salient aspects of education quality, context, and equity (Unterhalter, 2014). These examples suggest that monitoring systems should transition away from focusing only on quantifying the provision of goods and services to incorporate variables that have a high value for decision-making, such as indicators on educational outcomes or water quality and system reliability.

The previous chapters suggest that in-order to establish fit-for-purpose information systems, it requires careful analysis of allocation of responsibility across polycentric institutions and understanding the constraints on debating information with risk narratives. This is reinforced with specific suggestions from a set of critical voices, summarized by Shepherd et al (2015), who argue the need to redesign SDG monitoring systems around principles of value-of-information and placing decision-making needs at the centre of information systems to enable policy-makers to evaluate return on investments and prioritize the most informative variables.

The arsenic contamination provides a very specific and immediate problem to explore design of information systems in relation to decision-analysis across multiple levels of institutional action, not only under an SDG reporting framework but also for household decision-makers and municipal authorities allocating limited budgets.

This could take the form of expanding efforts to establish a national information system, beyond the limits of previous initiatives such as the short lived National Arsenic Mitigation Information System (NAMIC) or the more narrowly defined recent efforts in the Rural Water Supply Database or the National Water Resources Database. A Bangladesh Drinking Water Management Information System could build off the precedent and lessons from the Indian Government's Integrated Management Information System (IMIS). The IMIS system offers two unique features, it seeks decentralized government agencies report monthly as mechanisms to hold regional actors accountable for their ongoing projects implementation. This is designed around a multidimensional dataset covering population, habitation, regional public sector planned and actual expenditures, infrastructure access, quantity consumed per capita, and water quality results. Although Wescoat et al (2016) identified a series of limitations of the system, specifically a lack of clarity around which decision-makers were using the data, the system provides a model for other countries. A data system of this nature and composition, where habitation level data is overlaid with access measures and service performance metrics, provides the type of accountability mechanism for the central government and municipal governments to use to ensure transparent allocation of public services, specifically when targeting the poorest or most vulnerable communities.

If linked with the municipal water committees decision-making process, it could address some of the concerns raised by van Geen et al (2016) around inequitable distribution of deep tubewells. This could contribute certain inputs to help safe guard against local politics of exclusion, and give additional weight and influence to voices of the most vulnerable sub-populations, what Cleaver (1999) argues are voices often constrained in the context of elite capture of distributed public services. There is a clear opportunity for the Government of Bangladesh to design and launch a new information system, building on lessons and advancing newer technologies than a decade ago which address decision analysis at national, regional, municipal, and individual levels.

- b) As suggested in both Chapters 5 and 6, the Bangladesh statistics office, in coordination with line ministries and Government agencies, have an opportunity to modify national monitoring systems to support reflexive institutional responses framed by the widened set of problems. Specifically, under the political leadership of the SDG Coordinator based in the Prime Minister's office, there is an opportunity to explore integration of information from sources in the broader data ecosystem, beyond household surveys. Table 3 in Chapter 2 discusses and proposes potential additional data types to help monitor the components of drinking water security formalized in SDG 6.1.

One major opportunity is to leverage the increasingly efficient and sophisticated automated data reconciliation software tools could further facilitate aggregation of municipal administrative records and regional DPHE engineer reports into standardized national datasets. This could further be paired with continued efforts to introduce digital reporting, including mobile-phone based data entry, to simplify the existing paper-based reporting

structure around water point installation, tariff collection, water quality results from regional DPHE laboratories, and functionality or repair events.

- c) Building on the findings of polycentric decision-making with a dominance resting at the self-governing level, there is an opportunity to explore models of citizen science and peer-monitoring. Extensive work was conducted in Bangladesh in the 2000s around information demand at the household level and low-cost testing and reporting technologies (Barnwal et al., 2017; George et al., 2012; Madajewicz et al., 2007; van Geen et al., 2006; Zheng, Ravenscroft, Rahman, & Hakim, 2012). Disconnected from this debate, are the influential studies economists Stiglitz and Hoff which identified, in the case of Grameen development bank in Bangladesh, how information dissymmetry could be addressed using peer-to-peer monitoring within the loan structures to reduce uncertainty (Hoff & Stiglitz, 1993; Stiglitz, 1990). The concept, more advanced in broader water resource management applications, has an opportunity to be applied in Bangladesh with hand-held devices and automated mobile reporting. As discussed by Buytaert et al (2016), citizen science, seen through the lens of polycentric information systems, is an opportunity for further research and trials in Bangladesh's rural water sector and help connect nodes or reduce information dissymmetry between users and regulators.
- d) At a global level, the JMP and UN-GLAAS provide key globally comparative data systems around drinking water. These rely on national governments to collect, process, and or authenticate national data including household surveys and census data. This creates numerous dependencies and limitations on the data sets but also advances their authority in global and national policy debates. The UN-GLAAS, now expanding into TrakFin, offers a key

platform to standardize further sub-indicators and pilot tools to help governments automate or facilitate reconciliation of administrative data. New software programs applied across the health care information infrastructure, could be developed for government administrative data.

International monitoring systems have several key opportunities for SDG 6.1. The first, argued throughout this thesis, is to transition from primary monitoring of provision of service to one focused on mitigating multiple overlapping risks. Global debates and methods have advanced since this dissertation was started in 2015, however these previous chapters show slow adoption at the national level and non-uniform inclusion of new indicators such as water quality in the MICS. The expansion of indicators under 6.1 and momentum of JMP, offer the wider international community opportunities to develop new monitoring tools from citizen science, smart sensors, to reconciling administrative data. The challenge is to standardize the methods and sources in ways which are comparable across countries. JMP is already exploring standardized administrative data in pilot case studies.

* * *

To conclude, the complexity of multiple dynamic risks in the era of the SDG, and the new scales of uncertainty across geographies, social classes, and domains are overwhelming multi-level institutions. These institutions were designed around previous politics and mentalities focused on acquisition of goods, not ones focused on mitigation of loss and harm. The process allocating responsibility through contested socio-technical narratives is constrained by political and economic interests, largely framed at a governance level around the tension between self-governing and pooled-risk mechanisms. There is a continued asymmetry of information, and major gaps of available data, between overlapping levels of the decision-making processes, which if addressed, could enable more sustainable finance under a regulated blended finance enterprise model.

This research has demonstrated how the phenomena of risk theory advance the mapping of decision-making and understanding of the limits of institutional responses, specifically in the rural drinking water sector. It raises concerns that self-supply and private enterprise approaches in global development practices, which are increasingly pursued as an avenue for reaching development targets, are instead unintentionally creating problems by occurring outside the reform of other political, technological, and institutional domains of collective responsibility. This thesis suggests further research is needed to understand how to reconcile neoliberal allocations of self-governed risks with effective governance. Reflexive risk regulation, adapted to the distribution of decision-making responsibility in polycentric institutions, is one approach considered and offers multiple areas of further research.

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APPENDIX

DECLARATION OF AUTHORSHIP

Name: ALEXANDER MONTGOMERY FISCHER

Candidate number: 676899

College: ST EDMUND HALL

Supervisor/Adviser: ROBERT HOPE

Title of Thesis: RISK NARRATIVES AND INSTITUTIONAL RESPONSES: CHARTING THE EVOLUTION OF UNREGULATED DRINKING WATER SERVICES IN RURAL BANGLADESH, 1972-2016

Word count: 78,721

Please tick to confirm the following:

I have read and understood the University's disciplinary regulations concerning conduct in examinations and, in particular, the regulations on plagiarism (*The University Student Handbook* Section 8.7; available at <https://www.ox.ac.uk/students/academic/student-handbook>).

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I have read and understood the Education Committee's information and guidance on academic good practice and plagiarism at <https://www.ox.ac.uk/students/academic/guidance/skills?wssl=1>.

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The dissertation I am submitting is entirely my own work except where otherwise indicated.

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It has not been submitted, either partially or in full, either for this Honour School or qualification or for another Honour School or qualification of this University (except where the Special Regulations for the subject permit this), or for a qualification at any other institution.

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I have clearly indicated the presence of all material I have quoted from other sources, including any diagrams, charts, tables or graphs.

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I have not used the services of any agency providing specimen, model or ghostwritten work in the preparation of this thesis/dissertation/extended essay/assignment/project/other submitted work. (See also section 2.4 of Statute XI on University Discipline under which members of the University are prohibited from providing material of this nature for candidates in examinations at this University or elsewhere: <http://www.admin.ox.ac.uk/statutes/352-051a.shtml>).

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I agree to make any such electronic copy available to the examiners should it be necessary to confirm my word count or to check for plagiarism.

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Candidate's signature: Date: 13 September 2019

Detailed contribution of co-authors

Chapter Title: Risk narratives and institutional responses: the historical evolution of drinking water safety in Bangladesh, 1980-2016

First author: **Alex Fischer**
School of Geography and the Environment (SoGE) and Smith School of Enterprise and the Environment (SSEE), University of Oxford

Co-authors:

Rob Hope (SoGE, SEE)

- Feedback for development of the theoretic framework.
- Reviewed survey instruments.
- Provided comments to final draft of the article.

David Bradley (SoGE, Department of Zoology, University of Oxford)

- Reviewed survey instrument.
- Provided detailed edits and comments to final draft of the article.

Adnan Ibna Hakim (UNICEF-Bangladesh)

- Reviewed survey instrument.
- Provided support and access to archival data.
- Provided edits to final draft of the article paper.

We confirm that Alex Fischer led the paper and methodology design, data collection, analysis and interpretation of the results, writing the manuscript, and managed the submission and revision process – with our contributions as specified above.

Professor Rob Hope

Date:



26 August 2019

Professor David Bradley

Date:



13 September 2019

Mr. Adnan Ibna Hakim

Date:



9 September 2019

Detailed contribution of co-authors

Chapter Title: Risky responsibilities for rural drinking water institutions: the case for regulating self-supply in Bangladesh

First author: **Alex Fischer**
School of Geography and the Environment (SoGE) and Smith School of Enterprise and the Environment (SSEE), University of Oxford

Co-authors:

Rob Hope (SoGE, SEE)

- Feedback on the development of the theoretic framework.
- Reviewed survey instruments.
- Provided edits and comments for the article.

Achut Manandhar (Institute of Biomedical Engineering, Department of Engineering Science, University of Oxford)

- Feedback on analytic methods of Water Audit data.
- Provided statistical analysis support and review of lead authors analysis.
- Provided overall edits and comments for the article.

Sonia Hoque (SoGE, SEE)

- Provided cleaned Water Audit data from Khulna Polder 29.
- Provided overall edits and comments for the article.

Adnan Ibna Hakim (UNICEF-Bangladesh)

- Reviewed survey instruments.
- Provided support to access archival data from DPHE.
- Provided overall edits and comments for the article.
-

Md. Sirajul Islam (icddr,b)

- Provided input to survey design.
- Supported training of enumerators.
- Provided overall edits and comments for the article.

Tim Foster (Institute for Sustainable Futures, University Technology, Sydney)

- Provided input into comparative regional analysis.
- Provided input into financial modelling.
- Provided overall edits and comments for the article.

David Bradley (SoGE, Department of Zoology, University of Oxford)

- Feedback on analytic methods of the Water Audit data.
- Provided edits and comments for the article.

We confirm that Alex Fischer led the paper and methodology design, data collection, analysis and interpretation of the results, writing the manuscript, and managed the submission and revision process – with our contributions as specified above.

Professor Rob Hope
Date: 26 August 2019

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Dr. Achut Manandhar
Date: 09/09/2019

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Dr. Sonia Hoque
Date: 09/09/2019

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Mr. Adnan Ibna Hakim
Date: 26.08.2019

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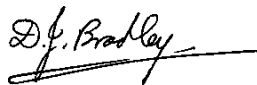
Dr. Md. Sirajul Islam
Date: 16.9.2019

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Dr. Tim Foster
Date: 13.09.2019

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Professor David Bradley
Date: 13/09/2019

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LIST OF CONFERENCES

Date	Title	Role	Output
Dec 2015	REACH Annual Conference	Discussant	Co-author to diagnostic study for Bangladesh Observatory, REACH
Aug 2016	World Water Week	Participant	Co-author of briefing note with Xylem on data gaps in the SDG 6.
Sept 2016	REACH Annual Conference	Discussant	Topic: Matlab Observatory Research Plan
Nov 2016	Budapest Water Summit 2016	Participant	Lead author of white paper with WHO/UNICEF: “Tackling the Challenges of SDG Monitoring: A Roadmap Outlining the Costs and Value of a Water Sector Monitoring System”
April 2017	Skoll Forum	Discussant	Topic: WASH small enterprise models and smart monitoring in Bangladesh
Aug 2017	World Water Week	Paper	Co-author of white paper with Xylem on value of information in water sector: “The Value of Water Information”
Sept 2017	UN SDSN	Paper	Author on data reconciliation approaches for SDG 6.1 in Bangladesh (Appendix)
Mar 2018	WASH Futures	Paper (accepted but didn’t attend)	Smart monitoring for rural schools in Bangladesh
June 2018	REACH Annual Conference	Paper	Policy briefs on DPHIL papers.
Oct 2018	Asian Development Bank-Asia Water Forum 2018: Information, Innovation, and Technology	Presentation	Role of smart monitoring to support self-supply and small enterprises performance in rural Bangladesh
Mar 2019	REACH Global Conference	Presentation	Presentation of Chapter 6
Apr 2019	American Association of Geographers	Paper (accepted but didn’t attend)	Presentation of Chapter 5. Awarded first place for Stan Brunn graduate student paper.

Table 13 Summary of academic papers accepted, and academic conferences attended

LIST OF INTERVIEWS

Sector	Interviewee Position/Title	Organization
Government of Bangladesh	1. Executive Director	Centre for Environmental and Geographic Information Services (CEGIS)
	2. Chief Engineer 3. Executive Engineer (Planning) 4. Executive Engineer (Ground Water Circle) 5. Executive Engineer (Chandpur) 6. Superintendent Engineer (Ground Water Circle) 7. Executive Engineer (Research & Development) 8. Programmer, MIS/GIS Unit 9. Local Engineer (Matlab)	Department of Public Health and Engineering (DPHE)
	10. Director General 11. Principal Scientific Officer	Water Resource Planning Organization (WARPO)
	12. Principal Country Economist	Bangladesh Water and Development Board (BWDB)
	13. Project Director, Participatory Small-Scale Water Resources Development Sector Project	Local Government and Engineering Department
	14. Mayor of Matlab Baazar	Matlab Pourshava
Academic	15. Professor, Department of Development Studies 16. Professor, Institute of Disaster Management and Vulnerability Studies	U. Dhaka
	17. Professor, Institute of Water and Flood Management	BUET
	18. Research Team- Water Sector 19. Senior Director, Innovation Team	BRAC
NGO	20. Country Manager 21. Project Manager 22. Field Officer	Asian Arsenic Network (AAN)
	23. Executive Director 24. Senior Director, Health Systems and Population 25. Senior Scientist, Climate Change and Health 26. Director of Matlab Field Director 27. Field officer (Matlab)	Icddr,b
	28. Disaster Risk Management Specialist	World Bank
INGO	29. Senior Water Specialist	Asian Development Bank
	30. Chief of WASH 31. WASH Specialist 32. Media and Communications Officer 33. Arsenic Project Officer	UNICEF
Community	34. Three market vendors of handpumps. 35. Driller of tubewells 36. Ten water point owners (male and female) 37. Ten female water point users. 38. 5 school administrators 39. Manager of piped water system 40. Community committee managing piped water and pumping station.	Civil society in Matlab, Chandpur District

Table 14 Summary of semi-structured qualitative interviews

QUALITATIVE INTERVIEW QUESTIONNAIRE

Semi-Structured Interview Questionnaire

BASIC INFORMATION AND PARTICIPANT AGREEMENT

Name of Respondent:			
Name of Institution:			
Name of Department:			
Name of Team (if applicable):			
Position:			
Tasks:			
Received Participant Information Sheet:		Y	N
Consent Given:		Y	N

For informed consent read provided paragraph on consent form (Text also below).

STUDY TITLE:

Drinking water institutions and information in Bangladesh: Water Risk Society

PURPOSE OF STUDY:

The purpose of this study is to analyse the evolution of drinking water risks from an institutional and information perspective in Bangladesh. The goal is to understand how information is used within the decision-making processes within different levels of water institutions. It will consider both historical evolution of water institutions and discuss the potential impact of new water data systems. We are contacting you to request an opportunity to speak with you regarding _____ (the organization) and the related information systems.

We request your consent to discuss the topics related to your organization. All information will be written notes in this first stage of the study and we will return in the fall 2016 for a second, more focused discussion. Do you give consent to have this discussion?

The follow list of questions is for general a semi-structured interview and do not need to be read verbatim. This should be accompanied by a review of the organizations documents which review their mandate, structure, and actions (summarized in the diagnostic desk-based report). Additional participant observation from meetings and discussions while on premises of the organisation should be included with interview notes.

A. INSTITUTIONAL STRUCTURE AND MANDATE

Mandate and Authority

1. What is your role within your organization?
 - a. Please specify your role related to drinking water.

History of agency/unit/department within broader institution

2. In what year was the organisation created and under what conditions? (*Authority from parliament? Legal mandate? Policy creation? International agency funding?*)
3. In the view of the interviewee, what is your organizations (current) responsibility in providing safe, reliable drinking water?
4. What has changed and been added and roughly what year? (List out 5 and identify time/year)

Structure and Actors

5. Review organization's organigram when available: *Confirm all agencies, departments, groups, teams and sub-teams are identified. Review and note each of the key units in the organigram's mandate with respect to drinking water provision.*
6. Discuss role and responsibility for each unit using typology. (Initial categories: Policy making; implementation; monitoring; regulation; enforcement; asset ownership; decision-making; risk allocation; budget allocation)
7. Define the main three actions related to drinking water that each unit can undertake (Initial categories: act and law; policy; strategy and planning; data collection; investment; service provision; new institution; other)
8. What is the distribution of roles & responsibilities for other institutions? *Check with typology of actors: government, semi-gov. organizations, development partners (e.g. World Bank), NGO's, CBO's, Private Sector, Others (Researchers, Consultants)*
9. How have the actors and partners changed in the past 20 years?
10. What are main sources of funding for your organization? Define choices and ask if there is difference across different units of organigram? (Annual government budget, international aid, tax revenue, other)

Specific Roles & Responsibilities

11. What are the coordination mechanisms between different institutions? How does this agency coordinate with other institutions and with which one mainly?
12. Are there any overlaps or functional imbalances internally or with other organizations? Why?

Example: government tube wells are funded by both DPHE and LGED/Municipal Pourshavas- are those distributed through the same processes, who decides where to build them for each organisation or are they coordinated, who builds them, how is cooperation set with other agencies, municipal governments and communities, who monitors them, who tests their water quality, who repairs them, is there variation between organizations long-term responsibility to manage the installed systems?

B INFORMATION SYSTEM AND ACCESS

13. Do you maintain a written summary or inventory of both public and internal data sets?
14. Would you be able to share your data inventory and any meta data? *We are not seeking access to the data, only to understand the information systems used and accessible by your department as related to your responsibilities and decision-making processes.*
15. If they have inventory- ask questions off that list.
16. If no formal or compiled list, please describe the data that your organisation collects or manages that represents the following categories (SDG categories: *Access, Quantity, Quality, Functionality, Reliability, Affordability, Sustainability, Equity*)
17. Which information do you use from other organizations?
18. How does the organisation staff and structure data programs? (By subgroup/agency or centralized?)
19. Is there a specific staff member we can contact for a follow up discussion?
20. Is this organisation explicitly mandated to collect specific information for other government agencies? What information is considered the responsibility of this organisation to collect and at what frequency?
21. Will this organisation modify or change the data it collects in response to the government's efforts to achieve the Sustainable Development Goals?
22. What are the organizations policies on sharing data? What percentage is available publicly online versus internal?
23. Do you maintain use records of data requests, data downloads, data sharing? If so, who can we speak to about this?

24. In your opinion, what are the 3 key pieces of information needed (within the drinking water data framework) Why are they important? What would that information tell you that you don't already know?

C. ACTION

25. Who uses that data for decision-making? What data is used for internal versus external planning (decision-making/action/response to water risks)?
26. Who is taking actions and when and based on what information? Or which processes require evidence-based or data-driven decision justifications?
27. Discuss timeline of Government policies as one example of institutional response.
Feedback from interviewee on implementation, efficacy, relevance of the formal rules.
- a. *Acts & Rules, Policies, Strategies & Plans, Data collection, Regulation, Investment, Creation of new agencies (SLIDE)*
28. What are key events that have influenced the mandate of organization? (example arsenic in 1990s changed x, y, z or specific study or funding?)
- b. Can they draw a timeline and mark key events that we should be aware of in terms of influence on drinking water actions?
29. Do you see a change in recognition of water risks in policies over time based on data collection? (*TIMELINE*)
30. To what extent do events (e.g. flooding) influence policy change/prioritisation of institutional responses

D. INFORMATION SYSTEM AND ACCESS

Data Collection Protocol

31. Who is responsible for data management within your organization?
32. Who funds the data collection (either the department or specific data collection initiatives)?
33. What information is collected on an annual basis (or can ask daily, weekly, monthly, quarterly, semi-annually, annually)?

Data Access and Use

34. Is an inventory available online? Are you able to download the data online? Do they record users? If yes, who manages those requests? Can we set up a future meeting with them?

MEDIA INVENTORY CODED FORM

QUESTIONS	CHOICES	INSTRUCTIONS
Section 1 Basic Article Information		
1.1 Please take a photograph of the article		
1.2 Please translate the title into English.	Please be careful and consistent in the translation of key terminology between articles.	
1.3 Please enter the year of the article	4-digit integer above 1972 and below 2018	
1.4. Please enter the month	2 digits below 12	
1.5 Please enter the day	Enter 2 digits	
1.6 Please enter the page number		
1.7 Please identify the section of the newspaper where the article first appears.	Front Page Second page Country International City Port Village News of Chittagong and hilly region News of Rajshahi News of Khulna News of Sylhet Sports Culture Literature Editorial/Opinion Letter Female corner Health concern Business and trade Last page other	
1.8 Please select all key words that appear in this article that relate to drinking water.	Select all that apply - Drinking water (general) - Health outcome (only) - Risk- Supply (quantity) - Risk- Access for individuals/households - Risk- Functionality /Maintenance - Risk- Affordability or cost for users - Risk- Financial investment/budgets for gov and service providers - Infrastructure- Shallow tube wells - Infrastructure- Deep tube wells - Infrastructure- Piped water supply - Infrastructure- Rainwater Harvesting - Infrastructure- Pond Sand Filter	NOTE: If an article only discusses health outcomes, please select health outcome only and the specific health topic. NOTE: If these topics are discussed in an article but not in relation or reference to drinking water, please do not include them in the key word list.

	- Infrastructure- Pond (or canal/ditch) - Water quality- Arsenic - Water quality- Microbiological (sludge management/sanitation) - Water quality- Salinity - Water quality- Iron (and drinking water) - Water quality- Heavy metals/toxicity (related to drinking water) - Climate change (related to drinking water) - Flood (related to drinking water) - Drought (related to drinking water) - Hygiene AND drinking water - Health Outcome- Diarrhea (or Dysentery or E-Coli) - Health Outcome- Cholera - Health Outcome- Arsenicosis or arsenic poisoning - Health Outcome- Legionnaires - Health Outcome- Typhoid fever - Other	
OTHER Key Word: Please enter.	Enter text Common additional categories: Risk: Administration, Management (Corruption included) Risk: Water efficiency (avoid lost water/wastewater) Public Awareness, media, communication Health-Jaundice Infrastructure-surface including river, pond, canal, ditch Risk: Political Risk (Party politics) Water quality- General Infrastructure: Water purification and treatment	
1.9 Please select the key word that represents the main or primary focus/subject of the article.	Select One: Choices are populated from selection in question 1.8.	This is based on the reviewer's perception of the main subject of the article.
1.10 Please select the keyword that represents the secondary focus of the article.	Select One Choices are populated from selection in question 1.8.	
1.11 Please select the geographic scale of the article.	Please select one: - National in scale - Region specific in scale (division or district)	For example, does the article discuss the issues related to national policy, to regions of

	- Union, Pourshava or smaller in scale - International in scale	concern, or to specific localities?
1.12 Which division does the article refer to?	Select one: - Barisal - Chittagong - Dhaka - Khulna - Mymensingh - Rajshahi - Rangpur - Sylhet	
End or Continue	Please say NO if the article only discusses health outcomes and no explicit link with drinking water. Please say yes 1/3 of the articles, randomly selected. Please also say yes to all front-page articles and opinion/editorials.	
Section 2 Vulnerable Communities		
2.1 Does this article explicitly discuss either rural or urban issues?	Select One: No specific reference Rural Urban Specifically refers to both	Please pick both if the article explicitly refers to both, or none if there is no explicit reference.
2.2 Does the article specifically identify "poor" or "ultra-poor" communities as at risk for drinking water?	Select One: Yes/No	These are categories defined by the Government of Bangladesh and cited widely. Please select yes even if these specific terms are not referenced.
2.3 Does the article specifically identify women or men as at risk to the drinking water issues in the article?	Select One: No gender focus Women Men	
2.4 Does the article specifically identify as children (under 5?) as at risk for drinking water issues in the article?	Select One Yes/No	
Section 3 Information and Uncertainty		
3.1 Does the article reference specific data or information sets?	Select One: Yes/No	This means providing figures, maps or numbers within the article. This could be statistics, study results, government figures, service numbers, impact figures or NGO findings.

3.2 Does the article reference or cite expert opinion or knowledge?	Select One: Yes/No	Expert opinion and knowledge are different from data, information or figures. This is a quote or citation of an expert's opinion and knowledge. This does not need to refer to specific data or studies.
3.3 What type of data is referenced?	Select all that apply - Water quality - Water quantity - Water access - Water reliability - Water affordability - Other: <u>Please specify</u>	This is the category of data, not specific type of data.
3.4 What type of water quality data was identified?	Select all that apply - Arsenic - Salinity - Iron - Microbiology - Toxicity - Other	
3.5 Who does the article cite/attribute the data as belonging to?	Select all that apply: - Not clear or not cited - Bangladeshi academic institute (Example: BUET, U. Dhaka, etc) - International academic institute (Example: Columbia University, University of Oxford, etc) - Government agency (Example DPHE) - Non-Government (Example: WaterAid) - Local citizen group, advocacy or community group - International Agency (Example: UNICEF or World Bank) - Other	
3.6 If you see something unusual or interesting, please add a brief description of the data cited.	Text	For example: launch of national arsenic water point mapping, first report of arsenic, specific use of data in relation to article topic.
3.7 Please add the reference or citation information IF available	Text	Publisher, study number, author, specific source.
3.8	Select one: - Low trust. Questions certainty, accuracy, reliability, or source.	Please specifically identify when the article expresses opinion or

Does the tone of the article express distrust of the data?	- High trust. Language expressing support for high certainty, accuracy, reliability or source. - Neutral. Expresses no judgement.	uses language that questions the validity or reliability of the data. Does the article challenge directly, or cite other sources, challenging the validity of the data? Or inversely actively and explicitly supporting the data?
Section 4 Responsibility		
4.1 Does the article assign a specific group/actor/entity with the responsibility to manage/address/fix the drinking water issue?	Select one Yes/No	For example, if the article discusses an issue with drinking water supply or water quality, does the article say who is responsible to fix it like a private owner, WASA/Pourshava, national government, NGO, international organization?
4.2 Who does the article identify as responsible?	Select Multiple - Private individual or household - Private group of owners - An informal public group or collective of water users - A formal public local water committee - The national government - The local government - A national NGO (example BRAC) - A local NGO (civil society group) - An international organisation (UNICEF or World Bank) - No actor/entity identified - Other (<u>Specify</u>)	
4.3 If the national government is assigned the responsibility, please identify which department or agency.	Select Multiple - Department of Public Health Engineering (DPHE) - Ministry of Local Government, Rural Development & Cooperatives (LGD) - Local Government Engineering Department (LGED) - Other Water and Sanitation Authority (WASA) - Bangladesh Water Development Board (BWDB)	

	- A political party (Awami) - The Prime Minister - Department of Environment (DOE) - Other	
4.4 If an NGO, IGO or CBO is assigned responsibility, which one?	Select multiple - UNICEF - Water Aid - BRAC - NGO Forum - World Bank - Local community NGO - Other	
Section 5 Action		
5.1 Does the article refer to a specific government policy, act, strategy or plan?	Select One: Yes/No	
5.2 Which government policy, act, strategy or plan are mentioned in the article?	Select all that apply - Embankment and Drainage Act-1952 - National Water Plan- 1986 - National Flood Action Plan -1988 - Water and Flood Management Strategy -1995 - Water Supply and Sewerage Authority Act -1996 - National Policy for Safe Water and Sanitation -1998 - National Water Policy -1999 - National Water Policy -2000 - National Water Management Plan- Development Strategy - 2001 - National Policy for Arsenic Mitigation -2004 - Implementation plan for Arsenic Mitigation in Bangladesh - 2004 - National Water Management Plan -2004 - Pro Poor Strategy for Water and Sanitation Sector -2005 - National Sanitation Strategy -2005 - Sector Development Framework Water Supply and Sanitation -2004 - National Drainage Policy -2006 - National Vetting Guidelines -2009 - Bangladesh Climate Change Strategy and Action Plan -2009 - Local Government (Amendment) Act for Pourashavas and City Corporations -2010 - National Plan for Disaster Management -2010 - National Cost Sharing Strategy for Water Supply and Sanitation in Bangladesh -2011 - WSS Sector Development Plan -2011 - National Strategy for Water and Sanitation in Hard to Reach Areas of Bangladesh -2011 - Water Safety Framework in Bangladesh -2011 - Disaster Management Act -2012 - Water Act -2013 - National Strategy for WSS -2014 - Water Quality Testing Guidelines -2015	

	- National Hygiene Promotion Strategy for Water Supply and Sanitation Sector in Bangladesh -2012 - Geo Code Based Water Point Identification System -2014 - 7th Five Year Plan -2015 Other	
5.3 Does the article reference a drinking water program, project or investment?	Select One: Yes/No	
5.4 Was there a main actor/entity identified as implementing the project/program/action?	Select all that apply - Private individual or household - Private group of owners - An informal public group or collective of water users - A formal public local water committee - The national government - The local government - A national NGO (example BRAC) - A local NGO (civil society group) - An international organisation (UNICEF or World Bank) - No actor/entity identified - Other	If they do not know, please enter -999
5.5 Who was identified as providing the investment or funding?	Select all that apply - Government of Netherlands (Dutch) - USAID - World Bank - Asian Development Bank - Government of United Kingdom, DFID - Government of Bangladesh, DPHE - Government of Bangladesh (Not DPHE) - UNICEF - Water Aid - BRAC - NGO Forum - Local community NGO - Private investors (example of a company or bank) - Other	
Section 6 Conclusion		
6.1 Please enter any notes about the article. These are meant to be reminders of the article or specific things that identify unique, unusual, or important parts of the article. For example,	Text	

could be the first article announcing arsenic or a new study or a new policy.		

WATER AUDIT QUESTIONNAIRE

QUESTIONS	CHOICES	INSTRUCTIONS FOR ENUMERATORS
Section 1 Introduction and Identifiers		
Section 1.1 Consent		
1.2 Identification number of enumerator	SELECT ONE 1 - Putul Rani 2 - Shahida Akter 3 - Liza Akter 4 - Rupali Rani 5 - Saleha Akter 6 - Khaleda Akter 7 - Sirajum Monira 8 - Nasima Akter 9 - Halima Akter 10 - Ruma Akter	
1.3 Collect the GPS coordinates of this household	PRESS GET COORDINATES Stand directly in front of the household main entrance. Accuracy level should be at least 5m.	Coordinates will be captured automatically once it gets below an accuracy threshold of 5m.
1.4 Consent and confidentiality agreement	Good morning/afternoon, I would like to invite you to participate in a study on handpumps and drinking water for icddr,b in this village. My name is _____. I would like to ask you a few questions about the history of the handpump and the formal management to help research with icddr,b on water safety. The survey should take about 20 to 30 minutes for all the important information. There is no obligation to participate and the data is confidential. You can stop the interview at any point, and you do not have to share any information that makes you uncomfortable. No video or audio recording will happen during this interview. The data will be provided to a research team for analysis. Again, the information will be confidential, and you can stop this interview at any point. We would also like to be clear that there are no benefits for participating in this study. As with all other icddr,b studies, this is voluntary participation. If you have any questions, please call Dr. Siraj Islam, 0173049989.	
Confirm Consent	Please confirm the respondent agreed to continue and complete the written consent form.	
1.5 Second Consent	If the respondent does not give consent for a full interview, please ask if you have permission to do a rapid visual inspection of the water point.	
Section 1.2	This next section only appears if consent was given in 1.4 or 1.5. If no consent is given, the questionnaire automatically continues to the end to thank the respondent and submit the form.	
1.6 Is this an abandoned well?	Select One: Yes/No/DNK/No Response	Abandoned well includes not used, no handpump, only pipes with no pump.
1.7 Is the tubewell working (functioning)?	Select One: Yes/No/DNK/No Response	Please use the pump (or turn it on if electric) for a minute or two and ensure there is steady flow of water.

1.8 Does the tubewell have any labels/markings for to warn of arsenic?	Select One: Yes/No/DNK/No Response	This could include a spout painted red or green or a metal band with written information. Please select one.
1.9 Is there a plaque or sign board with information about the tubewell? IF Yes, please take a photo.	Select One: Yes/No/DNK/No Response	This could include information about date of installation, cost, depth, or ownership.
1.10 Is there a latrine within 15 feet of the tubewell?	Select One: Yes/No/DNK/No Response	Please look around and see if there is a latrine within roughly 15 feet (or 5m). About 15 steps from the water point.
Tubewell Physical Observations		
1.11 Please look at the tubewell and select the type of tube well.	Select One: - Tubewell- #6 - Tubewell Tara - Electric pump only - Do not know	
1.12 Please select which manufacturer of the #6 handpump.	Select One: - RFL - Gazi - RML - other	Please look at the markings on the side of the handpump to determine which kind of handpump is installed.
1.13 Please select which model of the #6 handpump.	Select One - Samarat - Popular - Popular Heavy - Super - Heavy - Other - Do Not Know	Please look at the markings on the side of the handpump to determine which kind of handpump is installed.
1.14 Does the tubewell have any additional pipes, pumps, tanks besides the handpump?	Please select all that apply: - Pipeline connected to the tubewell or hand pump or storage tank (Not drainage) - Storage tank above ground (ex: Gazi) - Storage tank underground - Electric pump - Other types of pump - Base platform, including drainage - Only the handpump - Other types of modifications (If other please specify)	
1.15 Please take a photo of the tubewell	Please make sure the photo includes the platform, the pump stand, the handle, the spout, and the pump head.	
1.16 Please take a picture of the sign board/plaque.	Please make sure the photo includes the platform, the pump stand, the handle, the spout, and the pump head.	
Respondent Information	Please ask to see the icddr,b FVR (Family Visit Registration) card to confirm the following information.	

1.17 Please select the village where this interview is occurring	Rayerkandi (VB3) Taltoli (VB1) Daribond (V80) Chosoi (V76) Titerkandi (P00) Shahpur (K00) Aswinpur (N00) Barogaon (DXO) Lamchari (H00) Amuakanda (T00) Torkey (V18) Hatighata (V17) Kaladi (W00) Doshpara (V59) Upadi (V72) Goalbhar (V08) Mandertoli (D99) Sarderkandi (C00) Maizkandi (D93)	
1.18 Please enter the bari number	Integer	If you or the family don't know, please ask for the icddr,b household health visit card to verify the code (FBR). For non-bari area please enter 996 for religious facility (mosque), 997 for public facility, 998 for school and 999 for health clinic.
1.19 Please enter the household/family number from the family visit registry of the owner of the tubewell.	Integer	The household/family number of the household that owns tube well. If it's an institution, enter 996 for religious facility (mosque), 997 for public facility, 998 for school and 999 for health clinic.
1.20 Please enter the respondents' number from the FBR. This is the individual number (ind. No)	Integer	For institutions and someone outside the bari, please enter 0
1.21 Are you the water point's owner, manager, user, relative to owner or have another role?	Select One: - Owner - Manager - Relative of owner, family member - User of the tubewell - Other	If none of the selection, please ask if you can find the owner, manager, family member or user of the water point. If a public facility, find the manager-
1.22 Please select the gender of the respondent	- Male - Female - No Response	
1.23 How many years have you lived in the village?	Integer	If they don't live in village but manage well, enter -999

Section 2 History and Use	We would now like to ask you a few questions about the history and current use of the tubewell.	
2.1 Is this tubewell provided by the government (DPHE)?	Select One: Yes/No/DNK/No Response	
2.2 How many years ago was the tubewell installed?	Integer	If under 1 year put 0.
2.3 How do you know the year of installation?	Select One - Written record (Paper or information on handpump) - Memory - Unsure, is guessing - Does not know	
2.4 Who installed the tubewell?	Select One: - Household/Owner - Jointly, group of households - External/ Non-household person (remittance, external family member, etc) - Community committee - DPHE - Department of Public Health and Engineering - Public facility (school, health care clinic, religious centre, market) - Pourshava government - BRAC/ NGO - UNICEF - Charity (religious) - Other Do not know/Not sure	
2.5 Did you need permission to install this tubewell?	Select One: Yes/No/DNK/No Response	
2.6 If you needed permission to install the tubewell, who gave you that permission?	Please select all that apply - Permission from the government regulator (DPHE or any other government agency) - Permission from the Pourshava or municipal official - Permission from a community leader or elder - Permission from the landowner - Other (Please specify)	
2.7 Why did you or the owner decide to install the water point?	Please select all that apply - Owner wanted private water source - Group of households or community wanted their own water point - Price/costs was reduced for drilling or equipment - Users had more money, increased income - Government, NGO or relative provided money or helped to install the system - A new loan was available to borrow money to pay for the water point - Needed alternative to arsenic contaminated well - Needed better water quality (ex: odour, taste, colour, etc)	Please select all that apply. Please ask in open ended question first. After initial response, please prompt by reading the list if respondent is unsure of the response.

	- Required to change by NGO, Government or other entity - Do not know - Another Reason	
2.8 Who owns this water point?	Select One: - It is owned by one specific family or individual - It is owned by a group of households or individuals - It is owned by a committee or cooperative - It is owned by a public facility (school, mosque, clinic) or the government - It is owned by a business institution or any other institution like NGO - There is no one specific owner - Another owner (Please specify) - Do not know	Please read the options and select all that apply.
2.9 Who is using the water currently?	Select all that apply - Households, any purpose - Health care facilities - Schools, any levels - Business or factory (ex: brick factory, office) - Restaurants, hotel, bus station, local markets, public WASH facilities - Mosque or religious centre - Farmer for irrigation - Other	Please read the options and select all that apply.
2.10 How do households use the water?	Select all that apply: - Drinking - Bathing - Washing (dishes) - Cleaning (house/clothes) - Cooking - Livestock (example cows or ducks) - Other purposes - Do not know/Not sure	Please read the options and select all that apply.
2.11 Before this tubewell, was installed, what was the main source of drinking water?	Select all that apply: - Tubewell - Piped water system - Pond water - River water - Ring well - Canal/ditch water - Trucked water - Rainwater harvesting system - Pond Sand Filter - Other - Do not know	Do not read unless requested by respondent.
2.12 How many households are using this tubewell on an average day of the week during the dry season?	Integer	Please estimate the average number. If they do not know, please enter -999
2.13 Does the number of households change in the wet season?	Select One: - Increased number of users/ households	

	- Decreased number of users/households - No change in the number of users/households	
2.14 If number of households increases, how many total households use on an average day in wet season?	Integer	Please estimate the average number. If they do not know, please enter -999
2.15 If number of households decreases, how many total households use on an average day?	Integer	Please estimate the average number. If they do not know, please enter -999
Section Two Facility Schools		
2.16 Please enter the school level/type.	- Primary school, Government of Bangladesh - Primary school, BRAC - Primary school, registered - Secondary school, high school - Madrasah - Other	
Section Two Facilities Health Clinics		
2.17 Please select the health facility type	- Public clinic - Private clinic - Hospital - Pharmacy - Other	
Section Three Management		
We would now like to ask you a few questions about the management of this tubewell.		
3.1 Who is responsible for overall management of water point?	Select One - Private individual or head of household (Owner) - A private caretaker on behalf of someone else (paid individual) - Shared by multiple household members (private group) - A committee or cooperative - Public facility (school, health care clinic, religious centre, market) - Government engineer (regional or national DPHE) - Municipal government engineer (Pourshava) - BRAC- NGO - Private enterprise (private engineer, factory, company or office) - Do not know	Management could include responsibilities for repairs, cleaning, collecting fees, communication to users or controlling access.
3.2 Are specific tasks managed by different and specific people?	Select One: Yes/No/DNK/No Response	
3.3-3.6 These questions have been removed due to enumerator confusion and lack of formal disaggregated roles		
3.7 Is there a management committee for the water point?	Select One: Yes/No/DNK/No Response	A committee refers to a group of people making decisions together, in some organized way, about the water point.

3.8 How many years has the committee been in place?	Integer	If they do not know, please enter -999
3.9 How many people are on the committee?	Integer	If they do not know, please enter -999
3.10 How many of the members are women?	Integer	If they do not know, please enter -999
3.11 Are there any written records from the committee?	Select One: Yes/No/DNK/No Response	
3.12 Can you please show us the records?	Select One: Yes/No/DNK/No Response	
3.13 Please take a picture of the records		
Section Four Information I would now like to ask you a few questions about the depth of the tubewell.		
4.1 Is this a deep tubewell?	Select One: Yes/No/DNK/No Response	Do not prompt respondent, this is a question about their perception.
4.2 How many feet deep is this well? What is the depth?		Please record in feet. If they do not know, please enter -999
4.3 How many pipes were used?	Integer	Please ask in number of pipes used. Each pipe is 15 feet. If they do not know, please enter -999
Section Four Water Safety I would now like to ask you a few questions about the water safety and quality.		
4.5 As the \${respondent_position}, do you think that the water is safe to drink?	Select One - Safe to drink - Not safe to drink - Not sure if safe or not - No response	Safe means that it will not make you sick in short or long term.
4.6 Have any of the users told you they are worried/concerned about the water safety?	Select One: Yes/No/DNK/No Response	This question only appears if owners are collective or public.
4.7 If you are concerned, why is this not safe to drink?	Select all that apply - Worried about arsenic - Worried about iron - Worried about salinity - Worried about waste from latrine or other germs - Appearance is bad (smell, taste or colour) - Worried but don't know why - Other	Please wait for a response, do not read the list.
4.8 Which issues did users say they are worried/concerned about for this water point?	Select all that apply - Worried about arsenic - Worried about iron - Worried about salinity - Worried about waste from latrine or other germs - Appearance is bad (smell, taste or colour) - Worried but don't know why	Please wait for a response, do not read the list.

	Other	
4.9 If unsafe, do you or the users still use this source for drinking water?	Select One: Yes/No/DNK/No Response	
4.10 Which type of source is preferred as an alternative for drinking water by users?	Select all that apply - Tubewell - Piped water system - Pond water - River water - Ring well - Canal/ditch water - Trucked water - Rainwater harvesting system - Pond Sand Filter - Other - Do not know	
4.11 Has anyone who drinks this water been sick with diarrhoea in the past 2 weeks?	Select One: Yes/No/DNK/No Response	
4.12 How would you describe the taste of the water from the handpump?	Select One: - The taste is excellent - The taste is good - The taste is acceptable - There is a bad taste / not drinkable	
4.13 How would you describe the colour of the water from the handpump?	Select One: - The colour is very clear and fine - The colour is mostly clear - The colour is not clear - The colour is very dirty / not drinkable	
4.14 How would you describe the water smell coming from the handpump?	Select One: - There is no smell at all - The water smells a little - The water has smell but drinkable - The water smells very bad / not drinkable	
4.15 Have you ever invested money to fix the bad taste, smell or appearance?	Select One: Yes/No/DNK/No Response	
4.16 Have you ever changed sources because of a bad taste, smell or appearance?	Select One: Yes/No/DNK/No Response	
Section Four Arsenic		
4.17 As the \${respondent_position}, do you think the water point is contaminated with arsenic?	Select One: Yes/No/DNK/No Response	
4.18 Please describe, in a few words, why you don't think the water is contaminated, even though it is labelled red.	TEXT	Example: someone told them it was safe; that was a long time ago and they think it has changed; it tastes fine, etc
4.19 How do you know that the well is contaminated with arsenic?	Select all that apply - We tested by yourself - It was tested by the government (DPHE)	Please read the options and select all that apply.

	- It was tested when installed by the driller or other professional service - It was tested by icddr,b or another NGO - Our perception - A neighbour or friend told us - Heard on radio, school or other public communication	
4.20 If you test the water yourself, please briefly explain how?	TEXT	Please enter short description. (ex: lentils change colour, or lemon juice changes water colour)
4.21 As the \${respondent_position}, what did you do when you found it was contaminated?	Select one - Did nothing (ignore) - Changed to another existing water source (no new investment) - Invested or built a new water source - This isn't a problem to use - Installed a water filtration system/or treated the same water source (purified) - It's not my responsibility to do anything - Other	Select their first action
4.22 Which source do you pick as an alternative?	Select all that apply - Tubewell - Piped water system - Pond water - River water - Ring well - Canal/ditch water - Trucked water - Rainwater harvesting system - Pond Sand Filter - Other - Do not know	
Section Four Salinity		
4.23 As the \${respondent_position}, do you think the water point has a problem with salty water (salinity)?	Select One: Yes/No/DNK/No Response	
4.24 Does the water become saltier at certain times of year?	Select One: Yes/No/DNK/No Response	
4.25 Which seasons does the water become saltier?	Select One - Rainy season (June-Sept) - Dry Season (Feb-April) - Winter season (Oct-Jan)	
4.26 Would you switch to another drinking water source because of salinity problems?	Select One: Yes/No/DNK/No Response	
4.27 Which type of source is preferred as an alternative for drinking water by users?	Select One: - Tubewell - Piped water system - Pond water - River water - Ring well	Please select the most preferred source.

	- From the government such as Pourshava or local DPHE engineer. - From radio, TV or other public announcements. - Do not remember/do not know - Other	
4.36 Did the test report a problem with water safety for drinking?	Select One: Yes/No/DNK/No Response	Water safety defined as above a government defined safe level. Or reported by the tester as not safe for drinking.
4.37 What was identified in the test as a problem for drinking water?	Select all that apply - Arsenic - Bacteriological - Salinity - Iron - Do not know - No response - Other	
4.38 Do you trust and agree with the results of the test?	Select One: Yes/No/DNK/No Response	
4.39 What did you do when you found out?	Select all that apply - Did nothing (ignore) - Changed to another existing water source (no new investment) - Invested or built a new water source - This isn't a problem to use - Installed a water filtration system/or treated the same water source (purified) - It's not my responsibility to do anything - Other	
4.40 Which source did you switched to?	Select all that apply - Tubewell - Piped water system - Pond water - River water - Ring well - Canal/ditch water - Trucked water - Rainwater harvesting system - Pond Sand Filter - Other Do not know	
4.41 Was the tubewell water tested any time after it was first installed, meaning after operational and being used?	Select One: Yes/No/DNK/No Response	For example, it could be tested by icddr, b 2 years after first installed.
4.42 How many times has the water quality been tested after it was installed?	Integer	If they do not know, please enter -999
4.43 Who conducted the/these water quality test?	Select all that apply - Government of Bangladesh - icddr,b - BRAC	

	- Individual conducted the test - Community group - Formal company or business - Other - Do not know	
4.44 Which water quality parameters were tested after the tubewell was installed?	Select all that apply - Arsenic - Bacteriological - Salinity - Iron - Do not know - No response - Other	
4.45 Do you know the results of the test?	Select One: Yes/No/DNK/No Response	
4.46 How did you hear the about the initial test results?	Select all that apply - Directly from the person/group who tested the water - In writing from person/group testing the water - Indirectly from a neighbour, organization - Indirectly from a written post, flier - From the government such as Pourshava or local DPHE engineer. - From radio, TV or other public announcements. - Do not remember/do not know Other	
4.47 Did the test report a problem with water safety for drinking?	Select One: Yes/No/DNK/No Response	Water safety defined as above a government specified safe level. Or reported by the tester as not safe for drinking.
4.48 What was identified in the test as a problem for drinking water?	Select all that apply - Arsenic - Bacteriological - Salinity - Iron - Do not know - No response Other	
4.49 What did you do when you found out?	Select all that apply - Did nothing (ignore) - Changed to another existing water source (no new investment) - Invested or built a new water source - This isn't a problem to use - Installed a water filtration system/or treated the same water source (purified) - It's not my responsibility to do anything Other	
4.50 Which source did you switch to?	Select all that apply - Tubewell - Piped water system	

	- Pond water - River water - Ring well - Canal/ditch water - Trucked water - Rainwater harvesting system - Pond Sand Filter - Other	
	Do not know	
4.51 Do any of the users filter or treat this water?	Select One: Yes/No/DNK/No Response	This could be at the pump or at home before use. This could include boiling, filtration devices.
Section Five Financial Information I would now like to ask you a few questions about the costs and fees related to this water point.		
5.1 Do you have any of the following written records about the tubewell?	Select One: Yes/No/DNK/No Response	
5.2 What type of records do you keep?	Select all that apply - Records on installation costs (drilling, tubewell hardware, technician) - Records on payments or fees by users - Records on expenses for maintenance and repairs - Records like bills or payments for operation costs (electricity) - Other	
5.3 If there are written records, may I take a picture of the first page?	Take a photo	Skip if no records or if same as the management committee in previous question.
5.4. Who paid for the tubewell when it was first installed?	Select all that apply. - Household - External/ Non-household person (remittance, external family member, etc) - Jointly, group of households - Loan - Community committee - Government- DPHE - Government- Pourshava - BRAC/ NGO - Public facility (school, health care clinic, religious centre, market) - Charity - Private office, store, garage, business or factory - Other - Do not know	Please select all that apply. Please prompt by reading the list if respondent is unsure of the response.
5.5 Can you remember the total amount that you originally spent when installing this tubewell.	Integer	This includes drilling, hardware, technical support, labour. Please enter in taka.
5.6 How do they know the cost?	Select One - Written record (Paper or information on handpump)	

	- Memory - Unsure, is guessing - Does not know	
Section Five Costs Please ask if they remember the costs for specific components of the tubewell. Please read the list and ask if they remember the costs. Please enter 0 if they didn't spend money on it. If they don't remember, please enter -999.		
5.7 New Replacement Handpump Costs:	Integer	If no investment, enter 0. If they do not know, please enter-999
5.8 Base Platform, including drainage costs:	Integer	If no investment, enter 0. If they do not know, please enter-999
5.9 Pipelines (connecting tank or handpump) Cost:	Integer	If no investment, enter 0. If they do not know, please enter-999
5.10 Electric/Diesel Pump:	Integer	If no investment, enter 0. If they do not know, please enter-999
5.11 Water Storage Tank Above Ground:	Integer	If no investment, enter 0. If they do not know, please enter-999
5.12 Water Storage Tank Underground:	Integer	If no investment, enter 0. If they do not know, please enter-999
5.13 Testing water quality after installation:	Integer	If no investment, enter 0. If they do not know, please enter-999
5.14 Any other cost for tubewell:	Integer	If no investment, enter 0. If they do not know, please enter-999
Section Five Fees and Revenue		
5.15 Please identify if ANY users contribute money, pay regular fees, or never pay for use of this water point.	Select One - Users determine how much they contribute (voluntary) - Manager/owner/someone else decides the amount users contribute (fees for use) - Users never contribute any taka (no cost) - Other	
5.16 Which of the following describes the frequency/type of payments?	Select One - Pay at once for a period of time - Pay when water point breaks - Pay when users have money - Pay for each time water point is used - Other - Do not know	
5.17 On average, how often are contributions made?	Select One - Once a year - Monthly - Weekly - Pay as you use - Other	
5.18 Who collects and manages the contributions?	Select One - Users of the water point - The owner or manager - Someone from the community	

	- The hired caretake (individual) - The water management committee - A government engineer (DPHE) - Someone from an NGO - A technician or mechanic - Other - Do not know	
5.19 On average, how much do each user contribute per \$ $\{revenue\_vol\_frequency\}$?	Integer	
5.20 How much taka (money) was collected in total from all users in the past 12 months?	Integer	
5.21 Which of the following describes the frequency/type of payments?	Select One - Pay at once for a period of time - Pay when water point breaks - Pay when users have money - Pay for each time water point is used - Other - Do not know	
5.22 How often are payments requested?	Select One - Once a year - Monthly - Weekly - Pay as you use - Other	
5.23 Who decides the amount being payed?	Select One - Users of the water point - The owner or manager - Someone from the community - The hired caretake (individual) - The water management committee - A government engineer (DPHE) - Someone from an NGO - A technician or mechanic - Other - Do not know	
5.24 Who collects the payments?	Select One - Users of the water point - The owner or manager - Someone from the community - The hired caretake (individual) - The water management committee - A government engineer (DPHE) - Someone from an NGO - A technician or mechanic - Other Do not know	
5.25 Who manages the payments?	Select One - Users of the water point - The owner or manager - Someone from the community - The hired caretake (individual) - The water management committee - A government engineer (DPHE) - Someone from an NGO	

	- A technician or mechanic - Other - Do not know	
5.26 On average, how much do each user contribute per $\{revenue\_vol\_frequency\}$?	Integer	
5.27 How much taka (money) was collected in total from all users in the past 12 months?	Integer	
5.28 Does the payment/contribute amount vary by user?	Select One: Yes/No/DNK/No Response	
5.29 Are poorer families asked to pay a lower amount?	Select One: Yes/No/DNK/No Response	
Section Five Operation Costs		
5.30 Did you have enough money to pay for the repairs this past year?	Select One: Yes/No/DNK/No Response	
5.31 Are you planning to spend any taka in the next year on your water source?	Select One: Yes/No/DNK/No Response	
5.32 What is the priority for your investment in the next year?	Select all that apply - Install a new hand pump - Install a new automatic pump - Install a new storage tank - Connect to a piped water system - Install rainwater system - other	
5.33 Why you are now planning/willing to invest more taka?	Select all that apply - Want a handpump that doesn't break so frequently/ is more reliable - Need more water for users - The cost has decreased, and users can now afford - Users have more money and can afford - Users want better water quality - Users received a grant - Neighbours suggested - Electricity is now available. - Access to loan - Additional users of the system require more supply - Water source was insufficient - Other	
Section Six Maintenance I would now like to ask you a few questions about the maintenance and functionality of the system.		
6.1 What type of maintenance do you do?	Select all that apply - The owner conducts maintenance on a regular basis to prevent it from break.	

	- The owner conducts maintenance when he/she thinks the pump is about to break. - Repairs happens after the infrastructure breaks - No maintenance has been done on this hand pump - Other - Do not know	
6.3 Do you clean the hand pump?	Select One: Yes/No/DNK/No Response	
6.4 Do they clean inside the spout?	Select One: Yes/No/DNK/No Response	
6.5 How many times in total has the tubewell broken or not had flowing water since it was first installed?	Integer	Broken is defined as no flow as a result of hardware malfunction or lack of water supply. Please enter 0 if it has never broken. Please enter -999 if they don't know.
6.6 Last time it was broken, how many days was it not working/ not flowing or broken last time?	Integer	Please record number of days it was not flowing water or limited/partial water flow. IF never broken in Q 6.5, will enter 0- mistake in final programming.
6.7 Has it not worked because of no water supply? (water table decline)	Select One: Yes/No/DNK/No Response	This could be drought or ground water depletion. This means the handpump works but there is no water in the ground. Priming the well means it still works.
6.8 Which seasons do the supply run out?	Select all that apply - Rainy season (June-Sept) - Dry Season (Feb-April) - Winter season (Oct-Jan)	
6.9 When the handpump was broken, what source did you use as an alternative?	Select all that apply - Tubewell - Piped water system - Pond water - River water - Ring well - Canal/ditch water - Trucked water - Rainwater harvesting system - Pond Sand Filter - Other - Do not know	
6.10 Did you need permission to use the alternative source?	Select One: Yes/No/DNK/No Response	
6.11 Does this alternative source take more time, less time, or the same amount of time to access?	Select one - It takes more time to walk to - It takes less time to walk to - It is almost the same distance	

	- Do not know	
6.12 If it takes more time, how many additional minutes?	Integer	
6.13-6.14 Numbering error after shifting questions during pilot		
6.15 If it takes less time, how many less minutes to walk to?	Integer	
6.16 Was the tubewell repaired any time in the past year?	Select One: Yes/No/DNK/No Response	This could be not flowing or flowing at low level. This could mean parts broken.
6.17 Which parts did you repair in the past year?	Select all that apply - Washer - Bucket - Pump handle - Base platform - Pipe - Other - Do not know	Please select all that apply. Please prompt by reading the list if respondent is unsure of the response.
6.18 Who performed the repairs to solve the problem?	Select all that apply - Users of the water point - The owner or manager - Someone from the community - The hired caretaker (individual) - The water management committee - A government engineer (DPHE) - Someone from an NGO - A technician or mechanic - Other - Do not know	
6.19 How much did the last repair cost in total?	Integer	Please enter taka. Please enter -999 if you do not know.
6.20 If you can remember, how much did you spend in total the past year on the water point repairs?	Integer	This includes maintenance, treatment, repairs, cleaning, administration. Please enter -999 if you do not know.
6.21 Who paid for the repair?	Select all that apply - Household - External/ Non-household person (remittance, external family member, etc) - Jointly, group of households - Loan - Community committee - Government- DPHE - Government- Pourshava - BRAC/ NGO - Public facility (school, health care clinic, religious centre, market) - Charity - Private office, store, garage, business or factory	

	- Other - Do not know	
Section Seven Close Interview and Hanna Meter Please thank the person for participating in the questionnaire and sharing information about the water point. Please tell them the interview is now over.		
7.1 Please ask if they are willing to share a contact phone number of the water point manager.	TEXT	Please explain that this is optional, not required, and would only be used if there are additional questions from the research team. If needed, please repeat that is a research project and will not provide any other forms of support.
This section is for the enumerator only, not the respondent.		
7.2 Did the respondent understand most of the questions?	Select One - Understood all the questions well - Understood most of the questions, but not all - Understood some of the questions (roughly half) - Did not understand many questions (less than half) - Understood very few questions	Did you notice hesitation, uncertainty or problems answering the questions?
7.3 How would you rate the accuracy of the respondent's answers?	Select One - Accurate - Satisfactory - Average - Poor	How satisfied are you with the answer of the respondent?
Section Seven Hanna Meter		
7.4 Is this a HannaMeter Test?		Select no to finish survey.
We would now like to take a quick test of your water quality.	Instructions: Pump the tubewell for a minute or two until the water flows through and is fresh. Rinse the plastic jug 3 times and rinse the meter times before taking the reading. Press the Mode button to turn the Hanna meter on. Press the right button to select ph. When taking the reading, place the meter into the water and wait until the clock symbol on the left disappears. The numbers should stop moving.	
7.5 Please enter the temperature.	Integer	
7.6 Please select if its C or F units	Fahrenheit Celsius	
7.7 Please enter the pH reading	Integer	
7.8 Please enter the EC reading	Integer	
7.9 Please enter the TDS reading	Integer	
7.10 Please select TDS unit's ppm or ppt.	Select One - ppm - ppt	