Water, Sanitation and Hygiene

GROUNDWATER – WASH NEXUS IN ASIAN CITIES

Hanoi, Kathmandu and Khulna

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Water Sanitation and Hygiene

GROUNDWATER – WASH NEXUS IN ASIAN CITIES:
Hanoi, Kathmandu and Khulna

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GROUNDWATER – WASH NEXUS IN ASIAN CITIES: Hanoi, Kathmandu and Khulna

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FOREWORD

Providing safe and reliable WASH (Water, Sanitation and Hygiene) services is a major challenge for sustainable development. Access to WASH is uneven in many countries due to multiple factors ranging from infrastructure availability to the income gap, poverty, and culture. Groundwater is a vital resource for the improvement of WASH services as it provides almost half of the drinking water worldwide. However, the contribution of groundwater to WASH services is not adequately recognised and remains unknown in many Asian cities. Inadequate attention to understanding this nexus and the failure to manage groundwater sustainably can reduce the likelihood of achieving the WASH related targets of the sustainable development goals (SDGs).

The Institute for Global Environmental Strategies (IGES) is an international research institute conducting practical and innovative research for realising sustainable development in the Asia-Pacific region. In line with its mission, water security in the region is one of IGES' core areas of research. This working paper explains the close linkage between groundwater and WASH in three Asian cities. This publication is timely because the year 2016 marks the beginning of the implementation of the SDGs which is expected to drive the unfinished tasks of improving water and sanitation left by the UN Millennium Development Goals (MDGs) and the International Decade for Action 'Water for Life' 2005-2015. I believe the findings of this working paper will contribute to raising awareness of the groundwater-WASH nexus, framing appropriate policies and action to manage the nexus, and to achieving WASH related targets of the SDGs.

Hideyuki Mori

President

Institute for Global Environmental Strategies

FOREWORD

Globally, improving WASH services is a priority issue for sustainable development. Governments in developing Asian countries have allocated a significant amount of resources to improve WASH services over the past few decades.

Groundwater plays an important role in developing easily accessible, affordable and safe WASH services. For many people, groundwater is the default source for water supply due to its widespread availability and easy access. However, the contribution of groundwater is not well acknowledged in the development of WASH services. Failure to recognise and understand the groundwater-WASH nexus can undermine the cost-effective delivery of WASH services. Furthermore, unplanned use of groundwater and improper disposal of human waste can threaten the sustainability of groundwater resources on which the continuity of WASH services depends.

The Graduate School of Global Environmental Studies (GSGES), Kyoto University has undertaken various research activities to understand and improve WASH services in Asian countries. In order to carry out research activities and to train our students, GSGES promotes collaborative research with Japanese organisations, our overseas satellite campuses and overseas researchers. This working paper is an outcome of collaboration of GSGES with IGES, National Institute for Environmental Sciences (NIES), and the University of Marketing and Distribution Sciences (UMDS).

I would like to congratulate IGES and the author for producing this report, noting that the SDGs have WASH related targets listed under Goal 6 “Ensure availability and sustainable management of water and sanitation for all”. I hope the findings of the study will be useful to policy makers, officials and researchers dealing with groundwater and WASH issues in Asian cities.

Shigeo Fujii

Professor and Dean

Graduate School of Global Environmental Studies (GSGES), Kyoto University

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ABSTRACT

This working paper assesses the groundwater-WASH (Water, Sanitation and Hygiene) nexus based on an analysis of domestic water uses in three groundwater dependent Asian Cities: Hanoi (Viet Nam), Kathmandu (Nepal), and Khulna (Bangladesh). The paper analyses the pull (benefits) and push (constraints) factors for use of groundwater by residents in these cities based on five decision criteria: preference, access, adequacy, affordability and quality.

The study has found a close linkage between groundwater and WASH. Groundwater plays a critical role in improving access to WASH in the three cities. The study finds that groundwater is one of the primary choices or the only source of water for residents in the studied cites. Access to groundwater was the primary pull factor in all cities to overcome the water supply deficit resulting from a lack of piped water connection or unreliable supply. Poor groundwater quality was the major push factor identified in all the cities. Due to quality concerns, residents were reluctant to use groundwater for direct consumption. Groundwater was therefore mostly used for sanitation (toilet flushing) and maintaining hygiene (bathing, washing, and cleaning). Cost was both a push and pull factor depending on the amount of water used by a family. For low volume use in households (<100 litres/person/day), a cheap hand-pump or a dug well was a major enabling factor (i.e., pull factor), whilst for high use households (>100 litres/person/day) groundwater was found to be more expensive than tap water (i.e., push factor).

All the cities have a plan for or have already introduced new surface water supply systems to boost the coverage and quality of water services. This is a step towards finding a long-term solution to water shortages and will reduce the pressures on groundwater. However, due to an increasingly uncertain water supply, groundwater still holds the key to city water supply security. Cities should therefore find ways to make tap water and groundwater affordable in order to balance the excessive reliance on one source over another and to raise the profile of groundwater in the city's water security planning. Further efforts will be needed to avoid groundwater contamination and increase the quality of groundwater for consumption in addition to ensuring its continued availability for sanitation and hygiene. Any development of WASH services should incorporate safeguard measures to prevent likely depletion of the water table and degradation of water quality. Cities in Asia could consider alternative pricing policies and use stronger regulatory measures to minimise unplanned development of their groundwater resources, control wasteful use of water, and promote a culture of safe disposal of waste, wastewater, and harmful chemicals.

Keywords: access, adequacy, affordability, groundwater, preference, WASH, water quality

LIST OF ACRONYMS

Cd	Cadmium
COD	Chemical Oxygen Demand
DPHE	Department of Public Health Engineering
Fe	Iron
FGD	Focus group discussion
IGRAC	International Groundwater Resource Assessment Center
JADE	Japan Association of Drainage and Environment
KCC	Khulna City Corporation
KVWSL	Kathmandu Valley Water Supply Limited
KWASA	Khulna Water Supply and Sewerage Authority
MDGs	Millennium Development Goals
mld	Million litres per day
NH_4^+-N	Ammonium nitrogen
Pb	Lead
ppb	Parts per billion
SDGs	Sustainable Development Goals
UN	United Nations
USD	United States Dollar
WASH	Water, Sanitation and Hygiene
WHO	World Health Organisation
WSP	Water Supply Plant

LIST OF TABLES AND FIGURES

1 INTRODUCTION

Sustaining WASH services in cities is one of the main challenges for water security. Groundwater is a major determining factor for providing WASH services in cities, towns and villages. It has been reported that almost half of the global drinking water supply is sourced from groundwater (WWAP 2009). Although it is a little acknowledged fact, groundwater played a crucial role in realising the drinking water and sanitation targets of the United Nations (UN) Millennium Development Goals (MDGs). According to the International Groundwater Resource Assessment Center (IGRAC), universal access to WASH services cannot be achieved without development and proper management of groundwater as envisioned in Goal 6 of the SDGs (IGRAC 2015). Unplanned abstraction, exceeding the natural recharge of the aquifer, could threaten the continuity of WASH services dependent on groundwater. Inappropriate WASH practices and disposal of untreated wastewater can pollute underlying aquifers and increase health risks. Ignoring this linkage can seriously undermine the SDG targets related to improving WASH services, especially, in those areas where groundwater is the primary source of economically accessible water. The role of groundwater should be properly recognised, while the preferences and concerns of the main beneficiaries (i.e., city residents) should be properly addressed when formulating policies and actions on WASH.

In this working paper, the groundwater-WASH nexus is highlighted as an important policy issue for urban planners and decision makers in cities and municipalities dealing with urban water management and provisioning of WASH services. Understanding this nexus will help them develop strategies for securing WASH services and safeguarding groundwater resources from depletion in terms of quantity and degradation in terms of quality. This understanding will also induce conversations among relevant stakeholders (municipalities, water supply authorities, private sectors, users) to find effective solutions to achieve the WASH related targets of the SDGs.

This paper is structured in seven sections. After this introduction, Section 2 discusses the need for groundwater-WASH nexus thinking in Asian cities as a way to manage the two-way relationship between the groundwater resource and the service it provides to urban residents. Section 3 outlines the objectives and methods used in this study. Section 4 assesses the groundwater dependency in the case study cities, and Section 5 examines the groundwater-WASH nexus based on five criteria. Section 6 evaluates the pull-and-push factors and identifies potential options for managing the groundwater-WASH nexus, and Section 7 concludes with recommendations for managing this nexus.

② WHY PROMOTE THE GROUNDWATER-WASH NEXUS?

What is WASH?

WASH is essential for leading a healthy life and for environmental sustainability. WASH is directly linked with education, gender equality, dignity, and realisation of human rights to water and sanitation[1]. Water-borne diseases such as diarrhoea – a result of inadequate or unsafe WASH services – are among the top ten leading causes of death, killing 1.5 million people in 2012, especially infants under five in many developing countries (WHO 2014). The indispensability of WASH services to sustainable development was emphasised in the UN MDGs, although there was no explicit target for WASH in the MDGs. WASH has been clearly prioritised in the targets under Goal 6 of the SDGs (**Box 1**), especially, targets 6.1, 6.2, 6.3, 6.a and 6.b.

Box 1 Sustainable Development Goal 6: Ensure availability and sustainable management of water and sanitation for all

Targets

6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all
6.2: By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations
6.3: By 2030, improve water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
6.5: By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate
6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
6.a: By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies
6.b: Support and strengthen the participation of local communities in improving water and sanitation management

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[1] On 28 July 2010, through Resolution 64/292, the United Nations General Assembly explicitly recognised the human right to water and sanitation and acknowledged that clean drinking water and sanitation are essential to the realisation of all human rights (Source: http://www.un.org/waterforlifedecade/human_right_to_water.shtml).

Achieving universal access to WASH services by 2030 will be challenging as more than 740 million people are still without access to basic drinking water services and over 2 billion people do not have access to improved sanitation facilities (WHO/UNICEF 2014). A huge amount of resources and innovative measures for its effective mobilisation will be needed to achieve the WASH targets in the shortest possible time-frame. Ensuring sustainable and equitable access to WASH services necessitates that both quantitative and qualitative requirements are met. The quantitative requirement is about increasing physical access to WASH services, which is directly related to expanding coverage by the development and renovation of services at various points such as households, schools, health posts, communities and so forth. The qualitative requirement is about ensuring uninterrupted safe and well-maintained WASH services that are free from contamination and do not pose the risk of transmission of water borne diseases such as diarrhoea. There are even claims that the real progress of MDGs on water and sanitation targets are at the same level (i.e., over two billion without access to safe water and sanitation) if qualitative aspects are also considered (UNSGAB 2014, Cumming, et al. 2014). The qualitative requirement is essential for progressively minimising the huge inequality and disparity that is prevalent across groups (rural vs. urban; slums vs. formal settlements; rich vs. poor; men vs. women, one ethnic group vs. another race/caste) throughout the process of initial design to the final use of WASH services.

Relative advantages of groundwater for WASH

Systematically collected and comprehensive data on groundwater use trends are scattered and not readily available. An approximate estimation is that globally over 1.5 billion urban dwellers are now using groundwater for various purposes (Foster, et al. 2010).

Due to ease of development and other advantages, groundwater could act as the fastest route in closing the gap between rapid urbanisation and access to WASH services. Groundwater could be an all-purpose source of water depending on the environmental state of aquifers. **Table 1** summarises the relative advantages of groundwater over surface water sources. Groundwater is the primary choice for many people for safe drinking and other uses when other water supply options are unavailable, inaccessible or too polluted. Wide spatial coverage and relatively stable storage are two important attributes of groundwater that contribute to reliable supply even during extreme events such as droughts, floods or during an emergency situation (Vrba and Verhagen 2011). Use of groundwater can also be flexible as aquifers can be accessed on-site, on-demand and in the quantity required. There is no discrimination between rich and poor for accessing groundwater as it is relatively cheap to develop an abstraction facility (a well or hand-pump) near the point-of-use and it is often quick to install wells, hand-pumps or bore wells. In the majority of Asian countries, groundwater could be accessed without restriction due to absence of or weak implementation of legal/regulatory control measures. Except in the cases of human-induced pollution (nitrate, coliform, heavy metals, organo-chemicals, nuclear accidents) or naturally occurring contaminants (arsenic, fluoride, salinity), groundwater quality is relatively stable and fit for direct consumption. Therefore, groundwater is usually preferred by food-and-beverage industries and water utilities to reduce water treatment costs.

Table 1 Relative advantages of groundwater to surface water sources

Criteria	Advantages
Availability	-Perennial source and wide spatial coverage -Self-recharging natural storage (suited for individual and area-wide water supply networks) -Available at variable depths and adequate to meet usual needs -Reliable supply, high buffering capacity against short-term external climatic variability (drought, floods, evaporative losses) and ease of access even during emergencies (earthquakes, floods, typhoons)
Accessibility	-In-situ access -On-demand access -Unrestricted access (in majority of Asia where legal/regulatory control measures are either absent or weakly implemented) -Easy to extract (using manual and mechanical power (electric/diesel pumps))
Affordability	-Low to moderate initial investments -Short gestation period for construction (a shallow hand pump can be installed in less than a day) -Low to moderate extraction cost
Acceptability	- Suitable for multiple uses including household (WASH), agriculture, and industrial uses
Quality	-Naturally good quality (except those contaminated with arsenic, fluoride, or iron) -Could be used without or with minimal treatment (except contaminated cases) -Impacts of anthropogenic pollution appear relatively slowly, but once polluted the contamination is highly persistent and remediation, if at all possible, is often costly and requires a lot of time

Groundwater use in rapidly urbanising Asia

As is true across the globe, Asia is urbanising at an unprecedented rate. Nearly 45% (1.8 billion) of the region's population were living in urban areas in 2010 (**Figure 1**). The urban population in 2010 was 7.5 times larger than that in 1950. In 2010, Asia had 221 cities with a population greater than 1 million, 13 of which were mega-cities (>10 million population) (UNDESA 2014). It has been estimated that more than 64% of the population in Asia will be urbanised by 2050 (*ibid*).

This rapid rate of, often unplanned, urbanisation in Asia has outpaced the development of infrastructure, including WASH services. This is evident from the fact that 80% of Asia's rivers are in poor health due to pollution from discharge of untreated wastewater and agricultural runoff containing pesticides and pollutants (ADB/APWF 2013). The high rates of urbanisation have resulted in a growing gap between the levels of WASH services available and those that are needed. This can be observed in the failure of governments and cities in the region to achieve universal access to improved water sources and sanitation. Where there has been progress on improving water supply and sanitation in urban areas, those achievements could be undermined by insufficient development of WASH services to match the growing demand from the ever expanding urban population.

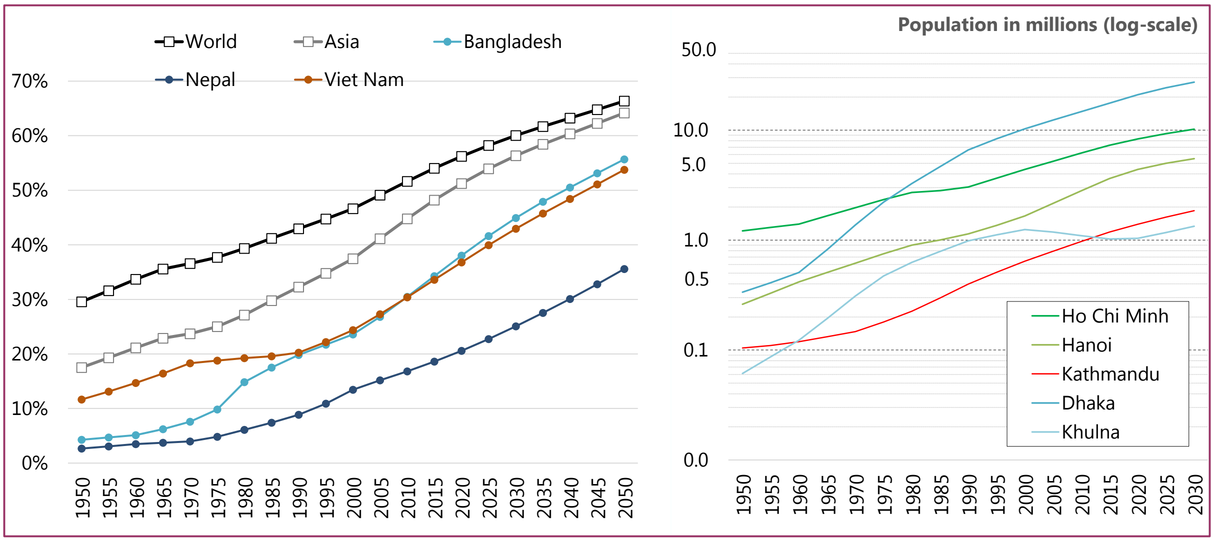


Figure 1 Urban population growth in selected Asian countries (left) and their major cities (right) *(UNDESA 2014)*

Another problem facing cities is the poor access to basic WASH services in low-income clusters such as slums. Although the MDG target to achieve a significant improvement in the lives of at least 100 million slum dwellers by 2020 was realised well in advance, the progress is dwarfed by an upward trend in the slum population in many Asian cities. Concerted efforts will be necessary to improve the coverage to slum dwellers.

In Asia, urbanisation and groundwater development have been found to be co-occurring phenomena (IGES 2007). Many Asian cities are either fully dependent (such as Khulna-Bangladesh, Kumamoto-Japan, Lahore-Pakistan) or rely significantly (Hanoi-Viet Nam, Jakarta-Indonesia, Vientiane-Lao People's Democratic Republic, Yangon-Myanmar, Cebu and Manila in Philippines and Beijing-China) on groundwater for the cities' water supply (WWAP 2015, Shrestha, et al. 2016). This heavy dependence of WASH services on groundwater in Asia is not well acknowledged by policy makers, planners, and resource managers, and often ignored by the end-users. As a result, unplanned development and uncontrolled use of groundwater are common in Asian cities, especially, in the early stage of urbanisation, which is characterised by a rapid population growth, development of infrastructures, and growth in industries, trade and tourism. Indiscriminate development of groundwater resources to support rapid urbanisation and inappropriate disposal of waste and wastewater has been found to be a growing threat to resource sustainability (IGES 2007, Takizawa 2008, Taniguchi 2011, WWAP 2015). Urbanisation has often been found to have a negative impact on groundwater resources due to over-exploitation and contamination (IGES 2007, Shrestha, et al. 2016).

There are only a few cases about balanced development and management of groundwater resources. Cities such as Bangkok, Tokyo, and Osaka successfully managed the problems associated with their uncontrolled groundwater use such as groundwater depletion, land subsistence and sea water intrusion into freshwater aquifers that they experienced during peak urbanisation periods (IGES 2007). Adoption and effective implementation of policies and legal measures, as well as provision of water from alternative sources contributed to reducing the groundwater problems in these cities. However, there are still a large number of groundwater dependent cities in Asia such as Bandung, Delhi, Dhaka, Hanoi, Jakarta, Manila, Karachi, Kathmandu, and Tianjin, where problems have become acute over time (IGES 2007, Taniguchi 2011, WWAP 2015).

Groundwater-WASH nexus

Groundwater and WASH (Water, Sanitation and Hygiene) impact each other and are intrinsically linked but this interrelationship is often overlooked during the development of groundwater resources. **Figure 2** shows this relationship as part of the urban water cycle. Aquifers are natural underground water stores and serve as multi-purpose sources of reliable water for millions of private users, small and large utilities, beverage industries, and private water vendors. In addition to consumption and production purposes, groundwater is used for sanitation, washing, and hygiene, which are important for leading a healthy life, including preventing illness from water-borne diseases.

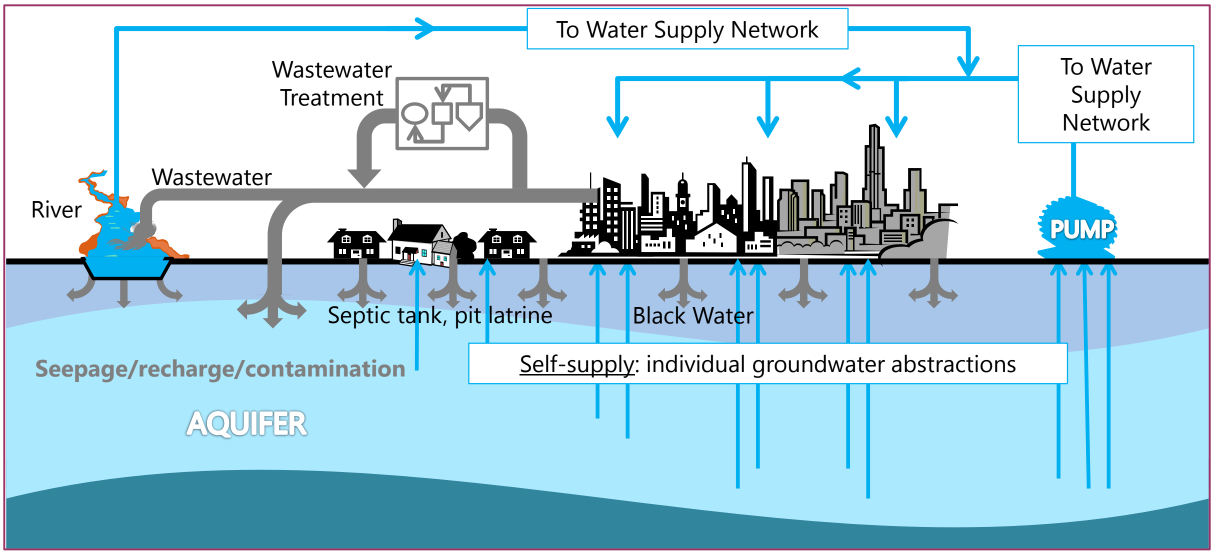


Figure 2 Physical interlinkages between groundwater and WASH (source: author's modification from Foster et al. 2010)

In order to sustain these benefits, it is important to balance the management side of the relationship which is about sustainable development and use of groundwater resources. Groundwater is vulnerable to quality and quantity threats caused by inappropriate use and mismanagement. Excessive exploitation of aquifers beyond their natural replenishment capacity could lead to the emergence of problems such as water table depletion and its secondary impacts, such as land subsidence, sea water intrusion, etc. Similarly, inappropriate WASH practices, unsafe disposal of wastewater and pollutants could also create problems for safe water supply through contamination of aquifers, placing public health at risk.

While greater use of groundwater offers a quick route to achieving WASH targets, short-cuts that neglect the vital issue of resource sustainability should be avoided. The focus should not be merely be on constructing facilities to provide WASH services, leaving the issue of treatment and safe disposal of excreta and wastewater unresolved. A holistic view of the groundwater and WASH linkages in the context of the urban water cycle is needed.

3 RESEARCH OBJECTIVES AND METHODS

Most groundwater problems have been investigated from a macro-perspective such as urban water supply, rural water supply or irrigation (Foster, et al. 2010, Kataoka and Shivakoti 2013). These investigations have only touched on the outside framing of the problems and have paid less attention to priorities of end-users – the ultimate beneficiaries – who are some of the key agents for increased use of groundwater. High dependency on groundwater for WASH services exists in many Asian cities, but understanding of the multiple dimensions of the groundwater-WASH nexus is poor due to a lack of proper assessment of interactions at the end-user level. Better understanding of the end-user preferences for WASH services can help identify the key determinants of effective and safe delivery of WASH services. A detailed assessment at the end-user level could expose previously unknown realities about groundwater-WASH interactions in an urban setting and assist in finding measures to manage this nexus in a sustainable manner.

Objectives

With a focus on end-users, the main objective of this working paper is to assess the existing interrelationships between groundwater and WASH services in selected groundwater dependent cities in Asia. The approach of this study is to examine major push-and-pull factors as determinants of groundwater for WASH needs. Preference, access, adequacy, affordability and quality (as it relates to environmental and health risks) are the criteria used to understand the major push and pull factors. Recommendations for policy measures to manage the groundwater-WASH nexus in a sustainable way are drawn from the analysis. It is hoped that the diagnosis of these factors could assist in framing user-centric policies and programmes to improve safe and affordable WASH services and manage groundwater in a sustainable manner.

Methods

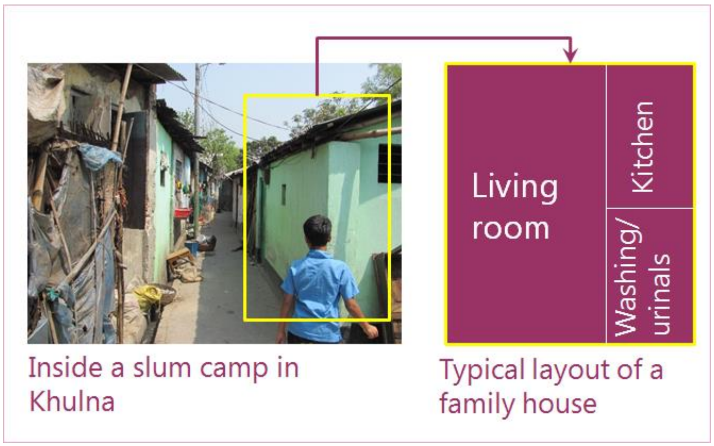
A case study approach is used. The case studies are the cities of Hanoi, Kathmandu and Khulna and focus on the key dimensions of the groundwater-WASH nexus. Hanoi and Kathmandu are the capitals of Viet Nam and Nepal, respectively, whereas Khulna is the third largest city in Bangladesh. These cities share four important features which makes them ideal candidates for case studies. First, groundwater is a principle source of water either as a part of water supply networks or through private abstractions in all cities. Second, as rapidly urbanising cities, they are all facing with challenges to manage their water resources and provide WASH services to their residents. Third, to deal with the increasing demand for water, these cities are developing water supply systems based on surface water sources as a long-term solution. This shift to surface water sources could change the groundwater dependency profile in these cities in the future. Fourth, all the cities are facing the problem of pollution of water sources as they lack adequate facilities to treat and safely dispose of the excreta and wastewater generated from residents and industries. Inappropriate management of wastewater and pollutants could lead to groundwater contamination and eventually reduce the utility of groundwater for WASH in the three cities. Despite these similarities, the case studies were not intended to draw comparisons between cities; rather, they were selected to examine the key dimensions of groundwater-WASH nexus in three different local contexts.

The research aims at understanding the preference of the end-users, i.e., households and communities, for using groundwater for WASH services in the case study cities. As **Figure 3** shows, a pre-assessment of each case study was conducted using available literature and secondary data. This was followed by key informant interviews, focus group discussions (FGDs) and questionnaire surveys with households and communities to identify the major factors of end-user choice "regarding use of groundwater for WASH", and potential impacts of "WASH practices on groundwater". This study mainly relies on analysis of end-user perceptions and did not conduct direct measurements to verify answers on the qualitative and quantitative aspects of water use.

Case study Cities	**Hanoi**	**Kathmandu**	**Khulna**
Pre-assessment	Literature review, review of background information, collection of secondary data		
Data collection	Household survey	Household survey	FGDs and household interviews at slum camps
Analysis	Determinants of groundwater-WASH nexus (preference, access, adequacy, affordability, and quality)		
Outcomes	Policy options for integrated management of groundwater and WASH in Asian cities identified		

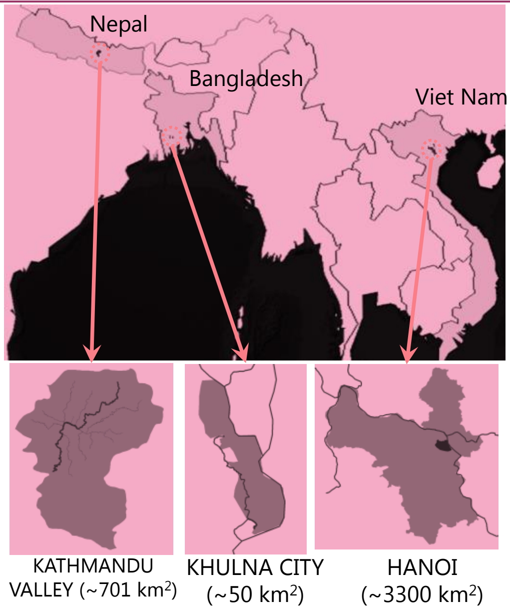
Figure 3 Methodology of the study

Figure 4 provides an overview of selected features of the three case study cities. Further description of each city is provided in Section 3. In Hanoi, investigations were carried out in three districts covering a total of 60 households: Hoang Mai, Long Bien and Phu Xuyen. In Hoang Mai district houses are connected to the tap water network of Son Da Water Supply Plant (WSP), which came into operation in 2009. Before Son Da WSP was built, the residents relied on groundwater. In Long Bien district, groundwater production wells are used to supply tap water to houses. Phu Xuyen district, which is downstream of a suburban area in Hanoi, has a predominantly rural landscape and people rely on private groundwater wells (tube wells and dug wells) and rooftop rainwater harvesting to meet their daily water needs.



In Kathmandu Valley, 228 households were interviewed to understand their perception of groundwater-WASH nexus in the context of acute water shortages. The survey covered Kathmandu, Patan and Bhaktapur districts in the Valley. A variety of households were interviewed. They differ in terms of water sources (tap water, bottled water, tanker supply, dug well, tube wells, and deep boring), area (urban and peri-urban), economic groups (rich and poor), and house ownership (owner and house tenants).

In Khulna, FGDs and interview were conducted with individuals living inside the six slum camps to understand the situation regarding WASH services. Each slum has 150-500 houses. There were 5-6 members on average living in each dwelling, which in most of the cases is a single storey and a single room type. People in the slum camps are living in difficult conditions; up to 14 members of a family were found living in a room. A contrasting view of the groundwater-WASH nexus was assessed in Khulna by surveying an extremely poor group of people living in the slum camps.



Features	Hanoi	Kathmandu	Khulna
Area (km²)	3324.3	899 (Kathmandu, Bhaktapur and Lalitpur districts)	4394.4 (whole division)
Core city (km²)	1070	97.03	51
Urban Population (million)	3.4 (2014)	1.1 (Kathmandu municipality, 2014)	1.1 (2010)
Projected urban population 2030 (million)	5.5	1.8 (Kathmandu municipality)	1.3

Figure 4 Overview of the case study cities (source: author's compilation)

Household Questionnaire Survey in Kathmandu

Household Questionnaire Survey in Hanoi

Focused Group Discussion in Khulna

4 GROUNDWATER DEPENDENCY

The preliminary assessment found groundwater to be a key source of water supply in all three case study cities. The tradition of groundwater use in all three cities is as old as their settlements. Before 2009, Hanoi used to rely fully on groundwater for its water supply. In Khulna, groundwater is the only available option the city has to meet its water needs. In Kathmandu, people have been relying on natural springs and dug-wells for their water supply for a long time.

Due to population growth, urbanisation, lifestyle changes, pollution of surface water sources, inadequate and less reliable piped water supply and a lack of alternative water sources, the use of groundwater has become more and more extensive. For instance, groundwater use in Hanoi increased by more than five-fold in the period between 1978 and 2006 (Phuc 2008). In Kathmandu, groundwater use increased exponentially from less than 40,000 m^3/year in 1970 to 25.52 million m^3/year in 2009 (Pandey and Kazama 2014). **Table 2** compares the dependency on groundwater for WASH services in the three cities. Groundwater use in each case study city is described in detail below.

Hanoi

Hanoi is the capital of Viet Nam. It is located in the north of the country along the Red River Delta (Figure 4). Its administrative area was expanded to 3324.4 km^2 in 2008. There were 7 million people living in Hanoi in 2014; 3.4 million in urban districts and 3.6 million peri-urban/rural districts (GSOV 2014, UNDESA 2014). Hanoi is urbanising rapidly with its urban population expected to reach 5.5 million by 2030 (UNDESA 2014).

More than 70% of the total piped water (1.1 million m^3/day) in Hanoi is sourced from groundwater while the rest is drawn from the Song Da River. There are 105 production wells (50–70m deep) that are connected to the piped water distribution network (Nga 2008). Although coverage of the tap water distribution network is wider in Hanoi than the other two cities, the active service area is considered to be less than 50% due to a high amount of leakage which accounts for more than 40% of non-revenue losses (Bao, et al. 2013). Non-revenue water losses, old infrastructure, unplanned abstraction of groundwater and water pollution are the major issues related to water supply. The existing gap in water supply is generally met through private abstraction by individual households and private vendors who sell bottled water (20 litre containers) for drinking and kitchen use.

In order to meet the growing demand for water from its residents, Hanoi developed the Song Da WSP, which sources water from the Song Da River. The Song Da WSP has provided about 27% of the total piped water supply since 2009. There is a plan to upgrade the capacity of the Song Da WSP to 1.2 million m^3 per day by 2030.

Table 2 Dependency on groundwater for WASH uses in the case study cities

Features	Hanoi	Kathmandu	Khulna
Major water sources	- Surface, groundwater, rainwater	- Surface, groundwater, rainwater (fewer cases)	- Groundwater
Groundwater dependency for water supply	- For piped water: >70% ~ 100% for households without piped water supply	~ 70%	100%
Public water supply	- Capacity: 1.1 million m^3/day - Coverage: < 50% (due to estimated 40% supplied water lost through leakages)	- Capacity: 106 million litres per day (mld) in the wet-season and 75 mld in the dry-season; - Coverage: 83% but available water is adequate to cover 37% of demand in the wet season and 22% in the dry season	- Capacity: piped water (16,200 connections) and public tube wells (~10,000 = 6,000 deep tube wells +4,000 shallow tube wells that can supply 102 mld (42 mld for piped + 60 mld for tube well) - Coverage: 40%
Water related problems/ issues	- Uncontrolled groundwater pumping by unregistered private users - Groundwater quality degradation (nitrate, microbial pollution), arsenic contamination, high iron and smell - Leakages and non-revenue losses of public water supply	- Piped water inadequate to satisfy increasing demand - High non-revenue water loss (>40%) (ADB, 2004) - Old infrastructure - Unplanned groundwater abstraction (households, water vendors and tankers, apartments, industries) - Pollution (nitrate, coliform), high iron and smell	- Inadequate piped water coverage - Illegal connections, old infrastructure, non-revenue losses (~25%) - Lack of information about exact number of private wells - Pollution and geogenic arsenic
Alternative solutions to improve water supply that will also reduce pressures on groundwater	-Capacity of Song Da Water Supply Plant will be upgraded to supply 1.2 million m^3/day by 2030 in addition to use of groundwater	-An inter-basin water transfer water supply project under development that plans to bring 170 mld into Kathmandu Valley through a 26 km long tunnel construction from the Melamchi River with a potential to upgrade to 340 mld	- Surface water supply project under development (110 mld, additional 75,000 households) that will fill the 55-60% coverage deficit - Expected to be of good quality, reliable, affordable (special consideration for low income group)

Kathmandu

Kathmandu is Nepal's capital and the country's largest city. It sits in the centre of the Kathmandu Valley (Figure 4). The Valley (including Kathmandu, Bhatkapur and Lalitpur districts) has an estimated area of 899 km^2 (CBS 2012). The highly urbanised core parts consist of five municipalities or metropolitan cities— Bhaktapur, Kathmandu, Kirtipur, Lalitpur, and Madhyapur Thimi— covering about 97 km^2 (~ 10.7% of the valley) (*ibid*). The rest of the Valley is composed of natural forests and small farming villages. The city has attracted migrants from different parts of the country in search of new opportunities and better services over the past fifty years. An influx of new residents has caused a rapid increase in the urban population. The total population of the five major cities in the Kathmandu Valley and the whole valley is already over 1.4 million and 2.5 million, respectively, according to 2011 National Population and Housing Census (CBS 2012). The population in the five major cities is expected to increase to 1.8 million by 2030 (UNDESA 2014).

Demand for groundwater has been increasing in Kathmandu over the past three decades mainly driven by rapid growth of the urban population. The public utility for the water supply, Kathmandu Valley Water Supply Limited (KVWSL), was able to supply 106 million litres per day (mld) (37.8% of demand) in wet and post-wet seasons (June-January) and just 75 mld (22.5% of demand) in the peak dry season (Feb-May) in 2011 (Shrestha 2012). Groundwater abstraction through 57 deep tube wells contributes about 70% of the KVWSL supply. The existing shortfall in demand is mainly supplemented by private groundwater abstraction by individual users and housing complexes by means of hand-pumps, dug-wells, or the use of electric pumps. Groundwater is also used by private vendors who sell it to households in the form of bottled water (20 litre containers) for drinking or through tankers (5~12 m^3 capacity).

Faced with the challenge to secure long-term water supply, the government started an inter-basin water transfer project, the Melamchi Water Supply Project, in 2000 that plans to bring 170 mld water into Kathmandu Valley through a 26 km long tunnel from the Melamchi River. The project has the potential to expand its capacity to 510 mld by providing 340 mld from two other rivers (ADB 2000, Shrestha, et al. 2012). The project is seen as a viable alternative to minimise excessive groundwater pumping; however, the progress of the project is slow due to delays in construction works. The planned completion target of 2016 seems to be unattainable according to the latest update of the progress (MWSDB 2016).

Khulna

Khulna, which is located in the coastal Khulna Division, is the third largest city in Bangladesh. The Rupsha and Moyur Rivers flow through the city. Khulna City has an area of around 65 km^2. The urban population of Khulna was already over 1.1 million in 2014 and is expected to increase modestly to 1.3 million by 2030 (UNDESA 2014). The outskirt areas of Khulna City are predominantly rural and dominated by tracts of agricultural land and scattered small towns, markets and local industries (such as brick-making factories and jute mills). Khulna also has slums, which are informal settlements with a cluster of five to more than 100 households. In 2014, there were 1,143 slums (made up of 20,536 households) in Khulna, which is about 8% of all slums in the country (BBS 2015).

Groundwater is the only source of water for city residents in Khulna. The Khulna Water Supply and Sewerage Authority (KWASA), an independent body established in 2008 by the Government of Bangladesh for providing city water supply and wastewater services to Khulna City Corporation (KCC), relies on groundwater to supply water. The current piped water supply hardly covers 18% of Khulna residents through different sizes of 111 deep (>275m) production wells (ADB 2011a). At present, there are nearly 16,200 connections in the piped water supply. In addition to these, KWASA also owns 10,000 community tube-wells that along with the pipe-water supply provides approximately 40% of the total water demand. The remaining supply is from alternative water sources, mainly dug bore holes at an individual or community level. It is estimated that in 2010, Khulna had an over 71,000 shallow tube-wells and over 18,000 deep tube wells, which are used by private households and enterprises, and are either powered by electricity/diesel or involve manual lifting of groundwater (i.e., hand pumps) (ADB 2011a). The total groundwater abstraction in Khulna has been estimated to be 98.76 mld, of which 49.7 mld is accounted for by private deep tube-wells, 30.1 mld by KWASA deep tube wells for piped water supply, and 18.96 mld by shallow tube wells (*ibid*).

Similar to Hanoi and Kathmandu, development of a centralised surface WSP is being considered as a durable alternative to meet long-term water supply needs (ADB 2011b). The project aims to establish a water purification facility and renovate and increase the water supply network to a capacity of 110 mld. Construction of the planned WSP is expected to fill the existing 60% gap in the city water supply.

5 UNDERSTANDING GROUNDWATER –WASH NEXUS: END-USERS' PERSPECTIVE

End-users are the ultimate beneficiaries of groundwater and WASH services. For the successful achievement of WASH related targets, city planners and policy makers should take into account the preference and priorities of its residents, i.e., the end-users. The interplay of various pull-and-push factors determines user preference for a particular WASH service. Pull factors are positive attributes that enhance the reliability and acceptance of a WASH service. On the other hand, push factors are the constraints that a user has to cope with in order to secure a reliable and safe WASH service. If the user cannot cope with the push factor, it could lead to reliance on an inferior WASH service and health-related hazards. **Figure 5** shows an inverse relationship between water quality and quantity for various household water uses. Groundwater, as a critical element of a WASH service, could be a push or pull factor to fulfil both quality and quantity requirements.

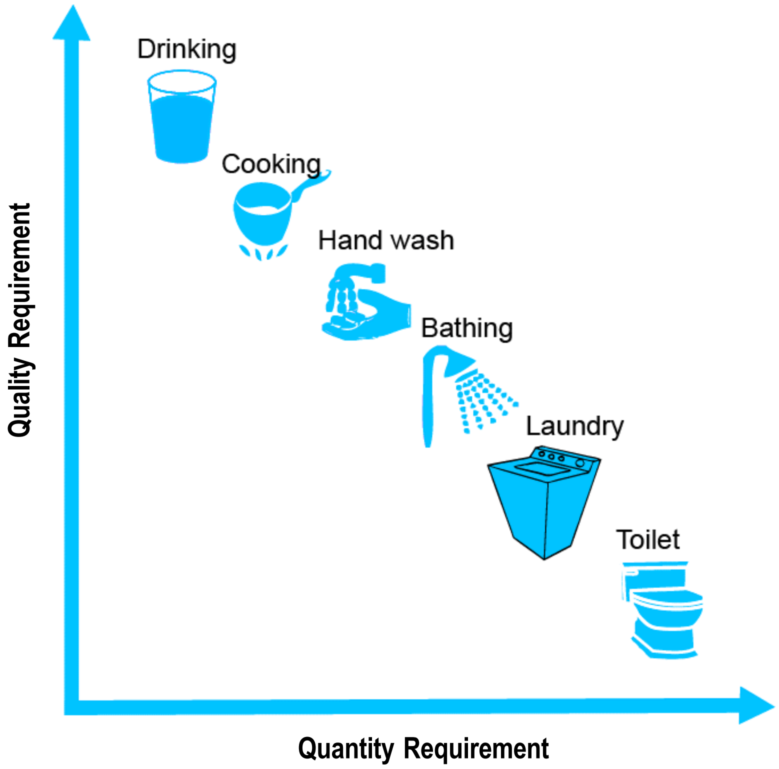


Figure 5 Relative requirements for water quality and quantity for WASH (Source: author)

Water quality is a vital safety consideration for direct consumption such as for drinking and cooking. Groundwater could be a pull factor when the aquifer is not contaminated and it meets drinking water quality standards. In contrast, sanitation (toilets) and hygiene (hand washing facilities, showers, and laundries), require a higher quantity of water that does not necessarily have to meet high-quality standards. An aquifer providing moderate or low quality water could still be a pull factor to meet high volume requirements. However, this distinction between quality and quantity may not always apply. For instance, high-quality tap water or groundwater could be used for all purposes when there is an abundant supply. In this situation, convenience could be a primary criterion for choosing tap water or groundwater. In other cases, users might use moderate-quality water when high-quality water is beyond their physical or economic reach. In still other cases where there is an inadequate supply of good-quality water, a user may economise on good-quality water for low volume consumptive uses and resort to moderate-quality water sources (rivers, lakes or unprotected wells) for high volume non-consumptive uses.

Preference for groundwater in case study cities

Initial assessments revealed that residents prioritise 'groundwater for WASH' based on various preference criteria, which are often dictated by local circumstances. In all cities, reliability of water supply and convenience were pointed out as common benefits of groundwater as shown in **Figure 6**.

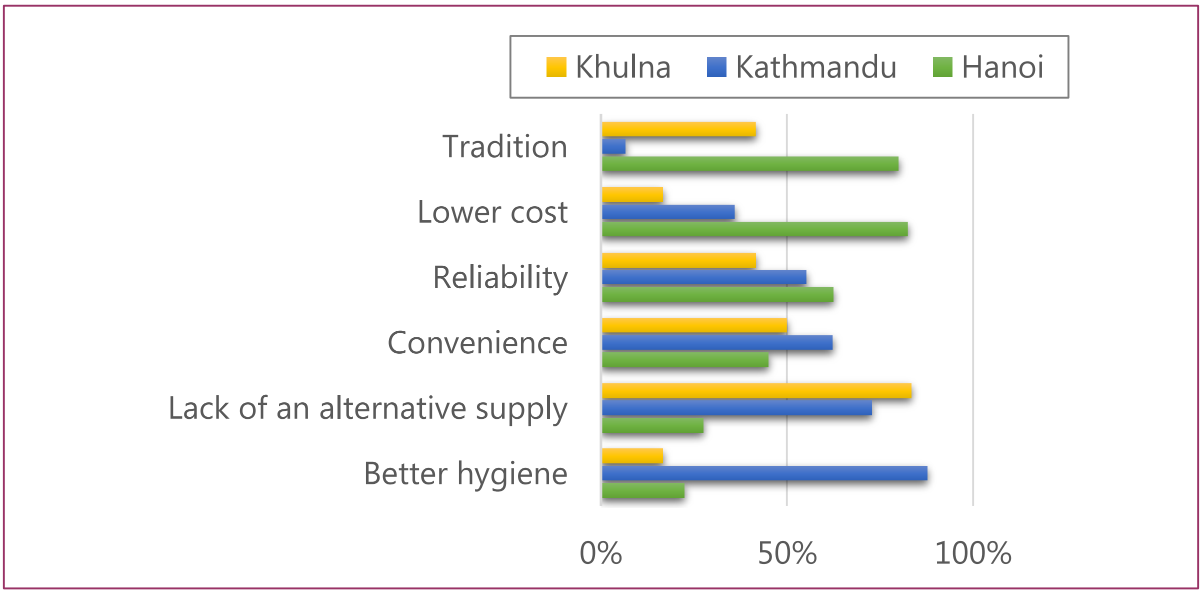


Figure 6 Users' evaluation for choosing groundwater as a source of water supply (% of respondents)

In Hanoi, tradition and lower cost were two pull factors for choosing groundwater. Tap water in Hanoi is in relatively stable supply, but it is relatively more expensive than in Kathmandu and Khulna. Groundwater is valued as an important alternative source. Respondents in Hoang Mai district, where houses are connected to the new Son Da WSP distribution network, mentioned that they consider groundwater taste superior to tap water, which may be related to their long-held tradition of using groundwater, and that the cost of abstraction is low. In Kathmandu and Khulna, a lack of alternative water supply was found to be a prominent push factor behind increased use of groundwater. In their water deficit situation, cost was not a major barrier for accessing groundwater.

A key pull factor for choosing groundwater in Kathmandu was that groundwater can be used for sanitation and hygiene purposes such as toilet flushing, taking a bath, washing clothes or cleaning, as it is available in large volumes. However, it is not fit for direct consumption due to high iron content and potential contamination caused by the unsafe disposal of wastewater and seepage from septic tanks or drainage pipes. In the slum camps in Khulna, groundwater was the only available option. An affordable tap water connection, which ensures a significant improvement in living conditions, could act as a pull factor in slum camps and thus reduce household dependency on groundwater.

Access to water sources and purpose of use

In all studied cities, users have more than one option of water supply, except in slum camps in Khulna where groundwater was the only available water source. **Figure 7** shows a comparison between water sources and different water use categories. In the figure, the size of the circle is proportionate to relative importance assigned by interviewed household members. In Khulna, deep tube-wells are used for drinking and kitchen uses, whereas shallow tube-wells are used for non-consumptive uses. Water from the deep-tube wells are often abstracted by using electric pump and stored in an overhead tank for distribution. Each surveyed slum camp had at least one overhead tank. In Hanoi and Kathmandu, where there are multiple choices, residents preferred one source over another depending on the reliability of supply, adequacy and quality. Groundwater is less preferred for direct consumption unless there are no other options as in Khulna. Sanitation and hygiene are main use categories due to easy access of groundwater, and its reliability. In Hanoi, residents were found to use groundwater for non-potable uses such as bathing, toilet flushing, laundry, and gardening. Tap water, rainwater, and bottled water (20 litre containers) are considered as reliable sources for direct consumption. However, this generalisation does not apply in all situations. Groundwater use was either absent or limited to gardening, consumption (due to good taste and quality) and washing floors or vehicles in households where there is 24-hour tap water supply. In this context, as tap water pressure was high enough to recharge the overhead storage tanks, continuing with the use of groundwater did not make much sense.

In Kathmandu, groundwater was used in all cases except for direct consumption by the majority of interviewed households. The few households that directly consume groundwater do so only after employing a system of filtration to remove iron and odour followed by boiling for disinfection. Tap

Rooftop rainwater harvesting in Hanoi

20 litres bottled water

Tanker for water supply in Kathmandu ($5\sim12$ m^3 capacity)

Shared water storage tank inside a slum camp, Khulna water is the preferred source for direct consumption even though it too requires filtration and disinfection before consumption. However, the supply of tap water is intermittent and inadequate. Other alternative sources for drinking and kitchen uses were bottled water (20 litres, each bottle costing about 0.6~0.8 USD) and water tankers (5,000-10,000 litres supplied by vehicle for storage and use), both of which could have been sourced from aquifers. Water supplied by KVWSL tankers will cost about 9 USD for 5,000 litres and 14 USD for 10,000 litres (KVWSL 2009). The cost for water supply by private tankers could cost higher (about 12 USD for 6,000 litre tanker and 20 USD for 12,000 litres) (Shrestha and Shukla 2010). Bottled water, though more expensive than other sources, is considered safe for direct consumption as it is sold only after undergoing necessary purification processes to make it potable. Water provided by tankers is considered equivalent in quality to tap water and can supply sufficient volume at one time for a family's weekly needs at least.

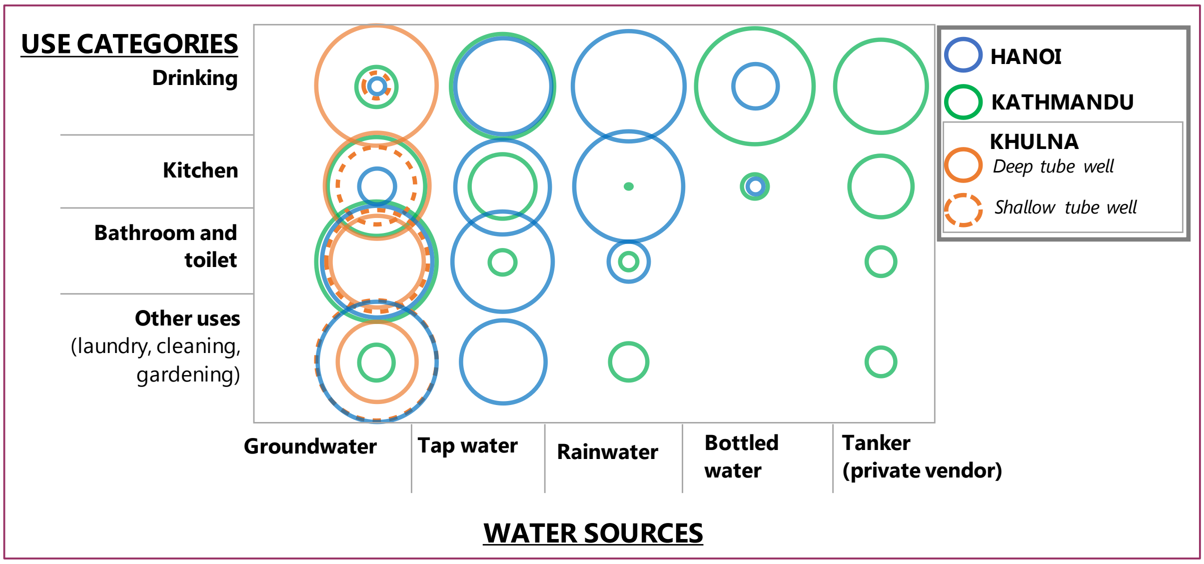


Figure 7 Relative importance of groundwater and other water sources for WASH. (Size of the circle indicates relative importance assigned by interviewed households.)

Adequacy of water supply

Figure 8 shows the range of water use by households and individuals interviewed in the studied cities. The volume of water use in all the case study cities varies significantly. Some households are using a low amount (<60 litres/day) while others are using as high as 8,000 litres/day. Non-uniformity of water use within and between cities is a reflection of changing water use habits and access inequity prevalent in Asian cities. Some of the residents in Kathmandu and in slum camps in Khulna are using amounts that are at the lowest margin of basic or minimum water requirements recommended by the World Health Organisation (WHO) (UNHCHR 2010)[2]. Among the studied

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[2] According to WHO recommendation "between 50 and 100 litres/person/day are needed to ensure that most basic needs are met and few health concerns arise. Access to 20-25 litres/person/day is a minimum, but this amount raises health concerns because it is insufficient to meet basic hygiene and consumption requirements. These amounts are indicative as they might depend on a particular context and might differ for some groups depending on their health status, work, climate conditions or other factors" (UNHCHR 2010).

cases, residents in Hanoi have the most reliable water supply, especially households connected to tap water. Average per capita water use is also higher than in Kathmandu and Khulna.

In Kathmandu, where there is acute water shortage and 24-hour piped water supply is rare, residents have been able to meet their daily water requirements through pumping groundwater. Although average water consumption was less than 100 litres/person/day, the use of groundwater has enabled some residents to "use water in excess" (i.e., >400 litres/person/day). The same is true in Hanoi, where the range of per capita water use was the highest among the groundwater users, especially, in suburban Phu Xuyen district. This observation signifies that the use of groundwater is often associated with adequacy of supply and can result in sanitation and hygiene benefits.

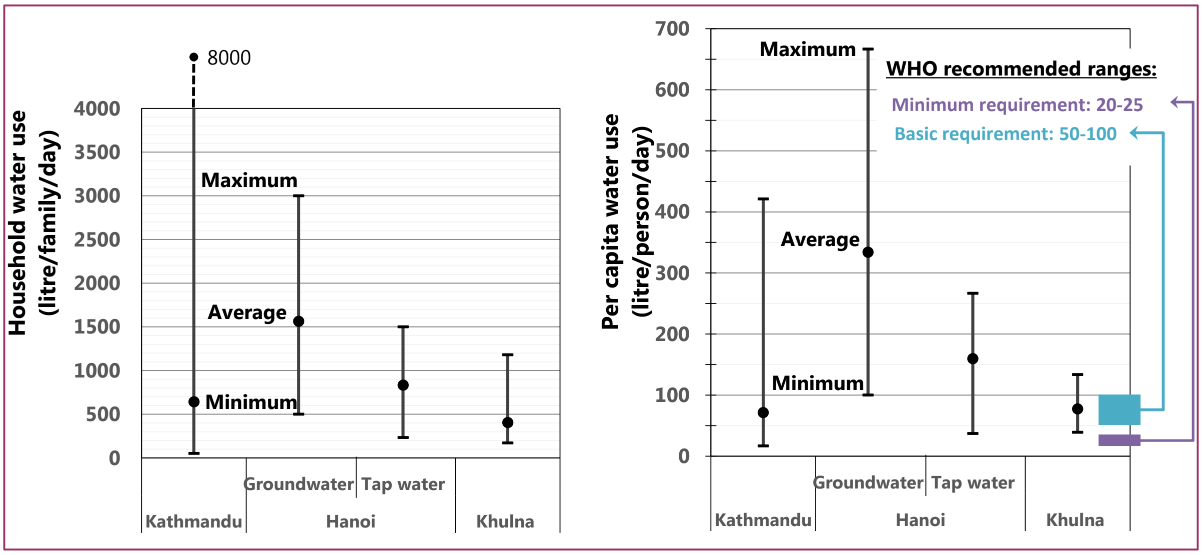


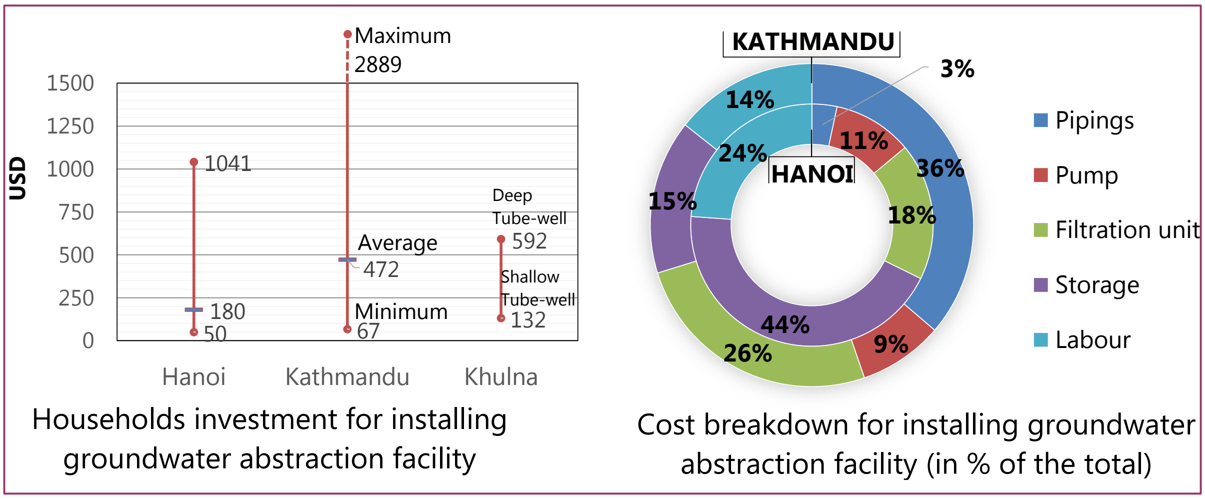
Figure 8 Water uses in surveyed households in three cities

Despite the use of groundwater, residents in the slum camps in Khulna could not secure adequate supplies of water to meet their needs. Residents in the slum camps were using the lowest amount of water (39~134 litres/person/day) among the studied cases. The low level of water use was associated with the limited number of tube-wells and overhead storage tanks which have to be shared among the residents in the slum camp (e.g., 7-10 tube-wells per 350 households in one camp). Besides, the use of hand-pumps is a laborious task involving pumping and carrying water (about 10-20 litres per time) to the house. If we consider this in terms of those households that use more water than the average (>400 litres/day), they would have to make from 20~40 trips (400 litres/day) to more than 50~100 trips per day (>1,000 litres/day). In this situation, it is quite obvious that residents will try to limit water use to the most essential activities and may not use adequate amounts of water for sanitation and hygiene as recommended by WHO. A similar situation was apparent in households who have installed only hand-pumps in Kathmandu. They were using less than the average amount of water used by households.

Affordability

Connecting to a tap water network can be an affordable and safe option for end-uses because they are generally exempt from any initial investment requirement, which is borne by the government or service provider, and water is supplied only after necessary treatment to comply with the drinking water quality standards. In all three cities, groundwater is integrated into the public water supply network as it is an accessible and relatively low cost option for utilities, as they do not have to spend much on treating groundwater compared to surface water sources. Besides utilities, groundwater is also attractive to end-users in a water-constrained situation or in places where a tap water connection has not been installed as they can lift groundwater themselves. Although groundwater is generally viewed as a cheap water source, it can sometimes be costly for private users and is sometime less convenient than other sources, considering the physical exertion expended in using hand pumps (or to pull water from dug wells) and to carry it to the point of use every day.

This study found that residents have invested varying amounts of capital to develop groundwater abstraction devices in their houses as shown in **Figure 9**. These devices can be simple hand-pumps or dug wells which are cheap to construct (~132 USD for a shallow tube-well in Khulna) and to operate and maintain. In some cases, as observed in Kathmandu and Hanoi, household groundwater abstraction is technically more complex and even resembles in miniature form the operations of a private utility. In these cases, groundwater is abstracted and made ready for consumption using a pumping unit, a filtration unit to remove iron and odour, and overhead storage tanks (500~5,000 litres capacity). Initial investment for such a system could be high (up to 1,041 USD in Hanoi and 2,889 USD in Kathmandu) (Figure 9). In Kathmandu, the purchase of piping, filtration unit, storage tanks and labour costs were the major expenses for installing a groundwater self-supply system. Electric pumps accounted for 11% of the total installation cost. In Hanoi, where pumping depths were shallow (<30m), piping accounted for only 3% of the total cost for installation. The residents' "willingness to invest" in groundwater was mainly driven by the necessity to meet their daily water needs in the absence of a reliable water supply. In these circumstances, the costs for using groundwater are high, but they are not a major barrier.



Households investment for installing groundwater abstraction facility

Cost breakdown for installing groundwater abstraction facility (in % of the total)

Figure 9 Initial investment for installing groundwater abstraction facilities at surveyed households.

Table 3 shows annual household expenditure on water for both tap water and groundwater. Evaluation of operation and maintenance costs for groundwater and tap water shows that tap water was relatively cheaper in all cases, except in the slum camps in Khulna where residents are paying a flat rate (<1USD/month) for use of shared tube-wells. However, payment and collection of this fee in the slum camps is problematic due to the low income base of the residents who are mostly daily wage earners (income of 1~5USD/day) and who might not have cash always in hand to pay the tariffs. Residents in Kathmandu were found to incur the highest cost for assessing groundwater, except for those households who are using less water. In Hanoi, costs for groundwater and tap water were comparable when the volume of water used did not exceed much beyond the average use. The difference between the costs for tap water and groundwater increased with the increase in volume of water used. Depending on well-depth and the height of overhead storage tanks, use of groundwater is directly proportional to the energy required to pump the groundwater.

Table 3 Annual household expenditure on water supply (in USD/household/year)

	Hanoi		Kathmandu		Khulna	
	Tap water	Groundwater	Tap water (estimated)#	Groundwater and others	Tap water (estimated)#	Groundwater
Maximum	120	360	480	867	73	-
Average	65	50	39	104	25	9.47*
Minimum	18	13	7	3	11	-

calculated based on tariff rate of 0.17USD/m^3 (Khulna) and 0.2 USD/m^3 (Kathmandu)
* flat rate of 0.79USD/month is collected from each family for using shared hand-pumps or deep tube-wells

Residents were found to spend a significant amount of money to access groundwater. Continuing with the use of expensive groundwater places an economic burden on households. However, it provides city governments and utilities with an incentive to expand the reach and reliability of the tap water network to ensure 24-hour service. Residents could be also persuaded about the appropriate pricing of tap water equivalent to the cost of groundwater abstraction.

Quality

For the end-users, the quality of the groundwater was the most worrisome and least understood variable associated with water supply in all the studied cities. Since consumption of contaminated groundwater is a health risk, the majority of residents in all cities were not using groundwater for direct consumption. Almost all, 76% and 68% of the residents in Khulna, Hanoi, and Kathmandu, respectively, thought that groundwater is not fit for direct consumption. Residents in the slum camps in Khulna expressed their concern about the negative health impacts of the consumption of water from the shallow tube wells. The quality concerns were related to both natural (geogenic) factors and human impacts such as contamination resulting from seepage from polluted rivers, aged sewer pipes, septic tanks

Groundwater filtration unit to remove iron and odour and farmland (agro-chemicals). High iron content and arsenic were the two major concerns shared by the residents. High iron content is usually associated with smell and development of colour (yellowish or reddish). It impacts immediate water uses, while long-term use causes discolouring of floors, utensils, teeth, and clothes. Precipitates from groundwater are also responsible for metal corrosion and blocked pipes. Groundwater filters, which employ aeration and sand filters, are used primarily for the purpose of removing the smell and colour.

Arsenic contamination was the biggest concern expressed by the end-users in Khulna, where there were already reported cases of its occurrence exceeding the Bangladesh standard (50ppb) (BGS and DPHE 2001). In Kathmandu, arsenic exceeding the WHO standard (<10ppb) has been reported in deep aquifers, which are not used by the residents (Shrestha, et al. 2012). In Viet Nam, there have also been reports about moderate occurrence of arsenic (<30ppb) in aquifers below the Red River Delta (Luong Yen and Yen Phu well fields), while in some well-fields in the south such as Tuong Mai, Phap Van and Ha Dinh had higher arsenic concentration (43-112 ppb) (Nga 2008). In our study sites, none of the respondents in Hanoi or Kathmandu raised concerns about arsenic.

The impact of human activities on groundwater quality was another emerging concern expressed by the surveyed residents. With increasing urbanisation, cities generate a huge volume of wastewater and waste every day. However, the three studied cities are still without the necessary sewer and wastewater treatment infrastructure to safely transport, treat and dispose all wastewater generated from households and industries. For instance, only 10% of generated wastewater is properly treated in Hanoi. Untreated faecal sludge is also a serious issue as the majority of households in Hanoi are using septic tanks to store black-water from toilets. Leachate from the septic tanks is considered a major risk to groundwater contamination. Seepage of polluted water from rivers into aquifers is another problem. As a result of polluted water in the Red River flowing through the core part of the city, the groundwater table now contains nitrate and ammonia in higher concentrations than the recommended standards for drinking (Phuc 2008). In the downstream Phu Xuyen district, the shallow groundwater table is contaminated by pollutants from the Song Hong River. The River flows through the upstream urban area where discharge of waste and other pollutants have led to the degradation of its quality. Consequently, the residents have stopped using groundwater—a traditionally preferred source— for consumption.

Surface and groundwater pollution in Kathmandu Valley originate mainly from domestic wastewater, solid wastes and industrial discharge (Shrestha, et al. 2012). Direct disposal of untreated wastewater has resulted in rapid degradation of the main Bagmati River. **Figure 10** shows the state of water quality along different sections of the river from upstream to downstream. The river water quality, as indicated by turbidity, dissolved oxygen, and chemical oxygen demand (COD), has deteriorated steeply. Groundwater samples taken from wells in Kathmandu reveal NH_4^+-N, Pb, Fe and Cd exceeding

Song Hong River in Hanoi

Bagmati River in Kathmandu

A pond in Khulna

Pollution of surface water sources

WHO guideline levels for drinking water, whilst water from shallow wells was found not suitable for drinking due to the presence of *E.coli* (Shrestha, et al., 2012).

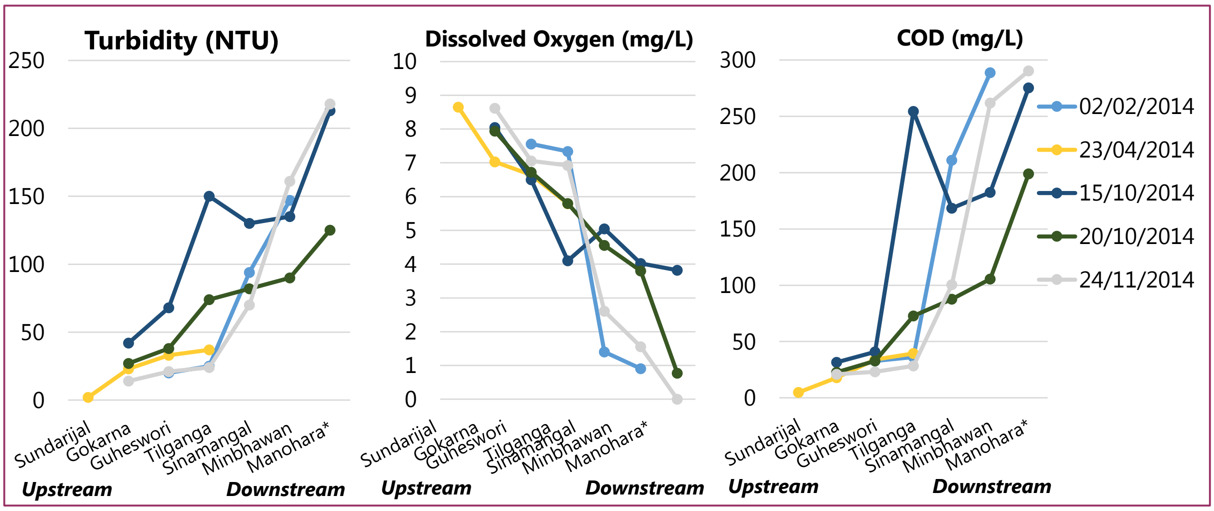


Figure 10 State of water quality along the Bagmati River in Kathmandu *(HPCIDBC 2015)*

In Khulna, researchers from the Japan Association of Drainage and Environment (JADE) mentioned that their investigation found the presence of *E.coli* in most of the shallow tube-wells and over 80% of the residents in the slum camps have experienced water borne diseases such as diarrhoea and dysentery (personal communication). Poor drainage, especially during the flooding season, is considered to be the main causal factor for contamination of aquifers. In addition to aquifer contamination from human activities, salinity intrusion from sea level rise is increasingly threatening the quality of Khulna’s aquifers.

⑥ MANAGING GROUNDWATER-WASH NEXUS

Ensuring reliable, affordable and equitable WASH services is a big challenge for city governments. In the studied cities, multiple little-known factors act as key decision criteria that are shaping the end-users' preferences for groundwater for a range of WASH uses. Based on the analysis, **Figure 11** provides a rating (0~1) of pull-and-push factors for choosing groundwater for WASH services. The rating is estimated using equal weightage based on the responses shared by the interviewees on different preference and decision criteria. Higher pull factors indicate the relative advantage of groundwater use. Higher push factors represent the constraints associated with the use of groundwater. For instance, access and adequacy were identified as two main advantages (pull factors) for using groundwater over other water sources in Kathmandu, whereas higher preference for tap water, higher costs of installation and operation of groundwater abstraction facility, and poor groundwater quality represent push factors. In Hanoi, preference and adequacy were identified as major pull factors, while there is a health risk associated with the use of poor quality groundwater (push factor). In Hanoi, groundwater was costly for certain households and relatively cheap for others. In Khulna, access and lower cost were the two main pull factors. Absence of alternative water supply options, such as tap water, has forced users to accept groundwater despite a strong preference for tap water, concern about poor groundwater quality and supply constraints (push factors).

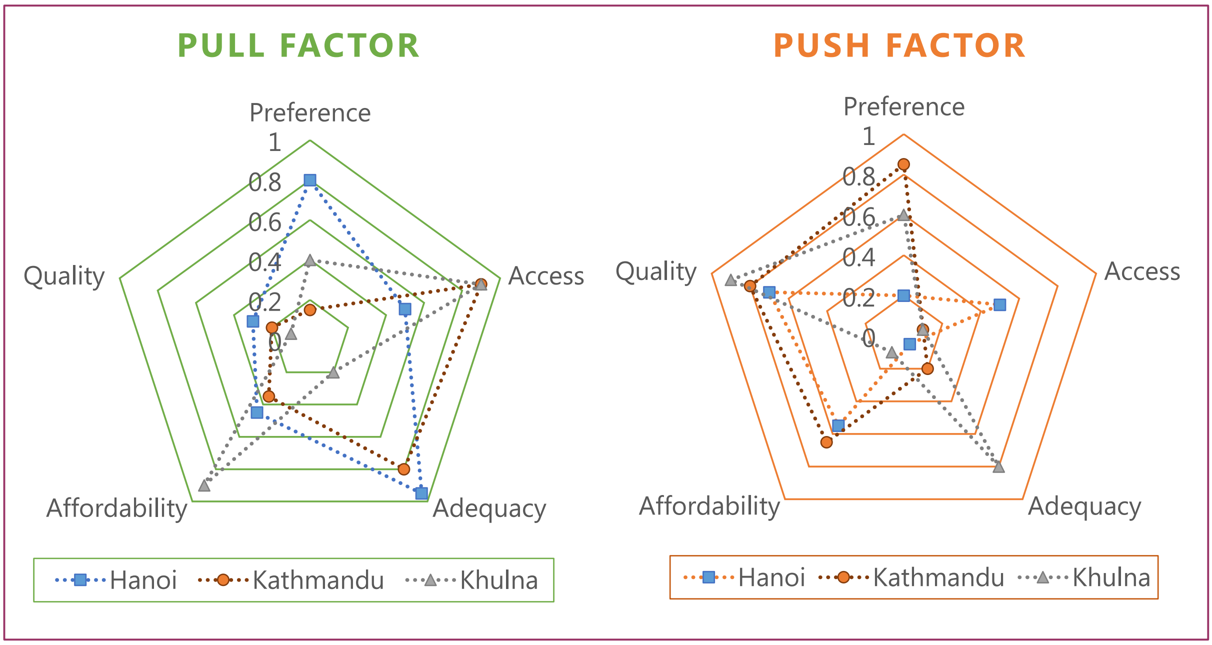


Figure 11 Co-occurrence of push and pull factors evaluated in terms of five decision criteria for choosing groundwater for WASH

The above examination underscores that the future management of the groundwater-WASH nexus should take into account practical concerns expressed by the end-uses. Addressing these concerns could improve the attractiveness of groundwater as a valuable and strategic alternative to meet WASH related targets of the SDGs. At the same time, this information can also assist in overcoming the constraints of city water supply and prioritise prevention of source degradation with respect to both quantity and quality. From this view-point, management of the groundwater-WASH nexus involves managing "groundwater for WASH" and "WASH for groundwater".

Managing "Groundwater for WASH"

Balancing end-user's aspiration for safe and reliable WASH services with the conservation of groundwater supply is the central aim of managing "groundwater for WASH". The long-term opportunity cost of groundwater use could rise if city governments fail to control abstraction and curb the contamination of aquifers. Groundwater was found to be a widely exploited water source in all studied cities. A lack of strong regulatory interventions and low public awareness of the limits of groundwater exploitation has led to the emergence of quantity and quality related problems. In all cities, the symptoms of the groundwater problems are already noticeable, although the exact state and severity of the problems have not been investigated in detail. Unplanned abstraction of groundwater has resulted in lowering of the water table (all cases), increased salinity in coastal aquifers (Hanoi and Khulna), and land subsistence (Hanoi). In Kathmandu, total groundwater abstraction was estimated to be 69.9 mld in 2009 which is already above the natural recharge rate (Pandey et al. 2012). Surveyed residents in Kathmandu and Khulna have already noticed a decline in the groundwater table. **Figure 12** shows the range of pumping depths. A wide variation in pumping depths in Kathmandu and Khulna is indicative of the groundwater table falling. Over the past 20 years, some of the respondent households in Kathmandu have had to re-dig their wells up to three times due to the falling water table.

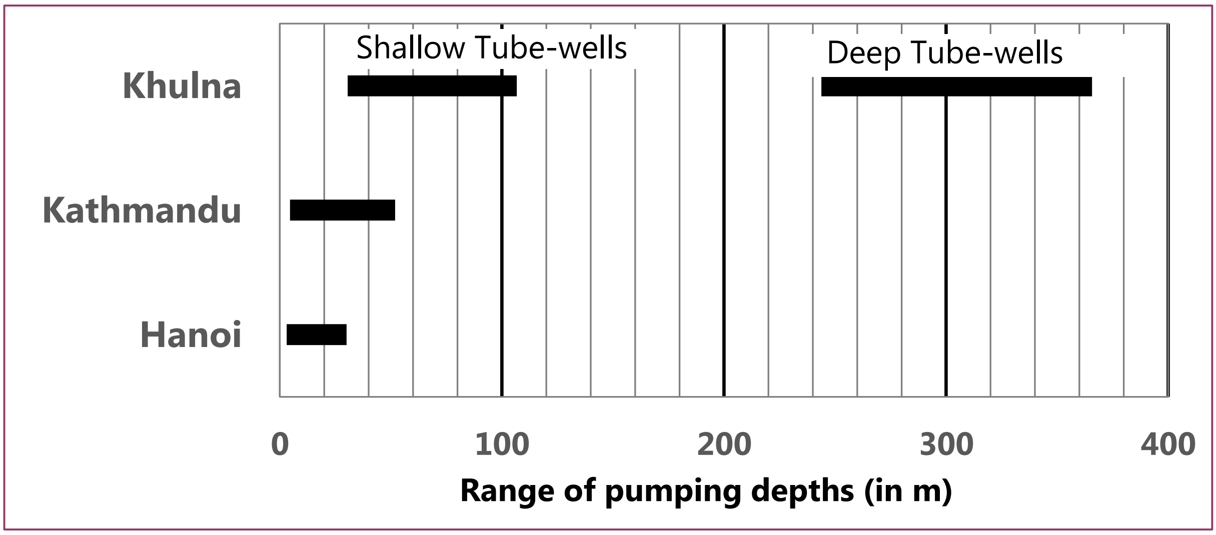


Figure 12 Range of well depths in the surveyed households

In addition, residents in Kathmandu are also finding it difficult to pump groundwater due to the irregular supply of electricity, which is available only 12 hours a day at irregular intervals. As a result

Irrigation by groundwater in the outskirts of Khulna city

of the falling water table, lack of electricity and corrosion or blocking of pipes due to poor water quality, frequent maintenance of groundwater supply system is now necessary.

In the slum camps in Khulna, groundwater from both shallow and deep tube-wells is now abstracted from deeper levels than in the past. Users have already experienced a fall in the water table, which has increased costs and the physical burden of water lifting. This is especially problematic for women and children. Women share most of the burden of carrying water as men are mostly working away from their homes. The increased effort required to pump groundwater as the water table drops could be detrimental to the health of children who do not have the physical strength to pump water for long periods. The root cause of the problem is the use of groundwater by industries and for irrigation in the pre-dominantly farming community in the outskirts of the city. Since the aquifers in Khulna are formed under alluvial layers, the impact of excessive groundwater abstraction in the surrounding area is already apparent in the city. Further studies are needed to understand and estimate the impact of high volume water use on the city water supply.

City governments, managers of city water resources, and water service providers should improve their capacity to manage groundwater resources by introducing informational, policy, regulatory and other management measures. They can establish information infrastructure that provides them with updated groundwater resources information. They can identify strategic aquifers for water supply and introduce regulations with limits for groundwater pumping, especially for high volume users. Some progress on these issues can be observed. For instance Kathmandu Valley Water Supply Management Board, through the Groundwater Management and Regulation Policy (2012), has taken concrete step towards controlling unplanned groundwater abstraction by introducing licencing for high volume users such as hotels and private water vendors (Pandey and Kazama 2014).

In addition to policy and regulatory measures, alternative source of water supply can be explored to reduce pressure on groundwater and ensure adequate access to safe WASH services for the city residents. Potential alternatives for improving water supply sources may include;

- Rainwater harvesting: Assuming negligible impact of atmospheric pollution, rainwater can be a safe source of water for direct consumption that does not require any treatment. Rainwater harvesting has already been tried in Hanoi, by some households in Kathmandu, and in the peri-urban area of Khulna. In Hanoi, rainwater harvesting is a long held tradition as Viet Nam generally receives frequent rainfall throughout the year. In Kathmandu, though rainwater harvesting is not in wide use, some households are collecting and storing rainwater as a strategy to deal with inadequate tap water supply. However, easy access to groundwater is a push factor acting against wider adoption of rainwater harvesting in Kathmandu. In the peri-urban area of Khulna and other parts of Bangladesh, rainwater has been promoted by the Department of Public Health Engineering (DPHE) and some non-government organisations as a safer alternative to groundwater to mitigate the risk of arsenic poisoning.

- Improving piped water supply: This option is already implemented, fully or partially, in all the studied cities. Construction of new WSP based on surface water sources is a long-term solution taken by the city governments to secure water supply. WSPs can offer co-benefits by reducing pressure on groundwater once the city residents are connected to tap water. This has been observed in Hanoi and could be realised in Kathmandu and Khulna.

Alternative water pricing is an economic instrument that can complement the implementation of different water supply options. This study has clearly shown that the development and use of groundwater could be costly, especially, when household water uses are high. The price that households pay for groundwater is also indicative of users' willingness to invest and pay for water services. A benchmark value could be established to ensure that water supplied from the utilities and groundwater abstraction are price competitive. However, this option is only appropriate when the city can improve both the quality and quantity of water services at an affordable price.

The stated options should be implemented by factoring in the future state of groundwater resources so that the benefits of groundwater uses for WASH can be sustained.

Managing "WASH for Groundwater"

"WASH for Groundwater" is among the least prioritised issues in the studied cities. Groundwater, as an invisible resource, is highly vulnerable to unsafe WASH practices. Groundwater vulnerability depends on multiple factors such as physical variables (e.g. topography, soil and the nature of the vadose zone), depth of the water table, and aquifer characteristics (e.g. size, geology, and hydraulic conductivity), but it is clear that human activities on the ground surface can directly alter aquifer vulnerability and increase the risk of aquifer degradation (ARGOSS 2001).

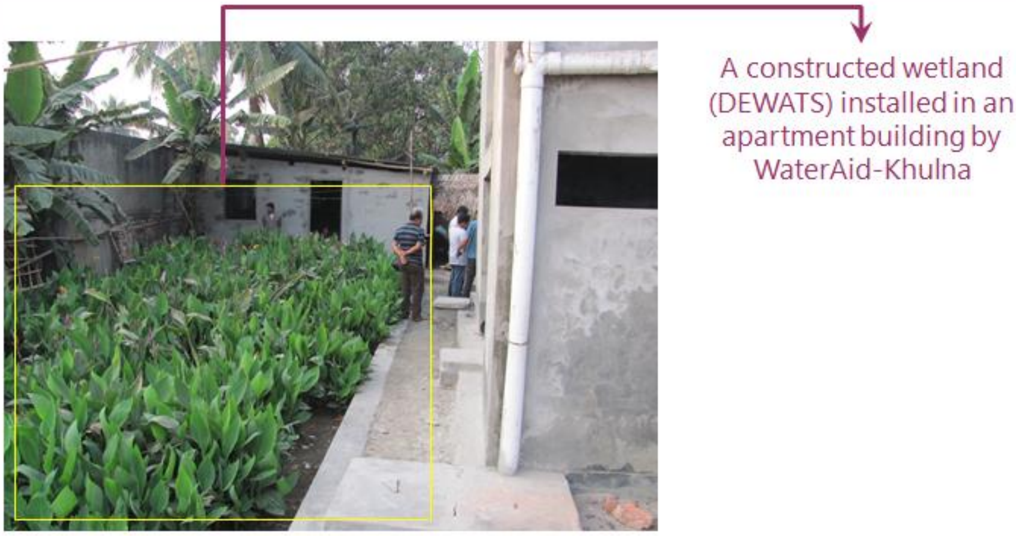
In this study, there were two main concerns of improper WASH practices on groundwater. The first is related to unsafe sanitation. It was found that it is often difficult to maintain a safe distance between toilets and groundwater abstraction points as housing density in the studied cities is very high. In Hanoi, most of the surveyed households have their wells within 3~25 m of their dwellings. In the slum camps in Khulna, where houses are closely connected and there is a lack of open space, groundwater pumps and toilets (shared) were located less than 10m apart. During interviews, none of the surveyed households shared serious concerns about the potential contamination of groundwater through percolation of leachate (such as microbial and nitrate contamination) from the septic tank in their house. This clearly signifies a serious lack of understanding about the potential risk of unsafe sanitation on groundwater.

The second concern is the impacts of the disposal of untreated wastewater on groundwater resources, which was found to be a serious problem in all three cities. Aged sewer infrastructure, inadequate wastewater treatment facilities, ineffective monitoring of discharges of industrial effluents, and ineffective operation of existing wastewater treatment facilities have contributed to the risk of groundwater pollution.

City governments could prioritise the following actions to minimise the impact of unsafe WASH practices on groundwater resources:

- Raise awareness about safe sanitation practices, safe management of septic waste such as timely desludging, and safe disposal of wastewater to prevent groundwater contamination;
- As it will take significant time to fully develop the necessary sewer and wastewater treatment facilities, introduce an interim plan for promoting eco-sanitation[3] and decentralised wastewater management options which are faster to implement, less costly to construct, and easy to operate;
- Carry out groundwater quality assessments to identify the pathways through which groundwater contamination occurs and take action to prevent the contamination;
- Employ groundwater safety as an indicator to monitor progress of WASH-related targets during the implementation of the SDGs.

Eco-sanitation toilet installed by JADE in Khulna district



A constructed wetland (DEWATS) installed in an apartment building by WaterAid-Khulna

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[3] Eco-sanitation or ecological sanitation is a term used to describe sanitation practices that use toilet wastes for useful purposes (such as in agriculture as organic fertilizer) and thus close the resource loop.

7 CONCLUSION AND RECOMMENDATIONS

This Working Paper assesses the groundwater-WASH nexus in three Asian Cities—Hanoi, Kathmandu, and Khulna—all of which are experiencing growing demand for water as well as groundwater degradation because of high rates of insufficiently planned urbanisation. The study was concerned with the lack of attention given by city governments and residents to the nexus between groundwater and WASH. This study examined different dimensions of the nexus in order to identify the factors affecting the choice of 'groundwater for WASH' and impact of 'WASH on groundwater'. Preferences of the end-users (households), a key beneficiary of WASH services, and four other decision criteria (access, adequacy, affordability, and quality) were the focus of the analysis.

The study found that groundwater and WASH are intrinsically linked irrespective of the studied city and irrespective of the fact that city governments may not explicitly acknowledge the existence of this linkage in their planning. Groundwater has an important role in fulfilling WASH needs in all the surveyed cities. Groundwater could become a connecting thread to co-manage three components (water-sanitation-hygiene) of WASH—a necessary condition to achieve Goal 6 of the SDGs.

Based on the findings and discussions in the previous sections, the following recommendations are suggested for city policy makers, managers of city water services, and relevant non-state actors (including research institutes, non-governmental organisations and development agencies working in the WASH sector and city development) for the sustainable management of the groundwater-WASH nexus in the studies cities as well as in other Asian cities experiencing difficulties in meeting water demands and degradation of their groundwater due to rapid urbanisation:

- For successful implementation of the SDG-related targets on WASH, plan WASH related programmes by taking into account the preference and decision criteria of the ultimate beneficiaries, i.e., the end users.
- Explicitly recognise groundwater as a strategic resource to achieve WASH targets in Asian cities and sustain the outcomes. More so than other sources, groundwater can be used to buffer the temporal variation in water supply which is likely to grow in areas susceptible to climate change impacts and in rapidly growing cities.
- Promote conjunctive use of available water resources to diversity the supply mix, including the use of water harvesting. This option is indispensable in situations where groundwater is already contaminated by geogenic arsenic or through seepage of pollutants. As observed in all the studied cities, development of a large scale alternative water supply scheme could narrow the deficit in water supply and reduce the pressure on groundwater resources, although groundwater will continue to play a significant role in securing WASH services.

- Introduce an alternative pricing policy to balance the cost of groundwater abstraction and use and tariffs for tap water, while taking into account the concerns of economically disadvantaged groups, such as people living in slum camps, who cannot afford high water tariffs.
- In managing the groundwater-WASH nexus, focus more on prevention of aquifer contamination by adopting safe WASH practices such as construction of leak proof septic tanks and drainage, maintaining safe distances between wells and toilets, timely desludging of septic tanks and employing eco-sanitation.
- Ensure services are adequate for appropriate disposal of wastewater and other potential groundwater pollutants. Progressively increase the ratio of safe treatment and disposal of wastewater such as by employing decentralised wastewater management.
- Adopt water quality safeguarding measures to enhance the usability of groundwater for consumption and maintain the quality at a level equivalent to a drinking water standard. This is particularly important to improve WASH services in situations where surface water is inadequate, unaffordable or too polluted for consumption.

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