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Water Supply in a War Zone

A Preliminary Analysis of Two Urban Water Tanker Supply Systems in the Republic of Yemen

Naif Mohammed Abu-Lohom, Yasuo Konishi, Yogita Mumssen, Bilkis Zabara, and Scott Michael Moore

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Acknowledgments

This discussion paper summarizes the results and implications of a study, "Initial Value Chain Analysis for Private Water Tankers in Yemen," prepared for the World Bank by Global Development Solutions, LLC, Alexandria, VA, USA, and the Water Environment Center, Sana'a University, Sana'a, Yemen, July 2017.

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Abbreviations

AU	autonomous utility
GARWSP	General Authority of Rural Water Supply Projects
INGO	international nongovernmental organization
LC	local corporation
MWE	Ministry of Water and Environment
NGO	nongovernmental organization
NWRA	National Water Resources Authority
NWSA	National Water and Sanitation Authority
NWSSIP	National Water Sector Strategy and Investment Program
TDS	total dissolved solids
UNICEF	United Nations Children's Fund
WASH	water supply, sanitation, and hygiene
WBG	World Bank Group
WEC	Water and Environment Centre

Summary

This discussion paper summarizes the results and implications of a study commissioned by the World Bank to conduct a rapid assessment of the state of private water tanker supply systems in two Yemeni cities, Sana'a and Aden. The study emanated from the World Bank's Water, Sanitation, and Health (WASH) Poverty Diagnostic for the Republic of Yemen, which identified serious gaps in access to basic water and sanitation services (World Bank 2017). A combination of poverty, water scarcity, armed conflict, and warfare has produced serious challenges for both water supply and sanitation in Yemen. Despite this urgency, little recent data is available on the state of the country's water supply and sanitation systems, in large part because key parts of the country remain inaccessible due to active conflict. The study described in this discussion paper accordingly presents one of the only detailed, survey-based assessments of water supply and sanitation in an active war zone. While it is based on a partial rather than a systematic survey, it highlights a number of key aspects of Yemen's urban water supply and sanitation situation. First, as a result of pre-existing challenges exacerbated by recent conflict, there is a considerable gap in the urban water supply sector. Second, this gap is being filled largely by private tanker trucks, on which urban Yemenis are increasingly dependent. Third, while the tanker truck system plays a critical role in filling this gap in the formal water supply system, it raises serious questions with respect to affordability, health, environment, and water resources management. Overall, the study suggests the need for urgent interventions to improve water supply and sanitation in Yemen's two largest cities.

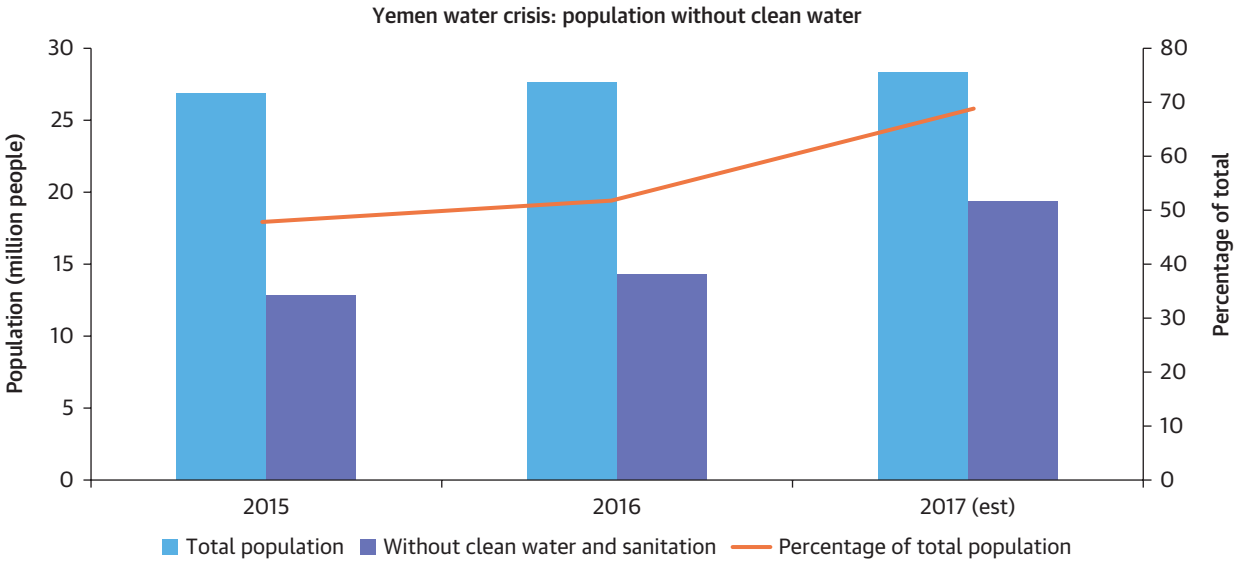
Introduction

Beset by poverty, water scarcity, and conflict, the Republic of Yemen is facing one of the world's most severe water supply and sanitation crises. The already high share of Yemen's population lacking access to clean water grew from 48 percent in 2015 to 69 percent in 2017 (figure 1). Today, approximately 19.4 million people in Yemen, including 10.2 million children, lack clean drinking water and sanitation,[1] contributing to the continued prevalence of disease.[2] As of the drafting of this report, more than 320,000 people in Yemen have contracted cholera since an outbreak in late April 2017.[3] The problem is especially acute in Yemen's cities. In 1990, over 96 percent of urban residents had access to an improved water source, but by 2010 the percentage had fallen to 72 percent (World Bank 2017).

Prior to the onset of conflict since 2010, Yemen's urban population gained access to water from a variety of sources, including both formal municipal water supply systems as well as informal sources including privately-operated tanker trucks, kiosks, and private wells. Today, many of the public services are no longer operating, as the Central Bank of Yemen has been unable to consistently pay salaries for civil servants since the summer of 2016.[4] At the same time, water scarcity has risen rapidly throughout the country due to population growth, climate change and unsustainable water resource management practices, including the over-use of groundwater mainly in the agriculture sector including the widespread cultivation of the narcotic *qat* (Moore and Fisher 2012).

The decline in formal urban water service provision has created a gap that has been filled to a significant degree by informal market players. Specifically, private tanker trucks have become more prominent in the water delivery supply chain as the availability of formal municipal water services has declined. While the presence of private tanker trucks has improved the availability of water services particularly in areas

FIGURE 1. Population without Clean Water, 2015–17



Source: World Data Indicators, https://data.worldbank.org/indicator, and World Bank 2017. 2017 population estimated from average population growth rates 2015–16. Data compiled by Global Development Solutions, LLC.

where public services have collapsed, it raises potential concerns over issues such as water quality, market pricing, service delivery, sustainable water resource management and the impact of private tanker use on the country, especially on the poor. Households that no longer have access to reliable water from water pipe networks or which cannot afford to purchase tanker truck water increasingly must rely on free water provided by mosques or other informal means, such as tapping standpipes. The proliferation of private water service providers and the absence of any government monitoring system makes it especially challenging to ensure water quality and prevent the spread of waterborne illness such as the cholera epidemic currently occurring in Yemen (World Health Organization 2018).

In light of the current situation, the World Bank Group (WBG) contracted Global Development Solutions, LLC (GDS), in partnership with the Water and Environment Centre (WEC), Sana'a University, to conduct a study to understand the current role of water tanker trucks within the broader context of urban water services in Yemen, and highlight changes that may have taken place since the conflict began. The study builds on a pre-conflict analysis of tanker services completed by WEC (Zabara et al. 2010) and the recent Water Supply, Sanitation and Hygiene (WASH) Poverty Diagnostic for the Republic of Yemen (World Bank 2017), and complements the WASH diagnostic efforts by focusing on private water tanker supply services. The study consisted of field surveys in two cities, Sana'a and Aden, that collected a wide range of data from households, water tanker truck drivers and owners, well owners, and other water supply sector stakeholders. The study also collected water quality data at initial source collection points as well as in tankers and upon delivery at households.[5] It represents one of the only such studies to be conducted in an active conflict zone.

This discussion paper presents some key findings from the study, with a focus on understanding the impact of conflict on water supply in Yemen and the relationship of these changes to key development outcomes in the country. It is organized into three main sections. The first describes the urban water supply system in Sana'a and Aden, and briefly notes the factors that have caused an increased reliance on private water tanker truck supply systems in the two cities. The second section details how this system operates, including a description of the basic value chain from water sources, which are primarily private wells, to households. The third section summarizes how this water supply system affects households in terms of water use and potential implications for livelihoods and health. The discussion paper concludes with some recommendations on the basis of this analysis for improving water supply services in light of the prevalence of water tanker delivery.

Before proceeding, some additional description of the methodology employed in this study and its limitations is warranted. Given limited availability of time and resources, this report reflects a rapid assessment of Yemen's water delivery services: data collection, analysis, and reporting for the assessment were all performed in the period from April 20 to June 30, 2017. Time limitations due to the month of Ramadan and uncertainty due to armed conflict prevented collection of a representative or statistically significant sample. Instead, the field team captured a non-random "snapshot" sample of water delivery facilities and households in each target region, with participants and the resulting analytic data acting as proxies for the socio-economic and market conditions among a wider range of water delivery sector stakeholders and households in the target regions. An important caveat is that the results of this study cannot necessarily be generalized to other cities, whether in Yemen or elsewhere. Nonetheless, given the general paucity of data related to water supply in conflict zones, this study offers a unique view of the effect of conflict on urban water supply in certain areas of Yemen.

This study also covers only the two largest cities in Yemen, Sana'a and Aden. These cities were selected

for several reasons. First, Sana'a and Aden have suffered a decline in municipal water services since the armed conflict began in 2010. The decline accelerated considerably after March 2015, after which the municipal water supply system in both cities has suffered severe damage. Second, both cities have public water utilities—water and sanitation local corporations (LCs)—which have almost collapsed due to the ongoing armed conflict. As a result, the citizens of Sana'a and Aden have become highly dependent on private water tanker truck delivery. Prior to the onset of the conflict, Aden's LC used to cover over 90 percent of the city's residents, and Sana'a's LC less than 50 percent. Third, existing World Bank and other survey data exists for these cities, and in the case of Sana'a these include a 2010 baseline survey which facilitates an understanding how the water supply situation has changed.

Within each city, sampling for the study was conducted at district level. This was done for several reasons. The settlement of internally displaced persons in major cities such as Sana'a and Aden has created additional stress on water resources, and water demand has reportedly been observed to have increased, yet no census of water demand is available on the district level.[6] Observations of the rate of access to free water in certain districts moreover suggest that citizens are unable to access water from other, more convenient sources, further necessitating a district-based study to assess access points by district. Moreover, in Yemen water prices differ considerably by district, necessitating a study of price by district. Finally, an understanding of private water tanker service areas can help inform future interventions.[7] For the household and tanker surveys, all ten districts in Sana'a city and all eight districts in Aden were sampled.

Basic Features of Urban Water Supply Systems in Sana'a and Aden

To understand the role that private water tankers play in urban water supply in Yemen, it is necessary to first understand the challenges that the sector has long faced, and the additional complications that have arisen as a result of Yemen's recent conflict. The county's water supply and sanitation sector has long faced significant financial, administrative, technical, and other constraints, but these have grown significantly worse as a result of the ongoing conflict that has affected Yemen since approximately 2010. These have critically affected virtually all important actors in Yemen's urban water supply sector.

Broadly speaking, there are three elements of Yemen's water supply and sanitation sector. The first pertains to formal municipal water services, which are delivered via LCs under the purview of the Ministry of Water and Environment (MWE). The General Authority of Rural Water Supply Projects (GARWSP) is responsible for water supply delivery in rural areas. The second relates to overall water resource management, including water use and allocation, which is primarily the responsibility of the National Water Resources Authority (NWRA). The third and final dimension concerns water quality and sanitation. While national WASH activities are coordinated by MWE and the United Nations Children's Fund (UNICEF) through GARWSP, Local Corporations, NWRA and, in the case of multi-lateral development projects, Urban Project Management Units, ultimately water and sanitation services are locally managed via decentralized local utilities. The institutional landscape for urban water supply is briefly outlined below, followed by similarly abbreviated descriptions of the regulatory framework and how urban water supply actors have been affected by the ongoing conflict.

Institutional Landscape for Urban Water Supply: MWE is the principal line ministry for water supply and sanitation delivery. It sets tariff policy, including approving tariff levels charged by urban utilities, and must approve senior appointments to local utility boards. MWE subsidizes capital costs and, in some cases, local utility operating and maintenance expenses. MWE is also responsible, through GARWSP, for developing rural water supply and sanitation services. However, direct urban water supply and sanitation service delivery is by law the responsibility of local utilities in the form of 23 local corporations (LCs) and 10 "annexed autonomous utilities" (AUs) that together provide water supply and sanitation services in most Yemeni towns. Each LC is established by decree, and features its own board with representatives from central and local government as well as from the community. Water prices are set by the LCs with management oversight from their respective Boards of Directors. MWE provides guidance to LCs on price- and tariff-setting.

Approximately 5 percent of Yemen's towns are not served by local utilities, and are instead served by the National Water and Sanitation Authority (NWSA). MWE also plays a role in water resource management via cooperation with an intermediate-level entity, the NWRA. NWRA has wide-ranging legal powers to implement water laws and regulations, allocate water rights, approve permits for drilling wells, and to undertake various other water resource management functions. However, in practice NWRA functions in a decentralized manner, operating through seven branch offices and five river basin committees established in Sana'a, Taiz, Saada, Turban, and Abyan. Apart from MWE, the Ministry of Agriculture and Irrigation plays a significant role in agricultural water management.[8]

Regulatory Framework of the Water Sector in the Republic of Yemen: The water sector in Yemen is guided by two primary regulations, namely the Water Law

and the National Water Sector Strategy and Investment Program (NWSSIP). The Water Law was ratified in 2002, with the primary objective being:[9]

> to regulate, develop and ration the exploitation of water resources, as well as the protection thereof from depletion and pollution, the improvement of the efficiency of conveying and distributing their uses and the proper maintenance and operation of the installation thereof and participation of the beneficiaries thereof in their management in the various states of their development, investment and conservation thereof.

The NWSSIP was developed through a multi-stakeholder initiative led by MWE to prepare a consolidated strategy, action plan and investment program for the water sector. The NWSSIP has several major objectives for sector management:[10]

- To ensure coordination among all partners working in urban and rural water supply and sanitation sub-sectors, within and outside MWE;
- To ascertain that policies in the urban and rural water supply sub-sectors are unified and that investments are equitably allocated among governorates according to unified rules and that no projects are duplicated, especially in rural areas, to ensure that investments complement each other;
- To integrate water policies and national policies of sustainable growth and poverty reduction;
- To ensure that sector financing effectively supports sector goals; and
- To monitor and evaluate the performance of water supply utilities.

The primary responsibility for monitoring and regulating water quality falls under NWRA, LCs and GARWSP. In addition, other ministries and agencies play an important role in monitoring and regulating water quality. Other stakeholders include the Ministry of Health, which is responsible for public health and recommending specific water quality standards.[11] The General Authority and Department for Awareness and Environmental Health under the Ministry of Public Works and Highways is responsible for supervising water quality in urban areas. Finally, Yemen Authority for Specification, Standards and Quality Control is responsible for setting water quality standards. In practice, actual water quality monitoring is conducted by several laboratories under MWE and NWRA. The MWE laboratory in Sana'a currently employs 30 lab technicians and is the largest water lab in Yemen, followed by the NWRA-Sana'a lab (with 7 technicians), and GARWSP (3 technicians).

Yemen's ongoing conflict has exacerbated long-standing challenges facing the country's urban water supply sector and its accompanying regulatory framework. The LCs that supply formal municipal water systems are increasingly in debt and unable to afford to operate or maintain water networks, or to conduct regular water quality tests. Tariffs levied for municipal water supply to households vary by quantity used, and range from 130 to 374 Yemeni rials (YER) per cubic meter (m^3) in Sana'a, equivalent to approximately US$0.52-1.50, and YER31-120/m^3, or US$0.12-0.48 in Aden. Although some LCs steadily increased tariffs prior to the conflict, in most LCs water tariff rates for municipal water supply have remained the same for years—in the case of Aden they have remain unchanged since 2000—and remain far below cost recovery rates.[12] Tariffs in Sana'a and Aden do not cover operating costs, but at the same time widespread unemployment since the onset of the current conflict in Yemen has made it difficult for most households to pay even minimal tariffs. In any case, the conflict has resulted in major disruptions to formal water supply systems in Sana'a and Aden. In Sana'a, the municipal piped water network operates only intermittently, and usually only long enough to fill household water tanks in one district at a time. Aden's piped water supply network operates more reliably, but is subject to major challenges including silt and

sodium buildup and salinization of source water supplies.

The conflict has also substantially disrupted water quality monitoring and supervision efforts. In a reflection of the increasing importance of informal water supply networks, multiple NGOs as well as the Ministry of Health distribute chlorine tablets free of charge to private tanker truck drivers to combat cholera. However, utilization is not systematic, and the predominance of informal actors results in little consistency or reliability in assessing and ensuring water quality. There is no apparent protocol for traceability in the water supply chain or chain of custody with respect to water quality, and little oversight and no formal registration or monitoring of tanker truck delivery services. Because of the security situation, it is difficult to assess water quality with any degree of accuracy.[13] However, anecdotal reports indicate that the conflict has severely and negatively impacted water quality in both Sana'a and Aden. According to Sana'a LC officials, well water consistently exhibits high levels of iron and nitrates. Moreover, aerial bombing has apparently affected several water treatment facilities. Consequently, the Sana'a LC at times is unable to treat or filter water before it is distributed, which has resulted in water quality and equipment degradation.

The situation is reportedly similar in Aden. The city's LC water testing laboratory is no longer functioning, due to both insufficient funds to cover operating costs and war damage that has apparently rendered the laboratory inoperable. Consequently, Aden LC is at the mercy of international nongovernmental organizations (INGOs) such as International Rescue Committee, the International Committee of the Red Cross, Oxfam and Mercy Corp to undertake chlorination treatment of wells.[14] Furthermore, Aden LC faces salinity issues in its Dar Almanasirah groundwater field, where some of the wells have a high concentration of salt, so the water is mixed with water from the other two fields to make it potable.[15]

The effective collapse of formal municipal water supply and water quality systems in Sana'a and Aden has created a substantial gap in water service provision. Specifically, according to an interview, Aden authorities currently supply around 24 million m^3 of water annually, whereas the demand is estimated to be more than 39 million m^3. Before the war, pumps operated 22 hours per day, but currently, pumps are operating less than 8 hours per day, and not on a regular basis. The water shortage problem continues to be further exacerbated by increasing numbers of refugees from Africa as well as internally displaced people. In response, illegal well drilling has apparently increased along with reliance on private water tanker trucks. In Aden, small-scale private desalination plants also operate to fill the water supply gap. The following section describes one of these informal adaptations, the private water tanker supply systems operating in Sana'a and Aden in greater detail.

Analysis of Private Tanker Truck Water Supply Systems in Sana'a and Aden

As noted in the Introduction, the core purpose of the study on which this discussion paper is based was to gather key data on the private tanker truck water supply system that has grown in importance for Yemen's cities since the onset of conflict. This section summarizes some of the data gathered as part of the study, and is divided into three sub-sections. The first describes the well-to-tanker supply chain, including data on prices and costs at each major stage of the chain. The second section presents data on well owners, and the third and final section highlights major findings from surveys of private water tanker truck drivers, including practices commonly employed to ensure or protect water quality. Box 1, meanwhile, describes the results of water quality sampling conducted as part of the study. The analysis overall shows that while the water tanker system fills a key gap in formal water supply services, there are few if any safeguards with respect to ensuring water quality to end-users.

Well-to-Tanker Supply Chain: The supply chain for private water distribution in Sana'a and Aden runs from private well owners to household consumers, with private water tanker owners and drivers acting as delivery agents. The majority of well water distributed through private water supply networks, approximately 56 percent in Sana'a and 57 percent in Aden, is eventually sold to household consumers.[16] In Sana'a, the 4 private well owners interviewed sell 60-80 percent of well water to tanker trucks, while in Aden, tanker trucks purchase 40-100 percent of the water extracted from the 3 private wells studied. In both Sana'a and Aden, interviewed well owners commonly donate the balance of their water (up to 40 percent) to mosques and/or charities.

The same general value chain exists with respect to private water tanker trucks. On average, households accounted for 82 percent of the water sold by the 40 tanker truck drivers surveyed in Sana'a and 85 percent of the water sold by the 40 tanker truck drivers surveyed in Aden, with customers such as businesses, government offices, construction sites, factories, farms, cafeterias and restaurants, and supermarkets accounting for the remaining tanker truck water sold. In the case of supermarkets, water is then resold to households. In Sana'a, some tanker drivers (up to 25 percent of surveyed tanker water trucks in three districts) reported being contracted by UNICEF to deliver water free to poor and needy households, rather than for direct sale to households.[17] In Aden, about half of the well water purchased by surveyed tanker trucks is desalinated at water purification shops prior to delivery to customers (based on customer request). Just over half (53 percent) of tanker drivers surveyed in Sana'a reported that they charge households higher prices than they do other customer types (e.g., commercial or government clients). In Aden, no price differentials by customer type were reported.

Sellers, both well owners and tanker truck companies and operators, set water prices based primarily on the prevailing market price and the distance traveled to deliver water. Reported prices for water vary widely by city and distribution channel. In Sana'a, interviewed well operators sold water to tankers for YER113-500/m^3 (US$0.45-2.00), while surveyed tanker truck drivers sold water to households for a very wide range of prices, ranging from YER226-1,000/m^3 (US$0.9-3.99). In Aden, surveyed tankers buy saline water at a relatively low rate, averaging approximately YER112/m^3 (US$0.45) from private wells, which is then re-sold to households at a considerably higher average price of YER1,832/m^3 (US$7.3). Most such water sold in Aden is

not directly potable, but instead requires desalination, which tanker truck drivers undertake as an additional service. If requested by the customer, tanker truck drivers take water to a third-party purification shop for desalination treatment which costs approximately YER2,000/m³ (US$7.98) and after an additional markup, desalinated tanker water may be sold to households by tanker truck drivers for YER4,000-YER5,000/m³ (US$15.96-19.95), based on the study sample.[18]

The need for desalination, along with increasing distances traveled to reach productive wells as those closer to the city become over-drawn, contributes to significantly higher water prices in Aden, where households may pay 8.1 times more for tanker truck drinking water than do Sana'a households (see figure 2). Further, the deterioration of the formal municipal water supply network in both cities means that Sana'a households purchasing water from private tanker trucks pay, on average, 3.8 times more for water delivered via private water tanker truck than they do for piped water, whereas in Aden, households pay 18 times more for non-desalinated water and 45 times more for desalinated water delivered via private tanker truck versus pipe.

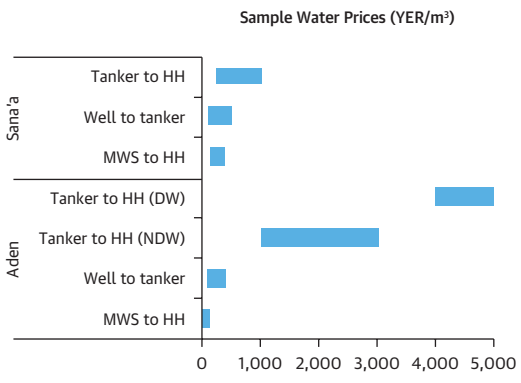
Besides obtaining water from private tankers or piped water delivery, households may buy water from purification shops. This method of obtaining water is commonplace for households that cannot afford a full tanker delivery or lack a home storage tank. Such sales generally are in small quantities as compared with those sold by tanker trucks, and prices reflect a much higher unit cost, the equivalent of up to YER20,000/m³ (US$79.8). When sold and delivered by the purification shop in bulk, prices may in contrast be as low as YER4,000/m³ (US$15.96).

Well Operations: In Sana'a, the average age of the studied private wells is 59 years, with some reported as having been in operation for over 100 years, with depths ranging from 60 to 600 meters, albeit with reported declining water depth and volume. Due to deteriorating public services, demand for private well water is high, and tanker trucks in Sana'a endure long wait times (90 percent of surveyed Sana'a tanker drivers wait in line 30 minutes to more than 1 hour to access wells). Compared to the Sana'a wells studied, Aden wells in the study are newer (average has been

FIGURE 2. Sample Prices for Water in Select Channels, Sana'a and Aden (YER/m³)

Sample water prices (YER/m³)

Sales channel		Sana'a Min	Sana'a Max	Sana'a Average	Aden Min	Aden Max	Aden Average
Well to tanker		113	500	240	100	400	112
Desalination process		*NA*	*NA*	*NA*	*2,000*	*2,000*	*2,000*
Tanker to HH	NDW	226	1,000	554	1,000	3,000	1,832
	DW				4,000	5,000	4,500
MWS (local corporation) to HH		130	374	146	31	120	100
Purification shop to HH		5,000	20,000	NA	4,000	20,000	NA



Sources: Global Development Solutions, LLC and Water and Environment Centre.
Note: DW = desalinated water; HH = household; NA = not applicable; NDW = non-desalinated water.

in operation for 9 years, according to interviewed well owners) and are shallower, with typical depths ranging from 13 to 40 meters. The majority (75 percent) of interviewed well owners in Sana'a reported being registered with GARWSP or the MWE, compared with none in Aden, where illegally dug wells are more common. Less than 3 percent of the Sana'a well owners and no interviewed Aden well owners ration or otherwise limit access to their wells, despite reported water table decline due to continued and increased water extraction. All well owners interviewed in Sana'a and Aden reported adding chlorine to the well. Notably, three of the four well owners interviewed in Sana'a, compared to only one in Aden, reported testing their water quality, though all expressed interest in doing so.

Sampled wells in Aden serve a higher number of private water tanker trucks than those in Sana'a (15-30 tankers/day in Aden versus 5-30 tankers/day in Sana'a), reflecting the smaller average tank capacity of trucks operating in Aden. Of the major well operating expenses (fuel; oil and filter; and repair and maintenance), fuel is the largest operating cost for well owners in both cities (70-80 percent of total cost in Aden and 50-90 percent of total cost in Sana'a). Data provided by interviewed well owners indicated profit margins[19] ranging from 8 to 40 percent in Sana'a and 33 to 56 percent in Aden.

Providers of Private Water Tanker Truck Delivery Services: Survey findings suggest that independent drivers dominate tanker truck water delivery services in Sana'a (95 percent of surveyed drivers in Sana'a), while in Aden, water delivery services more often are performed by tanker truck fleet owners who operate several trucks using hired drivers (100 percent of surveyed drivers in Aden). Given the continued availability of piped water in Aden, tanker truck water delivery services are a relatively new phenomenon (43 percent of surveyed drivers have been driving for less than one year), whereas in Sana'a, 45 percent of surveyed drivers have been driving tanker trucks for more than five years. Even in Sana'a, where private water tanker delivery services are more established, there are many new entrants (55 percent of surveyed tanker drivers have delivered water for less than five years). The maturity of the Sana'a market is further demonstrated by the customer structure. In the Sana'a sample, 63 percent of deliveries are on an on-call basis and 35 percent are delivered according to standing contracts, while in the Aden sample, 98 percent of deliveries are based on calls from customers.

The use of credit payment is another indication of a more mature market for tanker truck water delivery service in Sana'a than in Aden. According to surveyed drivers in Sana'a, 25 percent of household customers paid cash upon delivery for their water, and 23 percent of household clients purchased water on credit. In contrast, in Aden, drivers reported that nearly all household customers paid drivers cash on delivery for water (only 1 driver surveyed in Aden reported having customers who paid on credit).

The operational characteristics of the water tanker fleets in the two cities also demonstrate considerable differences. The four fleet owners interviewed in Sana'a served fewer districts but more households than the four owners interviewed in Aden (30-180 households in Sana'a versus 20-40 households in Aden). High demand for water delivery in both cities is evidenced by the long working hours of surveyed tanker truck drivers, with drivers in both Sana'a and Aden working, on average, 11-12-hour days, 6-7 days per week. Trucks in the Aden sample are relatively new (68 percent built between 2000 and 2016), while trucks in the Sana'a sample tend to be older (68 percent built between 1980 and 1999), in line with the more established service in Sana'a. There currently is no official entity that conducts vehicle inspections in Yemen, raising potential concerns regarding vehicle safety.

A greater concern, however, may stem from the potential effects of private water tanker delivery on public

BOX 1. Sampled Water Quality in the Well-to-Household Water Supply Chain

As part of this study, GDS/WEC drew water samples to assess water quality and determine at what point(s) along the supply chain water quality becomes degraded as it progresses from private wells to households in both Sana'a and Aden (World Bank 2017). Testing consisted of physical, chemical and microbiological (also referred to as bacteriological) analysis. Despite testing authorities in both cities listing WHO "standards" for properties tested, and operating under the authority of Yemen Authority for Specification, Standards and Quality Control (YASSOC), which is responsible for setting water quality standards, each laboratory tested according to individually-adapted parameters and specifications (World Bank 2017). For example, the testing laboratory in Aden did not test for free chlorine concentration; chlorine is commonly used globally to kill bacteria in drinking water.

In Sana'a, tested water exceeded limits for total dissolved solids (TDS) and coliform (including fecal *E. coli*) but featured below-standard concentrations of iron, ammonia and chlorine. Given the presence of contaminants across the entire supply chain in Sana'a, and the outbreak of cholera in Yemen, the low concentration of free chlorine in tested Sana'a supply chains may be a cause for concern. However, the Sana'a test results did not enable pinpointing of the specific points of origin for contamination or degradation, since tested parameters failed to meet various standards at each point in the supply chain. Thus, the problems may have originated at the source well and continued untreated throughout the supply chain, or may alternatively have been treated but later reintroduced at multiple points in the supply chain.

In Aden, tested water failed to meet many physical, chemical and microbiological standards for water quality. Although Aden test results showed higher nonconformity to laboratory testing standards than did those in Sana'a (World Bank 2017), which tested positive for both total and fecal coliforms at every point in the supply chains tested, Aden results indicated total coliforms tested negative at the well but tested positive at subsequent points in both chains. Fecal (*E. coli*) coliforms were not found at any point in Aden water supply chains at the sites tested. Such findings are consistent with the siting of cholera outbreaks, which are more prevalent in Sana'a than in Aden (World Bank 2017). Nevertheless, 28 percent of the 80 surveyed Aden households and 13 percent of the 80 households surveyed in Sana'a reported that HOUSEHOLD members have become ill from drinking water at home.

health (see box 1). Among the sampled population of tanker fleet owners and independent drivers, no tanker water was tested with a public agency such as an LC or central health laboratory. The absence of water quality testing, coupled with the lack of truck inspections, a fleet of old and aging tanker trucks (particularly in Sana'a), and the inconsistent application of chlorine suggests that the tanker truck water delivery services continue to operate in an unregulated environment that is ripe for water contamination and rapid spread of waterborne disease, and that an outbreak of disease, such as the ongoing cholera epidemic, could potentially be spread through the private tanker truck distribution system.

The sample of private water tanker truck drivers also throws into sharp relief Yemen's growing localized water scarcity. Twenty percent of surveyed Sana'a drivers observed source wells running dry in recent history, while only 2.5 percent of the surveyed Aden drivers

indicated the same. One of the most striking differences between private tanker truck operations in Sana'a and Aden is the wait time experienced by surveyed drivers at a well to pump water. For example, approximately 80 percent of drivers surveyed in Aden waited less than 10 minutes in line to pump water, while in Sana'a 90 percent of surveyed drivers waited from 30 minutes to more than 1 hour to access a well. Once at the well, no surveyed drivers in Aden reported that well owners were rationing water usage, while in Sana'a, only one surveyed driver reported that well owners were exercising water rationing.

Well depletion is also reflected in the higher water costs in the Sana'a sample as compared to the Aden sample. Well water prices are rising rapidly in both cities; nearly 58 percent of surveyed independent drivers in Sana'a indicated that the price of water paid to well owners had increased between 10 and 50 percent in the past 12 months, and 48 percent of drivers reported price increases of at least 25 percent in the past 12 months. In Aden, meanwhile, 48 percent of surveyed hired drivers indicated that the price paid for water increased more than 50 percent in the past 12 months. Indicative of the daily hardship incurred by households in Sana'a, a high number (83 percent) of the surveyed Sana'a tanker drivers reported losing customers in the past 12 months due to customers' loss of income and/or water price increases. Together, these two reasons accounted for 65 percent of reported customer loss.[20]

Of the major tanker fleet operating expenses (fuel, water, maintenance and repair, driver wages, and, in the case of Aden, desalination), water purchases account for the largest portion of operating cost in Sana'a (42-64 percent of total cost), while desalination is the largest operating cost for those surveyed in Aden (75-87 percent of total cost) (see figure 3). In Sana'a, interviewed water tanker fleet owners reported paying YER113-208/m^3 (US$0.45-0.83) of water and selling water for YER410-520/m^3 (US$1.64-2.08), while interviewed Aden fleet owners reported paying YER100-400/m^3 (US$0.4-1.6) for water, having it desalinated for YER2,000/m^3 (US$8.0), and selling it for YER4,000-5,000/m^3 (US$16-20), resulting in profit margins of 17-44 percent in Sana'a and 34-35 percent in Aden. Poor access to diesel fuel and traffic congestion led concerns of interviewed tanker fleet owners in both cities. Notably, private water tanker truck fleet owners did not cite high or rising water prices as a concern in either Sana'a or Aden, perhaps because truck owners simply pass price increases through to customers.

Similar results were found for independent tanker truck drivers in Sana'a. Of the major operating expenses of independent tanker truck drivers surveyed (fuel, water, and maintenance and repair), water is the largest operating cost (60-90 percent of total cost in Sana'a) (see figure 4). Independent drivers reported profit margins ranging from 1 percent to 49 percent in Sana'a, with some drivers potentially indicating net loss, due to poor or non-existent bookkeeping. Independent tanker services marked up water prices for water bought from private well owners and sold to households by 43-169 percent. However, these markups do not necessarily translate into accompanying profit margins, particularly for drivers operating older trucks or who travel to more distant source wells.

The survey results also provide some indication that private water tanker truck distribution does play some role in providing water to poor and disadvantaged populations. Besides selling water to households, some drivers in the Sana'a sample reported being contracted by UNICEF to deliver water. Specifically, the study found that 25 percent of drivers, all of them independent, surveyed in Old Sana'a, Al Wahdah, and Maein Districts were contracted by UNICEF in their respective districts to deliver water, particularly to the poor and needy

FIGURE 3. Sample Value Chain Maps for Tanker Truck Fleet Operations in Sana'a and Aden, by District

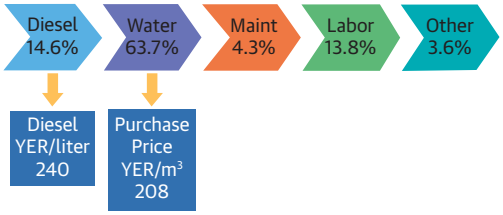
Sana'a

a. Al-Safia

Tanker Truck Company Value Chain

Tanker Truck Margins for Water Sales

Water purchase price by driver (YER/m³)	208
Water selling price to households (YER/m³)	410
Est. Profit Margin	20%

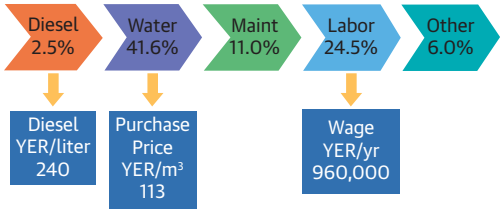


b. Maein

Tanker Truck Company Value Chain

Tanker Truck Margins for Water Sales

Water purchase price by driver (YER/m³)	113
Water selling price to households (YER/m³)	450
Est. Profit Margin	17%

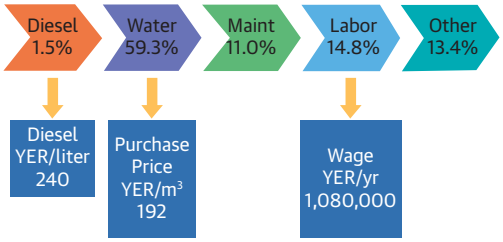


c. Shaoub

Tanker Truck Company Value Chain

Tanker Truck Margins for Water Sales

Water purchase price by driver (YER/m³)	192
Water selling price to households (YER/m³)	520
Est. Profit Margin	44%



d. Al Thawrah

Tanker Truck Company Value Chain

Tanker Truck Margins for Water Sales

Water purchase price by driver (YER/m³)	176
Water selling price to households (YER/m³)	420
Est. Profit Margin	36%

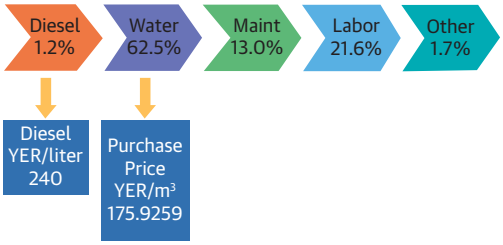


figure continues next page

FIGURE 3. continued

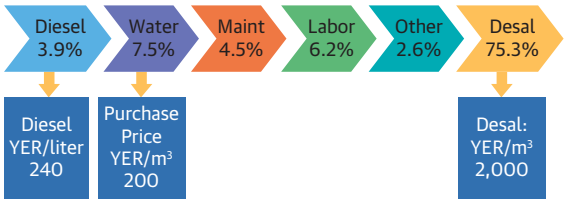
Aden

a. Ayman Abdu Alhakim (Zamzam)

Tanker Truck Company Value Chain

Tanker Truck Margins for Water Sales

Water purchase price by driver (YER/m³)	200
Water selling price to households (YER/m³)	4,000
Est. Profit Margin	33.6%

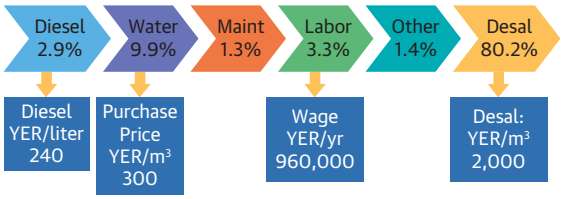


b. Almnsora

Tanker Truck Company Value Chain

Tanker Truck Margins for Water Sales

Water purchase price by driver (YER/m³)	300
Water selling price to households (YER/m³)	4,000
Est. Profit Margin	34.9%

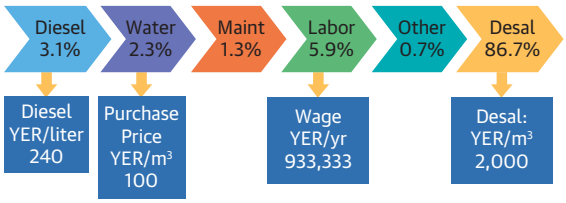


c. Al Mansoura

Tanker Truck Company Value Chain

Tanker Truck Margins for Water Sales

Water purchase price by driver (YER/m³)	100
Water selling price to households (YER/m³)	4,000
Est. Profit Margin	35.3%

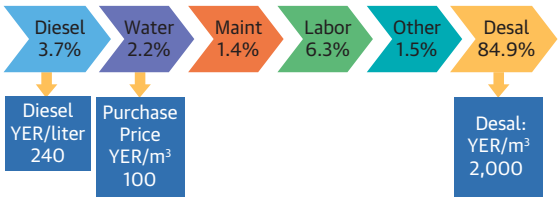


d. Al Slam

Tanker Truck Company Value Chain

Tanker Truck Margins for Water Sales

Water purchase price by driver (YER/m³)	100
Water selling price to households (YER/m³)	4,000
Est. Profit Margin	33.6%



Source: Global Development Solutions, LLC (GDS).
Note: Aden operations shown pertain to desalinated water.

(see figure 5). In Aden, no surveyed tanker drivers were contracted by UNICEF, but 20 percent of the drivers surveyed in Al Buraiqeh District reported being contracted by INGOs in their district to deliver water to the poor and needy. It was not readily apparent how the tankers identified suitable recipients of free water from UNICEF; however, interviews with INGOs suggest that beneficiary groups are identified during monthly INGO meetings.

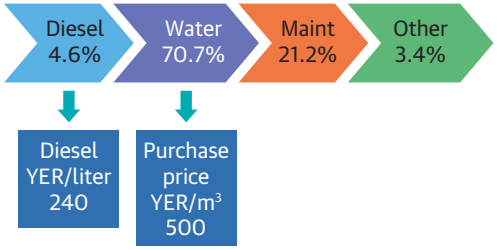
FIGURE 4. Sample Value Chain Map for Independent Tanker Truck Driver in Sana'a, by District

a. Al-Safia

Independent driver profitability analysis (lowest margin)

Tanker truck margins for water sales

Water purchase price by driver (YER/m³)	500
Water selling price to households (YER/m³)	1,000
Est. profit margin	1%

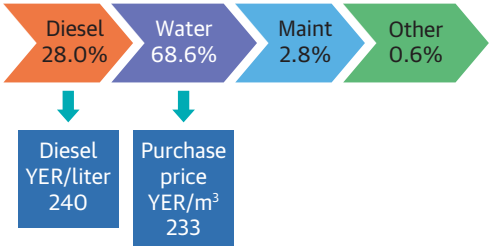


b. Azal

Tanker truck value chain (highest margin)

Tanker truck margins for water sales

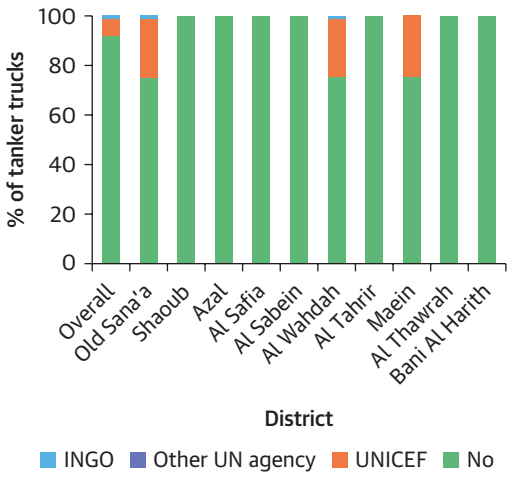
Water purchase price by driver (YER/m³)	233
Water selling price to households (YER/m³)	580
Est. profit margin	49%



Source: Global Development Solutions, LLC.

FIGURE 5. Sana'a Tanker Drivers Contracted by International Agency

		No (percent)	UNICEF (percent)	Other UN agency (percent)	INGO (percent)
	Overall	92.5	7.5	0.0	0.0
1	Old Sana'a	75.0	25.0	0.0	0.0
2	Shaoub	100.0	0.0	0.0	0.0
3	Azal	100.0	0.0	0.0	0.0
4	Al Safia	100.0	0.0	0.0	0.0
5	Al Sabein	100.0	0.0	0.0	0.0
6	Al Wahdah	75.0	25.0	0.0	0.0
7	Al Tahrir	100.0	0.0	0.0	0.0
8	Maein	75.0	25.0	0.0	0.0
9	Al Thawrah	100.0	0.0	0.0	0.0
10	Bani Al Harith	100.0	0.0	0.0	0.0



Sources: Global Development Solutions, LLC and Water and Environment Centre.

Note: INGO = international nongovernmental organization; UN = United Nations; UNICEF = United Nations Children's Fund.

Potential Implications for Household Livelihoods, Health, and the Environment

The study results show significant changes in household water use as a result of the conflict, and their consequent dependence on tanker truck deliveries for water supply in Sana'a and Aden. Survey results show that concerns regarding water availability are greater in Aden, while water quality is a greater concern in Sana'a. In both cities, however, private water tanker trucks play an increasingly important role in water supply. However, given the price differentials documented in the previous section, it seems likely that the lack of dependable coverage for municipal water supply and sanitation services has a regressive impact on the poor, while the lack of regulation for tanker truck operators poses its own risks. Further, as private tankers do not currently seem to have great incentives for water resources stewardship, there is a concern that their actions, together with the well owners from which they source, could exacerbate the already very tenuous water scarcity situation in Yemen's cities. This section is divided into three sub-sections that discuss potential implications of the private water tanker truck supply system for, respectively, household water use, and attendant potential implications for livelihoods, health, and the sustainable management of Yemen's very scarce water resources.

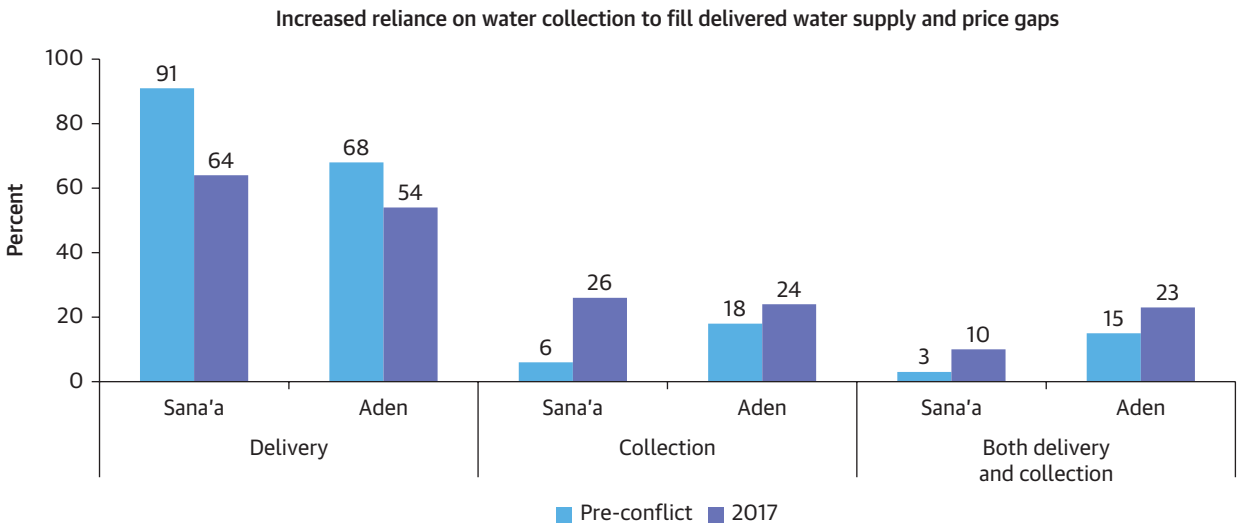
Household Water Use: Survey data conducted for this study suggest that increased dependence on informal private water distribution networks is associated with distinct changes in household water use, which in turn could have distributional and health-related implications. In general, the study indicates that the water usage rate was very similar in both Sana'a and Aden, although households surveyed in Sana'a placed greater importance on water safety (68 percent in Sana'a compared with 48 percent in Aden) compared to Aden, where greater importance was placed on water availability (26 percent in Sana'a vs. 40 percent in Aden).

Increased dependence on informal private water distribution networks seems to have also been associated with a decline in household water use. In both Sana'a and Aden, the average size of surveyed households included nine members, who together consumed an average of 8.2 m^3/month/household, implying average water use of 30 liters/person/day for all domestic uses. Many households, including 60 percent of the Sana'a sample and 44 percent of the Aden sample reduced water consumption in the past five years, due primarily to higher prices (cited by 45 percent of surveyed Sana'a households) and inadequate availability of water (cited by 35 percent of surveyed Aden households).

More concerning from a health and sanitation perspective is the fact that surveyed households in both Sana'a and Aden also reported decreasing use of delivered water whether by public or private pipe network or by tanker truck. In Sana'a, the share of households relying solely on delivered water fell from 91 percent pre-conflict to 64 percent at the time of research, while in Aden the share of households relying solely on delivered water fell from 68 percent to 54 percent (figure 6). This finding suggests that since the onset of the conflict more households face greater difficulties in regularly accessing water supplies for drinking and sanitation.

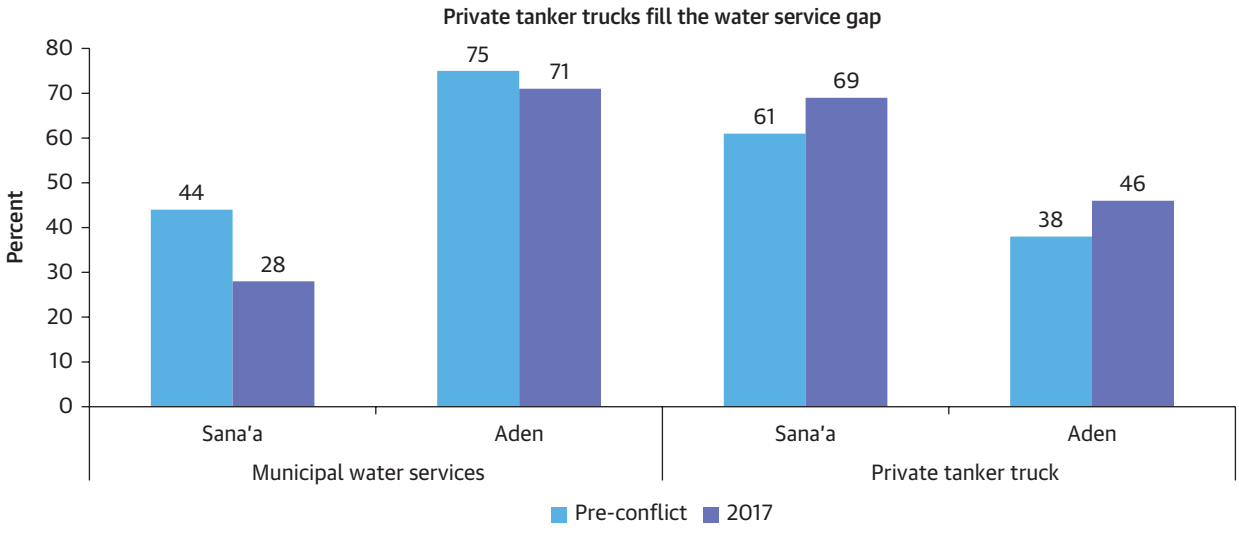
At the same time, households survey results confirmed that private water tanker trucks are increasingly filling the gap in water service provision caused by decreasing use of formal municipal water networks (figure 7). The transformation has been particularly marked in Sana'a, where municipal water service utilization fell from 44 percent of surveyed households

FIGURE 6. Household Utilization of Delivered and Collected Water



Sources: Household surveys, Global Development Solutions, LLC and Water and Environment Centre.
Note: Delivery includes pipe networks (public or private) and tanker trucks. Collection includes free (e.g., mosque, standpipe) and purchased sources (e.g., purification shop).

FIGURE 7. Household Utilization of Municipal Water Services and Private Tanker Trucks



Source: Household surveys, Global Development Solutions, LLC and Water and Environment Centre.
Note: Multiple responses accepted; households commonly rely on multiple means for water supply, including sources not shown (e.g., private pipe network, collection).

pre-conflict to 28 percent currently, while 69 percent of surveyed households have come to rely on private tanker trucks for water. The convenience of readily available tanker truck delivery service nonetheless comes at a high price. Surveyed Sana'a households pay YER400-1,000/m^3 (US$1.6-3.99) for water purchased from tanker trucks versus YER146/m^3 (US$0.58) for municipal piped water.[21] In Aden, surveyed households pay YER1,000-3,000/m^3 (US$3.99-11.97) for non-desalinated water deliveries and YER4,000-YER5,000/m^3 (US$15.96-19.95) for desalinated tanker truck water, while piped municipal water costs for households range from YER31 to 120/m^3 (US$0.12-0.48).[22] However, despite this cost differential, reliability issues prevent some households from being able to depend on the formal municipal water supply network. Some households using piped water have been unable to pay water bills, resulting in service shutoff. To restore water delivery, some households have made private agreements with LCs to pay a flat-rate water charge toward the accumulated water bill, further demonstrating the challenges facing the municipal network.

Implications for Access: The study results show that while private water tanker deliveries are considerably more expensive than municipal piped water, there is some evidence of market competition and efficiency with respect to the responsiveness of private service providers in delivering water to households. Private water tanker truck delivery service appears more efficient in Sana'a, where 41 percent of surveyed households indicated that water is delivered within 1 hour of making a call for delivery, than in Aden, where only 21 percent of surveyed households received delivery within an hour of calling for water, and 5 percent waited one to two days for tanker truck water delivery. Given these reported response times private water tanker truck delivery services appear to be considerably more reliable than the extant piped municipal water supply network, which currently operates only intermittently.

However, while private water tankers may be filling a critical market gap, the study results also suggest that they do not necessarily serve the poorest populations in Sana'a or Aden.[23] High water prices and income scarcity have translated to increasing household reliance on free water from standpipes, mosques and charity organizations. In the Sana'a sample, there is a high concentration of households with no income, particularly in Old Sana'a (38 percent), Azal (25 percent) and Maein (38 percent) Districts, and which are consequently unable to pay for water. In Aden, 4 percent of surveyed households reported having no income, and 8 percent reported a low income between YER1-5,000 (US$0.004-19.95). Such households must rely on collected free water or sources such as family and friends who offer remittances, gifts, or loans, in order to acquire water.

The burdens of collecting water appear to be considerable based on the survey results. In Sana'a, 36 percent of the surveyed households must now collect water for some or all of their household water needs compared with only 9 percent prior to the conflict, while in Aden, nearly half (46 percent) of the surveyed households must allocate time and resources to water collection for some or all of their household water, up from 33 percent pre-conflict. Overall, surveyed households in both Sana'a and Aden that collect water allocate at least 2 hours daily as a household to do so. Among surveyed households, the leading source for water collection in Sana'a is standpipes (tapped by 26 percent of households), while in Aden, water collectors rely on both mosques (33 percent of households surveyed) and standpipes (21 percent of households surveyed).

Apart from the direct additional burdens of water collecting water, these data suggest additional impacts on development outcomes, especially in Sana'a. These data indicate that on average surveyed households in both Sana'a and Aden spend at least 2 hours per day

collecting water, and at least one-third of the members of a surveyed household are required to devote upwards of 4 hours each day to collect water. Although not conclusively demonstrated by the survey data, this time commitment may prevent these household members from engaging in remunerative employment. Given the deteriorating water service infrastructure and depleting water resources, even if the current conflict is resolved, the ability of households in Sana'a to undertake employment may be limited by the need to designate a large number of household members to the task of collecting water.

Implications for Health: It is apparent from the survey data that the overall quality of water supply in Sana'a and Aden is low, and potentially poses health risks. Surveyed households overall considered safety as the most important issue in water supply, (68 percent in Sana'a and 48 percent in Aden), followed by availability (26 percent in Sana'a and 40 percent in Aden). However, there appear to be considerable differences in the quality of water between the two cities, especially that delivered by private water tanker trucks. Surveyed households in Sana'a reported a rapid decline in perceived water quality, as assessed by taste, color, smell and other characteristics, since the current conflict began, while some Aden surveyed households reported that such attributes improved. This discrepancy may imply that, compared to municipal piped water supply, the quality of tanker water from private wells is inferior in Sana'a and superior in Aden. A possible explanation for this is the fact that much water in Aden undergoes desalination treatment prior to delivery to households.

Even so, survey results indicate that water quality remains poor in Aden. Households were asked as part of the survey whether any household members had become ill from drinking water at home. The incidence of waterborne illness was relatively high, with 28 percent of surveyed households overall reporting illness. Ash Shaikh Outhman and Dar Sad Districts in Aden reported that at least 50 percent or more of surveyed households had a household member become ill from drinking water, while in Al Buraiqeh and Attawahi Districts, 30 percent of surveyed households had members become ill from drinking water.

As noted above with respect to declining water deliveries, the survey data further indicate that the cost and difficulty of obtaining water have caused many urban Yemenis to reduce water use considerably, potentially posing a health and sanitation risk. In Aden, 25 percent of surveyed households indicated that household water usage has declined more than 50 percent since prior to the conflict. This is particularly true in Ash Shaikh Outhman District, where 80 percent of surveyed households indicated that their water usage rate has declined by more than 50 percent. Conversely, between 10 and 30 percent of households surveyed in Al Mualla, Attawahi, and Khur Maksar Districts increased their water usage by over 10 percent. This discrepancy suggests that local differences in water availability may be producing differential effects on health and sanitation outcomes, although such a link is beyond the scope of this limited study.

Conclusions, Overall Implications, and Recommendations

While the presence of private tanker trucks will improve the availability of water services particularly in areas where public services have collapsed, it raises potential concerns over issues such as water quality, market pricing, service delivery, and sustainable water resource management. Water vendors typically operate outside or at the margins of established legal frameworks. Water tanker operators will always be able to purchase water from farmers as long as groundwater is available in the shallow urban/peri-urban agricultural wells because selling water to tanker operators is more profitable than farming. This uncontrolled, unregulated informal tanker markets may well lead to a steep fall in groundwater in urban and peri-urban areas, potentially affecting livelihoods and causing conflicts between farmers, water sellers and water end users. Moreover, while landowners who sell water profit from informal water markets, non-selling farmers suffer from falling groundwater levels, and landless laborers suffer from a loss of livelihood due to the elimination of agriculture activities. In addition, the increasing role of informal water markets in supplying water to cities may well encourage the expansion of illegal well-drilling, which may in turn lead to serious negative impacts on the groundwater aquifer, including a falling water table, land subsidence or sea water intrusion. All these effects threaten to negatively impact the overall water security and sustainability of Yemen's limited scare water resources.

As this paper and the study on which it is based have highlighted, Yemen's water supply and sanitation challenges are complex, and vary between Sana'a and Aden. However, it also clearly indicates that informal, private networks are becoming increasingly important for water supply in both Sana'a and Aden, suggesting that aid agencies and development institutions may need to adjust interventions in Yemen's urban water supply and sanitation sector. Table 1 summarizes some key challenges identified by the study, along with some possible interventions and an impressionistic ranking of priority for Sana'a versus Aden. Recommendations focus primarily on levers to mobilize and facilitate private sector development of private tanker truck delivery services, which is expected to continue to be a leading source of household water supply into the foreseeable future in Yemen. Placing an emphasis on this specific segment of Yemen's water supply and sanitation sector, rather than on the sector as a whole, may be more productive and pragmatic given the ongoing conflict. Going forward, it will be critical to expand the knowledge base on Yemen's water supply and sanitation situation, especially with respect to private tanker truck supply systems. Ideally, further research would expand on this research and conduct more systematic sampling as well as gather more data on pricing and water quality. These data could inform interventions, including possibly supporting mobile-based platforms to publicize water prices and facilitate household-level water treatment, that should be urgently adopted to help Yemen address one of the world's most pressing water supply and sanitation crises. Further emphasis also needs to be placed on awareness of and approaches to managing the use of Yemen's extremely scarce water resources.

TABLE 1. Recommendations to Improve the Private Water Tanker Value Chains in Sana'a and Aden

	Key challenge	Possible interventions	Priority for	
			Sana'a	Aden
	Well owners			
1	Inability to meet daily demand for water due to low ground water levels and poor well capacity	Take stock of available water reserves in target areas to help define a water management strategy	High	Not indicated in sample
2	High incidence of illegal well drilling	Register existing and future well owners through an independent/NGO-facilitated well owner's association, to coordinate water management and provide technical support such as access to chlorine, water quality testing and well drilling support	Not indicated in sample	High
3	No pumping limits imposed on users of wells	Include pump limits requirements in the overall water management strategy, to reduce stress on wells	High	High
4	Low rate of well water testing	Independent/NGO-facilitated district-level well owner's association could coordinate regular well water testing program, water management strategy, and chlorination programs with INGO/WASH cluster	High	High
5	Insufficient number of qualified pump maintenance engineers available in the market	NRWA could partner with NGOs/INGOs to train additional technicians/engineers qualified to repair pumps	Medium	Not indicated in sample
6	Monopoly among pump spare parts suppliers	Conduct a rapid value chain analysis of the pump spare parts industry to identify ways to improve industry competitiveness	Medium	Not indicated in sample
	Tanker truck fleet owners			
1	Low rate of water testing	Coordinate regular water testing and chlorination programs with INGO/WASH cluster; effectiveness could be enhanced through something like an independent/NGO-facilitated district-level tanker truck association (for owners and operators)[a]	High	High
2	Unregulated environment (e.g., lack of registration, inspection) poses public health and safety risk	Registration of water tankers is already planned by NWRA under the support of UNICEF, but may need additional support for implementation. Registration could be linked with a successful vehicle safety inspection	High	High
3	Blackouts prevent pumps at well head from operating	Partner with GIZ and other INGOs to develop a matching grant program to install solar panels to operate pumps during blackouts	Not indicated in sample	Medium
	Independent tanker truck drivers			
1	Absence of organization among large number of independent tanker truck operators	An independent/NGO-facilitated district-level tanker truck association (for owners and operators),[a] with direct ties to a similar association at the governorate level, could encourage the industry to adopt voluntary (self-regulating) guidelines to improve water quality and safety	High	Not indicated in sample
2	Coliforms present at each step in the well-to-household water supply chain increases risk of waterborne diseases	Partner with the Ministry of Health and the Central Health Laboratories to conduct regular-random water quality tests, both at the water source (prior to pumping), and at the point of delivery	High	Not indicated in sample
		Provide simple water testing systems for both self-regulation and oversight by independent/NGO-facilitated inspection body and water testing body, linked with UNICEF project to register or renew registration of trucks	High	Not indicated in sample

table continues next page

TABLE 1. Continued

	Key challenge	Possible interventions	Priority for	
			Sana'a	Aden
3	Fleet of old and aging tanker trucks creates a ripe environment for water contamination and rapid spread of water borne disease	Establish a matching grant and financing program to replace old water tanks from vehicles built prior to 1990 with the original tanks. The truck owner could be required to make a pre-determined down payment towards a replacement tank, which is matched by the program, and the remaining amount is paid back to the program through monthly installment plan based on a concessional interest rate	Medium	Not indicated in sample
4	Rapid water table decline due to continued and increased water extraction	An independent/NGO-facilitated district-level association of well owners, with direct ties to a similar association at the governorate level, is a possible way of organizing the industry to help introduce voluntary (self-regulating) guidelines to improve water resource management practices, and monitor water quality	Medium	Not indicated in sample
5	High price to households for water purchased from tanker trucks	Directory of service providers and their contact information should be created and made widely available allowing household consumers to contact multiple water delivery services to get the most competitive price. Creation of such a directory could be tied to an independent/NGO-facilitated district-level tanker truck association (for owners and operators)[a] or to truck registration	Medium	Not indicated in sample
	Hired tanker truck drivers			
1	Absence of organization among individuals who own multiple tanker trucks with hired drivers to deliver water	An independent/NGO-facilitated district-level tanker truck association (for owners and operators),[a] with direct ties to a similar association at the governorate level could be a way of organizing the industry to help introduce voluntary (self-regulating) guidelines to improve water quality and safety and build capacity to do so (training, access to finance)	High	High
2	Fleet of old and aging tanker trucks creates a ripe environment for water contamination and rapid spread of water borne disease	Establish a matching grant and financing program to replace old water tanks from vehicles built prior to 1990 with the original tanks. The truck owner could be required to make a pre-determined down payment towards a replacement tank, which is matched by the program, and the remaining amount is paid back to the program through monthly installment plan based on a concessional interest rate	Medium	Medium
	Households			
1	High concentration of households with no or very low income[b]	Conduct household census in selected districts to estimate the current and future (free) water demand among the poor and needy	High	High
2	Exceptionally low and low availability of water for consumption[c]			
3	Relatively high incidence of reported illness from drinking water at home[d]	Funding support and awareness raising campaign through NGOs and INGOs could help to distribute chlorine, and conduct regular water quality test through NRWA, Ministry of Health, Central Health Laboratories, and other institutions	Not indicated in sample[e]	High

table continues next page

TABLE 1. Continued

	Key challenge	Possible interventions	Priority for	
			Sana'a	Aden
4	Rapid decline in perceived water quality (taste, color, smell and overall water quality) from tanker trucks[f]	Partnerships between (a) tanker truck owners (independent fleet) and drivers in affected districts and (b) Ministry of Health and the Central Health Laboratories could be used to collect random water samples on a weekly basis and conduct tests to monitor water quality and to identify required interventions to improve water quality, and to prevent possible spread of diseases	High	Medium
5	Dramatic decline in MWS through LC and private pipe network,[g] and high cost of water sold through tanker trucks	Rapid assessment of municipal services to identify key binding constraints limiting their ability to deliver water services, and estimate the cost of recommissioning services	High	High
6	Need to recommission the water pipe network, particularly in districts where a high proportion of households have traditionally been dependent on the water pipe network to access water, and remain connected to networks, but have had to increase reliance on tanker trucks and water collection since start of conflict and war[h]	Conduct rapid assessment to determine the cost of rehabilitating, and the volume of water required to recommission the water pipe network	Medium	Medium
7	Rise in household dependence on mosques and charity organizations of water	Regular, free water quality testing for tanker trucks that deliver 10 percent or more of total water delivery to mosques and charity organizations free of charge could reduce likelihood of spread of disease through these channels	Not indicated in sample	Medium

Source: Global Development Solutions, LLC.
Note: GIZ = Deutsche Gesellschaft für Internationale Zusammenarbeit; NGO = nongovernmental organization; INGO = international nongovernmental organization; MWA = Municipal Water Services; WASH = water supply, sanitation, and hygiene; NWRA = National Water Resources Authority; UNICEF = United Nations Children's Fund; LC = local corporations.
a. Independent supervision (e.g., by WBG or another INGO) to draft standard bylaws and facilitate operation of such an association would be recommended as a best practice, to mitigate risk of cartel formation.
b. Household surveys indicated high proportion of households with no income in Sana'a districts of: Old Sana'a (37.5 percent), Azal (25 percent) and Maein (37.5 percent) and in Aden districts of: Dar Sad (20 percent) and Al Mansoura (9.1 percent). Household surveys indicated high proportion of households with very low income in Aden districts of: Al Mualla and Attawahi (20 percent), Al Buraiqeh (11.1 percent), and Craiter (10 percent).
c. Per household surveys, in at least 18.8 percent of the households in Sana'a overall and also very low availability of water for household consumption in Aden districts of: Khur Maksar, Craiter, Attawahi, Al Mualla, and Ash Shaikh Outhman districts.
d. Household surveys indicated high incidence of illness from drinking water at home in sample population, particularly in Aden districts of Ash Shaikh Outhman, Dar Sad, Al Buraiqeh, and Attawahi.
e. Priority not indicated in Sana'a by the household survey, but is of concern in Sana'a given the situs of cholera outbreak.
f. Especially throughout Sana'a overall and in Aden districts of Al Buraiqeh and Ash Shaikh Outhman.
g. Especially throughout Sana'a overall and in Aden districts of Al Mansoura, Dar Sad, and Attawahi.
h. Household surveys indicated that more than 87.5 percent of households surveyed in Sana'a districts of Old Sana'a, Shaoub, and Al Wahdah traditionally depended on the public water pipe network to access water have had to increase reliance on tanker trucks and water collection since start of conflict and war.

Notes

1. Yemen Humanitarian Response Situation Report (Save the Children 2016), as cited in World Bank 2017.
2. Estimated 12.9 million lacked clean drinking water as of March 2015. UN OCHA 2014, 2017.
3. Report draft submitted 17 July 2017. From 27 April to 11 July 2017, 320,199 suspected cholera cases and 1,742 deaths have been reported in 91.3 percent (21/23) of Yemen governorates and 87.7 percent (292/333) of districts (WHO 2017).
4. Situation Report: Yemen's Public Salary Disbursement Efforts, Embassy of the Republic of Yemen–Washington, DC, March 2017.
5. Target areas for study were determined by WBG; rationale for selection is detailed in the project *Inception Report* and in section *2 Methodology*.
6. As of September 2016, Sana'a reported 149,994 IDPs, and 26,658 IDPs in Aden. *Resilience Performance Indicators Jan-Sept 2016, GIZ Water Sector Program*.
7. Water and Environment Centre, Sana'a University (2017).
8. Agriculture utilizes about 90 percent of available water resources.
9. Article 3 of the Water Law, Republic of Yemen, July 2002.
10. National Water Sector Strategy and Investment Program (NWSSIP), Ministry of Water and Environment, the Republic of Yemen, December 2004.
11. The General Authority for Lands, Survey and Urban Planning is in charge of regulating private drinking water purification stations.
12. Political resistance to raising water tariffs was generally high, but with the support and encouragement of aid agencies several LCs did manage to increase tariffs.
13. Reportedly, registration of water tankers is planned by NWRA under the support of UNICEF; however, this had not yet been implemented at the time of field mission or data analysis.
14. Reconstruction of the Aden LC water testing facility began as of early July 2017.
15. Officials at Aden LC indicated that there have not been any incidents of illness from the use of municipal water.
16. The number of private wells currently operating in Sana'a and Aden is unknown.
17. UNICEF was the only I/NGO reported by tanker drivers surveyed as hiring tanker water delivery services. The household selection criteria were unknown.
18. The treatment is for desalination only and does not filtrate other residues and harmful particles.
19. Profit is defined as revenue minus cost. Profitability herein refer to profit margin, defined as profit as a percent of revenue.
20. Drivers surveyed in Aden did not report customer loss, since many drivers have not been operating long enough to have an established customer base.
21. Reported average MWS LC rate per household survey.
22. Aden household water prices are assessed in YER/liter; the equivalent YER/m^3 is shown here for comparison.
23. It should be recognized that this study relies on very limited data. A more comprehensive analysis of the relationship between water, poverty, and health was conducted as part of the Yemen WASH Poverty Diagnostic (World Bank 2017).

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