AMERICAN UNIVERSITY OF BEIRUT

REGULATING THE WATER TANKER SECTOR AS A SUPPLEMENT SOURCE IN WATER STRESSED URBAN AREAS

by
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AN ABSTRACT OF THE THESIS OF

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Title: Regulating the Water Tanker Sector as a Supplement Source In Water Stressed Urban Areas

Population growth and development are associated with increased water demand that often exceed the capacity of existing resources, resulting in water shortages, particularly in coastal urban areas, where more than 60% of the world's population resides. In many developing countries, water shortages often force households to depend on water tankers amongst other potential sources for the delivery of water for domestic and/or potable use. While water tankers have become an integral part of the water supply system in many countries, the sector is often underdeveloped, unregulated, and operates with little governmental supervision. Users are often unaware of the origin or of the quality of their purchased water.

In an effort to better assess this sector, a field survey of water vending wells and tankers coupled with a water quality sampling and analysis program was implemented in a pilot area (Beirut, Lebanon) to evaluate the socio-economics of water tankers in an urban setting in terms of quality and cost. Microbial counts, chloride, and Total Dissolved Solids (TDS) in sampled water exceeded drinking water quality standards. While the pollution source was largely correlated with wells, tankers were a source of total coliforms. Delivered water costs varied depending on the size of the tanker, the quality of the distributed water, and the treatment used ranging between 3.5 and 11 $/m^3, a markup of 685 and 2191% when compared with network water (0.46 $/m^3). The study concluded with a regulatory and institutional framework for consumer protection towards ensuring quality water at a reasonable cost.

Keywords: Water tankers, socio-economic impacts, water quality

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NOMENCLATURE

ANSI	American National Standards Institute
AWWA	American Water Works Association
BPWSP	Bureau of Public Water Supply Protection (New York)
CDC	United States Centers for Disease Control and Prevention
CDPHE	Colorado Department of Public Health and Environment
DHSS	Department of Health and Senior Services (Missouri)
DPH-DWS	Department of Public Health – Drinking Water Sector (Connecticut)
DWI	Drinking Water Inspectorate
FDB	California Food and Drug Branch
IBNET	International Benchmarking Network for Water and Sanitation Utilities
Meq	Milliequivalent
MDDEP	Ministère du Développement Durable, de l'Environnement et des Parcs (Québec)
MDEQ	Michigan Department of Environmental Quality
MassDEP	Massachusetts Department of Environmental Protection
MoE	Ministry of Environment (Lebanon)
MoET	Ministry of Economics and Trade (Lebanon)
MoEW	Ministry of Energy and Water (Lebanon)
MoIM	Ministry of Interior and municipalities (Lebanon)
MoJ	Ministry of Justice
MoPH	Ministry of Public Health (Lebanon)
N/A	Not Applicable
NGO	Non-Governmental Organization
NNEPA	Navajo Nation Environmental Protection Agency
NSF	National Science Foundation
OpCert	Operators Certified
PPE	Personal Protective Equipment
TNTC	Too Numerous To Count
UNEP	United Nations Environment Program
UNICEF	United Nations International Children's Emergency Fund
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

1. INTRODUCTION

Urban water distribution systems, which vary according to local needs and regulations, are increasingly under stress as a result of increased water demand spurred by population growth and development, and lately exacerbated by climate change (WHO, 2009). In general, surface water is distributed through a public water supply network that may be complemented by groundwater extraction, water tankers, and/ or bottled water in the event of water shortages or deterioration in water quality. Water tankers in particular, also known as cisterns, are a common mean of transporting water from wells or springs to communities lacking infrastructure or deprived of water sources (National Academy of Sciences, 2008; WHO & UNICEF, 2006). Water conveyance using tankers occurs in both developed and developing communities, largely as a response to water shortages or during emergencies. In developed economies, water hauling tends to be of short-term nature and relied upon in response to emergency cases such as water pipes freeze (OpCert, 2011), or used in regularly isolated rural communities (NNEPA, 2010) and always in accordance to governmental regulations and international standards (The Council of the European Union, 1998; Food Safety Act, 2009; State Government of Victoria, 2011) while most developing countries have failed to regulate the water tankers sector. In developing economies, water tankers are used mostly because many urban areas do not receive enough water from the public network (MassDEP, 2008; The Times of India, 2010), or during special events such as during the pilgrimage in Mecca (Mihdhdir, 2009), or even incorporated within the national water delivery network system such as the case of Nigeria where up to 78% of the water in the dry season is supplied by tankers (Nnaji *et al.,* 2013; Nigerian Industrial Standard, 2007). Whether used for emergencies or to supplement chronic shortages, water distribution by tankers remains a common occurrence of global dimension as depicted with a few examples in Table 1.

Table 1 Global examples of water tanker distribution

Continent	Country	State/city	Reason
Africa	Burkina Faso	Ouagadougou [a]	Network Shortage
	Ghana	Ashanti [b]	Limited access to piped-water
	South Africa	Mpumalanga [c]	Network Shortage
America	Canada	Manitoba [d]	Water delivery
	Caribbean islands	Dominican Republic [e]	Network Shortage
	United States of America	Alaska [f]	Freezing weather conditions
Asia	Bangladesh	Dhaka [a]	Limited access to piped-water
	Indonesia	Jakarta [a]	Limited access to piped-water
	Pakistan	Karachi [a]	Limited access to piped-water
	Philippine	Manila [a]	Limited access to piped-water
	South Korea	Seoul [a]	Limited access to piped-water
	Thailand	Bangkok and Chonburi [a]	Limited access to piped-water
Europe	Great Britain	England and Wales [g]	Emergencies or water piping fixtures
	Spain	Barcelona [h]	Severe Droughts
Oceania	Australia	State of Victoria [i]	Water delivery

[a] Kejjlen & Mcgranahan, 2006; [b] Nauges & Stand, 2013; [c] Duse et al., 2003; [d] Manitoba Health Protection Unit, 2013;
[e] Organization of American States, 1997; [f] OpCert, 2011; [g] DWI, 2010; [h] Keeley, 2008; [i] State Government Victoria, 2011

In this study, a large pilot urban area (Beirut, Lebanon) was considered to assess the socio-economics of a water tankers sector as a supplementary domestic water source and to develop a regulatory and institutional framework to assure safe water quality at a reasonable cost.

2. Materials and Methods

2.1. Pilot area description

Population growth and urbanization in the pilot area have resulted in chronic public water shortages raising the need for additional water sources to meet a continuously increasing demand particularly during the summer when municipal water is supplied for only three hours per day with many locations not receiving any (MOE/ECODIT, 2010). As such, households resort to bottled water for drinking purposes and water tankers for domestic uses, often originating from unregulated private wells located at the outskirt of the city with no proper licensing or monitoring thus constituting a health hazard and an economic burden. The lack of information on the sector, specifically regarding wells providing water and tankers delivering water to households, dictated screening the area for operational tankers. Operators observed carrying water were randomly stopped and interviewed to identify the wells relied upon. In addition, residents were asked about tankers and wells in their districts.

2.2. Field Surveys

Primary data were collected using standardized, close-ended, and structured questionnaires that were administered through face-to-face interviews after pre-tests to ensure that the questions are clear to respondents. Questionnaires of tanker[1] and well[2] owners were filled while the water was sampled.

2.3. Water sampling and analysis

Groundwater wells were sampled in December 2013, April 2014, and then again in October 2014, in an effort to capture the variation in water quality during wet and dry seasons. In addition, water samples from tankers were collected during the first round in an effort to define the impact of tankers on the water quality of the distributed water. The samples were collected directly from the pipe attached to the wellhead or tankers' outlets. Prior to sampling, outlets were disinfected by flame and left running for one minute to avoid the collection of stagnant water in the supply hose. Samples were transported to the Environmental Engineering Research Center (EERC) of the American University of Beirut (AUB) for laboratory analysis in accordance to Standard Methods for the Examination of Water and Wastewater (APHA, WEF, & AWWA, 2012). The samples were tested for physiochemical and microbiological indicators to assess water quality in comparison to international standards (Table 2).

---

[1] The questionnaire targeting tankers owners (Appendix A) focused on the mode of operation of the business of selling water (e.g. years of practice, number of tankers owned, tanker specifications, filling price, number of employees, and salary scale, etc.), hygiene practices, and perception of water quality for comparison with the actual water quality.

[2] The questionnaire targeting well owners (Appendix B) aimed at collecting data on the characteristics of wells (e.g. flow rate, well depth, licensing, water quality, treatment methods, etc.) and their mode of operation (e.g. whether they possessed tankers, amount of tankers filled per day, tanker capacities, filling prices, etc.). The data was used to estimate the average daily pumping rate from wells.

Table 2 Tested water quality indicators with corresponding analytical procedures

	Quality Indicators	Well Water	Tanker Water	Analysis	Methods of Reference	Purpose	Reference
Physical	pH	✓	✓	Electrometry	4500-H^+ B	Physiochemical analysis	(EPA, 2012; WHO, 2004)
	Conductivity	✓	✓	Electrometry	2510 B		
	TDS	✓	✓	Gravimetry	2540 C		
Chemical	Calcium Hardness	✓	✓	EDTA Titrimetry	3500-Ca B		
	Total Hardness	✓	✓	EDTA Titrimetry	2340 C		
	Alkalinity	✓	✓	Titrimetry	2320 B		
	Chlorides	✓	✓	Argentometry	4500-Cl^- B	Levels of salinity	(WHO, 1997)
	Nitrates	✓	✓	Colorimetry	4500-NO^{3-} B	Indicators of pollution by fertilizers or sewage	(EPA, 2012; WHO, 2004)
	Sulfates	✓	✓	Colorimetry	4500-$SO4^{2-}$		
	Bromide	✓		Colorimetry	4500 Br^- B	Assess the hydrochemistry of the water	(WHO, 1997)
	Potassium	✓		Flame Photometry	3500-K B		
	Sodium	✓		Flame Photometry	3500-Na B		
Microbiological	Total Coliform	✓	✓	Membrane Filtration	9222 D	Triggers adverse health effects on humans	(WHO, 1997)
	Fecal Coliform	✓	✓	Membrane Filtration	9222 D		

[a] (APHA, WEF, & AWWA, 2012)

2.4. Data Analysis

The field questionnaire data were sorted and entered into the Statistical Package for the Social Sciences: SPSS version 16.0 (SPSS Inc., 2007) and into the R statistical software (R Core Team, 2013). Descriptive statistics summarized the main features of the data quantitatively (i.e. licensed wells, cost of filling/delivering the water, tankers' specifications, and shortage periods). Determinants affecting the water delivery cost were assessed to establish correlations between quality, price, and the quantity of water delivered to the consumer. The well water quality data were tested for statistical differences between related means using the repeated measures ANOVA test. The test is commonly used when repeated measures are taken over time to accommodate for within-well variability while testing for inter-sampling variability. When the null hypothesis for repeated measures ANOVA was rejected, the pairwise t-tests with Homs's adjusted p-values were conducted to identify differences of significance between seasons. The log transformation was applied on all tested variables, except for pH and Bromides, in an effort to normalize the data. Bromides were square root transformed given the presence of a zero value. In addition, the Friedman Rank Sum Test, which represents the nonparametric equivalent of the one-way ANOVA with repeated measures, was used to analyze fecal and total coliform data. The test was adopted to account for built in dependency in the data, the presence of zeros, and the presence of right-censored data (Too Numerous to Count (coliforms > 300)). The Friedman test was used to assess if the seasonal differences in bacterial (TC and FC) levels across wells were significantly different. The test is commonly used when repeated measures are taken over time, as it can accommodate for within-well variability while testing for inter-sampling variability. When the null hypothesis for the Friedman Rank Sum test was rejected, post-hoc comparisons were conducted to identify differences of significance between seasons. Finally, paired t-tests were used to assess for differences in water quality between wells and their corresponding tankers.

2.5. Economic Impact

The cost of water extraction and distribution were estimated to assess the economic impact of water tankers on the consumer. The cost of water extraction depends on the initial investment cost, the pumping energy, which is a function of depth, added treatment, and labor (Equation 1). The cost of water distribution by tankers is a function of the opportunity cost, maintenance, registration, cleaning frequency, fuel and water cost (Equation 2). Note that the price of water does not include environmental externalities such as saltwater intrusion, which can be compensated for as a variance of treatment cost (see example calculation in Appendix C with corresponding unit costs).

$$E_c = (I_c + O_c + T_c + L_c) / Q_T \quad (1)$$

$$LT_c = LT_T / V_{LT} \quad (1a)$$

$$ST_c = ST_T / V_{ST} \quad (1b)$$

$$D_c\ (\$/m^3) = (((Op_c + Ma_c + Me_c + L_c + C_c) / T_n) + F_c) / V_T) + W_c \quad (2)$$

$$C_c = C_m \times V_{LT} \times C_f \quad \text{or} \quad C_c = C_m \times V_{ST} \times C_f \quad (2a)$$

$$W_c = LT_c \quad \text{or} \quad W_c = ST_c \quad (2b)$$

$$F_c = F_{c/tank} \times D / F_e \quad (2c)$$

Where E_c = Cost of water extraction, ($/m³)
I_c = Initial investment cost, ($)
O_c = Operating cost, ($)
T_c = Treatment cost, ($)

L_c	=	Labor cost, ($)
Q_T	=	Total amount of water hauled by large and small tankers, (m^3)
LT_c	=	Large Tanker unit cost, ($/$m^3$)
LT_T	=	Large Tanker Total cost, ($)
V_{LT}	=	Volume of Large Tanker, (m^3)
ST_c	=	Small Tanker unit cost, ($/$m^3$)
ST_T	=	Small Tanker Total cost, ($)
V_{ST}	=	Volume of Small Tanker, (m^3)
D_c	=	Distribution cost, ($/$m^3$)
Op_c	=	Opportunity cost, ($)
Ma_c	=	Maintenance cost, ($)
R_c	=	Registration cost, ($)
C_c	=	Cleaning cost, ($)
C_m	=	Cleaning means, ($)
C_f	=	Cleaning frequency, (m^3)
T_n	=	Number of trips per day
W_c	=	Water cost, ($)
F_c	=	Fuel cost, ($)
$F_{c/tank}$	=	Fuel cost per Liter (L)
D	=	Distance travelled to the consumer, (Km)
F_e	=	Fuel efficiency, (Km/L)
Q_D	=	Daily amount of water hauled by large and small tankers, (m^3)

Table 3 Parameters used to calculate the cost of water distribution

Indicator	Large Tankers	Small Tankers
Q_T (m^3)	> 10	< 10
Horsepower (hp)	> 50	11-20
Ma_c ($)	2000	500
R_c ($) For truck model (2001-2008) (Total, 2013)	476	80
C_m ($)	Addition of Clorox as a disinfectant: 1$/$m^3$	
$F_{c/tank}$ (m^3)	0.85$/L of diesel	1.15$/L of gasoline
F_e	6 Km/L [$Q_T < 8$ m^3] 3.5 Km/L [8 m^3 < Q_T < 15 m^3] 2 Km/L [Q_T > 15 m^3]	

Q_T	=	Total amount of water hauled by large and small tankers, (m^3)
Ma_c	=	Maintenance cost, ($)
R_c	=	Registration cost, ($)
C_m	=	Cleaning means, ($)
$F_{c/tank}$	=	Fuel cost per Liter (L)
F_e	=	Fuel efficiency, (Km/L)

2.6. Regulatory and Institutional Framework

A regulatory and institutional framework was developed to implement guidelines defined to manage and control the water tanker sector towards ensuring consumer protection by receiving quality water at a reasonable cost. For this purpose, the framework identifies gaps in the existing system and attempts to propose guiding principles from within the system that require minimal changes to safeguard enforceability during implementation.

3. RESULTS AND DISCUSSION

3.1. Field surveys

The field surveys identified 24 filling points some with up to three wells per location, summing up to 33 privately owned wells (Figure 1) supplying 34 tanker owners, some owning multiple tankers (reaching 100 tankers), and delivering water to the study area. A 92 and 100% response rate to administered questionnaires were accomplished among well and tanker owners, respectively. None of the wells were licensed or regulated by the government for domestic water distribution (twenty-one hold an agricultural license, three belong to car wash stations, two are for industrial use, and six had no license of any kind, and one refused to answer. All wells, often surrounded by residential buildings, were accessible by road and most were located along the coast within 100 to 2330 m from the seashore with a few locations having multiple wells. Some wells were in close proximity to rivers[3] while others were located within petroleum stations[4]. The wells date from as far back as 1913 to as recent as 2013 and are installed at depths ranging between 5 and 125 m with no provision for monitoring water quality and pumping rates which precluded a direct measurement of the amount of water pumped. As such, the reported number of tankers filled was used as a proxy to estimate the average daily pumping rates, which varied widely by season reaching up to 2000 m^3/day/well in the summer and ~80 (m^3/day/well) in the winter with operations being a function of demand rather than of recharge.

[3] Wells W6, W7, W8, W9, W10, W11, and W12 were between 24 m and 650 m away from Beirut river while well W24 was 70 m away from Antelias drainage.

[4] Wells W2, W4-5, W10, and W22

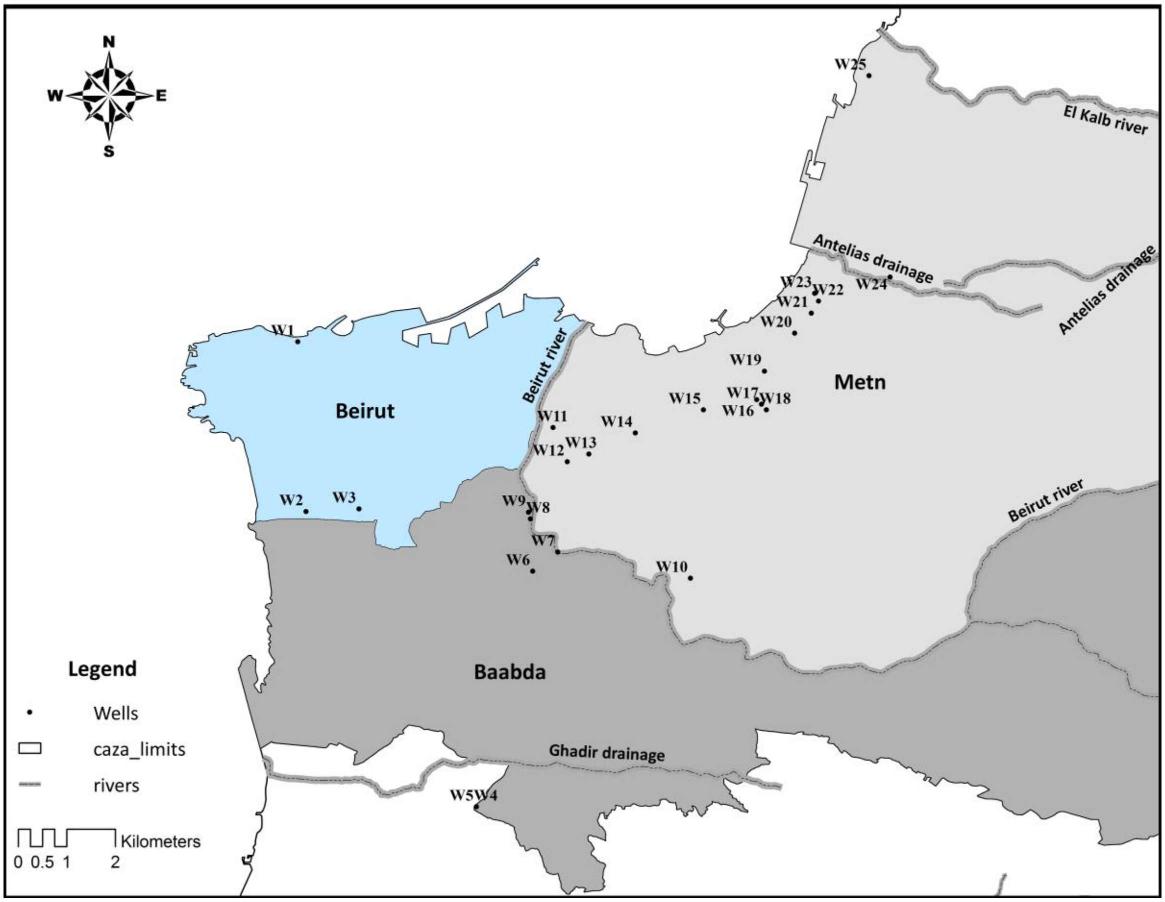

Figure 1 Locations of filling points

Some operators owned multiple tankers; therefore the administered questionnaires present data from 34 tanker operators of 100 tankers, all privately owned, with 63 carrying a valid public transport license plate and 37 with a plate not designated for public transport. The tankers' capacity ranged from 1.2 to 30 m^3, with a median of 20 m^3. Most tankers (89%) were made of steel including galvanized and painted cisterns with the rest being either stainless steel (10%) or plastic (1%). Given the lack of regulatory monitoring, 27% of tankers were never cleaned, 12% underwent sand suction occasionally, 12% were rinsed with water, and the rest (49%) underwent water cleaning with common household cleaning product (Figure 2). Similarly, most tankers (94%) did not follow any water treatment activity prior to distribution. Only two tankers were adding chlorine capsules provided by hospitals where the water would be delivered and four stainless steel tanks were equipped with cotton filters at their outlets. In addition, two well owners used onsite treatment: one had an RO system and the other a filter system. Tankers had the possibility to fill prior or after treatment.

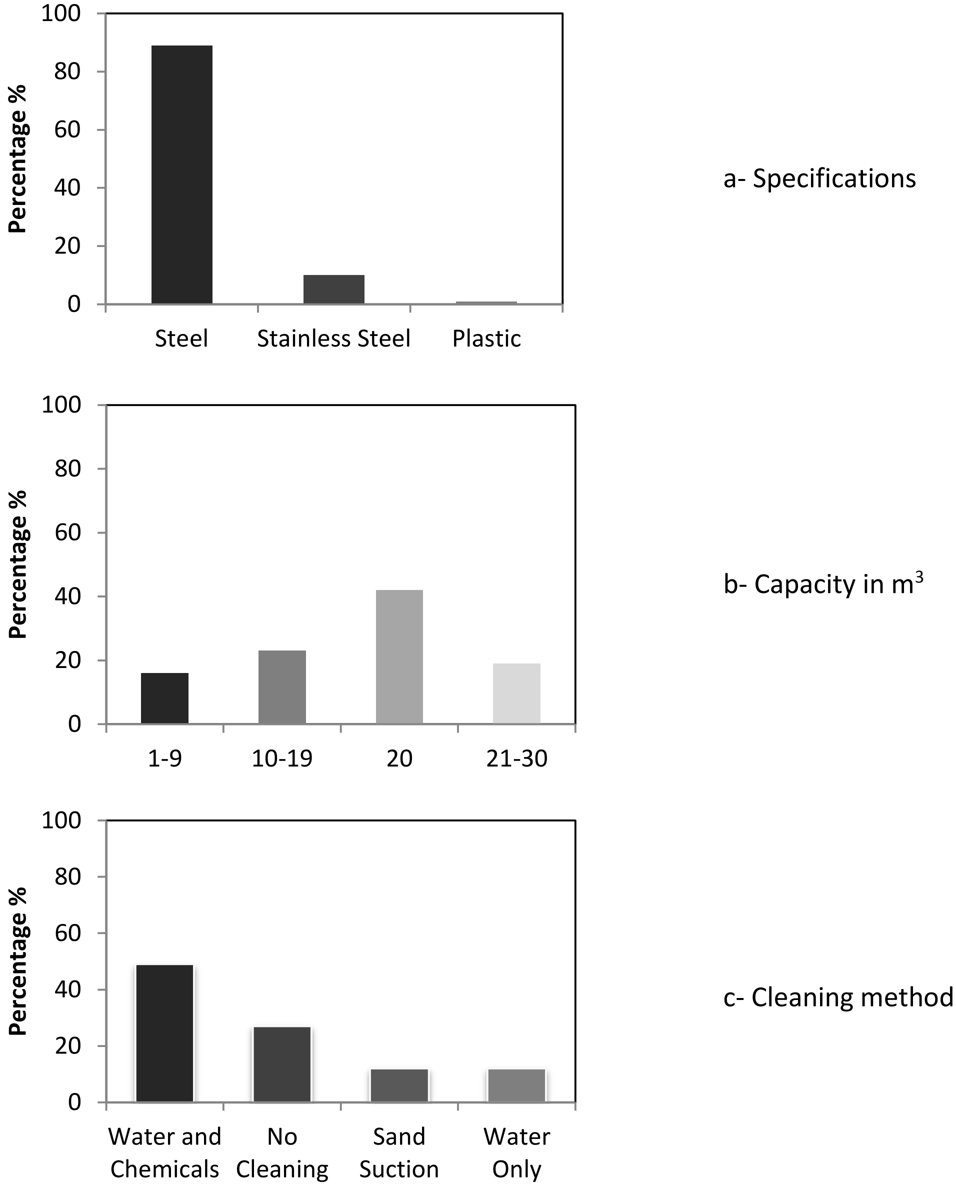

Figure 2 Tankers Characteristics

The maximum water distribution rate by an individual owner or company of water tanker(s) ranged between 1,233 (m^3/day) in the summer and 365 (m^3/day) in the winter. Since the calculated maximum extraction rate is 2000 m^3/day/well, many of these owners tap into multiple wells to satisfy their demands. Accordingly, and with the average supply rate of, as indicated above, tankers would have to utilize multiple wells in filling up so as to meet their average distribution figures. The daily number of trips by a single operator in the summer season varied between 1 and 50 trips/day, whereas in the winter, the number of trips does not exceeded 20 (trips/day), with many inactive operators (18) from December to April. As such, the total amount of water distributed during the summer season exceeds 8,453 (m^3/day), generating more than 395 (trips/day). In the winter, the total amount of water supplied represent around 16% of the summer volume (Table 4).

Table 4 Frequency of water distribution by tankers in winter and summer

	Summer Trips	Winter Trips	Volume distributed in summer (m^3/day)	Volume distributed in winter (m^3/day)
Smallest tanker operator	1	0	6	0
Largest tanker operator	50	20	1233	366
Average tanker operator	12	2.1	256	42
Combined operators	395	71	8453	1384

3.2. Water quality analysis

The TDS levels exceeded the 600 mg/L threshold level in 63%, 86% and 85% of samples collected in rounds 1, 2, and 3, respectively (Table 5). Similarly, the chloride threshold (250 mg/L) was exceeded 59% in round 1, 50% in round 2, and 61% in round 3. While TDS and chloride levels were expected to decrease in the wet season, an exceptionally dry year (~238 mm for the year 2013-2014 in comparison to the general average of 825 mm) resulted in only minor improvements to quality. Measured nitrate levels were below the WHO permissible limit of 50mg/L for NO^{3-} (WHO, 2006; WHO, 2011) for sampling rounds 1 and 2. In round 3, ~9% of samples exceeded the NO^{3-} standard. Similarly, the WHO permissible sulfate level of 250 mg/L, was exceeded in ~13% of samples collected in round 1, 4% in round 2, and 19% in round 3. Total coliforms were present in all samples of rounds 1 and 2 and in ~80% of the samples in round 3. As for fecal coliform 30 to 36 % tested positive across the three rounds. Lastly, groundwater samples across all sampling rounds exhibited a pH between 6.5 and 9.5 (Table 5), except for the water coming from the RO system in round 3. Note that several filling points are located in close proximity to residential buildings, which raises the risk of wastewater infiltration from sewage collection systems to nearby wells.

Table 5 Summary of the analytical results at filling points

Round	Parameter Tested	Range	Mean	Drinking Water Standards			Standard Exceedance by N Samples (%)
				USEPA	WHO	MoE-Lebanon	
1	FC (CFU/100ml)	0 - 140	10.82	0	0	0	7 (31.8)
	TC (CFU/100ml)	4 - TNTC	N/A	0	0	0	22 (100)
	pH	6.21 - 7.49	7.01	6.5 - 8.5	6.5-9.5	6.5-9.5	0 (0)
	TDS (mg/L)	310 - 7530	1638	500	600	500	14 (63.64)
	Chlorides (mg/L)	27.4 - 4920	752.5	250	250	200	13 (59.1)
	Nitrate (mg/L NO_3^-)	7.6 - 41	19.22	44	50	50	0 (0)
	Sulfates (mg/L SO_4^{2-})	7 - 475	121.4	-	250	250	3 (13.63)
2	FC (CFU/100ml)	0 - 180	16.36	0	0	0	8 (36.36)
	TC (CFU/100ml)	19 - TNTC	N/A	0	0	0	22 (100)
	pH	6.75 - 7.76	7.13	6.5 - 8.5	6.5-9.5	6.5-9.5	0 (0)
	TDS (mg/L)	217 - 7283.8	1516.7	500	600	500	19 (86.36)
	Chlorides (mg/L)	16.43 - 3400	564.2	250	250	200	11 (50)
	Nitrate (mg/L NO_3^-)	17.3 - 49.4	18.37	44	50	50	0 (0)
	Sulfates (mg/L SO_4^{2-})	12 - 340	99.2	-	250	250	1 (4.54)
3	FC (CFU/100ml)	0 - 1632	84.66	0	0	0	7 (33.33)
	TC (CFU/100ml)	0 - TNTC	N/A	0	0	0	17 (80.95)
	pH	5.64 - 7.85	7.04	6.5 - 8.5	6.5-9.5	6.5-9.5	1 (4.76)
	TDS (mg/L)	405 - 15560	3266.2	500	600	500	18 (85.71)
	Chlorides (mg/L)	29.7 - 8240	1469.4	250	250	200	13 (61.90)
	Nitrate (mg/L NO_3^-)	3.4 - 55.5	21.25	44	50	50	2 (9.52)
	Sulfates (mg/L SO_4^{2-})	7 - 1050	190.29	-	250	250	4 (19.05)

3.3. Data Analysis

Statistically significant differences were observed between the three sampling rounds (Table 6). Seasonal variations of chlorides and EC were statistically significant (p-value < 0.05). Post-hoc comparison showed that levels measured in rounds 1 and 3 and rounds 2 and 3 were significantly different. Seasonal variations were statistically significant too for calcium and total hardness, (p-value < 0.05). In contrast, magnesium hardness, alkalinity measured as CO_3 and

HCO_3, pH, nitrates and sodium levels did not show statistically significant seasonal variability. In terms of potassium and TDS, statistically significant differences were observed between rounds 1 and 2 on one hand, and rounds 2 and 3 on the other (p-value < 0.05). The seasonal variation for sulfates was only statistically significant between rounds 2 and 3, with a p-value of 0.0118. Bromide levels were statistically different across all sampling rounds. The FC levels did not show statistically significant differences across sampling rounds. However, seasonal differences were statistically significant (p-value of 0.00044) for total coliforms. Post-hoc comparison showed that TC levels measured in Round 3 were statistically different from those measured in Rounds 1 and 2, but the difference between Rounds 1 and 2 was not significant.

Table 6 Statistical difference between the seasonal variation

Parameters	Repeated Measures ANOVA	Difference S1-S2	Difference S1-S3	Difference S2-S3
Chlorides	5.34E-04	0.13	8.5E-04	4.18E-03
Calcium Hardness	2.74E-04	9.9E-03	0.11	2.4E-03
Magnesium Hardness	No Significance			
Total Hardness	1.12E-03	1.48E-02	0.33	3.8E-03
Alkalinity CO_3	No Significance			
Alkalinity HCO_3	No Significance			
PH	No Significance			
EC	3.97E-05	0.16	2.3E-05	1.6E-03
TDS gravimetry	9.43E-04	1.1E-03	1.1E-03	0.84
Nitrates	No Significance			
Sulfates	1.18E-02	0.37	6.7E-02	2.7E-02
Sodium	No Significance			
Potassium	2.62E-11	2.1E-06	5.10E-07	0.44
Bromide	2.08E-12	7.50E-05	6.60E-10	7.50E-05
Fecal Coliform	Friedman Rank Sum Test	No Significance		
Total Coliform		0.15	2.01E-03	2.8E-05

Assessing ionic ratios such as the Simpson ionic ratio of ($Cl^-/(HCO_3^- + CO_3^{--}$) and Jones Ratio Na^+/Cl^-, computed according to Darnault & Godinez (2008), can help assess the contamination of the groundwater by seawater (Ekhmaj *et al.* 2014; El Moujabber *et al.* 2006; Lee & Song 2007). The Simpson ratio is used to classify the salinization levels in water. Excessive pumping in groundwater wells impaired with saltwater intrusion induce an increase in chlorides levels and result in a strong linear relationship between ($Cl^-/(HCO_3^- + CO_3^{--})$) and Cl^- concentration. Simpson ratios less than 0.5 are indicative of good water quality. Ratios ranging from 0.5 to 1.3 suggest slightly contaminated water, ranges from 1.3 to 2.8 indicate moderate contamination, between 2.8 to 6.6 indicate harmfully contaminated waters, and those between 6.6 and 15.5 point to highly saltwater contaminated waters (Arslan 2013; Ekhmaj *et al.* 2014; El Moujabber *et al.* 2006; Lee & Song 2003). Some wells scored values in excess of 100, indicating the severe extent of deterioration in the tapped aquifers (Figure 3). As for the Jones Ratios (Na/Cl ratio), seawater contamination is implied when levels drop below 0.86 (Darnault & Godinez 2008). A similar pattern of salinization emerges for the sampled wells.

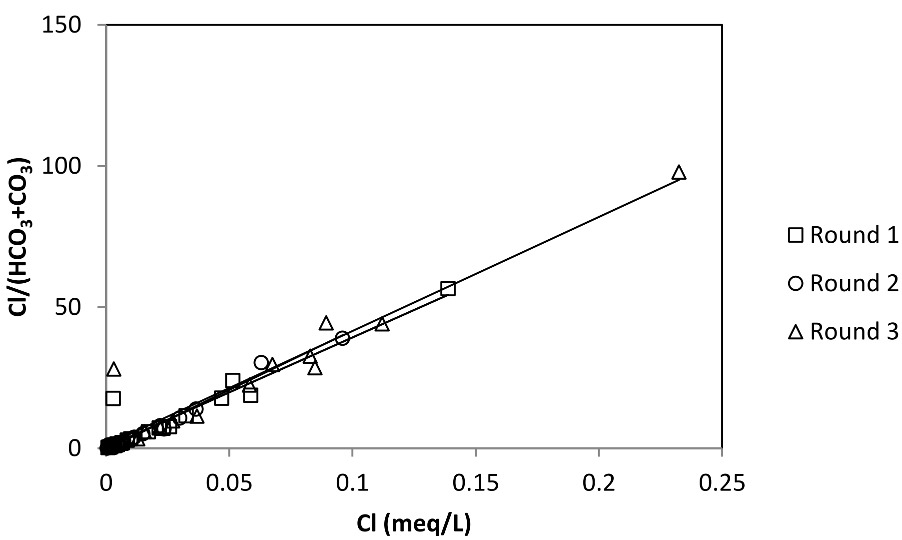

Figure 3 Correlation between $Cl/(HCO_3+CO_3)$ and Cl concentration (meq/L)

Table 7 categorizes the sampled wells based on quality using the two indices ($Cl^-/(HCO_3^- + CO_3^{--})$ and Na^+/Cl^-). Saltwater intrusion appears to be increasing over time, with most samples collected in round 3 showing poor quality. While the replenishment of the aquifer in the wet season (round 2) appears to have diminished the impact of saltwater intrusion, the improvement does not appear in all wells.

Table 7 Water contamination by seawater based on the Simpson ratio and the Jones ratio

Seawater Contamination		**Round 1**	**Round 2**	**Round 3**
$Cl^-/(HCO_3^- + CO_3^-)$	Good Quality <0.5	W10, W24, W25	W8, W10	W10, W24, W25
	Slightly contaminated by seawater <1.3	W8, W13, W17, W18	W4, W12, W15, W17, W24, W25, W18	W26
	Moderately contaminated by seawater <2.8	W11, W15, W16	W11, W15	W8, W11, W16
	Harmfully contaminated by seawater <6.6	W19, W20, W22	W7, W19, W20, W22	W15, W20
	Highly contaminated by seawater <15.5	W7, W9, W21, W23	W6, W9, W21, W23	W7, W9, W19
	Highly contaminated by seawater >15.5	W2, W3, W4, W6	W2, W3,	W2, W3, W4, W6, W21, W22, W23
Na^+/Cl^-	Seawater contamination <0.86	W2, W3, W4, W6, W9, W13, W16, W19, W21, W22, W23	W2, W4, W17, W18, W24, W25, W26	W2, W4, W6, W7, W8, W9, W11, W12, W13, W14, W15, W16, W17, W19, W20, W21, W22, W23, W24, W25, W26

Other molar ratios were also reportedly used to examine seawater intrusion including the Ca^{2+}/Na^+, Mg^{2+}/Ca^{2+}, HCO_3^-/Cl^-, SO_4^{2-}/Cl^-, Mg^{2+}/Cl^- and Na^+/Cl^-ratios (Arslan 2013; El Moujabber *et al.* 2006; Leboeuf *et al.* 2003; Mondal *et al.* 2011). Figure 4 depicts the molar ratios of groundwater parameters with respect to Cl^- levels in milliequivalents per liter (meq/L). The low Ca^{2+}/Na^+ molar ratios are indicative of saltwater intrusion with the decrease in the Ca^{2+}/Na^+ ratios coupled with an increase in Cl^- levels across the three seasons (R^2=0.45; log-log relationship). The negative slope in the Ca^{2+}/Na^+ ratio is a direct reflection of the increase in sodium levels originating from the sea. For every 10% increase in Cl^- molar equivalent, the Ca^{2+}/Na^+ ratio decreases by 4.2%. Similarly, the variation in the molar ratios of HCO_3^-/Cl^- with respect to the Cl^- concentration showed a negative correlation (R^2=0.87; log-log relationship). For every 10% increase in Cl^- molar equivalent, the HCO_3^-/Cl^- ratio decreases by 9.5% indicating that HCO_3^- levels are relatively constant while only Cl^- levels are varying. A similar relationship was observed for the log (Ca^{2+}/ Cl^-) ratio with respect to log (Cl) (R^2=0.81) whereby for every 10% increase in Cl^- molar equivalent, Ca tended to increase only by 4% on average and the Ca^{2+}/Cl^- ratio decreased by 6%. The molar ratio of SO_4^{2-}/Cl^- showed a negative correlation with Cl^- (R^2=0.65; log-log relationship). The negative slope indicates that for every 10% increase in Cl^- molar equivalent, there is a decrease of 5.5% on average in the SO_4^-/Cl^- and an overall increase of 4.5% for SO_4^- levels. A similar pattern was also observed between the Mg^{2+}/Cl^- ratio and the Cl^- concentration (R^2= 0.71; log-log relationship) with a 5.8% decrease in the Mg^{2+}/Cl^- ratio while Mg^{2+} increases by 4.2% for every 10% increase in Cl^- molar equivalent. All molar ratios consistently indicated that excessive pumping was inducing acceleration in saltwater intrusion across the tapped wells. Moreover, the relationship between the log (Cl) and the log ratios appeared to be largely stable over the three sampling rounds.

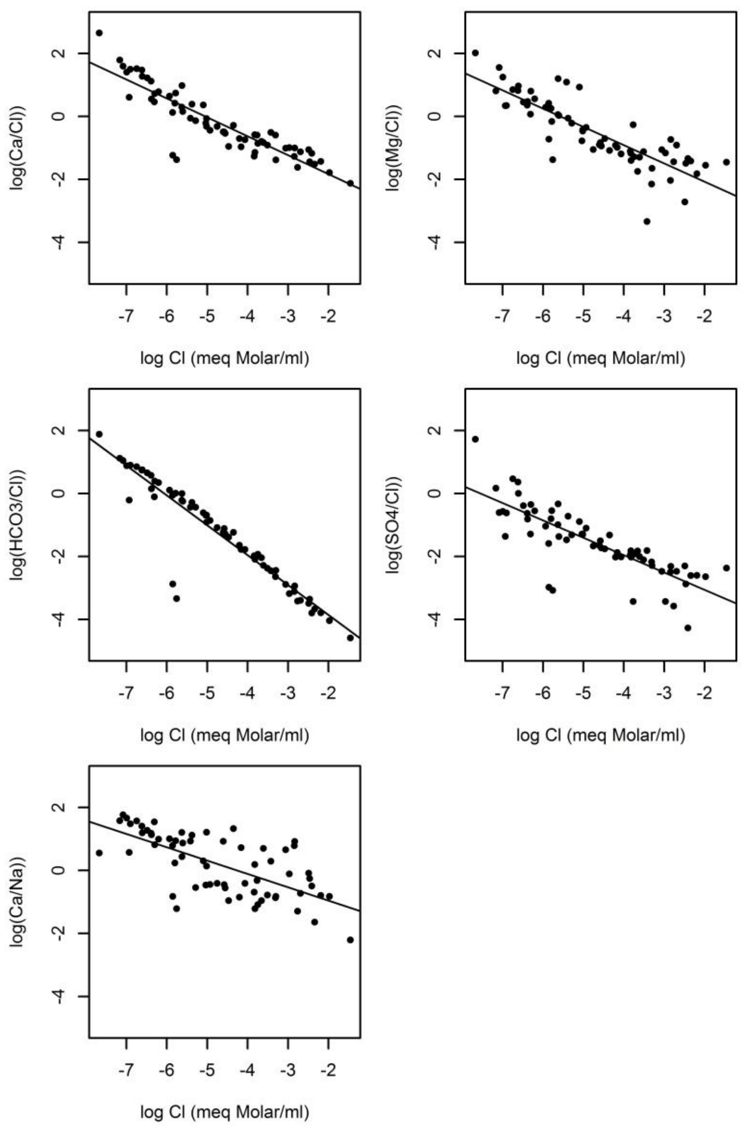

Figure 4 Molar ratios of groundwater parameters versus Cl^- concentration (meq/L)

The paired t-tests on water quality analysis results at 19 filling points in comparison with 30 tankers using Fecal and Total Coliform, chlorides, TDS, nitrates and sulfates as indicators showed that the differences were not statistically different at the 95% significance level (p-value of 0.24, 0.25, 0.22, 0.33, and 0.31, respectively) highlighting the importance of wells with regard to pollution levels. While overall, the difference in Fecal Coliforms was not significant, 8 tankers had higher concentrations than their source water, a strong sign of lack of hygiene in the filling and/or the cleaning procedures. The main variability in the water quality between tankers and wells was found in the Total Coliform (TC) concentrations. Due to the right censorship of the TC data, a parametric t-test could not be used. Replacing censored data with the upper detection limit is well known to bias the results from a t-test. As such, the non-parametric Wilcoxon signed-rank test for paired data was adopted. The test treats the data as ordinal and handles ties between paired entries. The null hypothesis under the test is that the median difference in the ordinal scale between a pair is zero. For the TC data, there was strong evidence to indicate that the TC values in the tankers were significantly higher than values recorded in corresponding wells (p-value=0.0001751), suggesting that the tankers are an important source of TC bacteria contamination. These results indicate that either the tanker material or the operators' hygienic practices do not conform to standards of water transport and are introducing bacteria to the source water. Table 8 compares the analytical results between wells and tankers for the dry season and shows the variability in quality.

Table 8 Summary of the analytical results of wells and tankers during the dry season

Parameter Tested	Outlet	Range	Mean	Drinking Water Standards: USEPA	WHO	MoE – Lebanon	Standard Exceedance by N Samples (%)
FC (CFU/100ml)	Well	0 - 140	10.42	0	0	0	6 (31.57)
	Tanker	0 – 146	8.32				14 (46.66)
TC (CFU/100ml)	Well	4 - TNTC	7 TNTC	0	0	0	19 (100)
	Tanker	13 - TNTC	22 TNTC				30 (100)
TDS (ppm)	Well	145 - 2700	989.68	500	600	500	12 (63.15)
	Tanker	76.2 - 2580	1054.17				22 (73.33)
Chlorides (mg/L)	Well	27.4 –2080	510.83	250	250	200	9 (47.36)
	Tanker	28.9 - 2075	564.39				18 (60)
Nitrate (mg/L NO_3^-)	Well	7.6 –25.3	16.65	44	50	50	0 (0)
	Tanker	7.8 – 27.9	16.54				0 (0)
Sulfates (mg/L SO_3^{--})	Well	7 – 280	106.84	-	250	250	1 (5.26)
	Tanker	6 - 270	100.87				2 (5.88)

3.4. Economic Impact

The reported extraction cost varied widely between 0.034 and 0.75 ($US/m^3). The price of water set by well owners varied by the tanker size whereby large tankers were charged 0.08 to 0.11 ($US/m^3), while small tankers charges ranged from 0.20 to 1.23 ($US/m^3). The cost of water distribution ranged between 0.49-7.92 ($US/ m^3) with an average of 2.56 ($US/ m^3). The water price that consumers pay on delivery differs depending on the distance from the filling point and the location of the water holding tanks in the building (roof vs. ground). The price of water paid for filling tanks on the roof is often greater than filling tanks on the ground. A comparison between the actual cost and the price paid for water tankers shows that tankers' profits for delivering water to ground tanks ranges between 16 and 414%, while profits for roof delivery ranges between 61 and 729% (Table 11). Moreover, a comparison between the price paid by a consumer for tanker water in comparison to municipal water charges of 0.46 ($US/m^3) [5] indicates that the markup ranges between 685-2191%, highlighting the significant economic burden on residents, excluding potential health

[5] This calculation is based on the annual subscription rate of 256000 L.L. per year. However the network supply is intermittent. Thus the actual cost/m^3 could be significantly higher.

impacts due to poor water quality at times. Furthermore a cost comparison between tanker water and typical desalination/reverse osmosis cost in the region (0.5 $\$/m^3$)[6] indicate a markup of only 8.7% to municipal water indicating a rather cheaper method than water hauling thru tankers.

Table 9 Summary of the cost of water distribution and the economic burden on consummers

Price/Cost on Supplier/Consumer	Well	Tanker	Consumer		Consumer	
	Water Price ($\$US/m^3$)	Distribution cost ($\$US/m^3$)	Tank on the ground ($\$US/m^3$)	Tanker profit (%)	Tank on the roof ($\$US/m^3$)	Tankers profit (%)
Average Large tankers	0.37	2.36	3.61	100.8	4.83	172
Average small tankers	0.44	2.98	8.71	205	10.54	288
Municipal Water ($\$US/m^3$/day)	0.46					
Increased cost on consumer (%)	685-2191					

3.5. Regulatory and Institutional Framework

The quality and economic of water tankers depend on guidelines set by institutions administering the sector. In many developing communities as is the case to the study area, tankers and wells appear to be completely unregulated or non-compliant with existing regulations (i.e. well permits, water quality standards). From a governance perspective, while several institutions are responsible for the water sector[7], (quality, tariff, protection, and enforcement) none are involved with directly regulating or monitoring tankers or enforcing the well permitting process. Accordingly, an enabling regulatory and institutional framework is imperative to organize wells and tankers alike including the establishment of monitoring requirements and providing consumers with a potable water supply at a reasonable tariff. The implementation of such a framework will require the involvement of various regulatory, protection and enforcement bodies, which in the context of the study area, suffer from outdated mandates, systemic gaps, and legislative fragmentation making it difficult to regulate the sector (Appendix E)[8]. A general framework with consumer

[6] (Eslamimanesh & Hatamipour, 2008)

[7] Water Establishment, Ministries of Energy and Water, Public Health, Environment, Interior, Economy and Trade

[8] Indicates the various policies existing in Lebanon

protection measures within existing regulatory and institutional limitations is outlined in Figure 5 and can be applied in most communities relying on water tankers. Stakeholders will be involved in regulating, monitoring, and overseeing enforcement within the sector based on protective environmental and health standards. Water tankers are relatively easy to control through the registration, certification, and license renewal / annual inspection process. Guidelines for Well inventory, aquifer monitoring, tanker specifications, tariffs setting and penalties are developed in Table 10 along with the institutional responsibility of each ministry. Public awareness through NGO (Non-Governmental Organization), stakeholder participation and the development of information dissemination programs (i.e. website, social media, etc…) may aid consumers in selecting the best available source from existing known wells and tankers.

Table 10 Management Guidelines for the water tanker sector under an enabling institutional and regulatory framework

Regulatory measures				Guidelines and Practices	Institutional Responsibilities
Delivery Operation	Well Owners / Operators		License [a]	• Well inventory: Identification, licensing and metering of wells for distribution • Aquifer monitoring: Installing piezometers to monitor the levels of water table • Approved and protected source with fence and locks • Hose suspended from a tower and capped when not in use • Good drainage to channel spilled water • Surrounding casing for wells to prevent flooding	MoEW MoE MoEW
			Water Quality	• Water quality analysis standards for human consumption • Provide tamper-evident seal for water quality and quantity assurance • Advise for the required water treatments	MoPH
			Inspection [b]	• Quarterly or half-year inspection depending on the hydrologic and chemical variation • Sample collected from the hose of the resource • Physical, chemical and microbiological parameters • Monthly inspection for pump operation and maintenance • Monthly check well protection and that the bore head is watertight and protected from surface water flow	MoE
			Training [c]	• Personnel training on the best hygienic practices	MoE
			Tariff	• Tariff setting on well water based on water availability and the revel of treatment	MoET
			Penalties [d]	• Ranging from fine to imprisonment	MoJ
	Tanker Owners / Operators	Tank Specification	Tanker registration [e]	• Identification number and license plate • Address of stored vehicles; mailing address and phone number of the company	MoIM
			Renewal [f]	• Annually upon passing the inspection Appendix D	MoIM
			Tank Material [g]	• NSF/ANSI: Standard 61; AS: 4020:2005 • Carbon steel or stainless steel, glass coating, aluminum smooth finishes, copper or ceramic • Galvanized steel only with food grade coating, non-toxic, non-absorbent	MoPH
			Access Port [h]	• Covered with a dust-proof lockable cover • 0.5 m wide for easy cleaning	MoIM
			Baffle Walls [i]	• Easy access for inspection and cleaning • Minimize the flow of water during breaks	MoIM
			Air Vents [j]	• Screened, and faced downward to prevent dust and vermin from entering the tank	MoIM
			Pumps [k]	• Regularly maintained • Installed outside the tank in a protective housing	MoIM

Delivery Operation				• Food grade: stainless steel, plastic or smooth finish aluminum	MoPH
			Lubricants [l]	• Food grade	MoPH
			Hose [m]	• NSF/ANSI: Standard 61; AS: 4020:2005 • Food grade, smooth and non-porous • With caps and kept in a sealed container	MoPH MoIM
			Backflow [n]	• NSF/ANSI: Standard 61; AS: 3500.1:2003 • Pressure is reduced by double checked valve	MoPH
		Maintenance	Chlorination [o]	• 0.5 mg/l; Amount should be added if levels are below 0.2 (mg/L) • Sampling from each load	MoPH MoE
			Disinfection [p]	• Certified bleach ANSI/NSF Standard 60 • 1L of bleach in every 1000L of water • 30min contact time • Flushed with potable water and discharged through bottom drain • PPE: goggles with shields, glove, apron	MoPH
			Frequency [q]	• Before usage, after maintenance, every three month • After four weeks of non-usage, and incase the tanker transported other type of food	MoE
			Record Book [r]	• Date, time, location of supply and delivery point, volume, chlorine residual, signature • Previous record of results	MoE
		Monitoring	Labelling [s]	• Name, address, capacity, source of water • Visible at all time, 5 cm heights at the upper left quarter of the tank rear	MoIM
			Inspection [t]	• Container, valve, caps, hose, pumps, fittings • Sampling from each tanker outlet	MoIM
			Sampling Frequency [u]	• Monthly to yearly • Analysis: physical, chemical and microbiological	MoE
			Personnel Training [c]	• Driving skills & maintaining the quality of the water • Proper usage of chlorine kit during emergency	MoE
			Tariff	• Set the price to the consumer level based on the amount supplied and the distance travelled from the filling to the delivery point	MoET
			Penalties [c]	• Ranging from fine to imprisonment	MoJ

Consumer	Awareness [v]	• Food grade storage tank: equal or larger than the tanker capacity • Water cannot be stored in the tank for more than three days • Tamper-evident seal for water quality and quantity insurance • Develop a website showing: - List of the licensed wells and tankers - Result of the last samples for each well and tanker - Feedback and consumer complain system	MoE / NGO
	Reporting	• Consumer protection through complaint forms and reporting	MoE

[a] Sundaram *et al.,* 2009; EPA, 2011; WHO, 2011; MDEQ, 2011; [b] Victorian Government Department of Human Services, 2009; [c] WHO, 2011; Vancouver Coastal Health, 2009; [d] State Government Victoria, 2011; DWI, 2010; BPWSP, 1991; [e] State Government Victoria, 2011; DWI, 2010; MDDEP, 2013; FDB, 2010; [f] DWI, 2010; BPWSP, 1991; [g] CDPHE, 2013; State Government Victoria, 2011; Government's Office of Emergency Services, 2007; EPA, 2011; NNEPA, 2010; DPH-DWS, 2008; FDB, 2010; MassDEP, 2008; WHO, 2011; MDEQ, 2011; [h] WHO, 2011; Manitoba Health Protection Unit, 2013; MDEQ, 2011; [i] MDEQ, 2011; [j] FDB, 2010;[k] WHO, 2011; NNEPA, 2010; Niagara Region Public Health, 2008; [l] FDB, 2010; MDEQ, 2011; [m] FDB, 2010; DPH-DWS, 2008; MassDEP, 2008; Vancouver Coastal Health, 2009; [n] Arkansas Department of Health, 2011; NNEPA, 2010; [o] WHO, 2011; EPA, 2011; CDPHE, 2013; [p] FDB, 2010; NNEPA, 2010; DPH-DWS, 2008; DPH-DWS, 2008; MassDEP, 2008; [q] Victorian Government Department of Human Services, 2009; [r] CDPHE, 2013; [s] FDB, 2010; BPWSP, 1991; MDEQ, 2011; [t] Environmental Health Branch, 2008; DHSS, 2008; Environmental Health Branch, 2008; [u] State Government Victoria, 2011; Vancouver Coastal Health, 2009; DWI, 2010; CDPHE, 2013; [v] DPH-DWS, 2008; NNEPA, 2010; WHO, 2011; Monroe County Health Department, 2004; DPH-DWS, 2008; Queensland Government, 2007;

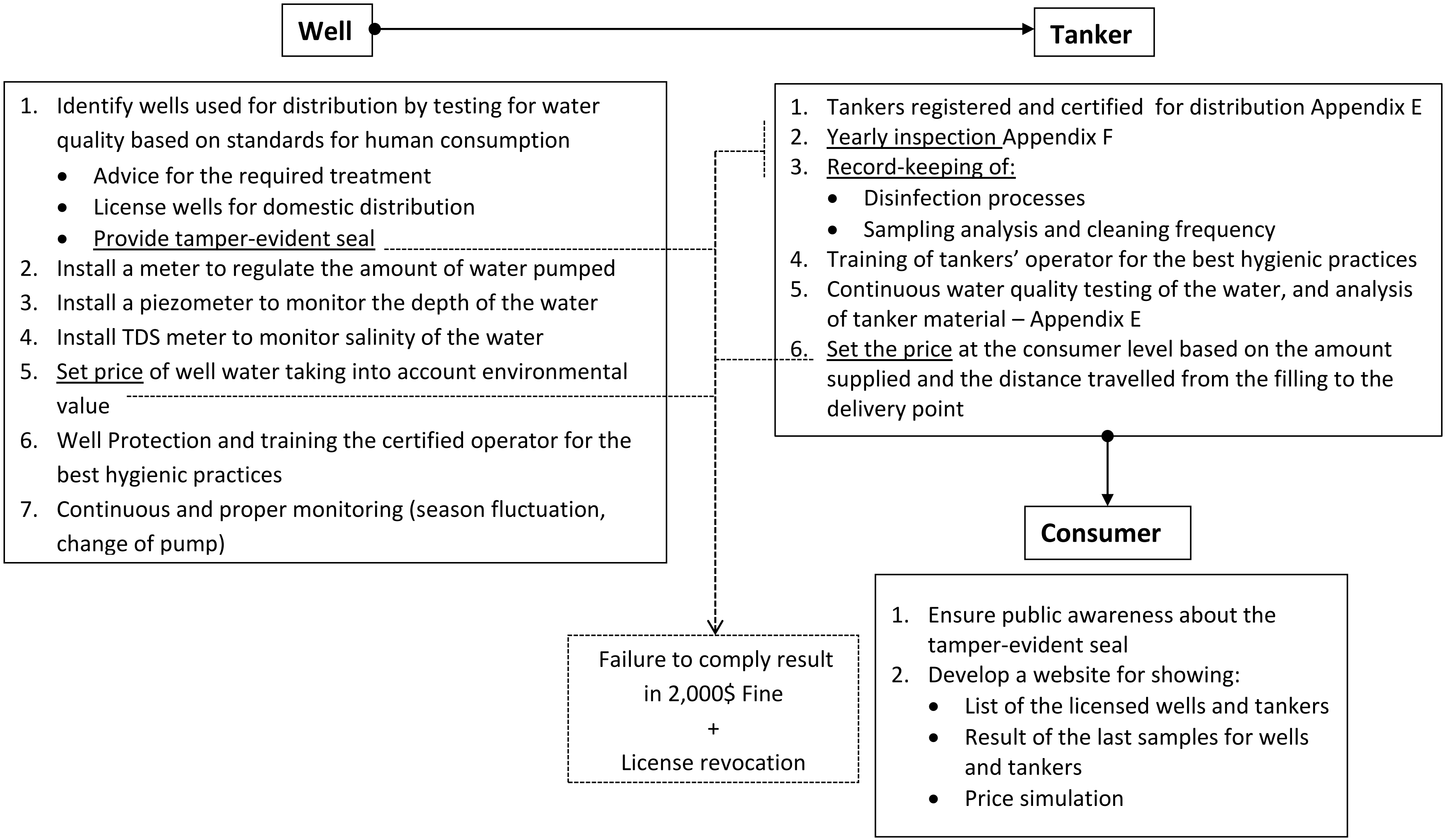

Figure 5 General framework for consumer protection

4. CONCLUSION

Water tankers are an essential complementary resource that is invariably relied upon to accommodate shortages in the public water distribution system. The socio-economic burden associated with water tankers depend on existing guidelines towards monitoring and controlling the sector. Under unregulated conditions of the pilot area, a mark up of 760-2410% on water supplied by tankers was documented reaching a 16% of an average family income for water of dubious quality with potential environmental externalities that were not accounted for in this study. Similar to the pilot area, many communities are faced with chronic water shortage with water tankers becoming an inherent part of the water supply system requiring guidelines within an enabling regulatory and institutional framework that was developed to provide proper licensing of wells and tankers, continuous monitoring / inspection, license renewal, penalties, license revocation, and public awareness towards ensuring access to safe water at a reasonable cost with guidelines at the filling and delivery points, as well as the water hauling.

REFERENCES

American Public Health Association, Water Environment Federation & American Water Works Association abc 30 Action News. (2014, July 24). *With wells drying up residents turn to water trucks*. Retrieved April 4, 2015, from abc 30 Action News: http://abc30.com/news/with-wells-drying-up-residents-turn-to-water-trucks/218373/

APHA, WEF, & AWWA. (2012). *Standard Methods for the Examination of Water and Wastewater* (22 edition ed.).

Arkansas Department of Health. (2011). *Arkensas Department of Health*. Retrieved January 07, 2014, from Arkansas.gov: http://www.healthy.arkansas.gov/programsServices/environmentalHealth/Engineering/crossConnection/Pages/default.aspx

Arslan, H. (2013). Application of multivariate statistical techniques in the assessment of groundwater quality in seawater intrusion area in Bafra Plain, Turkey. *Environmental Monitoring Assessment,185*, 2439-2452.

BPWSP. (1991, May). *New York State Department of Health.* Retrieved January 07, 2014, from New York State Department of Health: https://www.health.ny.gov/environmental/water/drinking/bulk_bottle/docs/subpart5_6.pdf

CDC & AWWA. (2012). *Emergency water supply planning guide for hospitals and health care facilities.* Atlanta: US Department of Health and Human Services.

CDPHE. (2013). *Drinking Water Guidance Monitoring Requirements fo Non-Regulates Water Haulers During Extreme Emergencies.* Colorado.

Central Intelligence Agency (CIA). (2014, June 20). *The World Factbook Middle East, Lebanon*. Retrieved September 12, 2014, from Central Intelligence Agency: https://www.cia.gov/library/publications/the-world-factbook/geos/le.html

Clasen, T., & Boisson, S. (2006). Household-Based Ceramic Water Filters for the Treatment of Drinking Water in Disaster Response: An Assessment of a Pilot Program in the Dominican Republic. In *Water Practice & Technology* (Vol. 1). United Kingdom: International Water Association.

Comair, F. (2007). *Water sector in Lebanon an operational framework for undertaking legislative and institutional reforms.* Lebanon: United Nations.

Conan, H. (2008). *Scope and Scale of Small Scale Independent Private Water Providers in 8 Asian Cities.* Manila: Asian Development Bank.

Darnault, C., & Godinez, I. (2008). Coastal Aquifer. In C. J. Darnault, *Overexploitation and contamination of Shared Groundwater Resources* (pp. 192-194). Bulgaria: Springer Science & Business Media.

DHSS. (2008). *Guidelines for Hauling Bulk Drinking Water for Emergency Distribution.* Missouri: Environmental Health Operational Guidelines.

DPH-DWS. (2008). *Bulk Water Hauling guidelines.* Connecticut.

Duse, A., da Silva, M., & Zietsman, I. (2003). Coping with hygiene in South Africa, a water scarce country. *International Journal of Environmental Health Research*, 13:S1, S95-S105.

DWI. (2010). *Legislative background to the Private Water Supplies Regulations 2009 (E&W) - of the Private Water Supplies: Technical Manual.* England and Wales: Private Water Supplies.

EDL. (2014). *EDL*. Retrieved May 2014, 25, from About EDL: http://www.edl.gov.lb/ABOUTEDL.htm

Ekhmaj, A., & Ezlit, Y. E. (2014). The Situation of Seawater Intrusion in Tripoli, Libya. *International Conference on Biological, Chemical and Environmental Sciences (BCES)*.

El Fadel, M., Tomaszkiewicz, M., Adra, Y., Sadek, S., & Abou Najm, M. (2014). GIS-based Assessment for the Development of a Groundwater Quality Index Towards Sustainable Aquifer Management. *Water Resources Management*.

El Moujabber, M., Bou Samra, B., Darwish, T., & Atallah, T. (2006). Comparison of Different Indicators for Groundwater Contamination by Seawater Intrusion on the Lebanese Coast. *Water Resource Management*, 161-180.

Environmental Health Branch. (2008). *Drinking Water Haulage Guidance Document.* Ontario: Public Health Division.

EPA. (2009, May). *National Primary Drinking Water Regulations.* Retrieved from United States Environmental Protection Agency: http://water.epa.gov/drink/contaminants/upload/mcl-2.pdf

EPA. (2011). *Planning for an Emergency Drinking Water Supply.* Washington, DC: Office of Research and Development - National Homeland Security Research Center.

Eslamimanesh, A., & Hatamipour, M. (2008, November 21). *Economical study of a small-scale direct contact humidification-dehumidification desalination plant.* Retrieved May 6, 2015, from ScienceDirect: http://www.researchgate.net/profile/Mohammad_Hatamipour/publication/222766600_Economical_study_of_a_small-scale_direct_contact_humidificationdehumidification_desalination_plant/links/0deec53b3c027a4de5000000.pdf

Established Drinking Water Standards, 1039 (Council of Ministries August 2, 1999).

FAO. (2007, May 19). *Water Lifting for Irrigation.* Retrieved from FAO Corporate Document Repository: http://www.fao.org/docrep/010/ah810e/ah810e04.htm

FDB. (2009). *Water Hauler's License Application.* California: California Department of Public Health.

FDB. (2010). *Procedure for Obtaining a Water Hauler License - License Application Form: CDPH 8605.* California: Department of Public Health.

FEMA. (2004). *Food and Water in an Emergency.* Federa Emergency Management Agency and American Red Cross.

Fernandez, M. (2012, February 3). Texas Drought Forces a Town to Sip from a Truck. *The New York Times*. Spicewood Beach, Texas, United States of America. Retrieved January 17, 2013, from http://www.nytimes.com/2012/02/04/us/texas-drought-forces-town-to-haul-in-water-by-truck.html?_r=1&

Food Safety Act. (2009). *Water Intended for Human Consumption Regulation.* Malta: Department of Information.

Goverment's Office of Emergency Services. (2007). *Multi-Agency Response Guidance for Emergency Drinking Water Procurement & Distribution.* California.

Guardianship Authority - Presidency of the Council of Ministers. (2013). *Cost of doing buisiness*. Retrieved April 3, 2015, from IDAL invest in Lebanon: http://investinlebanon.gov.lb/en/doing_business/cost_of_doing_business?catId=55

Hatch Company. (2007). *DR 2800 Spectrophotometer* (2 ed.). Germany: Hatch Company.

Hydraullic Institute. (2007). *Efficiency and Life-Cycle-Cost Calculation.* Retrieved from www.pumps.org: http://www.pumpschool.com/applications/Energy.pdf

Jones, Vengosh, Rosenthal, & Yechieli. (1999). Theory and Application of Transport in Porous Media. In J. C.-D. Bear, *Seawater Intrusion in Coastal Aquifers - Concepts, Methods and Practices* (pp. 69-71). Springer Science & Business Media.

Kariuki, M., & Acolor, G. (2000). *Delivery of Water Supply to Low-Income Urban Communities through the Teshie Tanker Owners Association: a Case Study of Public–Private Initiatives in Ghana. Conference Papers for "Infrastructure for Development: Private Solutions and the Poor".* Washington DC.: PPIAF, DFID and World Bank.

Keeley, G. (2008). *Barcelona forced to import emergency water.* Retrieved October 2, 2013, from The Gardian: http://www.theguardian.com/world/2008/may/14/spain.water

Kejjlen, M., & Mcgranahan, G. (2006). *Informal water vendors and the urban poor .* International Institute for Environment and Development. HumanSettlements

Discussion Paper Series, Theme: Water-3.

Kejllen, M. (2000). *Complementary water systems in Dar es Salaam, Tanzania: the case of water vending,* (1 ed., Vol. 16). International Journal of Water Resources Development.

Leboeuf, P. P., Bosh, A. P., Calvache, M. L., Vallejos, A., & Andreu, J. M. (2003). SO4-/Cl- and Mg2/Ca2 ratios as tracers for the evolution of seawater into coastal aquifers: the example of Castell de Ferro aquifer. *C. R. Geoscience, 335*, 1039-1048.

Lee, J. Y., & Song, S. H. (2003). Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. *The science of the Total Environment, 313*, 77-89.

Manitoba Health Protection Unit. (2013). *Bulk Water Hauling Guidelines.* Manitoba.

MassDEP. (2008). *Procedure for Emergency Tank Truck Bulk Water Hauling.* Massachusetts: Bureau of Resource Protection Drinking Water Program.

Mcgranahan, G., & Owen, D. I. (2006). *Local Water Companies and the Urban Poor. HumanSettlements Discussion Paper Series, Theme: Water-4.* International Institute for Environment and Development.

MDDEP. (2013, March 8). *Regulation respecting te quality of the drinking water.* Retrieved January 7, 2014, from Developpement durable, Environnement, Faune et des Parcs, Quebec: http://www.mddep.gouv.qc.ca/eau/potable/reglement/rqep-refondu-en.pdf

MDEQ. (2011). *Licensing of Water Haulers and Water Hauling equipment Regulations.* Michigan: Office of Drinking Water and Municipal Assistance.

Mihdhdir, A. A. (2009). *Evaluation of Bacteriological and Sanitary Quality of Drinking Water Stations and Water Tankers n Makkah Al-Mokarama.* Pakistan: Asian Network for Scientific Information.

Ministere du Developpement durable et de l'Environnement et des Parcs. (2013, March 8). *Regulation respecting the quality of the drinking water.* Retrieved January 7, 2014, from Developpement durable, Environnement, Faune et des Parcs, Quebec: http://www.mddep.gouv.qc.ca/eau/potable/reglement/rqep-refondu-en.pdf

MOE/ECODIT. (2010). Water Resources. In *State of Environment in Lebanon* (Vols. Section II, Chapter: 3, 45-93). Lebanon: Ministry of Environment.

MoEW, MOE, & CAS. (2012). *Water in Lebanon strategic management data national assessment matrix.* Lebanon: UNESCWA.

Mondal, N. C., Singh, V. S., Saxena, V. K., & Singh, V. P. (2011). Assessment of seawater impact using major hydrochemical ions: a case study from Sadras, Tamilnadu, India. *Environmental Monitoring and Assessments, 177*, 315-335.

Monroe County Health Department. (2004). *Bulk Storage Tank System Design & Sizing.* Michigan: Department of Environmental Quality.

National Academy of Sciences. (2008). *Water Supply by vehicule*. Retrieved January 7, 2014, from Safe Drinkign Water is Essential: http://www.drinking-water.org/html/en/Distribution/Water-Supply-by-Vehicle.html

Nauges, C., & Stand, J. (2013, May). *Water Hauling and Girl's School Attendance, Some New Evidence From Ghana.* Retrieved January 17, 2014, from The World Bank: http://elibrary.worldbank.org/doi/pdf/10.1596/1813-9450-6443

Niagara Region Public Health. (2008). *Guidelines for Drinking Water Haulers.* Ontario: Environmental Health Branch.

Nigerian Industrial Standard. (2007). *Nigerian Standard for Drinking Water Quality.* Abuja: Standards Organisation of Nigeria.

Nnaji, C. C., Eluwa, C., & Nwoji, C. (2013). *Dynamics of domestic water supply and consumption in a semi-urban Nigerian city.* Nigeria: Habitat International.

NNEPA. (2010). *Guidelines for Hauling and Transporting Regulated Water for Human Consumption.* Navajo: Public Water Systems Supervision Program.

OpCert. (2011). *Introduction to the Water Distribution System.* Alaska and Canada.

Organization of American States. (1997). *Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean.* Washington, D.C: UNEP - Intenational Environmental Technology Center.

Organization of American States. (1997). *Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean.* Washington, D.C: UNEP - Intenational Environmental Technology Center.

PennWell Corporation. (2010). *Middle East/North Africa*. Retrieved from Waterworld Website: http://www.waterworld.com/articles/wwi/print/volume-25/issue-5/regulars/world-news/middle-east-north-africa.html

Queensland Government. (2007). *Guide to workplace use of non-potable water including recycled waters.* Retrieved January 07, 2014, from Department of Employment and Insudtrial Relations: http://www.deir.qld.gov.au/workplace/resources/pdfs/non-potable_guide.pdf

R Core Team. (2013). *R: A Language and Environment for Statistical Computing.* Vienna, Austria: R Foundation for Statistical Computing.

Royal Academy of Engineering . (n.d.). *The Mathematics of Pumping Water.* United Kingdom: AECOM Design Build; Civil, Mechanical Engineering.

Sowers, J., Vengosh, A., & Weinthal, E. (2011). Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. *Springer Science*, 600.

SPSS Inc. (2007). SPSS for Windows, Version 16.0. Chicago.

State Government Victoria. (2011, July). *Guidelines for drinking (potable) water transport in Victoria - Guide for Victorian water carters.* Retrieved January 07, 2014, from Department of Health, Victoria, Australia: http://docs.health.vic.gov.au/docs/doc/EADB20A2854D01A4CA2578CE0016136E/$FILE/Guidelines%20for%20drinking%20(potable)%20water%20transport%20in%20Victoria%20-%20Guide%20for%20Victorian%20water%20carters,%20July%202011.d.pdf

State of Louisiana Department of Health and Hospitals. (2008). *Instructions for Emergency Tank Truck Bulk Water Hauling in Louisiana.* Louisiana: Office of Pulblic Health.

Sundaram, B., Feitz, A., Caritat, P., Plazinska, A., Brodie, R., Coram, J., et al. (2009). *Groundwater Sampling Analysis - A Field Guide.* Australia: Geoscience Australia.

Sundaram, B., Feitz, A., Caritat, P., Plazinska, A., Brodie, R., Coram, J., et al. (2009). *Groundwater Sampling and Analysis - A Field Guide.* Australia: Geoscience Australia.

The Council of the European Union. (1998, November 3). Quality of the Water intended for Human Consummption - Council Directive 98/83/EC. *Official Journal of the European*

Communities.

The Times of India. (2010, February 2010). *Tanker water all the way*. Retrieved January 22, 2014, from Times of India - Bangalore: http://articles.timesofindia.indiatimes.com/2010-02-22/bangalore/28149468_1_borewell-water-water-supply-bwssb

The World Bank. (2014). *GDP per capita (current US$)*. Retrieved July 17, 2014, from The World Bank: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD

Total. (2013). *جدول مواعيد دفع رسوم السير لكل السيارات والاليات والدراجات النارية خلال 2013*. Lebanon: Total Liban.

UNEP. (2011). *Water Conveyance by Tanker Trucks*. Retrieved April 3, 2014, from United Nations Environment Programme: http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8f/B/Conveyance3.asp

United Nations. (2013). Demographic Yearbook 2013. *Department of economic and social affairs*.

USACE. (2006). *ESF #3 Field Guide.* Retrieved January 22, 2014, from U.S. Army Corps of Engineers: https://eportal.usace.army.mil/sites/ENGLink/ESF3/Shared%20Documents/ESF%203%20Field%20Guide.pdf

Van den Berg, C., & Danilenko, A. (2011). *The IBNET Water Supply and Sanitation Performance Blue Book: The International Benchmarking Network of Water and Sanitation Utilities Databook.* Washington, D.C.: World Bank Publications.

Vancouver Coastal Health. (2009). *Bulk Water Hauling Guideline.* Vancouver: Health Protection.

Vengosh, A., & Pankratov, I. (1998). Chloride/Bromide and Chloride/Fluoride Ratios of Domestic Sewage Effluents and Associated Contaminated Grounwater. In A. Vengosh, *Ground Water* (Vol. 36, pp. 815-822). Hydrological Services.

Victorian Government Department of Human Services. (2009). *Making Sure your Private Water Supply is Safe - Groundwater.* Melbourne, Victoria: Food Safety and Regulatory Activities.

WHO & UNICEF. (2006). *Core Questions on drinking-water and sanitation for household surveys.* Retrieved January 20, 2014, from World Health Organization: http://www.who.int/water_sanitation_health/monitoring/oms_brochure_core_questionsfinal24608.pdf

WHO. (1997). *Guideline for drinking water quality* (2nd ed., Vol. 3 Surveillance and control of community supplies). Geneva: World Health Organization.

WHO. (2004). *Sulfate in Drinking-water.* World Health Organization.

WHO. (2006). *A compendium of drinking-water quality standards in the Eastern Mediterranean Region.* Retrieved from World Health Organisation: http://applications.emro.who.int/dsaf/dsa1183.pdf

WHO. (2009, March). 10 facts about water scarcity. Retrieved October 5, 2013

WHO. (2009). 10 Facts About Water Scarcity. Retrieved June 28, 2013, from from: http://who.int/features/factfiles/water/en/

WHO. (2011). *Guideline for drinking water quality* (4th ed.). Geneva: World Health

Organization.

WHO. (2011). *Technical notes on drinking-water. sanitation and hygiene in emergencies.* Retrieved 10 7, 2013, from World Health Organization: http://www.who.int/water_sanitation_health/publications/2011/tn12_safe_water_en.pdf

World Bank. (2009). *Lebanon: Greater Beirut Supply Project*. Retrieved June 28, 2013, from The World Bank: http://go.worldbank.org/ABLO5YFLV0

Appendix A: Questionnaire for water tankers

Questionnaire Identification					
AI1	**Zone**	I__II__I	AI3	**GPS coordinates**	N: ______________________________
AI2	**Street**	______________________	AI4		E: ______________________________

Schedule					
AV1	First Visit	DD.MM.YY |___|___|.|___|___|.|___|___|	AT1	Start of interview (time)	hh:mm |___|___|:|___|___|
			AT2	End of Interview (time)	hh:mm |___|___|:|___|___|
AV2	Second Visit	DD.MM.YY |___|___|.|___|___|.|___|___|	AT3	Start of interview	hh:mm |___|___|:|___|___|
			AT4	End of Interview	hh:mm |___|___|:|___|___|
AV3	**Total visits carried out** |___|				
AV4	**Editing Date**			DD.MM.YY	|___|___|.|___|___|.|___|___|
AV5	**Coding Date**			DD.MM.YY	|___|___|.|___|___|.|___|___|
AV6	**Data Entry Date**			DD.MM.YY	|___|___|.|___|___|.|___|___|

Staff					
AS1	**Interviewer**	|___|___|	AS4	**Coder**	|___|___|
AS2	**Supervisor**	|___|___|	AS5	**Data entry operator**	|___|___|
AS3	**Editor**	|___|___|			

Respondent			
AH2	**Name of main Respondent (optional)** ____		
AR1	**Interview status**		
	1	Interview completed	**COMMENTS:**
	2	Refusal converted	
	3	Partly completed	
	4	No usable information	
	5	No contact	
	6	Refusal	

Additional comments

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اسئلة حول الصهاريج

WT1 A	المنطقة	________________________________			
WT1 B	مصدر المياه	________________________________			
WT2	ما هو عدد الصهاريج التي تملكها؟	ا___ا ا___ا			
		الصهريج 1	الصهريج 2	الصهريج 3	الصهريج 4
WT2 A	سعة **(حدد الوحدة)**	ا__ا__ا___ا___ا___ا__ ا_ 98 لا جواب 99 لا أعلم	ا__ا__ا___ا___ا___ا__ ا_ 98 لا جواب 99 لا أعلم	ا__ا__ا___ا___ا___ا__ ا_ 98 لا جواب 99 لا أعلم	ا__ا__ا___ا___ا__ا__ ا 98 لا جواب 99 لا أعلم
WT2 B	عدد التقسيمات	ا___ا	ا___ا	ا___ا	ا___ا
WT2 C	نوع	1 حديد 2 بلاستيك 3 Stainless Steel 4 Galvanized St 5 Painted Steel 98 لا جواب 99 لا أعلم	1 حديد 2 بلاستيك 3 Stainless Steel 4 Galvanized St 5 Painted Steel 98 لا جواب 99 لا أعلم	1 حديد 2 بلاستيك 3 Stainless Steel 4 Galvanized St 5 Painted Steel 98 لا جواب 99 لا أعلم	1 حديد 2 بلاستيك 3 Stainless Steel 4 Galvanized St 5 Painted Steel 98 لا جواب 99 لا أعلم
WT2 D	ملكية الصهريج	1 نعم 2 اجار 3 عامل في ________	1 نعم 2 اجار 3 عامل في ________	1 نعم 2 اجار 3 عامل في ________	1 نعم 2 اجار 3 عامل في ________
WT2 E	المحروقات المستعملة	1 بنزين 2 مازوت	1 بنزين 2 مازوت	1 بنزين 2 مازوت	1 بنزين 2 مازوت
WT2 F	حدد ال- km بالتنكة	ا___ا___ا___ا___ا	ا___ا___ا___ا___ا	ا___ا___ا___ا___ا	ا___ا___ا___ا___ا ا
WT2 G	نوع النمرة	1 حمراء ملك 2 حمراء اجار سعر ______ 3 تابعة لمؤسسة	1 حمراء ملك 2 حمراء اجار سعر ______ 3 تابعة لمؤسسة	1 حمراء ملك 2 حمراء اجار سعر ______ 3 تابعة لمؤسسة	1 حمراء ملك 2 حمراء اجار سعر ______ 3 تابعة لمؤسسة
WT2 H	قيمة التعبئة	ا___ا___ا__ا__ا__ا **(حدد الوحدة)**	ا___ا__ا__ا___ا__ا	ا__ا__ا___ا___ا__ا	ا__ا__ا___ا___ا__ا__ ا
IWT2	مؤهل ل:	1 خزان مياه موجود على السطح 2 خزان مياه موجود على الارض	1 خزان مياه موجود على السطح 2 خزان مياه موجود على الارض	1 خزان مياه موجود على السطح 2 خزان مياه موجود على الارض	1 خزان مياه موجود على السطح 2 خزان مياه موجود على الارض

		3 تعبئة المسابح	3 تعبئة المسابح	3 تعبئة المسابح	3 تعبئة المسابح
WT2J	كم مرة بالأسبوع يتم تنظيف الصهريج من الداخل؟	1 لا ينظف 2 عند الحاجة 3 يومياً 4 أسبوعياً 5 مرتين في الشهر 6 شهرياً 7 موسمياً 8 غير ذلك_____ 98 لا جواب 99 لا أعلم	1 لا ينظف 2 عند الحاجة 3 يومياً 4 أسبوعياً 5 مرتين في الشهر 6 شهرياً 7 موسمياً 8 غير ذلك_____ 98 لا جواب 99 لا أعلم	لا ينظف 2 عند الحاجة 3 يومياً 4 أسبوعياً 5 مرتين في الشهر 6 شهرياً 7 موسمياً 8 غير ذلك_____ 98 لا جواب 99 لا أعلم	1 لا ينظف 2 عند الحاجة 3 يومياً 4 أسبوعياً 5 مرتين في الشهر 6 شهرياً 7 موسمياً 8 غير ذلك_____ 98 لا جواب 99 لا أعلم
KWT2	كيف ينظف من الداخل؟	1 أدوية كيمياويّة 2 بالمياه 3 بالمياه والصابون 4 مياه وديتول 5 مياه وكلوركس 6 شفط الرمل 97 N/A 98 لا جواب 99 لا أعلم	1 أدوية كيمياويّة 2 بالمياه 3 بالمياه والصابون 4 مياه وديتول 5 مياه وكلوركس 6 شفط الرمل 97 N/A 98 لا جواب 99 لا أعلم	1 أدوية كيمياويّة 2 بالمياه 3 بالمياه والصابون 4 مياه وديتول 5 مياه وكلوركس 6 شفط الرمل 97 N/A 98 لا جواب 99 لا أعلم	1 أدوية كيمياويّة 2 بالمياه 3 بالمياه والصابون 4 مياه وديتول 5 مياه وكلوركس 6 شفط الرمل 97 N/A 98 لا جواب 99 لا أعلم

اسئلة عن توزيع المياه

WT3	لمن توزع المياه؟	1 منازل 2 مؤسسات 3 للمنازل والمؤسسات 4 غير ذلك، حدد____________________ 98 لا جواب 99 لا أعلم
WT4A	في أية أشهر يزداد الطلب على المياه؟	من __________ إلى __________
	نموذج عند كثرة الطلب :ما هو عدد الرحلات التي تقام لتوزيع المياه، ما سعروها وإلى أية مناطق**(حدد الوحدة)**	

	WT4B منطقة	WT4C وتيرة	WT4D سعر على الأرض	WT4E سعر على السطح
1	________________	|___|يوم	|___|___|___|___|___|___|	|___|___|___|___|___|___|
2	________________	|___|يوم	|___|___|___|___|___|___|	|___|___|___|___|___|___|
3	________________	|___|يوم	|___|___|___|___|___|___|	|___|___|___|___|___|___|

WT5A	في أية أشهر يقل الطلب على المياه؟	من __________ إلى __________
	نموذج أسبوع عند قلة الطلب: ما هو عدد الرحلات التي تقام لتوزيع المياه، ما سعروها وإلى أية مناطق **(حدد الوحدة)**	

	WT5B منطقة	WT5C وتيرة	WT5D سعر على الأرض	WT5E سعر على السطح
1	________________	|___|يوم	|___|___|___|___|___|___|	|___|___|___|___|___|___|
2	________________	|___|يوم	|___|___|___|___|___|___|	|___|___|___|___|___|___|
3	________________	|___|يوم	|___|___|___|___|___|___|	|___|___|___|___|___|___|

WT6	هل يتم فحص المياه في المختبر ؟	1 2 97 98 99	نعم لا N/A لا جواب لا أعلم
WT7	كيف تصنّف نوعية هذه المياه؟	1 2 3 98 99	جيدة (دون لون، طعم، رائحة، ورواسب) متوسطة(بعض اللون، طعم، رائحة، ورواسب) سيئة (ذات لون، طعم، رائحة، ورواسب) لا جواب لا أعلم
WT8	هل حصل وكانت المياه مالحة؟	1 2 3 4 98 99	نعم، دائماً نعم، أحياناً نعم، في الصيف فقط كلا، أبداً لا جواب لا أعلم
WT9	هل تعالج مياه الصهريج قبل توزيعها؟	1 2 3 4 98 99	نعم، دائماً نعم، أحياناً نعم، في الصيف فقط كلا، أبداً لا جواب لا أعلم
WT10	ما هي طرق المعالجة المتّبعة؟	 97 98 99	__________ __________ __________ N/A لا جواب لا أعلم

WT11	هل هناك أكثر من مصدر؟	1 نعم 2 كلا 98 لا جواب 99 لا أعلم			
WT12		1 **المصدر 1**	2 **المصدر 2**	3 **المصدر 3**	4 **المصدر 4**
WT12A	إسم				
WT12B	حدد المنطقة	________________	________________	________________	________________
WT12C	ما هو مصدر مياه الصهاريج؟	1 نبع 2 بئر 3 شركة 98 لا جواب 99 لا أعلم	1 نبع 2 بئر 3 شركة 98 لا جواب 99 لا أعلم	1 نبع 2 بئر 3 شركة 98 لا جواب 99 لا أعلم	1 نبع 2 بئر 3 شركة 98 لا جواب 99 لا أعلم
WT12D	رقم التلفون	|__|__|/ |__|__|_|_|_|_|	|__|__|/ |__|__|_|_|_|_|	|__|__|/ |__|__|__|__|__|_|	|__|__|/ |__|__|__|__|__|_|

سوف اطرح اسئلة عن الموظفين في المؤسسة

WT13	منذ متى وأنت تمارس هذا العمل؟		________________________
WT14	هل لديك عملٌ أخر	1 نعم 2 لا 97 N/A 98 لا جواب 99 لا أعلم	
15WT	هل لديك موظفين يساعدون في ممارسة المهنة؟	1 نعم 2 لا	Go to WT6 Go to WT12

WT16	ما هو عدد الموظفين اللبنانيين ؟	|___|___|
WT17	A : طريقة الدفع	B : الإجرة في الليرة اللبنانية
	1 يومي	|___|___|___|___|___|___|
	2 شهري	|___|___|___|___|___|___|
	3 موسمي	|___|___|___|___|___|___|
	4 غير ذلك، حدد ______________	|___|___|___|___|___|___|
	98 لا جواب	|___|___|___|___|___|___|
	99 لا أعلم	|___|___|___|___|___|___|
WT18	ما هو عدد الموظفين الاجانب؟	|___|___|
WT19	A : طريقة الدفع	B : الإجرة في الليرة اللبنانية
	1 يومي	|___|___|___|___|___|___|
	2 شهري	|___|___|___|___|___|___|
	3 موسمي	|___|___|___|___|___|___|
	4 غير ذلك، حدد ______________	|___|___|___|___|___|___|
	98 لا جواب	|___|___|___|___|___|___|
	99 لا أعلم	|___|___|___|___|___|___|
WT20	المجموع في الليرة اللبنانية	|___|___|___|___|___|___|

Appendix B: Questionnaire for Well Owners

Questionnaire Identification					
AI1	**Zone**	|___||___|	AI3	**GPS coordinates**	N: ______________________________
AI2	**Street**	____________________	AI4		E: ______________________________

Schedule					
AV1	First Visit	DD.MM.YY |___|___|.|___|___|.|___|___|	AT1	Start of interview (time)	hh:mm |___|___|:|___|___|
			AT2	End of Interview (time)	hh:mm |___|___|:|___|___|
AV2	Second Visit	DD.MM.YY |___|___|.|___|___|.|___|___|	AT3	Start of interview	hh:mm |___|___|:|___|___|
			AT4	End of Interview	hh:mm |___|___|:|___|___|
AV3	**Total visits carried out** |___|				
AV4	**Editing Date**			DD.MM.YY	|___|___|.|___|___|.|___|___|
AV5	**Coding Date**			DD.MM.YY	|___|___|.|___|___|.|___|___|
AV6	**Data Entry Date**			DD.MM.YY	|___|___|.|___|___|.|___|___|

Staff					
AS1	**Interviewer**	|___|___|	AS4	**Coder**	|___|___|
AS2	**Supervisor**	|___|___|	AS5	**Data entry operator**	|___|___|
AS3	**Editor**	|___|___|			

Respondent			
AH2	**Name of main Respondent (optional)** ____		
AR1	**Interview status**		
	1	Interview completed	**COMMENTS:**
	2	Refusal converted	
	3	Partly completed	
	4	No usable information	
	5	No contact	
	6	Refusal	

Additional comments

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مصدر المياه

WWA	ما هو مصدر المياه؟	1	نبع	Go to WS2
		2	بئر	Go to WW1
		3	غير ذلك، حدد____________	
		98	لا جواب	
		99	لا أعلم	

مياه الينابيع

WS2	إسم النبع	____________________
WS3	حدد المنطقة	____________________

ما هي التكليفات		A:التكليفات	Bالسعر في الليرة اللبنانية
	1	كهرباء	___ ___ ___ ___ ___ ___
	2	طرمبة	___ ___ ___ ___ ___ ___
	3	موتور	___ ___ ___ ___ ___ ___
	4	تكرير	___ ___ ___ ___ ___ ___
	5	غير ذلك، حدد	___ ___ ___ ___ ___ ___
	6	لا كلفة	
	98	لا جواب	
	99	لا أعلم	

WS5	نوع الرخصة	1	زراعة
		2	صناعة
		3	غير ذلك، حدد ______________
		4	غير مرخص
		98	لا جواب
		99	لا أعلم
WS6	كمية المياه المستخرجة في اليوم	___ ___ ___ ___	**(حدد الوحدة)**
		98	لا جواب
		99	لا أعلم

مياه الآبار (Well Water)					
WW1	عدد الآبار التي تستعمل لتوزيع المياه	|___|			
WW2	هل كان لديك بئر قديم لم تعد تستخدمه؟ لماذا؟	1 نعم، لأنّ البئر القديم جفّ **حدد المنطقة** ______________ 2 نعم، لسبب آخر حدّد ________________________ 3 كلا 98 لا جواب 99 لا أعلم			
		1 **البئر 1**	2 **البئر 2**	3 **البئر 3**	4 **البئر 4**
WW3A	إسم				
WW3B	نوع البئر	1 خاص 2 مشترك 98 لا جواب 99 لا أعلم	1 خاص 2 مشترك 98 لا جواب 99 لا أعلم	1 خاص 2 مشترك 98 لا جواب 99 لا أعلم	1 خاص 2 مشترك 98 لا جواب 99 لا أعلم
WW3C	عمق البئر	|___|___|___| م |___|___|___| قسطل 98 لا جواب 99 لا أعلم	|___|___|___| م |___|___|___| قسطل 98 لا جواب 99 لا أعلم	|___|___|___| م |___|___|___| قسطل 98 لا جواب 99 لا أعلم	|___|___|___| م |___|___|___| قسطل 98 لا جواب 99 لا أعلم
WW3D	سنة الحفر	|___|___|___|___| 98 لا جواب 99 لا أعلم	|___|___|___|___| 98 لا جواب 99 لا أعلم	|___|___|___|___| 98 لا جواب 99 لا أعلم	|___|___|___|___| 98 لا جواب 99 لا أعلم
WW3E	حدد المنطقة	______________	______________	______________	______________
WW3F	عيار للبئر	1 نعم 2 كلا	1 نعم 2 كلا	1 نعم 2 كلا	1 نعم 2 كلا
GWW3	حدد الكمية	|___|___|___|___| N/A 97 98 لا جواب 99 لا أعلم	|___|___|___|___| N/A 97 98 لا جواب 99 لا أعلم	|___|___|___|___| N/A 97 98 لا جواب 99 لا أعلم	|___|___|___|___| N/A 97 98 لا جواب 99 لا أعلم

<table dir="rtl">
<tr><td>WW3H</td><td>نوع الرخصة</td><td>1 زراعة
2 صناعة
3 محطة للمحروقات وغسيل السيارات
4 غير ذلك، حدد ________
5 غير مرخص
98 لا جواب
99 لا أعلم</td><td>1 زراعة
2 صناعة
3 محطة للمحروقات وغسيل السيارات
4 غير ذلك، حدد ________
5 غير مرخص
98 لا جواب
99 لا أعلم</td><td>1 زراعة
2 صناعة
3 محطة للمحروقات وغسيل السيارات
4 غير ذلك، حدد ________
5 غير مرخص
98 لا جواب
99 لا أعلم</td><td>1 زراعة
2 صناعة
3 محطة للمحروقات وغسيل السيارات
4 غير ذلك، حدد ________
5 غير مرخص
98 لا جواب
99 لا أعلم</td></tr>
<tr><td>WW3I</td><td>ما هي التكليفات</td><td colspan="2">A: التكليفات
1 كهرباء
2 طرمبة
3 موتور
4 تكرير
5 غير ذلك، حدد
6 لا كلفة
98 لا جواب
99 لا أعلم</td><td colspan="2">B السعر في الليرة اللبنانية
|___|___|___|___|___|___|
___	___	___	___	___	___
___	___	___	___	___	___
___	___	___	___	___	___
___	___	___	___	___	___	</td></tr>
</table>

WW4	لصاحب البئرأو النبع صهاريج؟	1 2 98 99	نعم, Go to WT1 كلا WW5 Go to لا جواب لا أعلم		
ما هو عدد الصهاريج التي تعبأ في اليوم الواحد؟ وما هو سعرها؟ **(حدد الوحدة)**					
WW5A	عدد	|___|___|___|	|___|___|___|	|___|___|___|	|___|___|___|
WW5B	سعة	|__|__|___|__|___|	|__|__|___|__|___|	|__|__|___|__|___|	|__|__|__|__|___|
WW5C	سعر	|__|__|___|__|___|	|__|__|___|__|___|	|__|__|___|__|___|	|__|__|__|__|___|
WW6	هل تتم معالجة المياه قبل استعمالها؟	1 2 3 4 98 99	نعم، يدوياً بواسطة أدوية كيمياويّة Go to WW7 نعم، بواسطة فلتر Go to WW8 نعم، بواسطة نظام معالجة Go to WW10 كلا Go to WT1A لا جواب لا اعلم		

WW7	إذا تستعمل أدوية كيمياويّة ما هي هذه المواد؟

	إسم المادّة	ماذا يعالج؟	الكلفة السنوية بالليرة اللبنانية
WW7A	1___________________________	2___________________________	3___________________________
WW7B	1___________________________	2___________________________	3___________________________
WW7C	1___________________________	2___________________________	3___________________________

WW8	إذا كنت تستعمل فلتر، أين تضعه؟	1 2 3 98 99	على اول أسطل، حدّد ________________ على خزان مياه غير ذلك، حدّد ________________________________ لا جواب لا أعلم
WW9	ماذا يعالج هذا الفلتر؟	1 2 3 4 5 6 98 99	ملوحة لون تلوّث ميكروبي تكلّس رواسب غير ذلك، حدد ____________________ لا جواب لا اعلم
WW9A	ما كلفة شراء وتركيب الفلتر الواحد؟	 97 98 99	شراء وتركيب__________________________ ليرة N/A لا جواب لا اعلم
WW9B	ما كلفة صيانة الفلتر الواحد؟ (حدّد الفترة الزمنية)	 97 98 99	صيانة __________________________ ليرة شهريا N/A لا جواب لا اعلم
WW9C	كم كان عمر آخر فلتر عندما تمّ تغييره؟	 97 98 99	|___|___| سنة N/A لا جواب لا اعلم

	اذا كنت تستعمل نظام معالجة، ماذا يتضمن من وحدات معالجة؟				
WW10	هل يتضمن:	A تقطير للمياه (Water distiller)	B محلي للمياه المالحة (Reverse Osmosis)	C تخفيف عسر المياه (الاملاح المعدنية) (Water softener)	D نظام آخر، حدد ______________ أو مجموعة وحدات
		1 نعم 2 كلا 98 لا جواب 99 لا أعلم	1 نعم 2 كلا 98 لا جواب 99 لا أعلم	1 نعم 2 كلا 98 لا جواب 99 لا أعلم	1 نعم 2 كلا 98 لا جواب 99 لا أعلم
WW11	سنة الشراء	|__|__|__|__| 97 N/A 98 لا جواب 99 لا أعلم	|__|__|__|__| 97 N/A 98 لا جواب 99 لا أعلم	|__|__|__|__| 97 N/A 98 لا جواب 99 لا أعلم	|__|__|__|__| 97 N/A 98 لا جواب 99 لا أعلم
WW12	ماذا تعالج هذه الوحدة؟	1 ملوحة 2 لون 3 تلوّث ميكروبي 4 تكلّس 5 غير ذلك، حدد __________ 97 N/A 98 لا جواب 99 لا اعلم	1 ملوحة 2 لون 3 تلوّث ميكروبي 4 تكلّس 5 غير ذلك، حدد __________ 97 N/A 98 لا جواب 99 لا اعلم	1 ملوحة 2 لون 3 تلوّث ميكروبي 4 تكلّس 5 غير ذلك، حدد __________ 97 N/A 98 لا جواب 99 لا اعلم	1 ملوحة 2 لون 3 تلوّث ميكروبي 4 تكلّس 5 غير ذلك، حدد __________ 97 N/A 98 لا جواب 99 لا اعلم
WW14	ما كانت كلفة شراء وتركيب هذه الوحدة؟	• سعر إجمالي: ليرة ____________ 97 N/A 98 لا جواب 99 لا اعلم	• سعر إجمالي: ليرة ____________ 97 N/A 98 لا جواب 99 لا اعلم	• سعر إجمالي: ليرة ____________ 97 N/A 98 لا جواب 99 لا اعلم	• سعر إجمالي: ليرة ____________ 97 N/A 98 لا جواب 99 لا اعلم
WW15	ما كلفة تشغيل وصيانة هذه الوحدة: أدوية، كهرباء، فلاتر.	____________ ليرة في السنة 97 N/A 98 لا جواب 99 لا اعلم	____________ ليرة في السنة 97 N/A 98 لا جواب 99 لا اعلم	____________ ليرة في السنة 97 N/A 98 لا جواب 99 لا اعلم	____________ ليرة في السنة 97 N/A 98 لا جواب 99 لا اعلم

Appendix C: Sample calculations for well economic analysis

Formulas for Well analysis	Assumptions	
$E_c = (I_c + O_c + T_c + L_c) / Q_T$ **$E_c = (6.7 + 2.937 + 0 + 36.67)/600 = 0.08$ ($US/m^3)**	Labor = 550 ($/month) Energy = 0.077($/kWh) (EDL, 2014) Pump: Q=0.011 (m^3/s) g=9.81 (N/S2) ρ= to 1000 (kg/m^3) η = 80% (Royal Academy of Engineering ; FAO, 2007)	(1)
LT_c ($/m^3) = LT_T ($) / V_{LT} (m^3) **LT_c ($/m^3) = 13.33 / 20 = 0.67 ($/m^3)**		(1a)
ST_c ($/m^3) = ST_T ($) / V_{ST} (m^3) **ST_c ($/m^3) = 3.33 / 4 = 0.83 ($/m^3)**		(1b)
D_c ($/m^3) = $(((Op_c + Ma_c + Me_c + L_c + C_c) / T_n) + F_c) / V_T) + W_c$ **$D_c = ((((46.3 + 5.55 + 1.32 + 23.33 + 0.17)/5) + 8.42)/20) + 0.08 = 1.29$ ($US/m^3)**		(2)
C_c ($) = $C_m \times V_{LT} \times C_f$ or $C_c = C_m \times V_{ST} \times C_f$ **$C_c = C_m \times V_{LT} \times C_f$ = 1$ × 20 × 0.0083 = 0.034 ($)**		(2a)
W_c ($/m^3) = LT_c or $W_c = ST_c$ **Equals to the cost of water extraction when the well owner owns the tankers;** **$W_c = E_c = 0.08$ ($US/m^3)**		(2b)
F_c ($) = $F_{c/tank} \times D / F_e$ **$F_c = 17.33 \times 19.44 / 40 = 8.42$ ($)**		(2c)

Appendix D: Inspection form

Water Tanker Information

Company name: ____

Address: ____

Owner Name: ____

Phone Number: |___|___|___|___|___|___|

Plate Number: |___|___|___|___|___|___|___|___| ☐ Red ☐ White

License Number: |___|___|___|___|___|___|___|___|

Truck Driver Name: ____

Purpose of bulk water:

☐ Household and Companies ☐ Hotels and Restaurants ☐ Construction Site

☐ Other (Specify): ____

Chlorine Residual: ____

Water Resource Information

Name: ____

Location: ____

Type of Source: ______________Used since: ______________

Well Depth: |___|___|___| m

License Number: |___|___|___|___|___|___|___|___|

Owner Name: ____

Phone Number: ____

Treatments: ____

Type of Treatment: ☐ Disinfection ☐ Filter ☐ Reverse Osmosis

☐ Other (specify): ____

Tanker specification

Tank Capacity (m^3): |___|___|___|___|___|

Tank Material

☐ Stainless Steel ☐ Plastic ☐ Food Grade coating

☐ Other (Specify): ____

The following equipment are food-grade, non-corrosive, and accessible for cleaning:

Bulk Water Tank	☐ Yes ☐ No	Hose (s)	☐ Yes ☐ No
Pump (s)	☐ Yes ☐ No	Lubricants	☐ Yes ☐ No
Presence of: Caps	☐ Yes ☐ No	Drain bottom	☐ Yes ☐ No
Access Port (0.5m)	☐ Yes ☐ No	Backflow device	☐ Yes ☐ No
Air-vent: Downward	☐ Yes ☐ No	Screens	☐ Yes ☐ No

Number of baffle Walls: |___|

Tank disinfection: Name: _______________________

Amount: |___|___|/|___|___||___|___|

Frequency: |___|___|/___________

Has the truck been used for transporting other material prior to transporting bulk water?

☐ Yes (Specify): _______________________ ☐ No

Exterior condition of the truck and equipment

Sanitary	☐ Yes ☐ No	Rusted	☐ Yes ☐ No
In good repair	☐ Yes ☐ No	Other: _______________________	
Clear & Proper Labelling	☐ Yes ☐ No		

Sampling and Record Keeping

Sampling:	Quarterly on Physical & Chemical	☐ Yes ☐ No
	Monthly on Microbiological	☐ Yes ☐ No

Log Book:

Date, time and location of water filling	☐ Yes ☐ No
Date, time and location of each water delivery	☐ Yes ☐ No
Volume delivered to each site	☐ Yes ☐ No
Chlorine Residual	☐ Yes ☐ No
Date and time of equipment disinfection	☐ Yes ☐ No
Water sample results (attached)	☐ Yes ☐ No

Comments: ____

Date of Inspection (dd/mm/yyyy): _________________________

Signature of Operator: _________________________ Date: ______________

Signature of Public Health Inspector: _________________________ Date: ______________

Appendix E: Policies and Regulations in Lebanon

	Sub-text	Title	Date	Regulation number	Source	Department
Official Gazette – Issue # 46 – 8/6/1970 – MOEW – Decision 14438: Article 1 to 20	المادة: ١-٢٠	تنظيم التنقيب عن المياه واستعملها	١٩٧٠/٦/٨	مرسوم رقم ١٤٤٣٨	الجريدة الرسمية العدد ٤٦	وزارة الموارد المائية والكهربائية
MoEW – Decision 14597 – 14/6/2005 – Chapter 1 – Articles: 28, 30 (subsection 7)	الفصل الثاني، المادة ٢٨ و ٣٠ (٧)	نظام إستثمار مؤسسة مياه بيروت وجبل لبنان	٢٠٠٥/٦/١٤	مرسوم رقم ١٤٥٩٧	Sader Encyclopedia	وزارة الموارد المائية والكهربائية
MoPH – Decision 67 – 14/2/1972 – Article: 1 to 8	المادة: ١ - ٨	تحديد طرق الفحص الجرثومي للمياه	١٩٧٢/٢/١٤	قرار رقم ٦٧	المحافظة على الصحة العامة	وزارة الصحة العامة
Official Gazette – Issue # 45 – 25/10/2012 – MOIM – Law 243 – Articles: 175-6, 180, 181, 182, 192	المادة: ١٧٥ (٦)، ١٨٠، ١٨٢، ١٩٢	قانون السير الجديد	٢٠١٢/١٠/٢٥	قانون رقم ٢٤٣	الجريدة الرسمية العدد ٤٥	وزارة الداخلية والبلديات
MoPH – Decree 108 – 16/9/1983 – Section: 1 – Articles: 1 and 2	الباب الأول، المادة: ١ و ٢	إستثمار المياه والمرطبات المعبأة في أوعية	١٩٨٣/٧/١٦	مرسوم اشتراعي رقم ١٠٨ تنظيم	المحافظة على الصحة العامة	وزارة الصحة العامة
MoPH – Decision 67 – 14/2/1972 – Articles: 1 to 8	المادة: ١ - ٨	تحديد طرق الفحص الجرثومي للمياه	١٩٧٢/٢/١٤	قرار رقم ٦٧	المحافظة على الصحة العامة	وزارة الصحة العامة