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ORIGINAL PAPER

Provision of safe domestic water for the promotion and protection of public health: a case study of the city of Beirut, Lebanon

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Abstract Securing adequate safe drinking water and proper sanitation is a major challenge facing the developing world. The "Water for Life Decade" emphasizes the importance of upgrading national water quality and sanitation services. This study assessed the domestic water profile in the city of Beirut. Samples were collected from three types of household water sources (municipality, private wells, and vended water bottles) and assessed for their physiochemical and microbiological profile. At the same time, a cross-sectional survey assessing water consumption patterns and the prevalence of water-borne diseases was conducted. The results showed a deficient water quality profile in all three water sources. The measured physiochemical and bacteriological parameters reflected the high frequency of water-borne diseases. Action to secure a safe domestic water supply is essential. The plan should guarantee the protection of water sources, ensure sufficient treatment of domestic water and upgrade the national program for potable water quality control. Periodic quality monitoring and legislating the chaotic water-vending sector are indispensable. Additionally, the deterioration of private well sources by sea and wastewater infiltration necessitates the enforcement of legislation associated with the use and management of private wells. Consumer awareness and active contributions to promote and protect public health are important.

Keywords Major water ions · Bacteriological quality · Groundwater · Municipality water · Vending water · Water-borne diseases · Intervention plan · Lebanon

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Introduction

Provision of sustainable safe water resources is one of the major millennium goals defined by the "Water for Life Decade" (UN 2003). The proposed basic water requirement per day to sustain life is still controversial. For instance, Carter et al. (1997) suggested that the minimum water supply should be 20 l/c/day, whereas Gleick (1996) suggests 50 l/c/day for domestic water supply. Nevertheless, what is more important than adequacy of water is its quality as being safe for consumption, which is one of the fundamental human rights and basic conditions for promoting public health. Despite huge investments in water supply and sanitation systems in the past decades, millions of people still lack a water supply and proper sanitation facilities (Makoni et al. 2004). This problem is more serious in developing countries where one person in three needs a safe water supply and sanitation facilities (Palamuleni 2002). In fact, water-related diseases are part of the human tragedy. In 2002, an estimated 2.3 billion human cases worldwide as well as over 12 million deaths were reported (WSSD 2002). In developing countries, over one-third of deaths are caused by the consumption of contaminated water (Palamuleni 2002), and 60% of all infant mortality is linked to infectious and parasitic diseases, which are mostly water related (Hinrichsen et al. 1997).

In general, the main source of domestic water is derived from surface and ground water resources. The public sector manages water treatment plants and its subsequent delivery to the consumer through a distribution network. Contamination of pipelines due to intermittent water supply, low pressure in the distribution network, inadequacy of wastewater collection systems and leaking pipes are common problems in developing countries (Kjellen 2000; Saghir et al. 2000; Jurdi et al. 2002). Outbreaks of gastrointestinal diseases are mainly due to fecal contamination of drinking water resulting from deficiencies in storage tanks and cross-connections of sewer pipes with domestic water (Korfali and Jurdi 2007). On the other hand, the rapid increase in urban population challenges the ability of the public sector to comply with water demands (Bennet 1998; UN 2003; WHO 2006). Thus, households transfer to a number of other alternatives or complementary water sources that satisfy their need. These sources vary from owning private wells, "water vending and vended water bottles" and bottled water (Kjellen 2000; El-Fadel et al. 2003; Basma 2004; Korfali and Jurdi 2007).

The Lebanese context

Lebanon has been distinguished as the water reservoir in the Middle East. However, proper integrated management of its water resources is the major challenge. The key problems are encountered in providing water to overpopulated cities, such as Beirut and its suburbs (Jurdi et al. 2003). Beirut City and its suburbs (Greater Beirut) are overpopulated; it is the residence of about 2.416 million citizens, which constitute two thirds of Lebanon's total population according to the projected figure for the year 2010 (UN 2001). The surface area of Beirut is only 20 km^2 with a population density of 20,167 (MEO 2001).

Recent attempts to estimate water demands and availability in Lebanon and Beirut have revealed a significant deficit. Domestic water need in Lebanon is estimated at 850,000 m^3/day, with 450,000 m^3/day available. Beirut alone needs 280,000 m^3/day, where only 180,000 m^3/day is accessible (Jaber 1997; El-Fadel et al. 2003). The daily domestic water consumption in Lebanon was estimated at 165 l/c/day in the mid-1990s. This figure is expected, due to population growth, to reach 260 l/c/day in 2015 (MEO 2001; Amery 2002). Though a number of sources indicate the target capacity of 160 l/c/day, yet the actual delivery is much lower (64 l/c/day), indicating substantial system and distribution losses (water wastage) (El-Fadel et al. 2000; MEO 2001; Basma 2004). Beirut water authorities are the main suppliers of water for the capital. Water delivered to Beirut initiates from two springs (Jeita and Kachcoush) north of Beirut and is supplemented during the dry season by 26 (near Jeita, north of Beirut) groundwater wells near the seashore and by 13 coastal wells from south Nahmeh (south of Beirut) (the 13-well water supply represents 20% of the total water added to the spring waters). The raw water obtained from these various sources is treated at the water treatment plant of Dbayeh (north Beirut). The treated water is pumped to a main storage reservoir in the Ashrafieh area (Beirut). Then, the water is pumped to two subsidiary reservoirs within Beirut City (Burj Abou Haidar and Tallet El-Khayat). Finally, water is brought to Beirut home citizens through a network of pipe systems. In fact, due to the long distance of the distribution pipe system and leakage (deficient operation and maintenance), the actual delivery of water is much lower and can reach 50% of the supply (MEO 2001).

Consequently, the scarcity of water in Beirut has led the water authorities to apply some drastic measures, such as rationing the water supply to 10 h every other day (El-Fadel et al. 2003). Therefore, it is highly probable that water contamination is also induced throughout the distribution system by the negative pressure and inward suction during cutoff periods (Korfali and Jurdi 2007). Water rationing, as a remedial action, has become a firmly established practice for the past 4 decades. Consumers as such are resorting to using other complementary water sources. These sources are provided by water vendors, the industrial sector and by pumping private wells. Exploitation of ground water through private wells is uncontrolled and is still increasing up to the present time. The excessive exploitation of ground water over the years has led to the infiltration of seawater and the deterioration of the fresh water aquifer (Acra et al. 1983; Lababidi et al. 1987; Acra and Ayoub 2001; Korfali and Jurdi 2007). Parallel to the extraction of water from private wells, water shops are mushrooming. The estimated number of these shops is not available due to the complete absence of quality-control monitoring legislations. These practices have exposed the citizens to contaminated water and its resulting health problems (Al-Safir Newspaper 2002; El-Fadel et al. 2003; Basma 2004). Even though the assessment of the relative disease burden is deficient, still the disease registry of the Public Health Ministry is reporting increasing incident rates of diarrhea, dysentery, hepatitis A and typhoid (UNDP 1995; MOH 2000; Al-Safir Newspaper 2002).

With reference to the previous information, the assessment of the domestic water profile for the city of Beirut becomes a necessity. The assessment is attained through physical, chemical and microbiological analysis of domestic water samples.

In parallel, by conducting a cross-sectional survey assessing water consumption patterns and the prevalence of water-borne diseases (diarrhea, vomiting), an intervention plan to provide safe domestic water will be proposed according to the findings.

Materials and methods

Sampling sites and sampling

Domestic water samples were collected from three different zones within Beirut City (Fig. 1). The choice of these zones would display the variations of domestic water quality, the type of water used in households and the financial burden every citizen is facing to meet his/her water demands. Zone I (Ras Beirut) is a coastal zone, highly populated with excessive drilling of private wells. Zone I has already been the location of many previous studies to

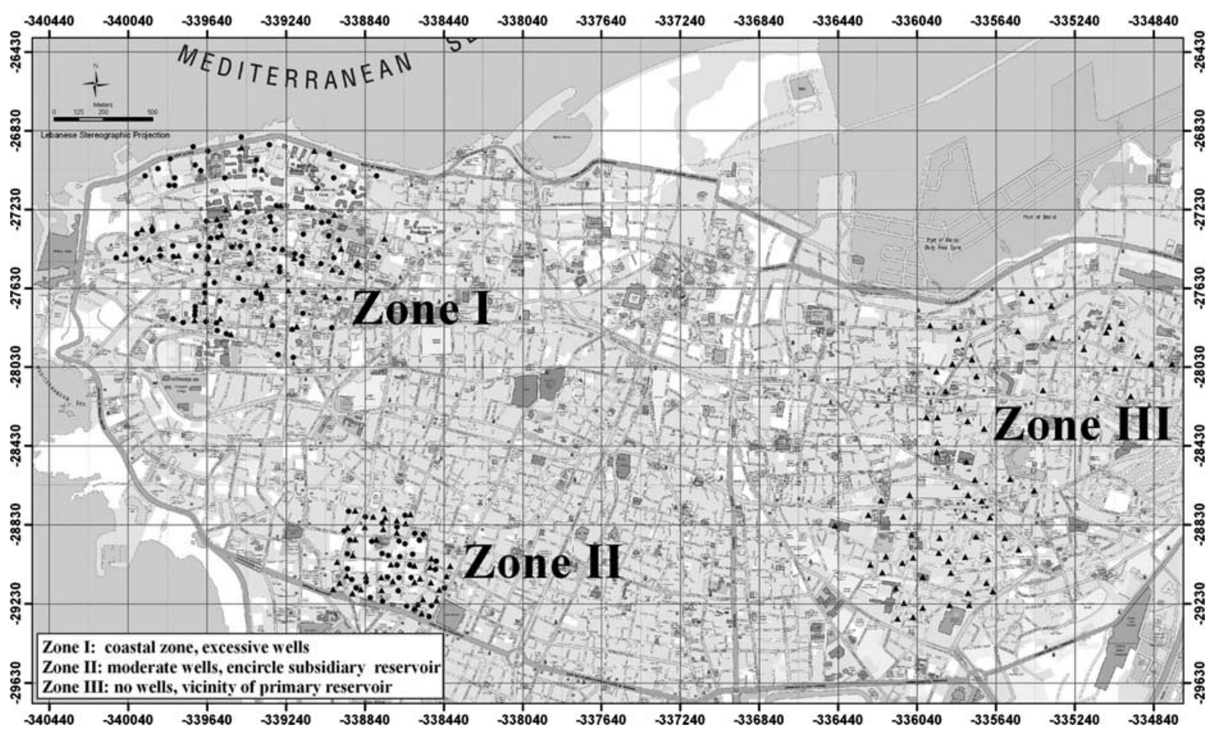


Fig. 1 Map of studied zones and sampling sites (• well; ▲ municipality)

scrutinize the degree of sea water intrusion into its groundwater aquifer and the quality of drilled well water (Pathan 1977; Acra et al. 1983; Acra and Ayoub 2001; Korfali and Jurdi 2007). Zone II (Tallet El Khayat) encircles the subsidiary municipality water reservoir with moderate drilling of private wells. Zone III is in the vicinity of the main municipality water reservoir with no private well drilling. Domestic tap water samples were collected during the dry season. The sampling sites (houses) were chosen after a preliminary survey based on the availability of municipality and/or complementary well water. One hundred fifty well-water samples were collected from zones I and II, and 75 municipality water samples were collected from zones I, II and III. Finally, 100 water-vended bottles from 25 companies were sampled from houses. A 1-l polyethylene bottle soaked overnight with 10% v/v nitric acid was used for water sampling collection. Water samples (300 ml) were also collected in borosilicate glass bottles for bacteriological analysis. The methods of sampling and collection are in accordance with Standard Methods for the Examination of Water and Wastewater (APHA et al. 1998).

Field analysis

Parameters sensitive to environmental changes were measured on site. Temperature, electrical conductivity (EC_w) and total dissolved solids (TDS) were measured using the Hach Model 44600 Conductivity/TDS Meter and the Hach pocket pH Model.

Laboratory analysis

One hundred milliliters from each collected sample was taken and acidified with nitric acid to pH <2 and stored at 4°C for future analysis of Na by flame photometer technique ("Thermo" FISHER, PFP7). Working standard solutions were prepared by dilution of stock solutions (1 mg metal/ml in 2% HNO_3) with MilliQ water. The total organic carbon was immediately analyzed using a TOC analyzer (SHIMADZU, VCPN). A titration procedure was used for alkalinity (0.02 N H_2SO_4), Cl^- (0.0141 N mercuric nitrate), Ca, Mg and total hardness (0.01 M EDTA) and colorimetric methods for NO_3^- (cadmium reduction), SO_4^{2-} (turbidimetry) and PO_4^{3-} (ascorbic acid) using the Hach Model ("HACH" Odyssey, DR, 2500). The bacteriological quality was determined by membrane filtration technique (Millipore).

Community survey

At the same time, for zone I (Ras-Beirut) citizens, a cross-sectional survey assessed: (1) water consumption patterns, (2) the financial burden and (3) the prevalence of water-borne diseases. A survey questionnaire was developed and distributed to 530 heads of households, of which 499 were completed and returned. The questionnaire was designed to assess the socioeconomic characteristics of the individuals (age, occupation, education and income), domestic water usage types, domestic water expenditure and the prevalence of water-borne diseases (vomiting, diarrhea, skin rash).

Software used in analysis

The statistical analyses of the community survey and the physio-chemical parameters were performed using the SPSS and SigmaStat softwares. AquaChem software was used to calculate the carbonate hardness (CH) and non-carbonate hardness (NCH) in water and the ratio of water parameters related to seawater.

Results and discussion

Water quality profile

Table 1 represents the mean values of the measured water parameters of the different domestic water type sources (well, municipally and vending water bottles) that were utilized at different locations within Beirut city. Locations (zones) were chosen based on their vicinity from: (1) the coast, (2) the primary municipality reservoir and (3) the subsidiary municipality water reservoirs. Zone I (Ras-Beirut) is a coastal zone, highly populated with excessive drilling of private wells. Most citizens utilize the three water type sources for their domestic activities. In zone II (Tallet El Khayat subsidiary reservoir), citizens also depend on the three water type sources. Zone III is in the vicinity of the primary municipality water reservoir with no private well drilling. Citizens in this zone complement their domestic water needs via water vended bottles (WVB).

Well water

A very high mineral content was observed for zone I well water. The conductivity and TDS levels in well water, as well as the concentrations of Cl^-, Na^+, Mg^{2+}, Ca^{2+} and $SO_4{}^{2-}$, are above the drinking water standards recommended by USEPA (2003). The mean conductivity value for collected samples is 3,015 μS/cm and is three times higher than the recommended upper limit of 1,250 μS/cm. The chloride (Cl^-) concentration of 1,234 mg/l is even five times larger than the USAPE recommended upper level of 250 mg/l. The concentrations of Ca 122 mg/l and of Mg 73 mg/l are also higher than the set standards by USEPA (check Table 1). Though WHO (2006) does not indicate the health hazards resulting from a considerable excess in ion concentrations, such as Cl, Mg and Ca, and there is an absence of existing data relevant to human health effects from high concentrations of these ions, still these ions affect the household infrastructure and impact the corrosion of domestic pipes, the leaching of metals and the water taste (WHO 2006; Korfali and Jurdi 2007). The high reported conductivity, Mg^{2+} and Cl^- concentrations in wells of the coastal zone (zone I) are mainly due to sea water intrusion. Previous studies have dealt with sea water infiltration into coastal aquifers and their temporal deterioration. These phenomena are clarified in Table 2, which reports the progressive temporal increase in the specified water indicators (conductivity, total hardness—TH, carbonate hardness—CH, noncarbonated hardness—NCH and Cl^-), and it reflects on seawater infiltration, as well as sea water intrusion indices (NHC/CH, Mg^{2+}/Ca^{2+}). This water

Table 1 Mean and maximum values of the indicated parameters of the different water types for studied zones and drinking water guidelines

Parameter	Well ($N = 150$)				Municipality ($N = 75$)						WVB ($N = 100$)	
	Zone I		Zone II		Zone I		Zone II		Zone III		WVB	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Temp. (°C)	23.5	28.1	21.6	25	22	25.5	22.6	28	20.6	26	20	21
pH	7.792	8.61	7.7	9.0	8.33	8.58	7.94	9.0	7.94	8.1	7.7	8.0
TDS (mg/l)	**1,508**	3,476	936	2,450	**708**	1,063	402	815	300	410	196	437
Con. (μS/cm)	3,015	6,952	1,816	4,910	1,415	2,125	808	1,630	600	820	393	874
DO (mg/l)	6.91	9.95	8.6	9.0	8.5	9.7	8.53	9.0	8.00	9.1	8.2	9.7
Alkal (mg $CaCO_3$/l)	325	480	260	370	255	300	234	300	163	180	136	166
T–H (mg $CaCO_3$/l)	**670**	1,150	575	1,515	430	795	314	610	197	250	144	220
CH–H (mg $CaCO_3$/l)	326	–	260	–	262	–	234	–	163	–	136	–
NCH–H (mg $CaCO_3$/l)	311	–	315	–	173	–	80	–	34	–	8	–
Ca (mg/l)	**122**	180	98	240	93	114	81	108	46	55	43	68
Mg (mg/l)	**73**	187	78	220	43	127	27	91	15	22	9.0	29
TOC (mg/l)	3	5	5	7.8	4.8	6.2	1.9	4.3	1.2	2.2	6.3	9.2
NO_3 (mg/l)	3.04	9.7	7.7	21	1.15	4.8	2.0	4.5	0.64	1.35	12	5.5
SO_4 (mg/l)	**85**	175	71	135	40	70	45	130	20	28	7.6	8
Cl (mg/l)	**1,234**	3,852	**883**	1,800	**383**	805	234	530	62	86	41	99
Na (mg/l)	**620**	1,231	370	800	188	405	90	234	12	20	10	31
Fe (mg/l)	**0.70**	21.6	**0.58**	12.3	0.55	2.19	**0.25**	1.8	**0.55**	1.9	0.05	.85
E. Coli	45%		22%		21%		12%		0		56	

Con. (μS/cm)	Ca	Mg	TH (mg $CaCO_3$/l)	Cl	SO_4	NO_3	Fe
400–1,250	100	30	500	25–250	25–250	5–10	0.05–0.2

Bold numbers are mean values higher than standard

Drinking water standards (USEPA—lower value recommended, upper limit maximum, mg/l)

WVB Water vended bottles

Table 2 Temporal variation of water parameters and indices that reflect sea water intrusion

Year	Con. (µS/cm)	Cl (mg/l)	TH (mg $CaCO_3$/l)	CH (mg $CaCO_3$/l)	NCH (mg $CaCO_3$/l)	NCH/CH	Mg/Ca
1971[a]	1,256	223	471	304	166	0.55	0.256
1978[a]	1,660	396	495	280	208	0.75	0.55
1982[a]	1,885	510	500	287	248	0.86	0.72
2005[b]	2,306	973	617	316	315	1.00	1.0
Present study	3,015	1,234	670	311	326	1.04	1.10

TH total hardness, *CH* carbonate hardness, *NCH* non-carbonate hardness

[a] Acra et al. (1983); [b] Korfali and Jurdi (2007)

profile is also justified by the reported value of the mean and maximum well water sodium concentration of 620 and 1,231 mg/l. The seawater intrusion is further proven through the AquaChem software model that predicted a Na–Cl water type for zone I well water and a Stiff plot similar to that of seawater (Fig. 2).

In zone II (Tallet El Khayat), the mean of the tested well water indicators was lower than those of zone I. However, the reported conductivity value (1,816 µS/cm) and Cl^- concentration (883 mg/l) are still higher than USEPA standards (Table 1). The high conductivity levels and chloride concentration in zone II wells arise from seawater intrusion and/or high rate of water extraction. Thus, the intrusion of sea water in wells of zone II is lower than that in wells of zone I. This is explained by the higher amount of carbonate hardness (CH) (315 mg/l) than non-carbonate hardness (NCH) (260 mg/l) in zone II wells, while the CH and NCH in zone I wells were similar (check Table 1). Furthermore, the predicted water type by AquaChem software is Mg–Ca–Cl–HCO_3, which reflects the bicarbonate occurrence that was underestimated in zone I by the overwhelming occurrence of chloride amounts (Fig. 2). Nevertheless, examining additional parameters, such as NO_3^- concentration, it was determined that its mean value is 7.7 mg/l with a maximum value of 21 mg/l. This maximum concentration exceeds both the recommended standards of USEPA and WHO (10 mg/l). Nitrate concentrations higher than 10 mg/l are the cause of methemoglobina (blue-baby syndrome) (WHO 2006). The presence of NO_3^- in water reflects an additional water deterioration profile resulting from the improper management of domestic sewage. Although regulations recommend providing septic tanks, these are replaced by cesspools because of the improper enforcement of regulations.

Municipality water

Table 1 revealed similar variation trends among the collected samples of the three zones with respect to most of the measured municipality water indicators (conductivity, alkalinity, total hardness, Ca^{2+}, Mg^{2+}, Na^+, SO_4^{2-} and Cl^-). The order of their concentration is: Zone III < II < I. High conductivity values were observed for the three zones and are higher than the lower recommended USPA value level for drinking (400 µS/cm). The conductivity of municipality waters of zone III (600 µS/cm) and of zone II (808 µS/cm) are lower than the maximum USEPA acceptable conductivity value (1,250 µS/cm), but that in zone I (1,415 µS/cm) is higher. It should be noted that all water samples were collected during the peak season of water shortage, thus for the period of maximum deterioration impacts. This period is characterized by a high deficiency in supplied domestic water versus an increase in water demand. During the dry season, the water authorities resort to water from nearby coastal wells and an additional 13 Nameh wells (south of Beirut) to cover the deficiency in water supply of the Jeita springs. The Nameh water is delivered to the subsidiary water reservoir (Tallet El Khayat). These changes in water sources supply result in high conductivity levels in water; thus, higher concentrations in tested water indicated parameters during summer. The variation in the conductivity level of domestic water in the three zones is mainly attributed to the managerial strategy. Zones I and II get minimal amounts of treated water during summer since the Tallet El Khayat subsiadiary reservoir is supplemented by water pumped directly from coastal wells south of Beirut exposed to seawater infiltration due to high extraction rates. Whereas in zone III water is mainly provided from

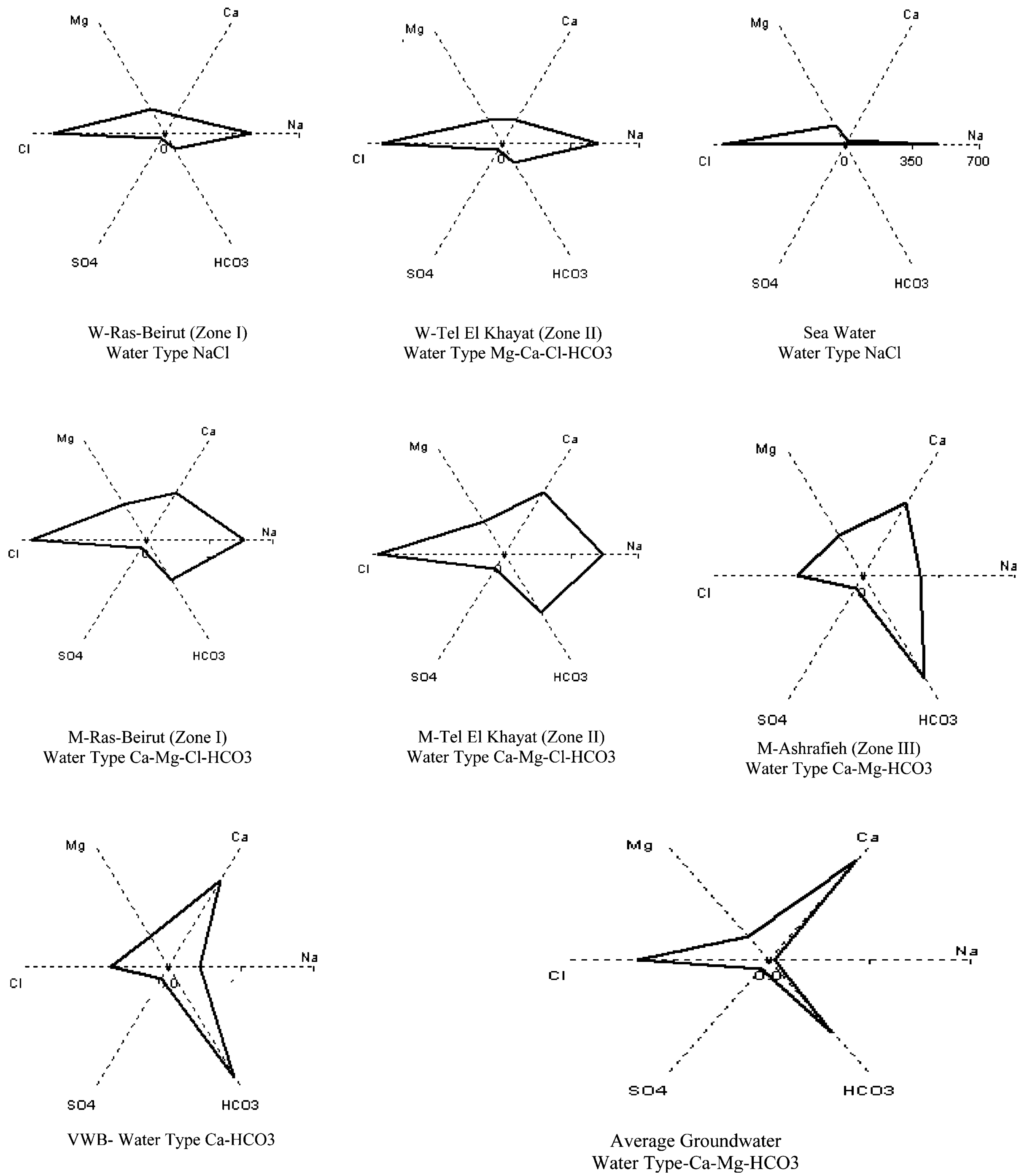


Fig. 2 Comparison of water type and major water ions of the different studied water sources and those of average Lebanese groundwater and sea water

the main water source of the Dbayeh treatment plant increased by the North coastal well waters, these are less exposed to seawater infiltration and heavy water extraction. The levels of Cl^{-} concentrations were higher in zones I and II where citizens use both municipality and private wells water as compared to those in zone III where citizens depend mainly on municipality water. The concentrations of chloride in municipality water of zone I (388 mg/l) and zone II (265 mg/l) are higher than the maximum limit (250 mg/l) recommended by USEPA for drinking. These high Cl^- concentrations in municipality water are most probably the outcome of mixing well water with municipality water during the dry season in houses that use both water sources (municipality and well). The mixing of municipality water with well water in zone I and zone II becomes evident by the water type that AquaChem software predicted, Mg–Ca–Cl–HCO_3, which reflects the Cl^- occurrence. The mixing process is not applicable to zone III, where private wells are non-existent. Consequently, AquaChem predicted water type Ca–Mg–HCO_3 for zone III municipality water and a Stiff diagram similar to Lebanon's average ground water (Fig. 2). This prediction is in accordance with a water type evolving from dissolution of limestone bedrock aquifer (Drever 1997, Korfali and Jurdi 2007). In conclusion, comparing the quality of water in the three zones reflects an acceptable water profile in zone III.

Water vended bottles

The average concentration of major water indicators in water vended bottles (WVB) is within the acceptable standard levels (check Table 1). The main problem is indicated by the prevailing nitrate concentration. The average NO_3^- concentration is 12 mg/l, and its maximum value of 25 mg/l is higher than the recommended drinking water value (10 mg/l). Salts of nitrates are all soluble in water; consequently, in agricultural zones because of the use of rich nitrate fertilizers, they leach into the groundwater. Agricultural zones are subjected to higher NO_3^- concentrations in their groundwater. A large number of water vending companies extracts water from agricultural and domestic zones allthrough the country. Hence, a possible source of nitrate can be related to a deficient sewage management and/or an excessive use of fertilizers (Jurdi et al. 2003).

Bacteriological water quality profile

While assessing the microbial profile of collected water samples, the data revealed that the most contaminated domestic water type source is water in vended bottles (WVB). Fecal coliform was reported in 56% of samples, which points out the lack of quality-control monitoring by these water shops and companies. These results are in accordance with the high levels of nitrate in this water source. Water shops are rapidly increasing, and they do not respect the Lebanese regulations of potable water (Decree issued in 1976 and enforced in 1983). These regulations require a permit from the Ministry of Health and another from the Ministry of Trade, as well as compliance with drinking water standards and minimal labeling requirements (Basma 2004). Water, sold in these shops, appears to be clean and free from turbidity, but it originates from wells and is only treated to reduce hardness. While the well water illustrated contamination levels lower than the water-vending bottles, fecal coliform was reported in 22% of samples from zone II and 45% in samples from zone I. The occurrence of contamination in well water is due to (1) the infiltration of waste water into aquifers or wells, resulting from the old deteriorating sewage network in the city, (2) the use of cesspools and (3) the cross-connection between domestic sewer pipes and domestic water pipes. While fecal contamination levels in municipality water varied between the two zones, zone III had no contamination. In zone III water is directly drawn from the treatment plant with no existing private wells. Conversely, fecal coliform was reported in 21% of municipality water of zone I and 12% in municipality water of zone II. Fecal coliform in these zones is due to deficient free residual chlorine to cope with contamination in the distribution network and/or deficient chlorine re-dosing at the subsidiary reservoir (Tallet El Khayat reservoir). The occurrence of contamination in these zones could also be due to mixing of well water with common house municipality water tanks and/or cross-connection of waste water pipes with domestic water pipes.

Water consumer pattern and health profile

Domestic water usage types and expenditure

The statistical analysis of the collected data from the community survey shows a heavy reliance of the end-user on complementary water sources to supplement municipality water. Figure 3 shows that, for general water use (washing), 32% of the population depends on well water, 52% on municipality water and 16% on vending water, whereas for cooking 55% trust vending water, 27% the municipality, 8% the well and 10% bottled water. When it comes to the source of drinking water, a reliance of 68% on vended water is found. The lack of trust in the quality of municipality water and the need to supplement the deficient amounts is an additional economical burden on households (Fig. 4).

Figure 4 shows that 25% of the sampled population spends more than \$100 on water, 35% of the sampled population spends \$100 and 36% of the sampled population spends \$50. Cross-tabulation between income and water expenditure reported 10–16% of low income basic salary spent on water, and 60% of this expenditure is on drinking water. Whereas the χ^2 test showed no statistically significant differences between income and money spent on water ($P < 0.001$), neither correlation was shown between income and water expenditure. This is due to

Fig. 3 Domestic water usage types

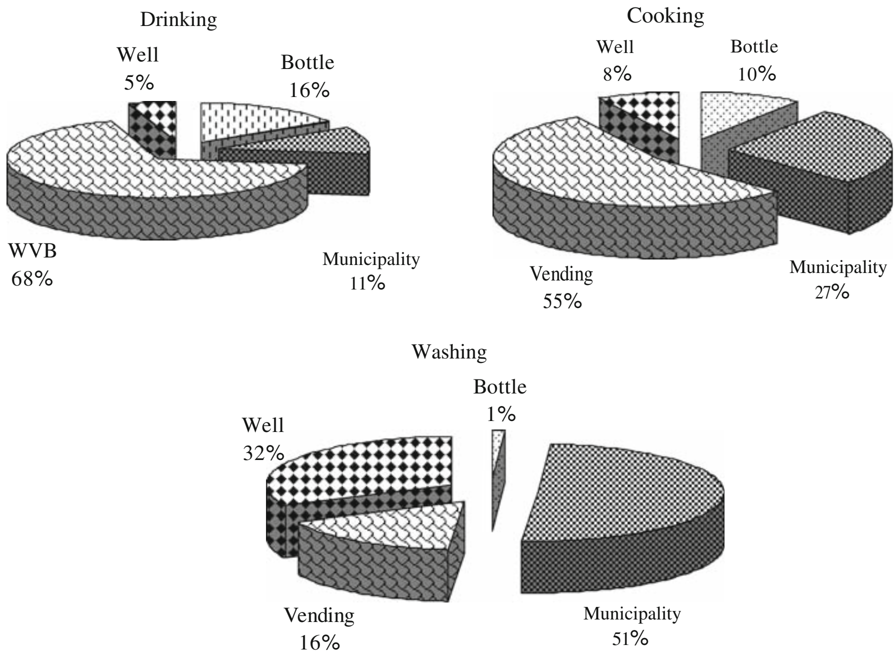
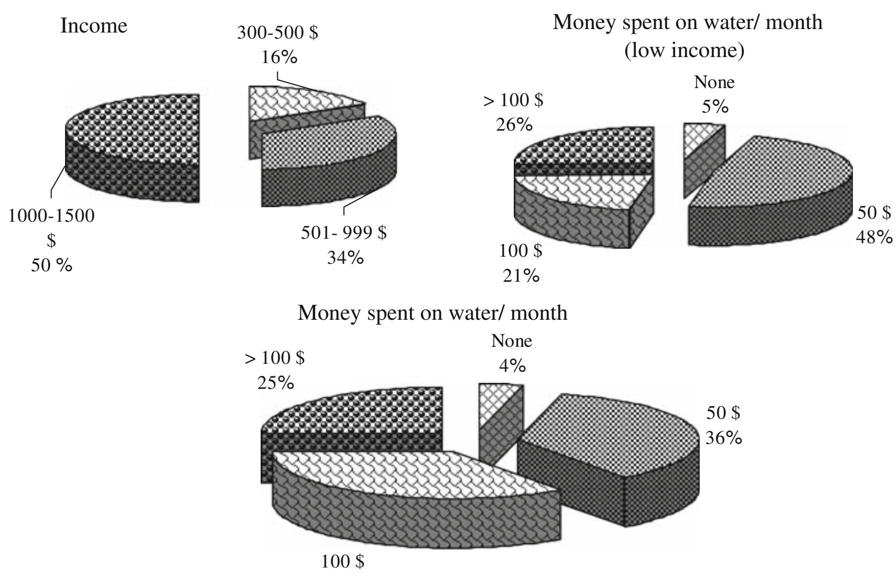


Fig. 4 Domestic water expenditure profile



the perceived low water quality that reflects on the additional financial burden of low income citizens.

Prevalence of disease

Due to the deficiency in the disease registry, the study depended on the prevalence of water-borne diseases as reported in the community survey. The survey revealed that 25% of the sample population experienced vomiting and/or diarrhea because of the water and 19% had a skin rash. For the sample population that had been sick, the cross-tabulation between sickness (vomiting and/or diarrhea) and the type of water used showed that 56% of the responses related it to the municipality water and 44% to the vended water. The cross-tabulation of skin rash with washing showed that 62% of the responses related it to well water, 30% to municipality water and 8% to vended water. Moreover, a statistically significant correlation was observed between sickness and well water ($r = 0.78$, $P < 0.01$) and between sickness and vended water ($r = 0.62$, $P < 0.05$).

Provision of safe domestic water: intervention plan

Based on the results of the study, it is evident that the situation is deteriorating at a fast pace. It is essential to intervene to secure provision of safe domestic water, halt the deterioration in the quality of ground water aquifers and control the mushrooming of the improperly controlled and monitored water vending. The proposed intervention plan to secure a safe domestic water supply relates to the upgrade of the water quality profile and consumer awareness as illustrated in the flow chart (Fig. 5).

Upgrade water quality profile

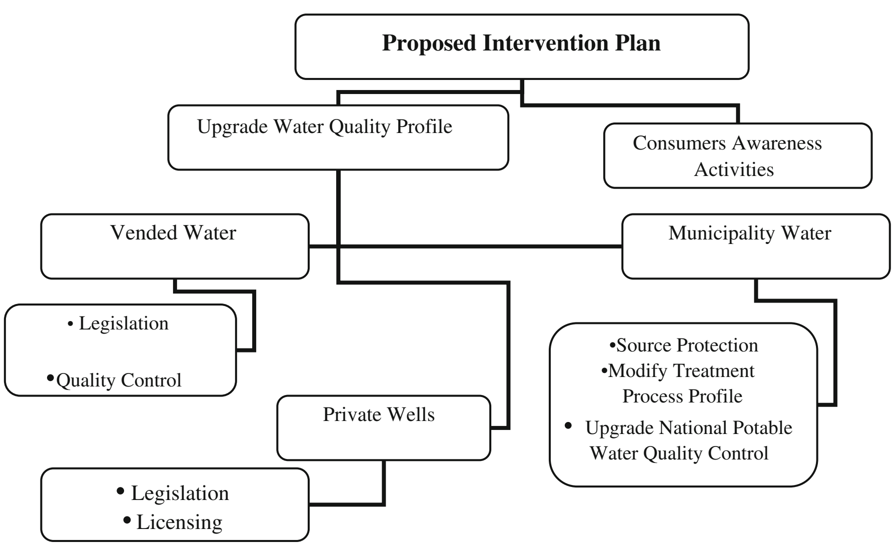
The water quality profile of the three major types of water used at the household level should be properly assessed, managed and upgraded, to ensure chemical and microbiological adequacy.

Vended water source

The problem of water vending is mushrooming in the absence of any type of efficient control. To achieve quality control of this sector, which is becoming a major environmental risk, the following should be undertaken:

- Development of guidelines for licensing this water sector (administrative and quality control jurisdiction). An attempt to regulate this sector was initiated in 1976 (Basma 2004). But the major limitation is enforcement of legislation.
- Initiation and implementation of quality-control monitoring activities by the proper ministry (Ministry of Public Health).
- Capacity building and resource allocation of the Ministry of Public Health to handle this challenge.
- Sustaining quality control based on Natural Guidelines and Standards for potable water.

Fig. 5 Flow chart of the proposed interventions plan for provision of safe domestic water



- Sustaining enforcement of regulations governing this sector.

Municipality water

At present the priorities for management and safe domestic water supply by official authorities should relate to the:

- Source protection: securing the lack of exposure of fresh water sources to quality deterioration as a result of haphazard management of municipal solid wastes, hazardous wastes and waste water. Between 1992 and 2004, the Council of Development and Resources (CDR) contracts awarded in the water supply sector amounted to around $535 million; only $11.5 million (2.1%) was allocated to water resource protection works (CDR 1998). Recommending more protection is necessary.
- Devising policies and plans for integrated management of solid waste to become an integral part within the national water management plan. At present the Ministry of Environment is working on a national plan for the management of domestic wastes (El Ard 2007, personal communication on Solid Draft Law). A number of projects have been implemented or are in the process of being implemented for the development of wastewater treatment facilities throughout the country. The major requirement is securing resources (mandatory and non-mandatory) to ensure the operation and maintenance of the plants. Involving municipalities in this process will enhance environmental impacts.
- Modify water treatment facilities processes to be able to cope with increased level of total organic content and water quality deterioration due to wastewater infiltration. This can be achieved through:

  (a) Short term, which involves:

    - Active proper coagulation processes to handle the wastewater intrusion.
    - The addition of activated carbon beds as part of sand filters to reduce the total organic carbon content of water to avoid problems when applying chlorination (trihalomethane production).

  (b) Long term, which involves:

    - Adopting the method of reverse osmosis to decrease on the overall mineral resulting from seawater intrusion.
    - Upgrading the existing National Water Quality Control Program. At present, the quality program is carried by the Ministry of Energy and Water. There is a need to upgrade and automate the system to develop a sufficient quality base for all water resource feeding networks. The Ministry of Public Health should monitor the water quality at the consumer level. The World Health Organization is currently helping the Ministry of Public Health to initiate such programs. However, sustainability of such programs remains the major challenge.

Private wells

The deterioration in the quality of well water requires an immediate intervention in the following areas:

- Regulate the use of private wells to reduce water deterioration by seawater infiltration. In 1967, the Lebanese Government legislated a law (86/87, December 28) that prohibits ground water exploitation for private usage in Greater Beirut. This law was never implemented. Mechanism for the implementation of the legislation from the respective authorities (Ministry of Energy and Water—MEW) should be addressed and be of high priority in the management and protection plans of water resources. As a whole, for Lebanon, the licensing of private well drilling should be approved based on the adequacy and quality of water, number of wells in the area and abstraction rate.
- Set strict enforcement on the permissible abstraction rate.
- Adopt water metering systems and pricing for private well water utilization.

Consumer awareness

The importance of consumer awareness is crucial. The lack of trust in supplied domestic water leads consumers to use compensatory water sources that are neither safe nor cheap. As such, the concept of water quality and its link to water-borne diseases should be made clear to the end user (Ministry of Public Health and Ministry of Environment). This can be attained by:

- Preparing short educational messages.
- Assuring transparency in the management system to ensure that consumers have access to quality-control activities conducted by official bodies.
- Building trust in domestic the water supply based on documented profiles.
- Motivating NGOs in consumer awareness programs.
- Instructing consumers on how to handle water quality problems in case of emergency.
- Instructing consumers on simple methodologies to ensure safe microbiological water quality.

Conclusion

Achieving water and sanitation millennium goals in developing countries is crucial for sustainable development. Meeting this challenge necessitates the development of integrated management of water resources. The results of the study emphasize the importance of water resource assessment to sustain the provision of adequate safe drinking water. Initiating and sustaining these activities will protect and promote public health, reduce disease burden and achieve socioeconomic growth and development.

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