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Health Implications for Children in Wastewater-Irrigated Peri-Urban Aleppo, Syria

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Abstract Despite widespread irrigation with diluted, untreated, or partially treated wastewater in developing countries, health implications of such irrigation on children living in wastewater-irrigated area have rarely been addressed. In a survey study, we investigated health implications of wastewater irrigation on children (8–12 years) in peri-urban Aleppo region, Syria. Six villages were selected within wastewater-irrigated area and six from freshwater-irrigated area. In consultation with the health officials and medical practitioners, two waterborne diseases (typhoid fever and gastroenteritis) and three non-waterborne diseases (flu, chickenpox, and strep throat) were selected along with eczema that may stem from watery or non-watery sources. Flu and strep throat had significantly higher prevalence rates in freshwater-irrigated area than those in wastewater-irrigated area while reverse was the case for gastroenteritis and eczema, i.e. significantly higher prevalence rates in wastewater-irrigated area. The prevalence rates of typhoid and chickenpox in both areas were low with non-significant differences between freshwater and wastewater areas. The annual health cost per child was 73 % higher in wastewater area than the health cost for the same age group in freshwater area. These findings suggest the need for hygiene education and an action plan that would help improving water quality and promoting the use of protective measures in handling wastewater and/or its products.

Keywords Water quality · Water reuse · Human health · Waterborne diseases · Non-waterborne diseases · Mediterranean region · Health cost

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Introduction

Water scarcity in dry areas has driven the farmers to use alternative water supplies to support irrigated agriculture (Friedel et al. 2000; Bradford et al. 2003; Toze 2006). The use of marginal-quality water resources such as urban wastewater has crucial importance for irrigation under water-limited conditions (Yoon et al. 2001; Qadir and Oster 2004; Qishlaqi et al. 2007; Murtaza et al. 2010). Wastewater is a reliable and often the only water source available for irrigation throughout the year under certain dryland conditions (Lazarova and Bahri 2005; Qadir et al. 2007a; Simmons et al. 2010).

Since urban wastewater contains a variety of pollutants, it needs adequate treatment before being used for irrigation or environmentally safe disposal (Ayers and Westcot 1985; Pettygrove and Asano 1985; Pescod 1992; Murtaza et al. 2010). Most developing-country governments have insufficient financial resources to treat urban wastewater (IWMI 2003; Minhas and Samra 2004; Scott et al. 2004; Qadir et al. 2007b). Wastewater treatment plants in most cities of the developing countries are non-existent or function inadequately.

In addition to limited investments in wastewater treatment, the lack of enforcement of environmental policies drives wastewater irrigation in most developing countries in untreated, partly-treated and/or diluted forms (Qadir et al. 2010). The use of wastewater in such forms in irrigated agriculture may pose potential environmental and health risks. Previous studies have shown a range of food safety and health risks stemming from vegetable or fruit crops irrigated with raw wastewater (Fattal et al. 1986; Birley and Lock 1999; Qadir et al. 2000; Steele and Odumeru 2004). Most farmers and some government agencies are not fully aware of these impacts.

Being the most vulnerable part of the communities in wastewater-irrigated areas, children raised in areas irrigated with raw wastewater may be at risk with greater possibility of suffering from waterborne diseases (Habbari et al. 1999; Lekouch et al. 1999). Waterborne diseases, such as diarrhea, originated from untreated wastewater or partially treated wastewater has affected children in several parts of the world (Harpham and Tanner 1995; Haller et al. 2007; Opryszko et al. 2010). The results of a survey study (Al-Salem and Abouzaid 2006) demonstrated that a large majority of the male schoolchildren (97 %) between the ages of 7 and 12 years in Afghanistan had prevalence of ascariasis. In the case of female schoolchildren within the same age group, the prevalence of ascariasis was found to be 80 %. Habbari et al. (1999) revealed that the prevalence of intestinal helminthic infections caused by five parasites (*Ascaris lumbricoides*, *Trichuris trichiura*, *Enterobius vermicularis*, *Hymenolepis nana* and *Taenia saginata*) in children living within wastewater-irrigated area was 31 % compared to only 6 % among children living in the control areas.

Although health implications of wastewater use have been the subject of several studies around the world for several years (Birley and Lock 1999; Qadir et al. 2000; Sedki et al. 2003; Ikehata and Pui 2008), fewer studies have been undertaken in developing countries, particularly comparing farming communities in wastewater- and freshwater-irrigated areas under similar agro-climatic conditions and farming practices (Fattal et al. 1986; Steele and Odumeru 2004; Van Der Hoek et al. 2005). In addition, health implications from uncontrolled wastewater irrigation in developing countries on a particular bulk of the population, such as children, have not been investigated and virtually no data is available on such fraction of the communities living in wastewater-irrigated area.

We undertook a survey study to investigate health implications of wastewater irrigation on children (8–12 years) in the peri-urban area of Aleppo in Syria where wastewater irrigation is a common practice. We selected six villages within wastewater-irrigated area and the same number of villages where freshwater (groundwater) is used for irrigation. In consultation with the district health officials and private medical practitioners to learn about disease occurrence in the area, a survey questionnaire was prepared and used for both wastewater- and freshwater-irrigated areas. The results of this study are presented here.

Materials and Methods

Study Area

In response to freshwater scarcity, farmers in peri-urban areas in Syria are irrigating with wastewater. This practice has served two purposes: (1) contribution to developing Syria's economy since freshwater could be used in domestic and industrial sectors; and (2) increase in water availability for farmers at a low cost. Currently, urban wastewater production in Syria is estimated to be more than 1300 million cubic meters per year. With access to diluted, untreated, or partially treated wastewater, farmers practice wastewater irrigation in Syria because: (1) wastewater is a reliable or often the only water source available for irrigation throughout the year; (2) wastewater irrigation often reduces the need for fertilizer application as it is a source of nutrients; (3) wastewater pumping from wastewater channel involves less energy cost than pumping deep groundwater; and (4) wastewater generates additional benefits such as greater income generation from crop intensification and diversification, which create year-round employment opportunities (Sato 2010).

The study site was in peri-urban area of Aleppo (Arabic name: *Halab*), which is one of the oldest continuously inhabited city in the world, dating back early second millennium BC. The city grew from its early origins as a major trading hub on the "Silk Road" to become the modern administrative and economic center of northern Syria. Currently, Aleppo is the second largest city of Syria. Wastewater collected from the urban settings of Aleppo is treated in a wastewater treatment plant, Wastewater Treatment Plant (WWTP) of Aleppo. After treatment, it is delivered to Qweik River, a small river which was used to carry freshwater from Turkey until the 1970s. In addition, freshwater from the Euphrates canal is also added to the river to further improve the wastewater quality during dry season (Fig. 1). While the treated wastewater flows through the river, surrounding areas are still not connected to sewer systems. The untreated wastewater from such surrounding areas is discharged into the tributaries of Qweik River or directly into the river. In addition, there are some small industries along the river that dispose of their wastewater into the river. In practice, the treated wastewater in Qweik River later turns into a domestic-industrial, treated-untreated, diluted-undiluted, mixed wastewater. The farmers along Qweik River pump wastewater from the river for surface irrigation of a range of crops.

The peri-urban area around Aleppo was selected as the study site where farmers irrigate with two distinct types of water resources, urban wastewater from Aleppo city carried by Qweik River and freshwater (groundwater). Wheat, sugar beet, and cotton are the major crops grown in freshwater-irrigated area where the major irrigation systems are drip

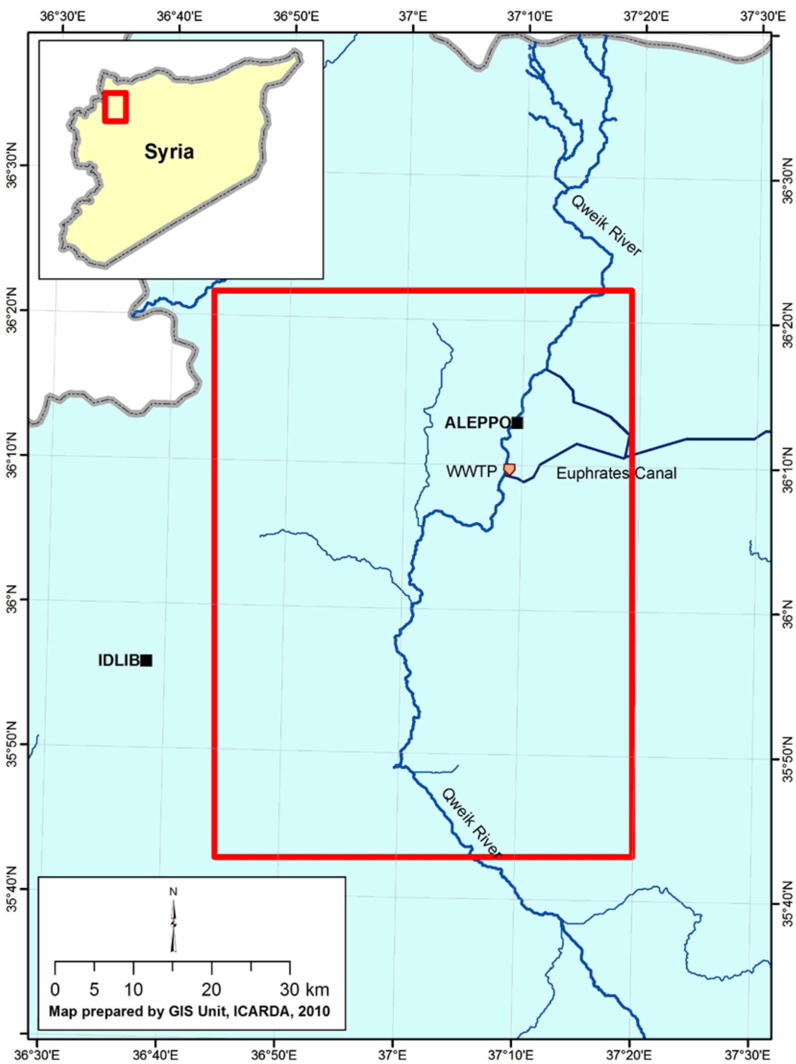

Fig. 1 Peri-urban area of Aleppo, where farmers practice wastewater irrigation to grow a range of crops

and sprinkler. In addition to these crops, vegetables are also grown in wastewater-irrigated area where irrigation is undertaken through flood and drip irrigation systems.

Selection of Villages for Survey

Six representative villages were selected in the wastewater-irrigated area (Al Wdayhi, Khane Tomane, Al-Hader, Al-Eiss, Jezraya, and Tell Mamo) and the same number of representative villages where freshwater (groundwater) is used for irrigation (Al-Jyna, Abeyn, Tel Hadya, Xcebia, Kosnya, and Al-Ousmania). Wastewater-irrigated villages were located along the wastewater-carrying Qweik River. Freshwater-irrigated villages, on the other hand, were using only groundwater for irrigation. There was no wastewater available or accessible in the freshwater-irrigated area.

In the wastewater-irrigated area, villages were selected at three sections—upstream, midstream, downstream—of Qweik River to cover the whole 45-km long wastewater carrier. Two villages from each section were selected. The upstream villages were Al-Wdayhi and Khane Tomane, the midstream villages were Al-Hader and Al-Eiss, and Jezraya and Tell Mamo were the downstream villages. In the case of freshwater-irrigated area, six villages practicing groundwater irrigation were selected randomly.

A qualitative method was used to collect health-related information. Data were collected from questionnaire based on interviews with the farming communities (a child of 8–12 years age and an elder family member, usually father). A community facilitator from the International Center for Agricultural Research in the Dry Areas (ICARDA) was involved in each interview to facilitate communication considering the sensitive nature of the questions and the language barrier. In addition to evaluating the distribution of certain diseases in children within wastewater- and freshwater-irrigated areas, the questionnaire also included investigation on the annual health cost per child as well as visits to a nearby government medical center and/or private medical practitioner for consultation and medical treatment.

Survey Sampling Method, and Data Collection and Analysis

To have a representative sample from each village, the village size and the number of inhabitants were taken into consideration. For all the villages, a random sample of families, having children between 8–12 years, was chosen. This age limit was considered based on the earlier consultations with the district health officials, private medical practitioners and pharmacists, and pre-testing of the questionnaire suggesting that children between 8–12 years usually play in the agricultural fields in the study area. The number of samples/children per village was proportional to the number of inhabitants per village. Therefore, the number of children included in the study differed from village to village. However, the total number of children was 40 from each irrigation scheme (wastewater or freshwater). In the case of 40 samples from wastewater-irrigated area, the number of survey interviews (reported in parentheses) within each village was: Al-Wdayhi (6), Khane Tomane (4), Al-Hader (15), Al-Eiss (8), Jezraya (4), and Tell Mamo (3). In the case of freshwater-irrigated area, the number of survey interviews within each village was: Al-Jyna (8), Abeyn (12), Tel Hadya (7), Xcebia (3), Kosnya (6), and Al-Ousmania (4).

In consultation with the district health officials, private medical practitioners and pharmacists, two waterborne and three non-waterborne diseases were selected as common diseases in and around the study area. The waterborne diseases investigated were typhoid fever and gastroenteritis. The non-waterborne diseases consisted of flu, chickenpox, and strep throat. In addition, eczema, a disease that may or may not be waterborne, was included in the study. The English names of the diseases were translated into Arabic language in order to facilitate communication and interview process. Due to the cultural norms in these settlements, all the interviews were conducted in a familiar setting at or near their homes. The survey team had to spend considerable amount of time (45–60 minutes per interview) to explain the objectives of the study and convince the households, particularly in wastewater-irrigated area, to become part of the study and to communicate on the questions to be asked. Thereafter, the people interviewed did not have major problems of communication and responded to the questions with high level of confidence. Hammal et al. (2005) used similar methodology when they investigated the environmental conditions and health status of residents in the peri-urban settlements of Aleppo resulting from mass rural-to-urban migration and uncontrolled urban population growth in developing countries such as Syria.

The data collected based on respondents' feedback was organized on the basis of the number of children affected by a specific disease in each village of the wastewater- and freshwater-irrigated area. This was followed by computing the number of children affected by a specific disease in wastewater- or freshwater-irrigated area. In the case of wastewater-irrigated area, data were also separated for the upstream, midstream, and downstream villages.

The disease incidences (presence and absence) and the playing habits/practices are binomial random variables and were analyzed by fitting the communities (i.e. wastewater and freshwater areas) effects using a generalized linear model with binomial errors and logit link function. Using the subset of data from the wastewater area, the stream effects were also fitted using such a generalized linear model. The cost data in US$ were analyzed to compare the community effects linear model based on normal errors. The estimates of prevalence rates for disease incidences and the playing habits/practices, and means for the costs were computed along with confidence intervals. The significance of difference between the communities and the streams for various variables were expressed as their p-value (the probability of observing more extreme data in absence of true difference between their prevalence rates) to indicate the level of significant difference. The computations were performed using Genstat software (Payne 2011).

Results and Discussion

Prevalence Rates of Diseases in Wastewater and Freshwater Areas

Non-waterborne diseases investigated in this study—flu, chickenpox, and strep throat—are common among children in southern Mediterranean countries such as Syria and are not usually related to a specific country or environment. The results presented in Table 1 for non-waterborne diseases reveal prevalence rate of 1.00 in case of flu for children in freshwater-irrigated area and 0.90 for children in wastewater-irrigated area, i.e. all children in freshwater-irrigated area were affected by flu while 9 out of 10 children in wastewater-irrigated area have had flu. The prevalence rate for strep throat in freshwater-irrigated area was 0.98 while it was 0.78 in the case of wastewater-irrigated area. The feedback from the district health officials and farmers around the study area also confirmed that flu and strep throat are common among children within and around the study areas regardless of the source of irrigation water. Contrary to large number of children affected by flu and strep throat in both the areas, few were reported to have chickenpox, i.e. prevalence rate of 0.05 in freshwater and 0.08 in wastewater area. The statistical analysis revealed significant differences between freshwater- and wastewater-irrigated areas for prevalence rates of flu ($p = 0.016$) and strep throat ($p = 0.004$). However, there were non-significant differences between freshwater- and wastewater-irrigated areas for prevalence rates of chickenpox ($p = 0.643$).

Table 1 Estimated prevalence rates (PR), estimated standard error (ESE), 95 % confidence intervals (Lower and Upper) for PRs, and level of significance (p-value) for various diseases in children in wastewater- and freshwater-irrigated areas

Disease	Wastewater-irrigated area				Freshwater-irrigated area				p-value[a]
	PR	ESE	Lower	Upper	PR	ESE	Lower	Upper	
Flu	0.90	0.047	0.81	0.99	1.00	0.000	1.00	1.00	< 0.016
Chickenpox	0.08	0.042	0.00	0.16	0.05	0.034	0.00	0.12	0.643
Strep throat	0.78	0.066	0.65	0.90	0.98	0.024	0.93	1.00	0.004
Gastroenteritis	0.75	0.068	0.62	0.88	0.13	0.052	0.02	0.23	< 0.001
Typhoid	0.10	0.047	0.01	0.19	0.03	0.025	0.00	0.07	0.152
Eczema	0.43	0.078	0.27	0.58	0.03	0.025	0.00	0.07	< 0.001

[a] p-value is probability of observing more extreme than their observed difference in the prevalence rates of freshwater and wastewater areas under the hypothesis that there is no difference in their true prevailing rates

In the case of waterborne diseases, there were large differences for prevalence rates of gastroenteritis in children living in freshwater-irrigated area (0.13) compared to wastewater-irrigated area (0.75) (Table 1). While investigating the risk of *Ascaris lumbricoides* infection and diarrheal disease associated with wastewater reuse in Mexico, Blumenthal et al. (2001) found greater risk of *Ascaris lumbricoides* infection and diarrheal disease in wastewater-irrigated area than control group (no wastewater irrigation), particularly in children aged < 5 years; the effects were stronger in the dry than in the rainy season.

In the case of typhoid, prevalence rate of 0.03 was found in freshwater-irrigated area and 0.10 in wastewater-irrigated area. In terms of the ratio between wastewater and freshwater areas for the intensity of prevalence rates in children, the following pattern was observed: gastroenteritis (6 : 1) > typhoid (3:1). Based on the average, the children living in a wastewater-irrigated environment have had 4 times greater prevalence rate for the investigated waterborne diseases than those with their age group living in freshwater-irrigated area. The statistical analysis revealed significant differences between freshwater- and wastewater-irrigated areas for prevalence rates of gastroenteritis ($p = 0.001$). However, there were non-significant differences between freshwater- and wastewater-irrigated areas for prevalence rates of typhoid ($p = 0.152$).

Eczema is a disease that may stem from watery or non-watery sources. The results presented in Table 1 for prevalence rates of eczema in children reveal large difference between wastewater- and freshwater-irrigated areas, i.e. 0.43 in wastewater-irrigated area while only 0.03 in freshwater-irrigated area ($p = 0.001$). These results suggest that the children living in an environment surrounded by wastewater irrigation appeared to be at risk. This may be attributed to some external factors around the wastewater area, influencing the risk of eczema. The presence of small industries along the Qweik River and the pumping of treated-untreated mixed wastewater from the river to irrigate the crops may have increased the possibility of eczema in children commonly playing in the wastewater-irrigated fields and occasionally taking bath in the river.

Studies undertaken in Cambodia (Van Der Hoek et al. 2005) have indicated possible association between exposure to wastewater and skin problems, such as eczema, among the people exposed to urban wastewater. About 22 % of the households engaged in the cultivation of aquatic vegetables in a lake contaminated by untreated wastewater reported to have skin problems. Contrasting this, only 1 % of the households living around the lake with no wastewater contact reported to have skin problems. The cause of the skin problems was not determined but was likely due to a mixture of both chemical and biological agents in untreated wastewater.

Prevalence Rates of Waterborne Diseases Along the Wastewater Channel

The distribution of waterborne diseases along the passage of wastewater channel was also investigated in this survey study. This was done by separating the results on disease prevalence in villages along Qweik River at three sections: upstream, midstream and downstream. A cross-tabulation of the location of villages and the distribution of waterborne diseases illustrated that the children living in upstream area had the highest prevalence rate of gastroenteritis (0.90) followed by children living in villages located in midstream (0.78) and downstream (0.43) areas. In the case of typhoid in wastewater-irrigated area, only 10 % of children in the upstream area (prevalence rate = 0.10) and 13 % children living in mid-stream area (prevalence rate = 0.13) were affected, while no child was reported to be affected by typhoid in the downstream area (Table 2). The statistical analysis revealed non-significant differences between the stream locations for prevalence rates of gastroenteritis ($p = 0.089$) and typhoid ($p = 0.429$). These results suggest that there was no significant effect of the location in the wastewater-irrigated

Table 2 Estimated prevalence rates (PR), estimated standard error (ESE), 95 % confidence intervals (Lower and Upper) for the PRs, and level of significance (p-value) for various diseases in children along the passage of wastewater channel, Qweik River, at three sections: upstream, midstream, downstream

Disease	Stream section	PR	ESE	Lower	Upper
Gastroenteritis	Upstream	0.900	0.09480	0.7142	1.0858
	Midstream	0.783	0.08600	0.6140	0.9512
	Downstream	0.429	0.18700	0.0620	0.7952
	p-value[a]	0.089			
Typhoid	Upstream	0.100	0.09487	0.0000	0.2859
	Midstream	0.130	0.07022	0.0000	0.2681
	Downstream	0.000	0.00192	0.0000	0.0038
	p-value[a]	0.429			

[a] p-value is probability of observing more extreme than their observed difference in the prevalence rates of freshwater and wastewater areas under the hypothesis that there is no difference in their true prevailing rates

Table 3 Estimated annual health cost per child, estimated standard error (ESE), level of significance (p-value) and 95 % confidence intervals (Lower and Upper) for health cost in the wastewater- and freshwater-irrigated areas

Cost type	Water type	Cost (US$)[a]	ESE	Lower	Upper
Physician cost	Freshwater	12.3	1.76	8.9	15.7
	Wastewater	23.0	1.76	19.5	26.4
	p-value[b]	< 0.001			
Medicine cost	Freshwater	26.4	1.64	23.2	29.7
	Wastewater	44.1	1.64	40.9	47.3
	p-value[b]	< 0.001			
Total cost	Freshwater	38.7	2.95	33.0	44.5
	Wastewater	67.1	2.95	61.3	72.8
	p-value[b]	< 0.001			

[a] Health costs converted from Syrian Pound (SP) to US dollars are based on the currency exchange rate (US$ 1 = 46 SP) in the year 2010 when the survey study was undertaken

[b] p-value is probability of observing more extreme than their observed difference in the health costs under freshwater and wastewater situations when there is no difference in their true health costs

area for the prevalence of waterborne diseases investigated in this study.

The results in terms of stream effect are in line with the water quality data at different stream sections of Qweik River for parameters such as fecal coliform and *Escherichia coli*. A fecal coliform is a facultative-anaerobic, rod-shaped, gram-negative, non-sporulation bacterium. In case of high levels of fecal coliform, there may be an elevated risk of waterborne gastroenteritis. Categorized as a gram-negative, rod-shaped bacterium, *Escherichia coli* can cause serious food poisoning in humans. Waterborne transmission of *Escherichia coli* may occur through swimming in contaminated water, drinking water mixed with wastewater, and eating contaminated food. Algal organic matter may provide a good nutritional source for bacterial growth and better maintenance of *Escherichia coli* cultivability (Bouteleux et al. 2005). The monthly average level of fecal coliform in Qweik River water was $20.3 \times 10^5/100$ mL at upstream, $16.8 \times 10^5/100$ mL at midstream, and $10.8 \times 10^5/100$ mL at downstream. The levels of *Escherichia coli* in Qweik River water followed similar pattern: $47.6 \times 10^5/100$ mL at upstream, $44.9 \times 10^5/100$ mL at midstream, and $23.7 \times 10^5/100$ mL at downstream.

Health Costs and Risks

In addition to evaluating the distribution of certain diseases in children within wastewater- and freshwater-irrigated areas, the annual health costs per child were also computed based on the feedback from the relevant households. Data presented in Table 3 suggest that wastewater-irrigating communities had annual spending in the range of US$ 61.3 to

Table 4 Estimates of playing habit rates (PHR) of children, estimated standard error (ESE), 95 % confidence intervals (Lower and Upper), and significance level (p-value) for various playing habits and practices of children in wastewater- and freshwater-irrigated areas

Playing habit/practice	Wastewater-irrigated area				Freshwater-irrigated area				p-value[a]
	PHR	ESE	Lower	Upper	PHR	ESE	Lower	Upper	
Play at home	0.85	0.0565	0.739	0.961	0.98	0.0244	0.927	1.000	0.038
Play at field	0.85	0.0565	0.739	0.961	0.98	0.0244	0.927	1.000	0.038
Swimming	0.30	0.0722	0.158	0.442	0.55	0.0786	0.396	0.704	0.023
Eating raw vegetables	0.75	0.0684	0.616	0.884	0.75	0.0684	0.616	0.884	1.000

[a] p-value is probability of observing more extreme than their observed difference in the PHRs of freshwater and wastewater areas under the hypothesis that there is no difference in their true PHRs

72.8 per child while the corresponding health cost per child in the case of freshwater-irrigating communities was US$ 33.0 to 44.5. On the average, the annual health cost per child in wastewater-irrigated area was US$ 67.1, which was almost 73 % higher than the annual health cost per child (US$ 38.7) in freshwater-irrigated area. In terms of cost distribution between physician and medicine costs in wastewater area, the average costs for physician and medicine were US$ 23.0 and 44.1, respectively. For the freshwater area, the average costs for physician and medicine were US$ 12.3 and 26.4, respectively. The differences between wastewater and freshwater areas for physician and medicine costs as well as total health related costs were statistically significant.

Although the health cost in the wastewater-irrigated area is almost 73 % higher than in the freshwater-irrigated area, the farmers from wastewater-irrigated area still use wastewater irrigation because of the perceived overall economic gains in the form of less or no expenses on fertilizer purchase and field application, less energy cost in wastewater pumping, and additional benefits through greater income generation from crop intensification and diversification (Sato 2010). The additional expenses on health are counterbalanced by just a part of the additional economic benefits from agriculture produce in wastewater-irrigated areas. Earlier investigations on evaluating economics of wastewater and freshwater irrigation reveal that the crops irrigated with wastewater gave substantially higher returns on investment than crops irrigated with freshwater (Qadir 2008). For wheat, the returns were US$ 5.31 (wastewater irrigation) versus 2.34 (freshwater irrigation) for each dollar invested, because of a combination of three factors in wastewater-irrigated area: higher yield, elimination or minimization of fertilizer costs (US$ 95 per ha), and lower pumping costs for wastewater from nearby channel.

Among the playing habits of the children, almost all children (98 %) living in a freshwater-irrigated area play at home and in the field while 85 % of the children in wastewater-irrigated area do the same. Interestingly, the children from both areas had similar eating habits, i.e. there was no difference in terms of eating raw vegetables from the field; 75 % of the children eat raw vegetables from the field (Table 4). The major difference rests with swimming activity. There is a greater tendency of freshwater irrigating communities to swim than the wastewater irrigating communities, i.e. 55 % versus 30 %. This difference stems from the fact that the children in freshwater irrigating area swim in pools filled with pumped groundwater while the children in wastewater irrigating area swim directly in the Qweik River, which carries wastewater.

In wastewater-irrigated area, children going to the field to play or work with their parents seem to have a higher risk of getting sick than the children playing in other places. Moreover, the children in direct contact with the water, such as swimming in the Qweik River, would have a much higher probability of getting a waterborne disease than those swimming in groundwater-pumped swimming pools.

Conclusions

Following are the conclusions based on the results of this study:

1. Among non-waterborne diseases investigated, flu and strep throat had significantly higher prevalence rates in children living in freshwater-irrigated area than those in wastewater-irrigated area. However, there were non-significant differences between freshwater- and wastewater-irrigated areas for prevalence rates of chickenpox.
2. In the case of waterborne diseases, there were large differences for prevalence rates of gastroenteritis, i.e. children living in freshwater-irrigated area had significantly lower prevalence rates than those in wastewater-irrigated area. For typhoid, the prevalence rates in both areas were low with non-significant differences.
3. For eczema, the prevalence rates in wastewater- and freshwater-irrigated areas had large differences, i.e. 0.43 in wastewater area while only 0.03 in freshwater area.
4. In terms of the distribution of waterborne diseases along the passage of wastewater channel, there was no signifi-

cant effect of the location in the wastewater-irrigated area for the prevalence of waterborne diseases.

5. The annual health cost per child in wastewater-irrigated area was 73 % higher than the annual health cost per child in freshwater-irrigated area. Despite this higher cost, the farmers in wastewater-irrigated area rely on wastewater irrigation because of the perceived overall economic gains in the form of less or no expenses on fertilizer purchase and field application, less energy cost in wastewater pumping, and additional benefits through greater income generation from crop intensification and diversification.
6. There is a need for the consideration of hygiene education and an action plan supported by pertinent policies that would help improving water quality and promoting the use of protective measures in handling wastewater and/or its products, along with minimum effects on the economic benefits of the farmers in wastewater-irrigated areas.

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