Irrigated urban vegetable production in Ghana: microbiological contamination in farms and markets and associated consumer risk groups

P. Amoah, P. Drechsel, R. C. Abaidoo and M. Henseler

ABSTRACT

Ghana is a typical low-income sub-Saharan African country facing significant sanitation challenges. In Ghana, fresh salads are not part of the normal diet, but have become a common supplement to urban fast food served in streets, canteens and restaurants. In Accra, about 200 000 people consume from such supplements every day. The figure also describes the size of the risk group from contamination, which comprises all income classes including the poor and children. The purpose of this study was to investigate widespread water pollution in urban and peri-urban areas, where 95% of the lettuce consumed in the city is produced. Over 12 months (April 2004–June 2005), lettuce samples from the same production sites in two cities were followed and analyzed along the "farm to fork" pathway for total and faecal coliform (FC) and helminth egg numbers. Questionnaire surveys were conducted among producers, sellers and consumers to quantify lettuce flows to the final risk group. The study identified the farm as the main point of lettuce contamination. Besides the irrigation water, contamination was also attributed to manure application and already contaminated soil. Despite poor sanitary conditions in markets, post-harvest handling and marketing did not further increase the farm-gate contamination levels. To reduce the health risk associated with the consumption of contaminated lettuce; safer farming and irrigation practices are required while the remaining risk could best be addressed where lettuce is prepared for consumption.

Key words | coliforms, Ghana, helminthes, lettuce, urban agriculture, wastewater

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INTRODUCTION

In most urban centers in sub-Saharan Africa (SSA), sanitation infrastructure is poor or inappropriate to cope with the urbanization rate. In the typical example of Ghana, only 4–5% of the population is linked with – infrequently functional – sewage systems and sewerage treatment plants. Most untreated wastewater ends up in stormwater gutter, streams and other water bodies (Keraita *et al.* 2002).

Urban and peri-urban (UPA) vegetable farmers in search of water for their crops have no other choice than to use water from these highly polluted sources. This raises public health concerns due to possible crop contamination with pathogens where vegetables are eaten uncooked (Amoah *et al.* 2006), while contamination through heavy metals appears to be less an issue, at least in Ghana (Mensah *et al.* 2001).

As a better wastewater treatment is not likely in the near future and authorities start to respect farmers' and traders' livelihoods and contribution to the city, alternative strategies for health risk reduction are looked for. This requires identifying (a) where and how (much) contamination occurs along the production–consumption pathway, and (b) who finally consumes the contaminated crops, i.e. the risk group. This paper reports the results from a corresponding study, carried out under the sister projects CP38

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and CP51 of the Consultative Group of the International Agricultural Research (CGIAR) Challenge Program for Water and Food. The study focuses on lettuce, a non-indigenous "exotic" vegetable in West Africa. Lettuce is consumed uncooked and, as an easily perishable crop, it is produced mostly in urban and peri-urban agricultural sites as facilities for cool transport and storage are still lacking in large parts of sub-Saharan Africa.

METHODOLOGY

Background of study areas

The study was conducted in the Ghanaian cities of Accra and Kumasi (Figure 1). In Accra, between 47–162 ha are cultivated with vegetables ("urban agriculture"), with the higher figure occurring in the dry season. In Kumasi, about 40 ha are cultivated throughout the year. The production takes place on some 5–8 major open spaces per city, usually along urban streams or drains or in inland valleys. In both cities, there are also 3–5 larger markets and a significant number of community or neighborhood markets, often specialized in vegetables and fruits. In this study, two major irrigated vegetable production sites were selected per city for sampling. Selection criteria were irrigation water sources and the type of vegetables grown (i.e. lettuce). The sites in Accra used water from drains and streams while those in Kumasi used water from streams or shallow wells close to streams of inland valleys. At least one of the two sites in each city had a group of farmers using piped water as an irrigation water source over a period of at least three years. All the sites had similar land use history in terms of continuous vegetable cultivation and the use of poultry manure as the preferred fertilizer source for at least five years.

Contamination pathway study

Two surveys in Accra and Kumasi were carried out along the contamination pathway from farm to consumer. The first survey was conducted from 2003 to 2004, and addressed 886 randomly selected farmers, wholesale and retail sellers, food vendors and consumers of irrigated vegetables in both cities. Structured and semi-structured questionnaires, also with open-ended questions, were used to gather information on the agronomic practices, handling

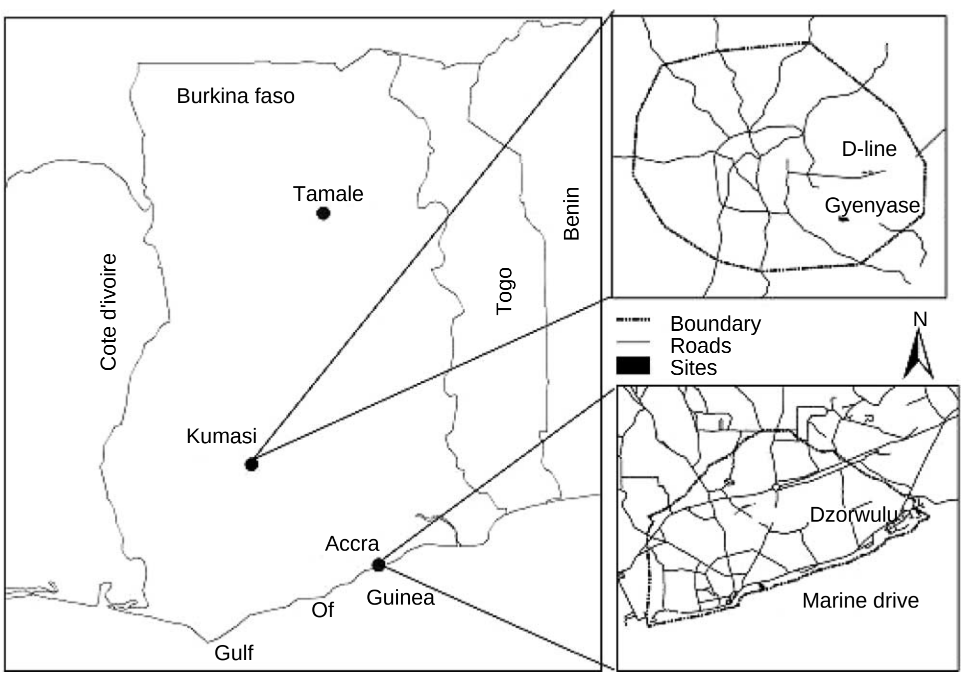

Figure 1 | Map of Ghana showing the vegetable growing sites in Kumasi and Accra used in this study.

and produce distribution. The second set of surveys was carried out in April–June 2005 in 26 main and neighbourhood markets, 56 restaurants and at 227 fast-food stands from a stratified subset of high, middle and low class suburbs (Henseler 2005). In markets, daily lettuce in- and outflows were quantified and analysed over two weeks through observations and about 600 interviews of sellers and buyers. The identification of the consumption risk group was based on interviews and observations of daily fast-food purchases as well as total lettuce turnover and average amount (fresh weight) in different food items.

Microbiological analysis

While in previous studies (Armar-Klemesu *et al.* 1998) contamination levels were compared between independent sets of farm-gate and market samples, this study followed the same set of crops from farm-gate to wholesale and retail. Efforts were made not to influence normally observed handling procedures.

Sampling

Over a period of 12 months, starting from May 2003 to April 2004, a total of 1296 lettuce samples were collected at different entry points from farm to the market. There were three main stages from harvesting on the farm to the main retail outlet where consumers were ready to buy: (1) farm, where samples were collected just before harvesting, (2) wholesale market, where sellers converge before finally selling to (3) retailer, where samples were taken 2–3 h after vegetables have been displayed and, in part, refreshed.

Twice every month, a minimum of three composite samples (each containing two whole lettuces) from each of the selected farm sites were randomly collected with sterile disposable gloves just before harvesting for sale at the market. These were put into separate sterile polythene bags and labeled as farm samples. The seller was followed to the wholesale market where another sample from the same original stock was colleted before being sold to a retailer. At the final retail point, three composite samples were again sampled after vegetables have been displayed on the shelves for at least 2–3 h, which is a typical turn-over period at the retail point.

The original set of lettuce was either irrigated with stream, drain, well or piped water. Sampled vegetables were transported on ice to the laboratory where they were analysed immediately or stored at 4°C until analysis within 24 h for total/faecal coliform and helminth counts. To eliminate potential biases during analysis, laboratory staff were blind to the source of the samples.

Microbiological examination

Samples were analysed quantitatively for total and faecal coliform and helminth eggs. Coliforms counts were estimated in about 20 g of vegetables, which was weighed into 180 ml of phosphate-buffered saline and rinsed vigorously. Further ten-fold serial dilutions were made and triplicate tubes of MacConkey broth (MERCK, KgaA 64271 Darmstadt, Germany) were inoculated from each dilution and incubated at 37 and 44°C, respectively, for total and faecal coliforms (FC) for between 24–48 h (APHA/AWWA/WEF, 2001). Positive tubes (acid or gas production or both) were selected and the numbers of bacteria were obtained from MPN (Most Probable Number) tables. Helminth eggs were enumerated using the concentration method (Schwartzbrod 1998 – a modified USEPA method (USEPA 1999)). The eggs were identified using morphological features like shape, size and color. The Bench Aid for the Diagnosis of Intestinal Parasites (WHO 1994) was used for preliminary identification.

Data handling and analysis

Survey and laboratory data were analyzed using SPSS for Windows version 10. Total and faecal coliform populations (MPN) were normalized by log transformation before analysis of variance (ANOVA). Results of analysis are quoted at $p < 0.05$ level of significance.

RESULTS

Exotic vegetables are not part of the traditional Ghanaian diet. However, with increasing urbanization, multi-cultural influenced customs have changed. Approximately 850 and 1250 tons of lettuce are sold annually on Kumasi's and Accra's markets, respectively (another 200 t produced in Kumasi are moved directly to Accra's markets). About 75% of the lettuce on Accra's markets originates from open space production in Accra (35%) or other cities, like Kumasi (40%). About 20% comes from peri-urban areas and only 5% from rural farms (Figure 2). In Kumasi, even 95% originates from irrigated urban agriculture in the city itself (Henseler 2005).

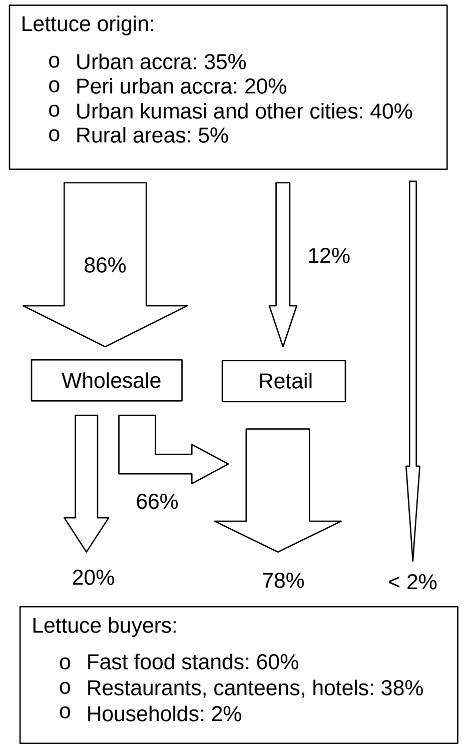

Figure 2 | Flow chart showing origin and distribution of lettuce along the farm-to-fork pathway in Accra (Henseler 2005; modified).

Microbiological quality of water used by farmers during the study period

Apart from piped water, all other sources of irrigation water sampled during the study period showed faecal coliform levels exceeding a geometric mean count of 1×10^3 $100\,\text{ml}^{-1}$ recommended by the World Health Organization (WHO 1989) for unrestricted irrigation (Table 1).

Microbiological quality of lettuce at different entry points along the production consumption pathway

Table 2 shows the faecal coliform contamination levels of lettuce at different entry points starting from farm to the final retail outlet. Irrespective of the irrigation water source, mean faecal coliform levels exceeded the recommended standard. There were no significant differences in the average lettuce contamination levels at different entry points (farm, wholesale market and retail outlet).

Figure 3 illustrates faecal coliform populations on lettuce samples collected in Kumasi at the farm gate, wholesale market and retail outlets over a 12 month period and for three irrigation water sources. Figure 4 shows corresponding graphics for the three irrigation water sources in Accra. High levels of faecal coliform counts (usually above the common acceptable standard of 1×10^3 $100\,\text{g}^{-1}$ wet weight) were recorded on all irrigated lettuce, including those irrigated with piped water.

Apart from stream water irrigated lettuce from Accra, higher levels of faecal coliform contamination were recorded in the rainy season than in the dry season but the difference was significant ($p < 0.05$) only in the cases of well and stream water irrigated vegetables from Kumasi, as has been previously described by Amoah *et al.* (2005). The results further showed that in 80–90% of the weeks sampled in Accra and Kumasi, there was no significant difference in the faecal coliform counts of samples analyzed from the farm gate to the markets and final retail points.

Helminth eggs

Helminth eggs, including that of *Ascaris lumbricoides, Hymenolepis diminuta, Trichuris trichuris, Fasciola hepatica and Strongyloides larvae*, were counted on lettuce samples at the different entry points. The helminth egg population ranged from one to six egg(s) $100\,\text{g}^{-1}$ wet weight. In the majority of cases, significantly ($p < 0.05$) higher levels were recorded in lettuce irrigated with polluted water than those from piped water irrigated sources. However, mean helminth egg populations on lettuce from the same original stock and irrigation water source did not show any significant difference from field to market (see Table 3).

Table 1 | Faecal coliform contamination levels of irrigation water used in lettuce production in two cities

		Log of geometric mean of faecal coliform counts (MPN** 100 ml^{-1})		
City	Irrigation water source*	Range	Geometric mean	Standard deviation
Kumasi	Well	3.36–6.62	4.81	± 0.64
	Stream	3.44–5.75	5.75	± 1.13
Accra	Drain	2.60–6.96	4.89	± 1.13
	Stream	2.95–7.18	4.99	± 1.12

*Piped water was excluded because no faecal coliforms were detected during the study period.
** Most Probable Number.

Agronomic and handling practices

Table 4 shows respondents' answers to practices on farm, market, street food selling stands and at the household level before the lettuce reaches the table. Lettuce producers used water from different urban sources for irrigation. Watering cans were predominantly used for irrigation in all the two cities (95% and 98% in Accra and Kumasi, respectively). The majority of respondents in Accra (60%) and Kumasi (52%) reported that they irrigate on the day of harvesting before the crops are harvested. This, according to the respondents, has a

Table 2 | Mean faecal coliform contamination levels at different entry points along the production–consumption pathway of lettuce

			Log faecal coliform levels (MPN* 100 g^{-1})		
City	Irrigation water source	Statistic	Farm	Wholesale market	Retail
Kumasi	Well	Range ($N = 216$)	3.00–8.30	3.10–8.50	3.20–7.00
		Geometric mean	4.54 (±1.32)**	4.44 (±1.23)	4.30 (±1.04)
	Stream	Range ($N = 216$)	3.40–7.10	3.60–7.20	3.50–7.20
		Geometric mean	4.46 (±0.81)	4.61 (±0.84)	4.46 (±0.91)
	Piped water	Range ($N = 216$)	2.30–4.80	2.60–5.30	2.40–5.10
		Geometric mean	3.50 (±0.70)	3.69 (±0.84)	3.65 (±0.82)
Accra	Drain	Range ($N = 216$)	3.40–6.00	3.00–6.80	3.00–6.50
		Geometric mean	4.25 (±0.74)	4.24 (±0.86)	4.48 (±0.78)
	Stream	Range ($N = 216$)	3.20–5.70	3.10–5.90	3.20–5.50
		Geometric mean	4.22 (±0.66)	4.29 (±0.62)	4.37 (±0.59)
	Piped water	Range ($N = 216$)	2.90–4.70	2.90–4.80	2.80–4.50
		Geometric mean	3.44 (±0.40)	3.46 (±0.43)	3.32 (±0.37)

*MPN, Most Probable Number.
** Figures in parentheses are standard deviations.

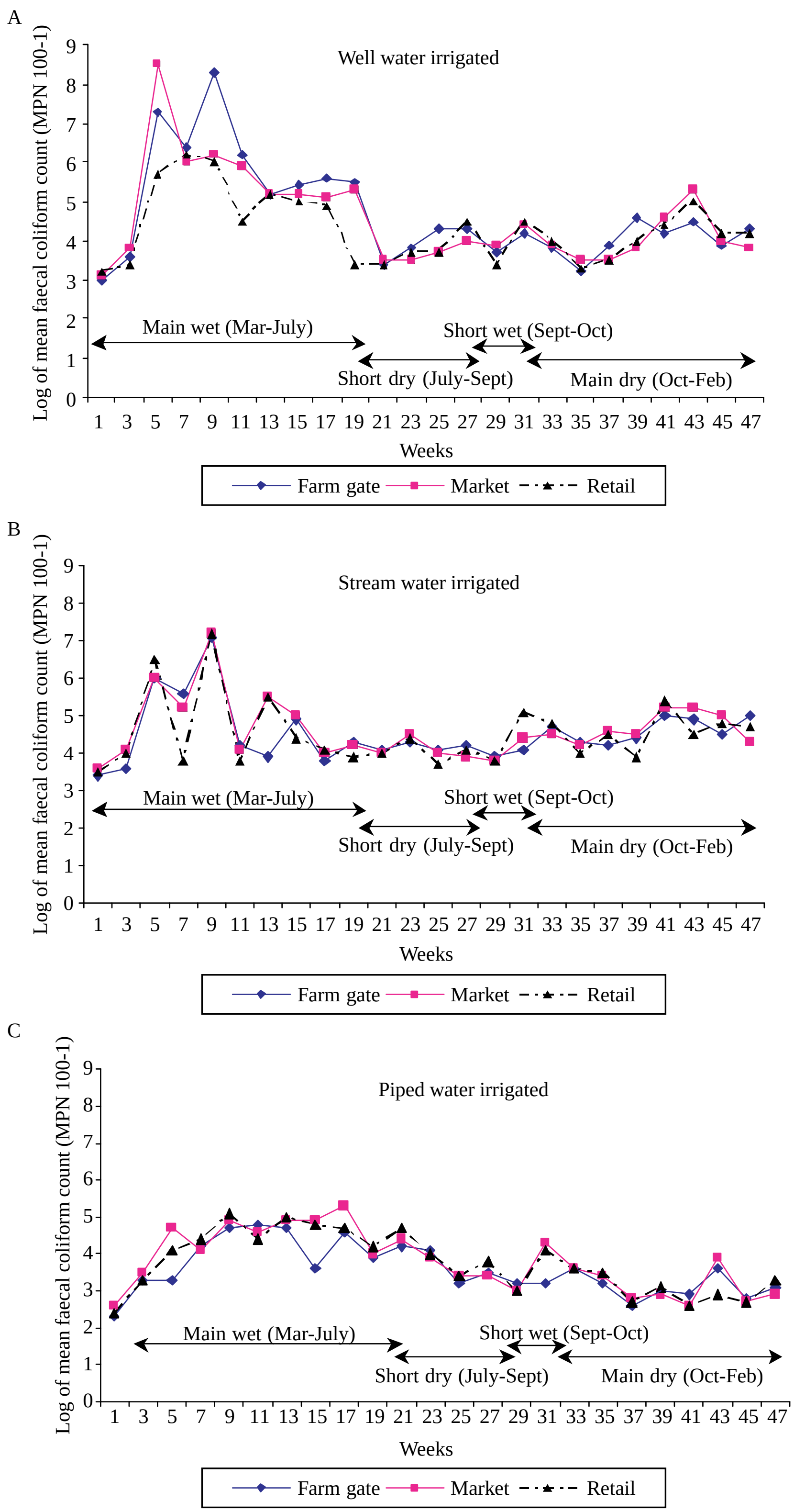

Figure 3 | Faecal coliform levels at different entry points on production–consumption pathway of irrigated lettuce using water from well (A), stream (B) and piped water (C) in Kumasi. (Total average rainfalls for the wet and dry seasons in Kumasi are: main wet (680 mm), short dry (220 mm), short wet (350 mm) and main dry (160 mm)).

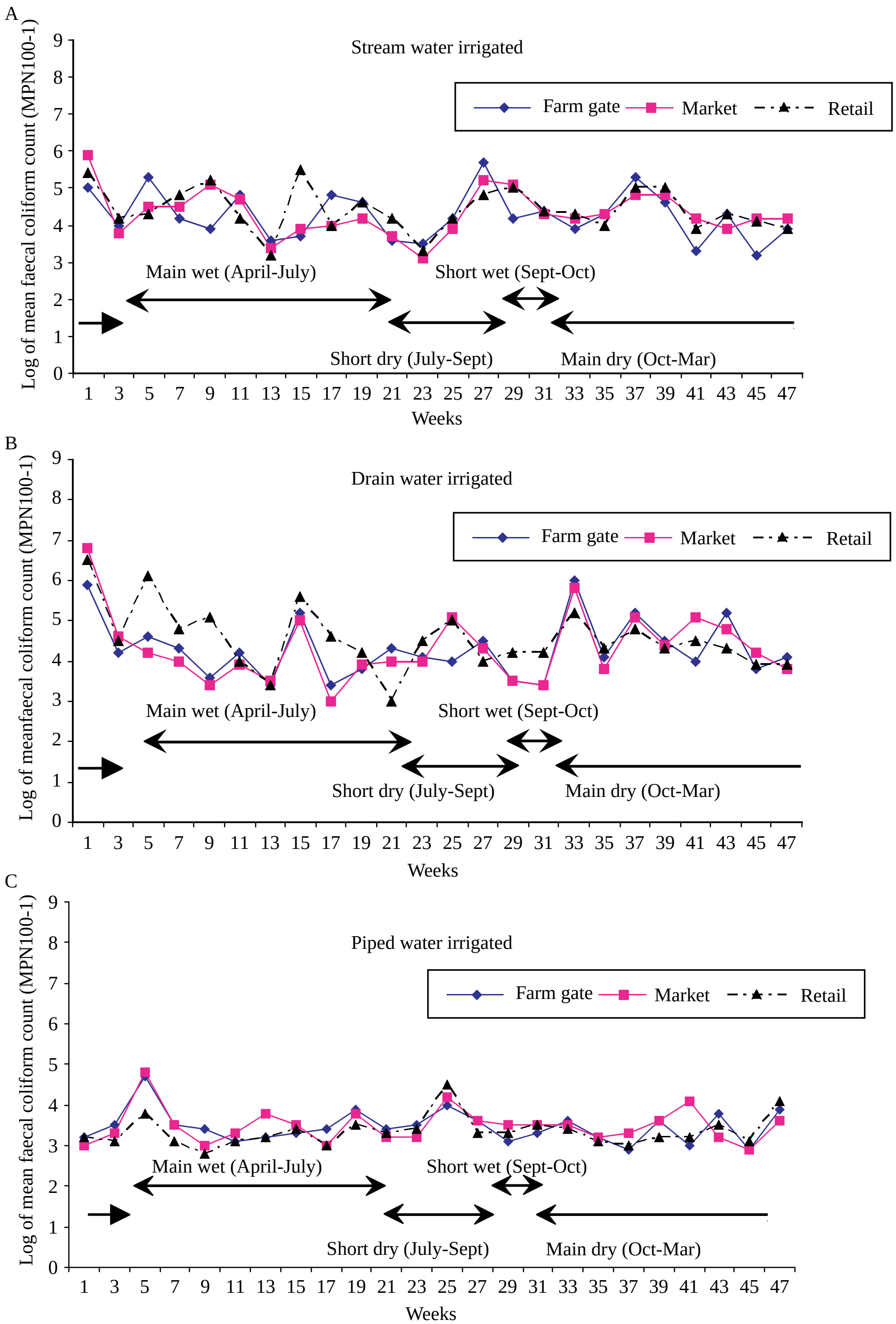

Figure 4 | Faecal coliform levels at different entry points on production–consumption pathway of irrigated lettuce using water from stream (A), drain (B) and piped water (C) in Accra. (Total average rainfalls for the wet and dry seasons in Accra are: main wet (620 mm), short dry (65 mm), short wet (145 mm) and main dry (92 mm)).

Table 3 | Arithmetic mean* of helminth egg contamination levels at different entry points along the production consumption pathway

		Helminth egg 100 g^{-1} wet weight		
City	**Irrigation water source**	**Farm**	**Wholesale market**	**Retail**
Kumasi	Well	4.1 ± (1.6) a**	4.9 ± (1.3) a	4.2 ± (1.3) a
	Stream	5.9 ± (1.4) b	4.9 ± (0.9) a	4.7 ± (0.6) a
	Piped water	1.9 ± (1.5) c	1.9 ± (1.2) b	1.2 ± (0.9) b
Accra	Drain	5.7 ± (1.1) a	5.9 ± (1.2) a	5.2 ± (1.5) a
	Stream	3.8 ± (0.9) b	3.1 ± (0.9) b	3.9 ± (1.2) ab
	Piped water	3.2 ± (0.7) b	2.1 ± (1.2) b	3.3 ± (1.0) b

*Mean numbers represent the mean of all the different types of eggs as well as Strongyloides larvae. ($N = 15$ for each irrigation water source.)
Figures in parentheses represent the standard deviation.
** Numbers in the same column with the same letters showed no significant difference between water sources per city ($p > 0.05$). For differences between farm, wholesale market and retail, see text for Figures 3 and 4.

desirable effect on the product's freshness and also makes harvesting easier. Poultry manure was most widely (over 70%) used by producers of irrigated lettuce in the two cities, with application of NPK (37% and 3% in Accra and Kumasi, respectively) mostly at the nursery stage.

Most lettuce retailers in both cities claim to wash their vegetables before selling. In Kumasi, it is common for wholesalers and also many retailers to use irrigation water on the farm to wash their harvested produce. In Accra most retailers say they use tap water on market for that purpose. The majority (over 90%) of lettuce-buying households claim to wash it at home with tap water. Also all fast-food sellers claim to wash the lettuce at home before they prepare it for their kiosk. Street sellers indicated that they use tap water, salt and/or vinegar: however, the amounts of added salt or vinegar are generally not sufficient to secure sufficient decontamination of the lettuce as repetitions under controlled conditions (Amoah *et al.* forthcoming) as well as other studies (Mensah *et al.* 2002) have shown.

Risk group analysis

The surveys in Accra and Kumasi showed that the majority of lettuce (60% in Accra and 83% in Kumasi) is purchased by street vendors selling fast food, especially "rice & chicken" from small kiosks. The remaining share goes to restaurants, canteens and hotels. Private households take only about 2% in each city, which shows the "exotic" character of lettuce in the Ghanaian diet (Figure 2). Street food with lettuce is available in suburbs of all income levels, with relatively more frequent lettuce supplemention in low-income areas. Customers are mostly male (70%) and buy fast food 3–4 times per week. Like the typical urban dweller, most live in low-class (50%) and middle-class (ca. 38%) suburbs, and work in the small-scale private sector, or are businessmen or students. Some of the fast food with lettuce supplement is the cheapest food available in town, attracting the poor and their dependants, as also mentioned by Essamuah & Tonah (2004).

To quantify the risk group, we calculated that about 150 000 fast-food customers are served with lettuce per day. This is based on estimates from field surveys that there are approximately 15 000 street food vendors in Accra. According to AMA statistics gathered from different suburbs, about one third of the registered vendors sell food known for its salad (lettuce and/or cabbage) supplement, mostly from urban agriculture. A survey among 90 sellers from this group showed that on average 50 units (per fast-food seller) are sold with a salad component per day. This gives a total of about 250 000 units or fast-food consumers.

About 60% (or 150 000 meals) of this fast-food served per day in Accra contains lettuce, the others only cabbage and other vegetables.

Alternatively, we estimated the number of fast-food customers by considering the total amount of lettuce traded on Accra's markets (950 t/yr) and extracting the fraction that goes to fast-food stands (60%) and dividing it through by the average weight of the lettuce in one fast-food dish (12 g). This resulted in about 130 000 fast-food meals with lettuce sold per day. Combining both assessments, it seems that about 130 000 – 150 000 units of meals with lettuce are served per day.

Under the additional consideration of cabbage and spring onions, it can be assumed that in Accra every day, probably more than 200 000 people consume uncooked vegetables outside their household. If we consider also canteens and restaurants another 80 000 meals are possible.

DISCUSSION

Household consumption of raw salad is less common in Ghana than its Francophone neighboring countries (Klutse 2006). However, with increasing fast-food consumption especially in urban centers, so-called "exotic" vegetables, like lettuce, are today a common feature of urban diets. Most lettuce derives from urban farms along polluted streams and drains. With the exception of piped water, faecal coliform contamination levels in the irrigation water used generally exceeded the WHO recommended standard for unrestricted irrigation. Similar faecal coliform contamination levels in surface water sources have been reported by Cornish *et al.* (1999), Mensah *et al.* (2001) and McGregor *et al.* (2002) in the same study areas.

The study revealed that the contamination of lettuce with pathogenic microorganisms does not significantly increase through post-harvest handling and marketing. This was not expected in view of the alarming hygienic conditions, including washing habits, clean display and handling of food as well as availability of sanitation infrastructure on market sites. Only 31% of the markets in Accra have a drainage system, 26% have toilet facilities and 34% are connected to pipe-borne water (Nyanteng 1998). Irrespective of irrigation water used, it seems as if the initial contamination on the farm is so high that it hides any possible post-harvest contamination. These results on microbiological contamination of lettuce (from field to market) question earlier statements by Armar-Klemesu *et al.* (1998). The authors attributed the significantly higher faecal coliform levels found on the market than the farm vegetables (including lettuce) to handling, even though the market samples could have come from farms different from those used in the study.

Another observation was that crop contamination also takes place under irrigation with piped water. Sources of contamination in these cases included the already contaminated soil (FC levels of 1×10^4 $10\,g^{-1}$ in the upper 5 cm (Amoah *et al.* 2005) and the frequent application of incompletely composted (poultry) manure (Drechsel *et al.* 2000; Amoah *et al.* 2005).

Vegetables can become contaminated with microorganisms capable of causing human diseases while still on plant on farm, or during harvesting, transport, processing, distribution and marketing, or in the home (Beuchat 1999). The main question of the authorities, then, is where intervention should be placed to reduce the health risks for consumers. The results suggest that post-harvest contamination is not a major contamination source in contrast to contamination on the farm.

To reduce the health risk associated with the consumption of contaminated lettuce, it is obvious, according to the study, to tackle the problem first of all at the farm level through good agricultural practices. This, however, is not as easy as is often recommended. Changes in irrigation methods, timing and crops might not be possible for the farmers due to a number of reasons, e.g. because of land insecurity, the relatively high turnover and demand for fresh vegetables, etc. (Drechsel *et al.* 2002). Therefore, other options are under investigation under the Challenge Program on Water for Food. Although the first trials by the International Water Management Institute (IWMI) show that the contamination levels can be reduced on the farm even through minor changes in practices, it is unlikely that contamination can be minimized below the threshold of safe consumption as the data from the use of piped water show. It will therefore be necessary to wash the crops in addition to on-farm techniques designed to reduce health risks. Here the last stage in the production – consumption chain, where food for personal consumption or fast-food for

Table 4 | Agronomic and handling practices

		Percentage of respondents*	
	Activity description	**Accra**	**Kumasi**
On farm	Irrigation water source		
	a) Drain	54	1
	b) Stream	15	68
	c) Shallow well	6	31
	d) Piped water	21	1
	Irrigation method used		
	a) Watering can	95	98
	b) Using a hose	5	2
	Irrigation on the day of harvesting	52	60
	Manure application		
	a) Poultry manure	73	98
	b) Cow dung	24	0
	c) Commercial fertilizer	37	3
	Harvesting		
	a) By hand (trader)	100	100
	Washing lettuce after harvest on farm (by trader)		
	1) Yes, with irrigation water	0	80 (wholesaler)**
	2) no washing	100	20 (wholesaler)
At market	Washing at market (Wholesale)		
	a) No washing	40	10
	b) Washing with tap water	60	10
	Washing at market (Retailers)		
	c) No washing	3	6
	d) Wash with tap water	97	48
	Refreshing of lettuce		
	a) No refreshing	3	2

Table 4 | (continued)

		Percentage of respondents*	
	Activity description	Accra	Kumasi
	b) Refresh with piped water***	93	98
	c) Change of refreshing water during day	20	25
	Display at market		
	a) Covered/protected from flies/dust	0	1
	b) Displayed unprotected	100	99
Street food sellers	Washing lettuce at home with tap water before preparing for kiosk	100	100
	Washing lettuce before serving	99	99
Household	Washing lettuce at home		
	a) Wash	93	92
	b) No washing	7	8
	Washing lettuce with tap water	100	100

*Sum more than 100 for each major activity description due to multiple response ($N = 886$).
** Forty six percent of retailers in Kumasi also washed with irrigation water while the rest do not wash on farm.
*** One-time fetched in the morning.

street sales is prepared, appears to be a good entry point as awareness for food safety is generally high and more than 90% of the food vendors and consumers wash salad anyway. However, individual methods vary largely and seldom meet the required standards. Consumers reduce health risks by trusting only food vendors with neat appearance and visually clean food (Olsen 2006), which is a first step but not sufficient to avoid contaminated food (Mensah *et al.* 2002).

CONCLUSION

The study has shown that the majority of microbial contamination of lettuce produced from urban sources in Accra and Kumasi occurs on the farm. The post-harvest sector is likely a relatively minor contributor to lettuce contamination. This suggests that risk reduction strategies should focus on the farm. Common guidelines for "wastewater irrigation" are, however, rarely adopted for a variety of reasons, e.g. economic constraints limit the level of wastewater treatment that can be provided in developing countries; also, small size and insecure land tenure are significantly constraining the farmer's ability to invest in farm infrastructure such as drip irrigation or on-farm sedimentation ponds, etc. (Drechsel *et al.* 2002). Future studies are necessary to identify alternative risk reduction strategies addressing modifications of the (manual) irrigation systems to reduce crop contact with the polluted irrigation water, the use of properly composted manure and effective die-off periods for already contaminated soil. In addition, further measures are crucial to always reduce the remaining risk for the consumer such as addressing street food vendors' misperception of "safe" washing.

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