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Pesticide and Pathogen Contamination of Vegetables in Ghana's Urban Markets

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Abstract. The objective of the study was to determine and compare the current level of exposure of the Ghanaian urban population to hazardous pesticide and fecal coliform contamination through the consumption of fresh vegetables produced in intensive urban and periurban smallholder agriculture with informal wastewater irrigation. A total of 180 vegetable samples (lettuce, cabbage, and spring onion) were randomly collected under normal purchase conditions from 9 major markets and 12 specialized selling points in 3 major Ghanaian cities: Accra, Kumasi and Tamale. The samples were analyzed for pesticide residue on lettuce leaves, total and fecal coliforms, and helminth egg counts on all three vegetables. Chlopyrifos (Dursban) was detected on 78% of the lettuce, lindane (Gamalin 20) on 31%, endosulfan (Thiodan) on 36%, lambda-cyhalothrin (Karate) on 11%, and dichloro-diphenyl-trichloroethane on 33%. Most of the residues recorded exceeded the maximum residue limit for consumption. Vegetables from all 3 cities were fecally contaminated and carried fecal coliform populations with geometric mean values ranging from 4.0×10^3 to 9.3×10^8 g^{-1} wet weight and exceeded recommended standards. Lettuce, cabbage, and spring onion also carried an average of 1.1, 0.4, and 2.7 helminth eggs g^{-1}, respectively. The eggs were identified as those of *Ascaris lumbricoides*, *Ancylostoma duodenale*, *Schistosoma heamatobium*, and *Trichuris trichiura*. Because many vegetables are consumed fresh or only slightly cooked, the study shows that intensive vegetable production, common in Ghana and its neighboring countries, threatens public health from the microbiologic and pesticide dimensions. Standard recommendations to address this situation (better legislations, law enforcement, or integrated pest management) often do not match the capabilities of farmers and authorities. The most appropriate entry point for risk decrease that also addresses postharvest contamination is washing vegetables before food preparation at the household or "chop" bar (street restaurant).

Sub-Saharan Africa is one of the regions most affected by urbanization. It has an annual growth rate of 2.8% in the total population and 5.8% in the urban population (World Bank 2000). In Ghana, the urban population is growing at an estimated annual rate of 4.2% compared with the overall population growth of 2.7% (Ghana Statistical Service 2002). The increase in urban population and food demand has catalyzed the use of urban open spaces for food production ("urban agriculture"). A typical expression of urban agriculture is the production of perishable high-value crops such as most exotic and some traditional vegetables. Because the demand for these vegetables is not seasonal, farmers attempt year-round production wherever irrigation water is available. This takes place closest to the urban markets on unused spaces in the urban environment. The production is input and output intensive with several harvests per year and depending heavily on irrigation, manure, and pesticide application.

The use of potable water for vegetable production is constrained because > 40% of city dwellers in Ghana are still without good drinking water. Therefore, the irrigation water used by these farmers is derived from different urban sources including drains, which are often highly polluted because no or little option exists for water treatment (Keraita *et al.* 2002). Another potential health risk derives from the use of pesticides, although this is beneficial in decreasing crop loss both before and after harvest (Clarke *et al*. 1997). Despite the recognition of urban agriculture as a source of urban food security, concern has been growing among city authorities. Efforts have been made toward safer cultivation of vegetables in Ghana (Sonou 2001) although few data exist on the actual gravity of the problem for guidance of appropriate interventions or policy formulation.

Therefore, to assess the public health implications, this investigation went beyond water analysis and aimed to assess the hygienic quality of irrigated vegetables produced and sold in major cities of Ghana. The objective was to determine the current level of exposure of the Ghanaian local population to fecal microorganisms and hazardous pesticides. The study is part of a larger investigation cofunded by the International Water Management Institute (IWMI) and International Development Research Centre (IDRC-AGROPOLIS), both of which target contamination at farm gates and markets as well as develop strategies to decrease health risks at different entry points (*e.g.*, water source, farm, markets, households).

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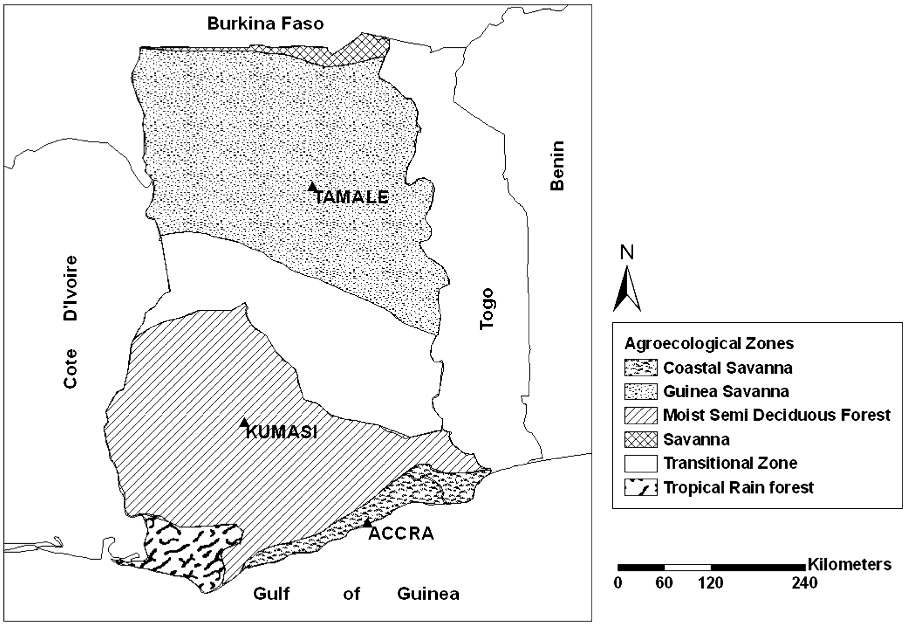

Fig. 1. Map of Ghana showing the study areas: Accra, Kumasi, and Tamale

Materials and Methods

The Study Area

The study was carried out in three main Ghanaian cities: Accra, Kumasi, and Tamale (Fig. 1). These cities are located in three different ecologic zones and represent the southern, middle and northern belts of Ghana, respectively.

Study sites. Accra is the capital city of Ghana with a population of approximately 1.7 million (Ghana Statistical Services 2002). It is located at the Gulf of Guinea in the coastal savannah belt. Kumasi is the capital town of the Ashanti region and the second largest city in Ghana with a population of approximately 1 million (Ghana Statistical Services 2002). Kumasi is located in the forest belt of Ghana. Tamale is the administrative and regional capital of the northern region. It is located in Ghana's savannah zone and has a population of approximately 300,000 (Ghana Statistical Services 2002). In contrast to Accra and Kumasi, Tamale municipality is poorly endowed with water bodies; there are only a few seasonal streams.

Sampling of Vegetables

This study was conducted during the 3 months from October to December, 2002. A total of 180 vegetable samples (lettuce, cabbage, and spring onion) were collected from 9 major markets and 12 specialized individual vegetable and fruit sellers (*i.e.*, sellers with permanent stalls outside of designated markets) in Accra, Kumasi, and Tamale (Fig. 1). At each market, samples were collected under normal purchase conditions from 3 randomly selected sellers. A minimum of 3 composite samples—each containing 2 whole lettuce heads, 3 bunches of spring onions (each containing 2 bulbs), and 3 cabbages—were collected from the upper, middle, and lower shelves of each seller, put in sterile polythene bags, and transported on ice to the laboratory where they were analyzed immediately or stored at 4°C until analysis within 24 hours.

Chemical Analysis for Pesticide Residues on Lettuce

Extraction. Approximately 5 g (fresh weight) lettuce was homogenized in a mortar and extracted by Soxhlet extractor. In accordance with previous studies (Ntow 2001), the samples were cleaned, concentrated, eluted with hexane in a solid-phase extraction column, and injected onto capillary gas chromatography columns connected to various detectors. For this purpose, the laboratory of the Water Research Institute in Accra was used.

Chromatographic Conditions

Gas Chromatography: Flame Ionization Detector. A Hewlett Packard 5890 series II chromatograph equipped with a flame ionization detector and a capillary column (60 m length, 0.25 mm i.d) coated with Varian CP SIL 8 CB, film thickness 0.25 μm, was used for the analysis. The oven temperature of 60°C (2 minutes) was increased at 35°C/min to 180°C, then increased at 2°C/min to 270°C, and finally increased at 5°C/min to 310°C and held for 10 minutes. The injection volume was 2 μl (splitless).

Gas Chromatography: Electron-capture Detector. A Hewlett Packard 5890 Series II chromatograph equipped with a ^{63}Ni electron-capture detector and a capillary column (length 30m, ID 0.53 mm, film thickness 1.5 μm) coated with DB-5 was used. The initial injector temperature was 180°C. Other working conditions were oven 150°C (2 minutes) to 275°C at 10°C/min, detector 310°C. The injection volume was 1 μl.

The lettuce samples were analyzed for lindane, endosulfan, lambda-cyhalothrin, chlorpyrifos and *p,p*'-dichloro-diphenyl-trichloroethane (DDT). Sample peaks were identified by their retention times compared with the retention times of the corresponding pesticide standard obtained from the International Atomic Energy Agency. The ability of the laboratory to identify these substances has been verified by cross-tests of river sediments in Ghana and Europe.

Table 1. Pesticide prevalence: Residue levels on lettuce (N = 60)

Pesticide	Lettuce with pesticide residues (%)	Range of pesticide residue on lettuce (mg/kg)	Average value of lettuce (mg/kg)	MRL of lettuce (mg/kg)
Lindane	31	0.03–0.9	0.3	0.01
Endosulfan	36	0.04–1.3	0.4	0.05
Lambda-cyhalothrin	11	0.01–1.4	0.5	1.0
Chlopyrifos	78	0.4–6.0	1.6	0.05
DDT	33	0.02–0.9	0.4	0.05

DDT = dichloro-diphenyl-trichloroethane
[1] MRL = maximum residue limit (Pesticide Safety Directorate 2005).

Microbiologic Examination

Lettuce, cabbage, and spring onion samples were analyzed quantitatively for total and fecal coliforms and helminth eggs. For coliforms, approximately 20 g of vegetables were weighed into 180 ml phosphate-buffered saline and rinsed vigorously. Additional 10-fold serial dilutions were made, and triplicate tubes of MacConkey broth supplied by Merck (Germany) were inoculated from each dilution and incubated at 37°C and 44°C for total and fecal coliforms, respectively, for 24 to 48 hours (APHA–AWWA-WEF 2001). Positive tubes (acid or gas production or both) were selected, and the numbers of bacteria were obtained from most probable number (MPN) tables. Helminth eggs were enumerated using the concentration method (Schwartzbrod 1998).

Statistical Analysis

Data were analyzed using SPSS for Windows 10. Total and fecal coliform populations (MPN) were normalized by log transformation before analysis of variance. Results of analysis were quoted at the $p < 0.05$ level of significance.

Results

Pesticide Residues on Lettuce Leaves

Table 1 shows pesticide prevalence, residue levels recorded on lettuce leaves, and maximum residue limits (MRLs) for consumption. In most cases, the pesticide residue levels observed exceeded the MRL. More than 60% of the lettuce samples had ≥2 pesticide residues. The data showed that 78% of the samples had chlorpyrifos residue. Only 14% had pesticide residue levels below detectable limits. There were no significant differences between pesticide residue levels observed on samples from the three cities except chlorpyrifos, for which significantly higher levels were recorded in Kumasi than in Accra.

Bacterial Contamination of Vegetables

Table 2 shows ranges of total and fecal coliform observed. Most of the vegetable samples showed high fecal coliform contamination levels. The highest level of fecal coliform contamination was recorded in lettuce, which had a geometric mean count of 1.1 x 10^7 g^{-1} wet weight. This may be related to the larger surface area exposed. Cabbage and spring onion showed geometric mean counts of 3.3 x 10^6 and 1.1 x 10^6 g^{-1} wet weight, respectively. There was no sample without at least 4000 fecal coliform g^{-1} (wet weight).

Table 2. Ranges of total and fecal coliform population on selected vegetables

Vegetable	MPN g^{-1} wet weight	
	Total coliform	Fecal coliform
Lettuce	9.3×10^5 to 1.5×10^{11}	4.0×10^3 to 9.3×10^8
Cabbage	2.6×10^5 to 1.5×10^{11}	1.4×10^4 to 2.8×10^7
Spring onion	9.3×10^5 to 1.9×10^{10}	1.5×10^4 to 4.6×10^8

MPN = Most probable number.

Intercity Comparison of Coliform Contamination Levels

Figure 2 shows both total and fecal coliform levels on vegetables from Accra, Kumasi, and Tamale. All vegetables from all cities were fecally contaminated with mean fecal coliform levels exceeding the International Commission on Microbiological Specifications for Foods (ICMSF) recommended level of 10^3 fecal coliform g^{-1} fresh weight.

Mean Helminth Egg Population on Vegetables

Lettuce, cabbage, and spring onion carried mean helminth egg populations of 1.1, 0.4, and 2.7 g^{-1} wet weight, respectively. No significant difference was observed in the mean helminth egg populations recorded in lettuce and cabbage; however, the difference between spring onion and both lettuce and cabbage was significant ($p < 0.05$). The eggs identified included those of *Ascaris lumbricoides*, *Ancylostoma duodenale, Schistosoma heamatobium*, and *Trichuris trichiura* with *A. lumbricoides* eggs predominating. Table 3 shows the percentage of vegetables contaminated with the different worm eggs. Approximately 30% of vegetables had no eggs.

Discussion

Pesticide Contamination

In Ghana, it is estimated that 87% of farmers use pesticides on vegetables. Insecticides are the most widely used among the

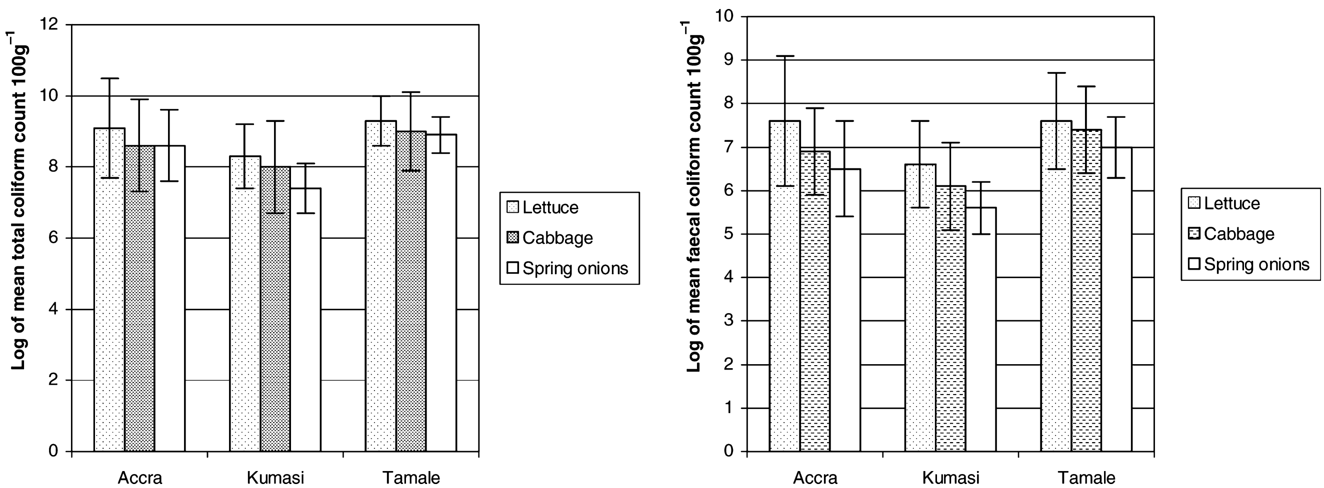

Fig. 2. Total (**left**) and fecal (**right**) coliform levels in vegetables from Accra, Kumasi, and Tamale

different classes of pesticides. Forty-one percent and 37% of these insecticides are pyrethroids and organophosphates, respectively. The rest are organochlorines and carbamates (Ntow 2004).

The results regarding pesticide residues indicated that several pesticides, especially chlorpyrifos, are widely used by vegetable producers in Ghana. This corresponds with other studies (Okorley and Kwarteng 2002). As also described by Danso *et al*. (2002), farmers mix cocktails of various pesticides to increase their potency. Vegetables are often eaten raw, and it is not surprising to read about evidence of chlorpyrifos contamination in "waakye," a popular Ghanaian dish (Johnson 2002).

Lindane and endosulfan are restricted for the control of capsids on cocoa, stem borers in maize, and pests on coffee, whereas DDT is banned in Ghana. However, the data show clearly that these more potent agrochemicals are used irrespective of whether they are approved for vegetable production or not.

The results regarding contamination levels, which often exceed the MRL, and the fact that only 14% of the samples had residues below detectable limits are strongly indicative of a potential health risk to consumers. For example, all 47 (78%) lettuce samples with detectable chlorpyrifos contamination exceeded the recommended residue level of 0.05 mg kg^{-1}, indicating a high probability of exposure to these chemicals; however, an assessment of actual pesticide intake was not possible in the framework of this study. A rough calculation shows the risk potential. For example, the acceptable daily intake (ADI; *i.e.*, the measurement of the quantity of a particular chemical or food that, it is believed, can be consumed on a daily basis during a lifetime without harm) of chlorpyrifos is 0.01 mg kg^{-1} body weight (World Health Organization [WHO] 1997). To exceed the ADI, a child weighing 30 kg would have to consume at least 0.3 mg/d. With a residue level of 1.6 mg kg^{-1} lettuce, the child would have to eat close to 200 g of lettuce/d. The amount of lettuce (usually served with other staples such as rice) is usually <30 g, indicating that even persons of low body weight are not presently at risk.

Attempts made to minimize the harmful effects of pesticides by promoting the use of neem seed extract have in most cases failed (Danso *et al*. 2002). The main constraints to neem use are supply and farmer awareness. Imported chemical pesticides are offered in the market at the lowest possible price because of the lack of import duties. Commercial neem oil products are available in Ghana, but they are expensive, and the motivation to produce their own neem seed extract is lacking (Gerken *et al.* 2001). Similar observations have been reported from Togo and other countries (PAN/CTA 1995). In fact, pesticides are considered "plant medicine," and the perception of their human health risks is very low.

A detailed study on this issue has been initiated by IWMI/UNESCO-IHE. Although some form of education on the use of toxic pesticides has been done (Ntow 1998), monitoring of pesticide residues on food is virtually nonexistent in Ghana (Clark *et al.* 1997), especially because the analysis is too expensive for public authorities. Because there is little incentive for farmers to change their practices and too few resources for authorities to control them, risk decrease should focus more on household education to create demand for safer and appropriate washing procedures.

Microbiologic Contamination of Vegetables

Several factors may account for the high levels of total and fecal coliform contamination recorded in most of the analyzed vegetables. Among these is the use of polluted irrigation water and fresh poultry manure. Both the irrigation water and the manure are applied on top of the crops. Another contamination source is market-related handling, especially where provision for better sanitary standards (*e.g.*, clean water for crop washing and "refreshing") is lacking. Previous studies in Accra showed fecal coliform population of irrigation water sources ranging between 4.8 x 10^3 and 2.8 x 10^6 100 ml^{-1} (Mensah *et al*. 2001; Cornish *et al*. 1999; Keraita *et al.* 2002), *i.e.*, usually exceeding the WHO recommended level of 1 x 10^3 100 ml^{-1} for unrestricted irrigation. Drechsel *et al.* (2000) reported that fresh poultry litter samples, sometimes used without sufficient drying for vegetable production in Kumasi, had equally high fecal coliform counts between 3.6 x 10^4 and 1.1 x 10^7.

Table 3. Proportions of vegetables with helminth eggs

Vegetable	Species	samples with eggs (%)
Lettuce	Ascaris	60
	Ancylostoma	5
	Schistosoma	2
	Trichuris	3
Cabbage	Ascaris	55
	Ancylostoma	3
	Schistosoma	3
	Trichuris	2
Spring onion	Ascaris	65
	Ancylostoma	3
	Schistosoma	1
	Trichuris	2

The mean fecal coliform levels of all three crops exceeded the ICMSF recommended level of 10^3 fecal coliform g^{-1} fresh weight. The relatively high total and fecal coliform populations recorded on some vegetables were also reported by Johnson (2002) and Armar-Klemesu *et al.* (1998), who analyzed street food and market crops in Accra, respectively. These findings correspond with the high number of food-borne and water-related diseases in Accra such as diarrhea (sometimes related to typhoid or cholera) as well as intestinal worm infections, but these must be noted in the context of generally suboptimal sanitary conditions in parts of the metropolis (Arde-Acquah 2002).

The results from the cities suggest that comparatively safer vegetables, in terms of total and fecal coliform contamination, are sold in Kumasi. The first reason for this could be that the majority of irrigated vegetable farmers in Kumasi use water from shallow wells, which appear to have a better water quality than sources in Accra and Tamale where the majority of farmers use water from drains with low water quality. Cornish *et al.* (1999), however, reported that water from shallow wells in Kumasi had better quality than nearby rivers but were still often polluted (1.4×10^3 to 2.1×10^4 fecal coliforms 100 ml^{-1}), perhaps caused by manure run-off from the field. The second reason is that almost all the sellers in Kumasi wash the vegetables with (often irrigation) water at the farm gate before selling it and that retailers at the market usually wash them again before selling. Often only one bucket of water is used during the whole day, thus making the vegetables dirtier (Drechsel *et al*. 2000).

Biologically, the highest health risk is for helminth infections compared with other pathogens because helminthes persist for longer periods in the environment, host immunity is usually low to nonexistent, and the infective dose is small (Gaspard *et al*. 1997). *A. lumbricoides* was the most predominant and was observed in 85% of the contaminated vegetables. This could be attributed to its high level of persistence and resistance.

Although there is enough general epidemiologic evidence in support of disease transmission through the consumption of contaminated vegetable irrigated with wastewater (Shuval *et al.* 1986), it is difficult for farmers and municipalities to comply with the WHO wastewater irrigation guidelines (WHO 1989) for various reasons (Drechsel *et al.* 2002). Simply banning the use of wastewater for unrestricted irrigation would deprive many farmers and sellers of their livelihood and drastically decrease the amount of many perishable vegetables in Ghana's cities (Cofie and Drechsel 2004). It also would not solve the problem of postharvest contamination. Therefore, more efforts are needed to test possible options for risk decrease at the farm, market, street restaurant, and household levels (Drechsel *et al.* 2002). The same investigators reported that market sellers improved their vegetable washing to better meet the demand of their customers (Drechsel *et al*. 2000). However, a requirement is that the sanitary facilities in the markets allow this, *i.e.*, there is permanent access to running water and support through education and awareness campaigns.

Like with the pesticide problem, however, the anchor point of risk decrease appears to be the kitchen where food is prepared for the household or for street vendors. Risk-decreasing strategies should sensitize consumers, especially parents, to potential health implications of themselves as long as the state does not have the means of control.

Conclusion

The results of this study showed that typical microbiologic and pesticide contamination levels of vegetables in Ghanaian markets pose a threat to human health. The potential harmful effects could be minimized through enforcement of legislation on harmful pesticides. However, this is not easy as long as human and financial resources are scarce. Also, the legislation against wastewater use could be improved, but more powerful entry points for risk decrease that maintain the value of urban and periurban agriculture are education and awareness campaigns in markets and households.

Washing or cooking food before eating is common in Ghanaian households. This could decrease or eliminate much of the microbiologic and pesticide residues if done more consciously. The comparison of both risks factors shows that efforts for health interventions should focus more on microbiologic crop contamination, especially on helminthes, while the pesticide problem, despite its dimension, is in comparison less critical for consumers' health in the given context.

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