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Physicochemical and parasitological quality of vegetables irrigation water in Ouagadougou city, Burkina-Faso

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The quality of irrigation water from different sources used by urban vegetable producers, the watered soils and vegetables in Ouagadougou was investigated. From December 2012 to December 2013, samples of water (97), lettuces heads (20), manure (10) and soil (9) were collected and analyzed for their parasitological quality using modified Bailenger methods. The result shows that parasites concentration in samples (1 to 11 egg/L in water, 0.45 egg/g on lettuce and 0.48 egg/g in soil) are above the threshold levels set by WHO/FAO for unrestricted irrigation. Different protozoa and helminthes belonging to 9 species were identified in the samples analyzed. These include *Ankylostoma duodenalis*, *Hymenolepis nana*, *Ascaris lombricoïdes*, *Taenias* ssp., *Strongyloides stercoralis*, *Entamoeba histolytica*, *Giardia lamblia* and *Entamoeba coli*. Despite variation in isolated parasites, eggs of *A. lumbricoïdes* and *A. duodenalis* were common in all water, soil and vegetables. Furthermore 14.87% of collected eggs have proven to be viable with predominance of helminthes eggs. As a result, farmers appear to be the most exposed group to helminthiasis.

Key words: Waterborne parasites, vegetables, urban-farming, Ouagadougou.

INTRODUCTION

Water is an essential factor in vegetables production in many urban agricultural sites, particularly in arid zones like in Burkina Faso. It is the fundamental input for rainfed or irrigated agriculture. The quality of the irrigation water is of great importance for safety reasons due to its potential effects on both human and aquatic ecosystems

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health (Amaro et al., 1995; Graczyk et al., 2011). According to Jofre and Blanchm (2010), a large number of major infectious diseases are related to water. Pathogens that are water-transmitted may follow various routes, ranging from water ingestion to transmission via insect vectors. They are classified into four categories according to Braks and de Roda Husman (2013) respectively: responsible for water-borne diseases, water-washed diseases, water-based diseases and water-related diseases. Water-borne pathogens are passively carried in water bodies. Water-borne diseases are caused by the ingestion of contaminated water. In some case irrigated products (such as vegetables) may carry these pathogens from field to the consumer. Water-washed diseases are the result of contact with contaminated water. Water-based diseases are caused by organisms that originate in the water or spend part of their life cycle in aquatic animals and come in direct contact with humans in water or by inhalation. Through the use of contaminated water for irrigation, famers can become highly expose to both water-washed and water-based diseases.

Finally, water-related infectious diseases are caused by pathogens that are transmitted by vectors that spend part of their life cycle in water, such as mosquitoes, black flies. By spending more time near water bodies, farmer can became more exposed to these last kinds of water-transmitted diseases. Moreso, by creating multiple pools, irrigation can act as factor of persistence and dissemination of those diseases. The most common human pathogens in water are enteric in origin (Leclerc et al., 2002). They enter the environment through the faeces of infected host (Hotez et al., 2008). Enteric pathogens in water include a variety of viruses, bacteria, protozoa and helminthic eggs. However, it has been well established that the main health risk in relation to polluted water irrigation is intestinal helminthic infection (Blumenthal et al., 2000). In addition, parasites in water are still poorly known and understood; they are often thought to be similar to other microorganisms such as bacteria and viruses even though they behave very differently. Therefore, it is necessary to give more attention to this category of pathogens.

The poor quality of water used for vegetables irrigation is one of the reasons for the presence of pathogens in fresh vegetables such as lettuces, tomatoes and onions (Cissé et al., 2002; Puto, 2012). Worldwide, it is estimated that a child dies every 8 s from water-transmitted diseases (Gerba, 2006). About 80% of illness and death in developing countries is water-related; in developing countries, half of the hospital beds are occupied by people with water-related diseases, and diarrhoea and malaria are by far the largest causes of mortality (Batterman et al., 2009). In Burkina-Faso, 20,000 children under five years die annually because of water related diseases (Maxwell et al., 2012).

The food and particularly vegetable demand in Ouagadougou, the capital city of Burkina Faso, located in a semi-arid zone, need the use of irrigation water in urban and peri-urban gardening (Cissé, 1997; Ensink et al., 2007; Cole et al., 2008; Kedowide et al., 2010). This lead to contamination risks that may expose population such as farmers and consumer to water transmitted diseases. Therefore, it is important to monitor the quality of water used for irrigation in agriculture, and specially that used for fresh vegetables in Ouagadougou.

During the last fifteen years, some studies (Amoah et al., 2004; Raschid-Sally and Jayakody, 2009;Diogo et al., 2010; Koffi-Nevry et al., 2011; Cobbina et al., 2013) highlighted contamination risks by analyzing contamination of vegetables by parasite linked to the quality of irrigation water in West Africa. But in Burkina Faso in particular and generally in the sub-Sudanian semi-arid condition, characterized by important water scarcity and highly increasing pressures on water resources there is still gaps to fill.

For this reason, the main objective of the present study is to determine the physicochemical and parasitological quality of irrigation water and irrigated products from urban and peri-urban gardening in Ouagadougou. The risk of disease transmission from pathogenic organisms present in irrigation water is also influenced by the persistence of the pathogens in the soil (Oliveira et al., 2012). The manures used can be a source of contamination. We, therefore, chose to evaluate contamination risks by analyzing the four matrices: irrigation water, irrigated soil, used manure and irrigated vegetables. A better knowledge of the parasites species and their load in the various water sources used for vegetables irrigation in Ouagadougou will help the government and stakeholders to implement suitable policies to reduce pathogen contamination levels in the environment.

MATERIALS AND METHODS

Study areas and period

The study was conducted in Ouagadougou, the capital city of Burkina-Faso. This city is situated in a Sudanese savannah, an arid zone with low and highly variable rainfall. The climate consists of two season: a dry season from October to April, and a rainy season from May to September averaging 700 mm of rain (Lindén et al., 2012). The dry season consists of two periods which are the “cold and dry” period (between November and January) and the “hot and dry” period between February and May.

Of 24 locations where vegetable crops are grown in Ouagadougou (Kedowide et al., 2010; Somé et al., 2014), 4 sites, the major production sites of irrigated vegetables, were selected for this study. The sampling lasted from December 2012 to December 2013. The 4 sites were selected based on the source of water used for irrigation (called irrigation water type) and the type of vegetables, with emphasis on the vegetables to be consumed uncooked. The first site (called "Boulmiougou") uses untreated natural water from wells and a reservoir having the same name, while the second (Maco) and the third sites (Wayalgin) use wastewater. For analysis, these two sites that are using the same types of water have been grouped on the term “Maco-Wayalghin”.

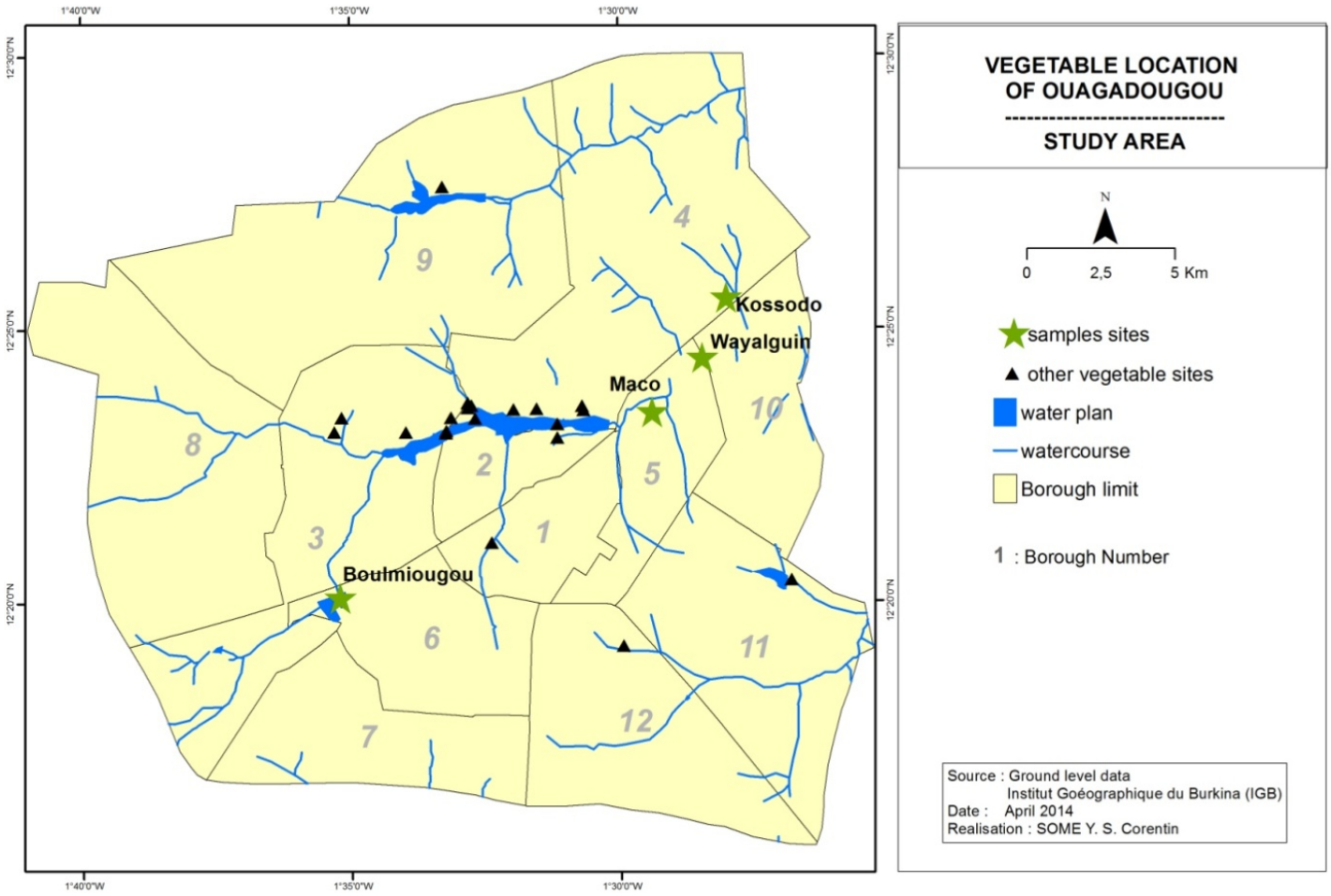

Figure 1. Distribution of the 4 selected vegetables site for survey.

The fourth site (called "Kossodo") uses treated wastewater from a wastewater treatment plant (Figure 1). All the sites had similar land use history. All sites have been used for vegetable cultivation for at least five years, and all the farmers used poultry manure as fertilizer.

Samples collection

Irrigation water collection

From December 2012 to December 2013, twice a month, samples were collected from each of the study sites from the water sources used for crop irrigation such as from well, reservoir, or canal. Two water samples of 5 L each were collected between 8 and 11 am and kept in sterile plastic containers for laboratory analyzes. The pH, electrical conductivity (EC), and temperature (T°C) of each sample were measured *in situ* with a multi-parameter TWT. The results were grouped by season (rainy season and dry season) for analysis.

The parameters obtained from this study were then compared with the World Health Organization (WHO) and Food and Agricultural Organization (FAO) guidelines, the standard parameters to determine the safety level of irrigation waters in Burkina-Faso (WHO, 2006). The water samples were kept in a refrigerated cooler and transported to the laboratory for analysis. The volume of water taken was determined in agreement with Schwartzbrod and Strauss (1989).

Vegetables collection

Once every month, three pre-harvest vegetable composite samples (each containing two whole lettuces) from each of the selected sites were randomly sampled and placed in sterile bag, during the dry season, from January up to May 2013. These collected samples were transported the same day to the laboratory in individual labeled sterile plastic bags for further analysis.

Soil and manure collection

Four composite samples of soil were randomly collected from the study sites on two periods: in December 2012 (cold and dry season), April 2013 (hot and dry season) and again December 2013 (cold and dry season). Leaves and debris on top of the soil were removed before collection of soil. About 250 g of soil from the surface until 7 cm beneath the ground depth were collected and kept in sterile and sealed plastic bags and transported to laboratory. In the meantime, four composite samples of manure used as

fertilizer by farmers were collected in sterile plastics bags and brought to laboratory.

Samples processing for parasites analyses

Samples processing to obtain liquid phase

In this study, we had the following matrices: soil, vegetables, manure and water. To detect parasites in these matrices (except water), we used methods with the intention to suspend the target organisms and to extract them into a liquid phase (Adamu et al., 2012). Therefore, in the laboratory we first proceeded by washing all samples with physiological saline solution (0.95% NaCl). For fresh vegetable, a sample of 100 g was chopped into small pieces and put into plastic carboys containing the physiological saline solution, enough to wash the vegetable sample. For soil and manure, 15 g of sample was sieved and added to 300 milliliter of physiological saline solution.

After removing fragments and debris from the washing saline solution, resulting from vegetables, soil and manure, the solution and water were allowed to settle overnight. The sludge was used after concentration for qualitative and quantitative analysis (Sylla and Belghyti, 2008).

Parasites quantification

Liquid phases (water and sludge from vegetables, soil and manure) were examined for parasites according to the modified Bailenger method (Mara et al., 1989; WHO, 1997). In order to allow further analyses of parasites viability, we adapted the modified Bailenger method by skipping the ether step. We did because ether can affect eggs and cysts viability. Note that, all reagents used for this study, were of purest commercial available grade and used without further purification. Briefly, each sample was allowed to settle over 24 h in the laboratory at room temperature. Then, the supernatant was removed using a siphon. The sediment was centrifuged at 1,000 ×*g* for 15 min. After that, the pellet was suspended in an equal volume of acetoacetic buffer pH 4.5. This pH was considered as the most favorable to concentrate parasites (Alouini, 1998). In the standard protocol of Bailenger, two volumes of ether must be added to the sample, as said above this step was skipped. The sample was then centrifuged at 1,000 ×*g* for 15 min. After recording the volume of the pellet, it was resuspended in five volumes of zinc sulfate solution (0.1 M $ZnSO_4$) with a gravity of 1.3 (density 33%) and mixed thoroughly. This density was considered as adequate, leading to a good purification of parasites (Gati, 1992). 50 µL were transferred to a slide for microscopic (Motic BA 200) counting (magnification of 100 and 400×). The number of ova or cysts per liter of water was calculated following the equation proposed by Ayres et al. (1996): N = A. X / P.V. in which A is the number of parasites counted on the Mac Master slide (REF 06 112 40, Lot 23001, Lauda-Königshofen, Germany); X the volume of the final product (ml); P theMac Master cell capacity (0.3 ml) and V the pellet volume.

Analysis of parasites viability

The viability of parasitic elements was determined with safranin O (C20H19CLN4) according to de Victorica and Galvan (2003) standard method. Briefly, after parasites quantification, one to two drop of safranin O were added to each sample. Some minutes later, 50 µL were transferred to a slide for microscopic counting. When they are still alive, the membrane activity avoids penetration of the stain (safranin O) in the cysts or eggs, keep their color and are not stained by the reagent. Those egg or cyst called viable are able to pursue their development and can then cause disease; but, as far as eggs or cysts are dedd the reagent can penetrate the cell and stain it. Those dead eggs and cyst are free of risks. Therefore, the non-viable eggs or cysts will be stained while the viable ones will not be stained.

Data analysis

The data were analyzed using R software. Continuous and binary data were obtained during this study. The continuous data were not normally distributed according to the Shapiro-Wilk test. Therefore, the Kruskal-Wallis non-parametric test was used to seek for links between measured parameters and sampling sites and dates. In addition, linear correlation analyses were performed to identify the relationship between the measured parameters. Analysis result are given at $p<0.05$ level of significance.

RESULTS

All in all, the following categories and number of samples were collected and analyzed: water (n=97), lettuces heads (n=20), manure (n=10) and soil (n=9).

Physicochemical quality of irrigation water

The temperature of vegetables irrigation water in our study sites ranged between 27.5 and 35.65°C, with a mean of 29.76°C.

The electrical conductivity (EC) values varied from 300 to 4410, 1732 to 13530, and 111 to 27890 µS/cm in the well water, treated wastewater and raw wastewater, respectively. The Kruskal-Wallis rank sum test showed significant difference ($p = 0.001$) in the EC values between the types of irrigation water. Analysis also showed significant variation of EC ($p = 0.01481$) within seasons, with the rainy season having higher conductance value than the dry season (Figure 2). Treated and raw wastewater showed high electric conductivity. When compared with FAO standards (FAO, 2003) for water used for irrigation of agricultural crops, which requires EC ≤3000 µS/cm, only the EC values for the well waters meet the FAO requirement.

The mean values of pH for all irrigation water types are slightly basic, and vary significantly ($p = 0.0001$) between water types. However, mean values of pH are out of standards for raw and treated wastewater (Figure 3).

Parasitological quality of irrigation water sources and irrigated produces

Parasitological load of irrigation water source

Of the 97 water samples collected and analyzed during this study, 36 were treated wastewater, 34 were well water, and 27 were raw wastewater. Of the 97 water samples collected, 35 contained at least one of the parasites species responsible for waterborne diseases. Observed parasites species belong to the two phylums:

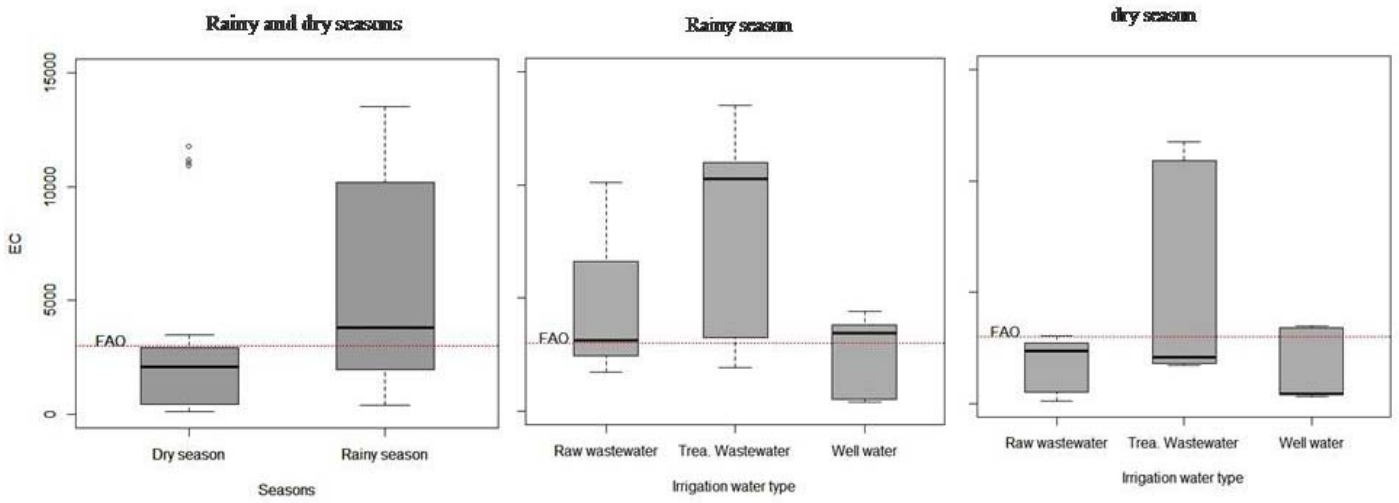

Figure 2. Seasonal variability of electrical conductivity in the different irrigation water types in Ouagadougou (surveys 2012 -2013).

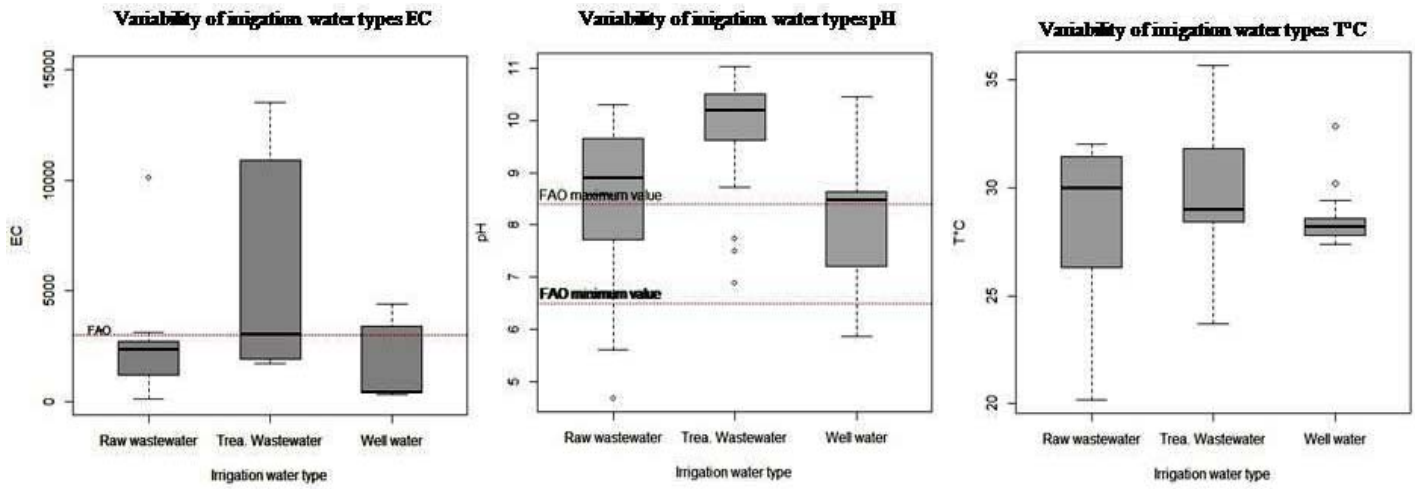

Figure 3. Comparison of physicochemical parameters of different irrigation water types in Ouagadougou (surveys 2012 -2013).

Protozoa and Helminthes. Those parasites are encountered under several forms: ova, larvae, cyst and trophozoite. *Ancylostoma duodenalis*, *Hymenolepis nana, Ascaris lombricoïdes, Taenia* ssp. and *Strongyloïdes stercoralis* eggs, which were helminthic parasites, were detected respectively in 31.42, 14.29, 8.57, 8.57 and 2.85% of the contaminated samples. The protozoa *Entamoeba histolytica*, *Giardia lamblia, Entamoeba coli*, were also found respectively in 22.86, 14.29 and 5.71% of contaminated samples. Table 1 shows the prevalence of each species.

Furthermore, in positive water samples, the eggs average densities were 16.94 and 11. 77 egg/L, respectively, in well water (Boulmiougou: natural untreated water), treated wastewater (Kossodo) and raw wastewater (Maco-Wayalgin). The density of cyst was 0.47; 6.22 and 0.0 cyst/L respectively in well water, treated wastewater and raw wastewater (Figure 4). Then, parasites density increases from well water to raw wastewater; But, there was statistically no significant difference between the total egg or cyst count/L in samples from different water types (p =0.2392). The average parasite density was significantly higher in dry season than rainy season (p = 0.04647).

In addition, the linear correlation analysis performed to identify the relationship between the parasites density and water physicochemical parameters showed that parasites density was only significantly and positively correlated with EC. (R2 = 0.5207, p = 1.333e-05). Furthermore, the linear model shows that density variation was significantly explained at 92.44% (p < 2.2e-16) by EC and T°C together.

Table 1. Occurrence and parasites load in the irrigation water sources in Ouagadougou (surveys 2012-2013).

Parasite	Parasites species	Occurrence (%)	Parasite load	Viability (%)
Helminthes	*A. duodenalis*	11.34 (11/97)	122.82	45.595
	A. lumbricoïdes	4.124 (4/97)	10	35.714
	Tænias sp.	3.093 (3/97)	26	38.482
	S. Sterticolis	1.031 (1/97)	1	100
	H. nana	2.062 (2/97)	8.66	69.169
Protozoan	*E. histolytica*	8.247 (8/97)	113.66	40.753
	E. coli	2.062 (2/97)	670.3	0
	G. lamblia	5.155 (5/97)	37	59.459

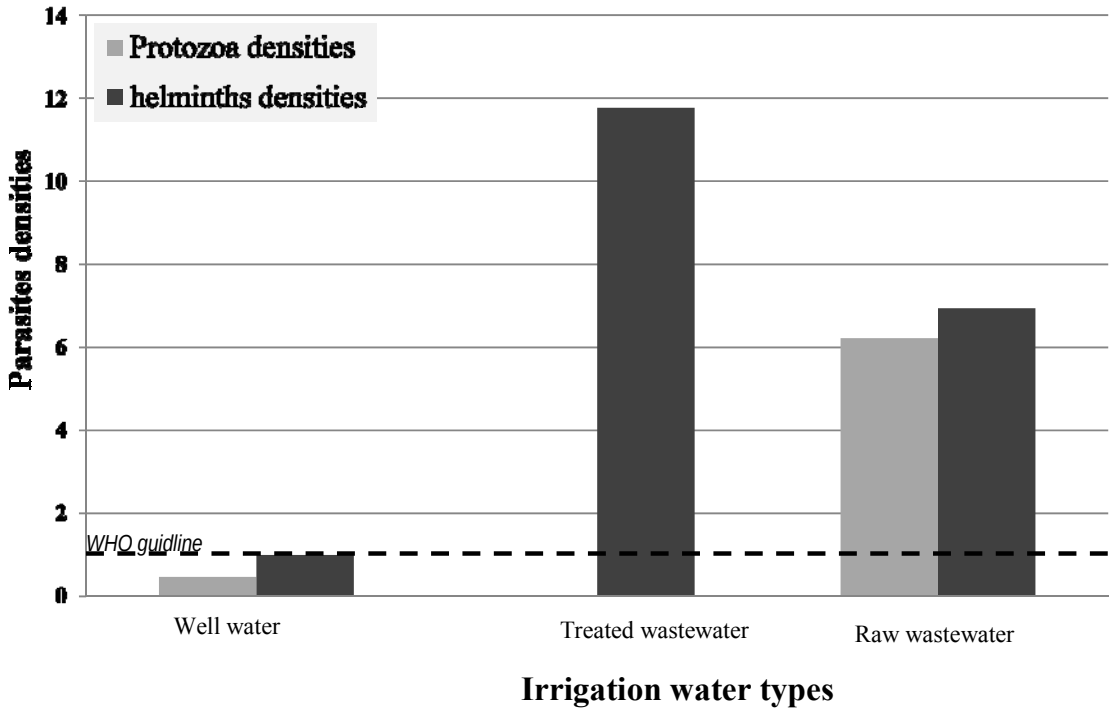

Figure 4. Comparison of parasites densities in the water sources between sampled sites in Ouagadougou (surveys 2012 -2013).

The assessment of viability of eggs/cysts recovered gave the following results: of the total 986 eggs/cysts collected, only 14.87% have proven to be viable. As shown in Table 2, the eggs of helminthes accounts for only 16.77% of parasitic elements collected. However, they represent up to 78% of viable parasitic elements with a predominance of *H. nana* with 69.17% viable, *A. duodenalis* with 55.88% viable. In the protozoa phylum, *G. lamblia* with 59.46% and *E. histolytica* with 48.32%, presenting highest rates of viability. All collected cysts of *E. coli* were non-viable.

Furthermore, the study of viable eggs/cysts distribution according to the seasons and sites shows a slight surplus in the cold dry season. Among sites, Maco-Wayalgin, where raw wastewater is used for irrigation, shows the highest viable rate (Figure 5). These differences are not statistically significant ($p>0.05$).

Parasitological load of irrigated produces

Up to 20% of 20 lettuce samples harvested during the study contained at least one of the following parasites species: *Ancylostoma duodenalis, Taenias* spp., *Entamoeba histolytica*. On the contaminated lettuce leaves, we counted an average of 0.45 egg-cyst/g. No

Table 2. Distribution of parasites species according to the irrigation water types in sampled sites in Ouagadougou (surveys 2012-2013).

Parasite	Parasites species	Raw wastewater (channels water)			Treated wastewater (WWTP water)			Untreated natural water (Wells water)		
		Occurrence (%)	Parasite load	Viability (%)	Occurrence (%)	Parasite load	Viability (%)	Occurrence (%)	Parasite load	Viability (%)
Helminthes	*A .duodenalis*	14.81 (4/27)	14.49	48.87	16.66 (6/36)	105.33	46.33	2.94 (1/34)	3	33.33
	A. lumbricoïdes	3.70 (1/27)	3	0	2.77 (1/36)	5	50	5.88(2/34)	2	0
	Tænias sp.	7.41(2/27)	25	40	2.77(1/36)	1	0	0	0	0
	S. Sterticolis	0	0	0	2.77 (1/36)	1	100	0	0	0
	H. nana	3.70 (1/27)	2	0	2.77 (1/36)	6.66	89.93	0	0	0
Protozoa	*E. Histolytica*	11.11 (3/27)	88	48.86	11.11 (4/36)	19.66	16.89	2.94 (1/34)	6	33.33
	E.coli	0	0	0	2.77 (1/36)	667	0	2.94 (1/34)	3.33	0
	G. lamblia	0	0	0	8.33 (3/36)	25	64	5.88 (2/34)	12	100

significant difference was observed regarding the repartition of contaminated lettuce both by site (by type of irrigation water) and season.

In contrast, while fertilizer samples were found to be free of parasites, 33.33% of analyzed soil samples contained eggs of *A. lumbricoides* and *A. duodenalis*. The average quantities of eggs in these soils were 0.48 egg/g. Also of 16.38 eggs or cysts collected from the soil and on lettuce leaves, only 3 were viable.

DISCUSSION

The most influential water quality parameter on crop productivity is the water salinity as being measured by electrical conductivity (EC). The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water. The higher the EC, the less water is available to plants. According to FAO which has set the acceptable threshold of EC to be less than 3000 µS/cm, only well water is in the acceptable range for vegetable production. This is the same case in Dakar (Senegal), where Ndiaye et al. (2010) investigation of the physico-chemical parameters of irrigation waters of vegetables indicates that the EC of those waters greatly exceeded the currents standards and could not be applied to soils without adverse consequences.

Results of our study indicate increase of conductivity in rainy season for all water types. Abakpa et al. (2013) also noticed the same trend in Nigeria. Reasons for this trend may be the increase in concentration of salts, organic and inorganic materials as a result of discharges by the runoff from domestic and other human activities into the river during the rainy season (Anhwange et al., 2012).

Water temperature is an important variable for waterborne pathogen concentrations. It has a varying effect on waterborne pathogens (Hofstra, 2011). Indeed, if some indigenous species of bacteria, amoebas and algae are able to grow in aquatic environments with higher temperatures, enteric bacteria, viruses and para-sites that are derived from human or animal faeces are not (Braks and de Roda Husman, 2013). In reservoir waters at 22 and 30°C, 45 and 11 days, respectively, were estimated for a 2 log reduction of *C. parvum* infectious oocysts (Carmena, 2010). Smith and Schad (1989) also showed that mortality of egg of *Ancylostoma duodenale* and Necator americanus increased exponentially between 15 and 35°C.

However, the mean values water temperature of our irrigation sources varied from 28.5 to 30.6°C. This may explain the fact that we have collected little oocyts and eggs in our irrigation water. Moreover, although using the Bailenger modified method as reference methods for the detection of parasites in environmental samples, the recovery rate remains low (30-74%) (Malicki et al., 2001). This necessarily leads to an underestimation of the actual parasite density. However, the average parasite density we obtained were higher than that reported by Nitiema et al. (2013).

Despite the low level of parasites recovered in Ouagadougou vegetables irrigation water, these parasitic densities exceed the standards established by WHO for unrestricted use. So, there is an evidence of potential disease transmission in association with the use of those waters in vegetables production.

The evidence strongly pointed to the helminthes as the number one problem, particularly in developing countries like Burkina-Faso and Botswana (Emongor, 2006; Karou et al., 2011). The parasitic contamination of water resources and soil reflects the epidemiological status of the local community (Carabin et al., 2009). In fact, numerous studies performed to determine the prevalence of intestinal parasites in the Burkinabe population has reported amongst others, *E. histolytica, E. coli, G. lamblia, Taeniae* sp., *Ancylostoma* sp., *A. lombricoïdes, H. nana* and *S. stercoralis* (Carabin et al., 2009; Ouermi et al., 2012; Fortunato et al., 2014). These same parasitic species were found in environmental matrices analyzed in this study. In general, intestinal parasites in the

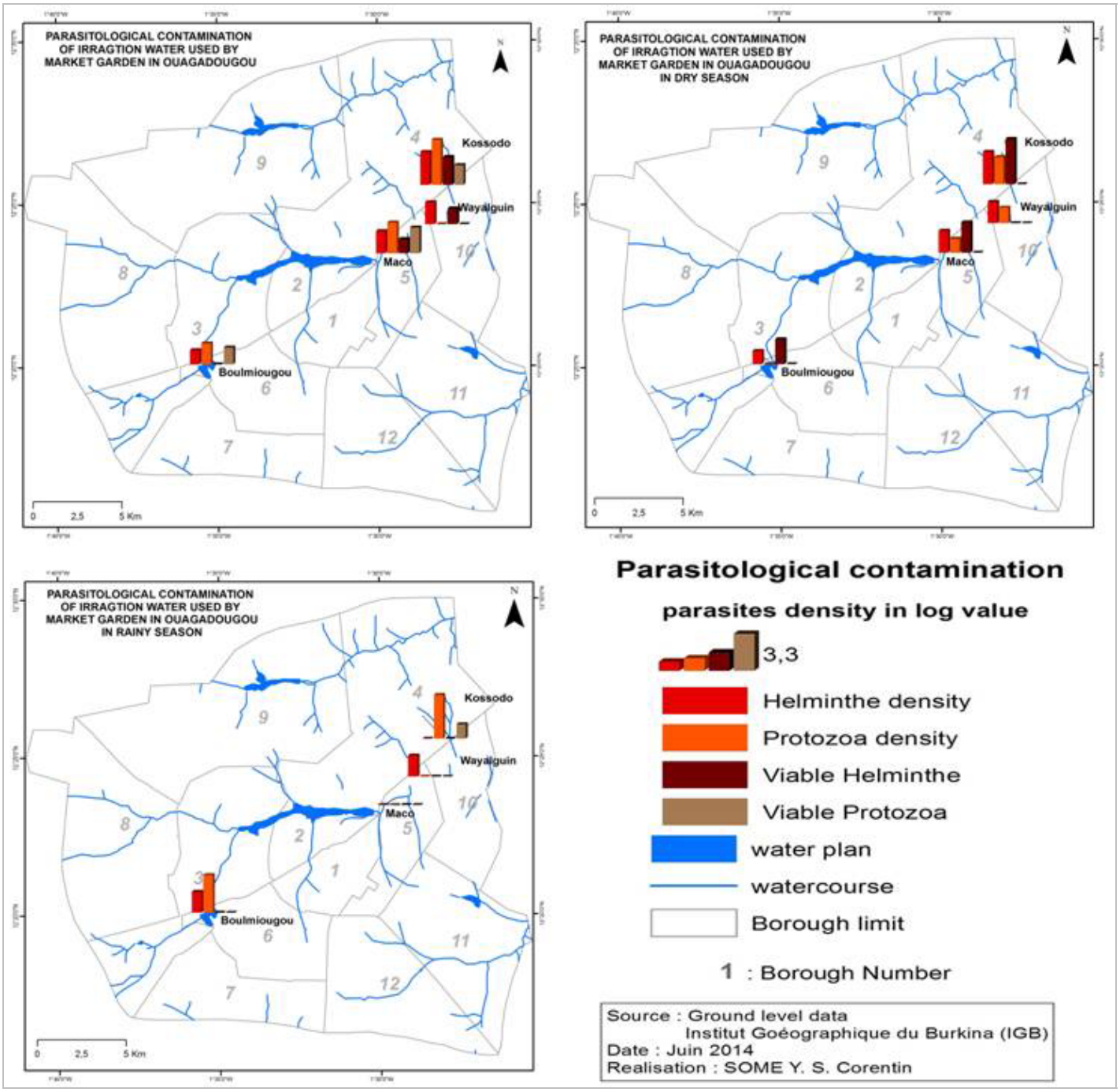

Figure 5. Variation of eggs/cysts viability according to sites and seasons.

Burkinabe community are due to protozoa in more than 50% protozoa (90.53 and 92% of infections against only 9.47 and 8% for helminths). This same trend has been observed in the environmental matrices. In addition, the study revealed a seasonal variation in the occurrence of parasites in water samples, where parasites are more likely during the dry season than in the wet season. This could well be because the soil-transmitted helminths, particularly hookworms were the most observed. Indeed, Brooker et al. (2006) showed that hookworms have ability to survive in high surface temperature which exceeded 38-40°C (which is similar to Ouagadougou temperatures during the dry season).

However, the mere presence of parasites in an environment is not a sufficient condition to induce a potential risk of contamination. One condition for that contamination

to occur is that the isolated parasite must be viable. In fact, viability is of prime importance in the epidemiology of parasitic infections, and can be defined as the capability of an egg to develop to its infective stage, thus being able to cause sickness. Results showed a high rate of viability of helminthes eggs as compared to protozoan cysts. In general, available evidence indicates that helminthes eggs are more resistance to environmental stresses than protozoan cysts. This can be attributed to the fact that helminthes eggs have strong membrane with several layers acting as barriers to environment condition (Maya et al., 2010). Contrary to *Escherichia coli* that shows no viable cysts, *E. histolytica* presented high rate of viable cyst. That could be explained by the fact that *E. histolytica* is the only protist characterized to date that has chitin in its cyst wall (Chatterjee et al., 2009). However, some will result in some resistance to environmental stresses.

In the aquatic environment, the fate of pathogenic microorganisms is governed by biotic and abiotic factors (Lafferty and Kuris, 1999; Zarlenga and Trout, 2004; Baudart and Paniel, 2014). In this work, it was abiotic factors which were represented by the physico-chemical phenomena. Indeed, different studies show that helminthes eggs and protozoan's cysts may be inactivated by high T°C, pH or EC (Baudart and Paniel, 2014). The value reported in literature for these parameters fall within a wide range (40 to 108°C for temperature, 9 to 10 for pH). But in practice, these conditions were not always valid. The reason for this variability is that each parameter does not act in an isolated way. As shown by the results of the correlation, they are interdependent producing combination which may be effective or not (Pecson et al., 2007; Minato et al., 2008). In addition to these factors, the reagents used for isolation also have impact on parasitic elements viability (Nelson and Darby, 2001). In fact, a wide range of reagents have been reported in the literature for use in isolating helminthes eggs and protozoan cysts from environmental samples. Among these reagents, $ZnSO_4$ solution is used for density flotation. However, experience has shown that $ZnSO_4$ solution appears to have a negative impact on the viability of parasitic elements (Nelson and Darby, 2001). Hence the low viability reported in this study even though the ether protocol was eliminated from earlier processing steps.

The quantity of eggs and cysts in irrigation water is expected to be directly related to the quantities of these parasitic elements on irrigated vegetables and soils. However, as indicated by work carried out in Nairobi, Kenya (Karanja et al., 2009), unlike some heavy metals that have the ability to accumulate in the soil and vegetables, parasites do not seem to have this ability. Only a small share of water parasite load can be found on fresh vegetables and irrigated soil. Parasitic species collected on our lettuces are in the range of those found usually live on irrigated vegetables by poor water quality.

Despite variation in isolated parasites, ova of *A. lumbricoides* and *A. duodenalis* were common to all water, soil and vegetables in studies. This could be due to the fact that these parasites can withstand a wide variety of adverse environmental condition which could serve as an indicator of water pollution and farmlands as observed by Damen et al. (2007).

In light of our results, four groups of people are seen as potential risk groups to parasitic infections related to the use of poor quality water in agriculture. There are children, consumers, farmers and population living nearby contaminated irrigated water field. However, the most exposed groups are farmers due to the duration and intensity of their contact with contaminated water and soil.

The source of agricultural water could determine the final safety of food production. Protecting and maintaining the quality of irrigation water is of great importance. The parasitological quality of irrigation water at the study sites are bad, as all water categories are contaminated even the well water assumed to be natural and free of parasites. This rise up the necessity for authorities and stakeholders to ensure better management of waste and wastewater in order to minimize contamination of surface and ground water.

Protective measures such as wearing boots and gloves and the use of irrigation methods that limit contact with wastewater could be enforced to reduce farmer's exposure. Farmers also can wash their arms and legs after immersion in contaminated water to prevent the spread of infection. These measures would benefit both the farmers and the consumers of fresh vegetables.

Conclusion

The results of this study provide an overview of the state of parasitological pollution of water used as a source for crops and vegetable irrigation in Ouagadougou. These contaminations are above the thresholds of WHO, without regard to water types (natural untreated, treated wastewater, raw wastewater), sites and seasons. The results reveal a low level of parasites transfer from irrigation water to irrigated vegetables. In addition, unlike eggs/cysts collected in irrigation water, nearly all those collected on harvested vegetables were non-viable. This suggests that of the four groups of people (children, consumers, farmers and population living nearby contaminated irrigated water field) identified by the WHO as risk groups to parasitic infections related to the use of poor quality water in agriculture, farmers would be by far the most exposed. It is appropriate to quantify the risk and plan future activities in order to control this potential source of spread of parasitic diseases in the population.

Conflict of interests

The authors did not declare any conflict of interest.

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