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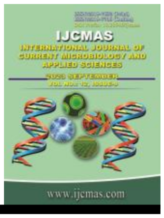

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Bacteriological and Physico-Chemical Quality of Vegetable Irrigation Water in the City of Ouagadougou, Burkina Faso

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ABSTRACT

The water used in the city of Ouagadougou for vegetables irrigation is often of questionable quality and can pose a public health threat to the population. The objectives of the present study were to estimate the concentration of microorganisms and physicochemical parameters in water used for irrigation. Water samples from three sites were analyzed according to standard methods. Total coliforms were on average 3.5×10^3 CFU / 100 ml; 2.8×10^3 CFU / 100 ml; 5.5×10^3CFU / 100 ml respectively for water from site 1, site 2 and the Tanghin dam. Fecal coliforms were 1.2×10^3 CFU / 100 ml; 4.1×10^2 CFU / 100 ml; 1.1×10^3 CFU / 100 ml respectively for site 1, site 2 and the Tanghin dam. The mean fecal enterococci were 4.9×10^2 CFU / 100 ml; 4.0×10^2 CFU / 100 ml; 7.4×10^2 CFU / 100 ml respectively for site 1, site 2 and the Tanghin dam. A sample from the Tanghin dam had magnesium concentration higher than the WHO standard. This study reveals that the site 1 and the Tanghin dam are not suitable for the irrigation of vegetables in Ouagadougou and measures must be taken to purify the water to the required standards.

Keywords

Water quality, physico-chemical, bacteriological, urban agriculture

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Introduction

Water is an essential natural resource and plays a determining role in the life of humans, animals and plants since it is necessary for all socio-economic activities (Ballouki, 2012; Aubry, 2013). Water becomes polluted because of anthropogenic activities and the natural processes like soil erosion and runoff from rain water (Aw *et al.*,2011).

Today, nearly 10% of the world's population consume food produced using wastewater for irrigation in urban and peri-urban areas (Christine, 2013; Tidjani *et al.,* 2018).

In Sub-Saharan Africa, 50 to 90% of vegetables consumed in large cities are produced in urban or peri-urban areas mainly with wastewater (Drechsel *et al.,* 2006; Atidegla *et al.,* 2017). This has become more common because of teaming youth without any other source of readily available employment. In Burkina Faso, some of the water used for urban agriculture comes directly from residential or domestic waste water (Compaoré, 2013).

This urban agriculture which is mainly market gardening can be an alternative solution to the problem of urbanization (Orsini *et al.,* 2013). Let's define market gardening here! In fact, market gardening allows the recycling of household waste as compost to amend the soil for vegetable production and hence helps in the reduction of unemployment, improves food security and reduces poverty in the cities (Agbossou *et al.,* 2003).

While such a practice increases agricultural yields and contributes to the city's food needs, there can be many hazards associated with the use of wastewater. According to Babadjidé (2001), polluted water is one of the elements that affects human health. In Burkina Faso, Traoré *et al.,* (2015) found a prevalence of 27% of *Salmonella* in surface water used for irrigation in the city of Ouagadougou. Indeed, water can be a source of disease due to the degradation of its physico-chemical and microbiological quality (Babadjidé, 2001).

According to Ouédraogo (2018), the city of Ouagadougou is largely supplied with market garden products grown using water from dams, wells and boreholes, but especially wastewater from ponds whose quality remains questionable. Under these conditions, the consumption of such market garden products could constitute a high risk to public health and safety. This study was initiated in order to better understand the bacteriological and physico-chemical quality of water used for irrigation of vegetables in the city of Ouagadougou.

Materials and Methods

Study site

The samples were taken from three sites in the city of Ouagadougou. The two sites were in the Ouaga 2000 district (site 1 and site 2) and the third site was the Tanghin dam. The Tanghin dam was chosen because it is part of the largest market gardening sites in the city of Ouagadougou. In addition, the Tanghin dam is one of the city's largest water reservoirs. The Ouaga 2000 sites were chosen because they are located in the middle of homes and most of the water comes from domestic wastewater. A total of twenty-four (24) samples were taken and analyzed with a replication of eight (08) samples per site.

Characteristics of study sites

Description of Ouaga 2000 Site 1

Due to its shallow depth the water is distributed over a large area. At a depth of less than sixty centimeters (60 cm) even in the rainy season the site remains waterlogged throughout the year. In the dry season, most of the water comes from domestic wastewater which flows through the drainage channels to reach the site. There are many plant species including water hyacinth and algae in the water. Vegetables irrigation is practiced in the dry season over the entire stretch of the site. We also noticed a strong use of organic manure (animal excreta) by market gardeners as well as the existence of numerous wastes (pieces of tissue, plant debris household waste etc.) in the water and around the site (Figure 1).

Description of Ouaga 2000 Site 2

The water of Ouaga 2000 site 2 mainly comes from runoff. The quantity of water gradually reduces in the dry season until they are completely exhausted by the end of March. This situation forces gardeners to use water from wells beyond this period for their vegetable cultivation. During the rainy season the site is flooded and rice cultivation is also practiced there. At this site, the volume of water is more with a depth of about 100 cm. Water hyacinth is also found but very little waste and organic manure around the water (Figure 2).

Description of Tanghin dam

The water of the Tanghin dam mainly comes from runoff and becomes stagnant in the dry season. This period is marked by a gradual decrease in the volumes of water and used for irrigation of vegetables. This dam is characterized by the presence of water hyacinth, algae, the strong use of organic manure and a lot of waste around (Figure 3).

Study period

This is a prospective study on the quality of water used in market gardening. The study was carried out from December 2018 to February 2019. Three (3) sites were surveyed to describe their environments (presence or not of water hyacinth other debris) and the use or not of organic manure.

Samples collection

During each field trip, two (2) samples were taken. For the physico-chemical analyses, one liter of polyethylene bottle previously washed with hydrochloric acid (5%) and then rinsed with distilled water was used to collect the water. At the time of collection, the sampling bottles were rinsed three times with the water samples. The water was taken from a depth of 10 to 50 cm from the surface of the water avoiding the penetration of air.

A sterile bottle of 500 ml was used for the microbiological analyses. For this, the sample was taken by first cleaning the external part with alcohol and directly immersing the vial in water before opening it in order to avoid contamination of the sample by other outside bacteria. A small space has been left free to allow the gas exchange of the microorganisms.

After collection, the samples were placed in a hermetically sealed cooler containing "ice boxes" and immediately transported to the laboratory for analysis.

Microbiological analyses of samples

For samples dilution, 1 ml (more concentrated samples) or 10 ml (less concentrated samples) of the stock solution were taken and made up to 100 ml with sterile distilled water and then filtered through nitrocellulose membranes (SIGMA Aldrich) with 0.45 µm pores sizes for the detection of fecal coliforms and enterococci, and 0.2µm pores sizes for *Pseudomonas aeruginosa* identification using the filtration technique.

After the filtration, membranes were placed on Chromocult Coliforms Agar Extra Selective CCAES (Merck, Germany) and incubated at 37◦C four48 hours. Dark red and blue colonies were identified as total coliforms and the dark blue colonies as fecal coliforms. Identification of *Escherichia coli* was made by picking out dark blue colonies in tubes containing indole-free peptone water and incubating at 35-37◦C for 24 hours and confirm by indole test.

Isolation and identification of intestinal enterococci was performed on Slanetz and Bartley (SB) culture medium after incubation at 37 °C for 48 hours. The red colonies were suspected enterococci colonies. Then the membrane was transferred to Bile Esculin Azide (Merck, Germany) and incubated at 44◦C for 2 hours, and the colonies showing a brown to black color in this medium were considered as enterococci. For *Pseudomonas aeruginosa* identification, the membrane (0.2 µm) was then transferred to Cetrimide agar (Oxoid, UK) supplemented with 15 mg/L of nalidixic acid. After incubation at 37°C ± 1◦C for 48 hours, the green colonies were considered as presumptive colonies and confirmatory tests were performed on King A medium with an inclined Plate Count Agar tube.

For *Salmonella* identification one (1) L of the sample was filtered using multiple membranes due to blockage. After the filtration step, the membranes

(0.45 µm) were introduced into 50 ml of buffered peptone water (EPT) and incubated at 37°C for 16 to 20 hours (pre-enrichment step). Then 10 µl of the pre-enriched broth was taken and homogenized with 10 ml of Rappaport Vasilliadis Soja (Oxoid, UK) and incubated at 44◦C for 24 hours (enrichment step). After enrichment, 10 µl of the enriched medium were taken and then inoculated by streaks on the Xylose-Lactose-Decarboxylase (Oxoid, UK).

After 24 hours incubation at 37°C, red colonies with or without black centers were suspected of *Salmonella enterica* and confirmed by API20E trip.

Physico-chemical analyses of samples

All the physico-chemical parameters were determined by the standard methods recommended by the American Public Health Association (APHA, 2012). In situ physical parameters like pH and electrical conductivity (EC) were measured using respectively a portable pH meter brand WTW and series 3110 pre-calibrated with buffer solutions (pH4 and 7) and SCHOTT conductivity meter.

Turbidity of the samples were determined by using portable 2100Q HACH turbidity meter.With regard to the quantification of mineral elements, the methods used were titrimetric and spectrophotometry methods. To determine the chloride (Cl^{-}) concentration, 100 ml of the sample was placed in a 500 ml conical flask using a volumetric flask. After adding 1 ml of the potassium dichromate solution (colored indicator) the mixture turned to yellow. The assay was then done immediately with stirring with the silver nitrate solution.

$$C(Cl) = \frac{(Vs - Vb)\ast}{Va}$$

where:

C (Cl) the concentration in mg / L of chloride, Va the volume of the sample (Va = 100 ml), Vbis the volume (ml) of the solution used for the titration of the blank, Vs is the volume of the silver nitrate solution used for the titration of the sample, C the concentration (expressed in moles) of $AgNO_3$ per liter of silver nitrate solution and f is the conversion factor(f = 3545mg / mol).

To determine total hardness, 50 ml of the sample was placed in a 250 ml conical flask. Then 4 ml of the buffer solution (pH 10) and 3 drops of the black Eriochrome T indicator (NET) were added to the sample. This gave a pink colored solution. This mixture is titrated with stirring with a 0.01 mol/L solution of ethylene diamine tetra acetic (EDTA).

$$C(Ca + Mg) = \frac{1000 \ast C}{V2}$$

where:

C (Ca + Mg) is the total hardness, C the concentration of EDTA solution expressed in moles per liter of,V1 the volume (ml) of the EDTA solution used for the titration and V2 the volume (ml) of sample (V2 = 50 ml).

The calcium concentration was determined by taking fifty (50) ml of the sample in a 250 ml Erlenmeyer flask, then 2 ml of a 2N NaOH solution and a pinch of colored calcium indicator (carboxylic acid calcone) were added. The mixture obtained was titrated with stirring using a solution of ethylene diamine tetra. -acetic (EDTA) at 0.01mol / l.

$$C(ca) = \frac{1000 \ast 40.08 \ast V}{V2}$$

where:

C (ca) is the calcium concentration (mg/L), V1 the volume (ml) of the EDTA solution, C the concentration (in moles per liter) of EDTA solution, V2 the volume of the sample (V2 = 50 ml)

The magnesium concentration was deduced from the total hardness and the calcium concentration and is given by the following formula:

$$\mathbf{C (Mg) = C (Ca + Mg) - C (Ca)}$$

where:

C (Mg) is the Magnesium concentration (mg/L), C (Ca + Mg) the total hardness (mg/L) and
C (Ca) is the calcium concentration (mg/L)

Spectrophotometric method was employed for the quantification of mineral elements, including ions such as nitrates (NO_3^-), nitrites (NO_2^-), ammonium (NH_4^+), total iron (Fe^{2+} and Fe^{3+}) and fluorine (F-) in water samples was performed using a UV spectrophotometer (model DR 3900).

Results and Discussion

Microbiological analyses of samples from different sites

In general, all samples were contaminated with varying degrees of bacteria (Table 1). Regarding total coliforms, the highest concentration was 6.8×10^3 CFU / 100 ml and the highest average concentration of 5.5×10^3 CFU / 100 ml, were observed in the samples from the Tanghin dam. The lowest concentration was 1.6×10^3 CFU / 100 ml and the lowest average was 2.8×10^3 CFU / 100 ml, were obtained from site 2 of Ouaga 2000. Site 1 of Ouaga 2000 is intermediate with concentrations ranging from 2.1×10^3 to 4.8×10^3 CFU / 100 ml to an average of 3.5×10^3 CFU / 100ml.

With regard to faecal coliforms, samples from the Tanghin dam had higher concentrations ranging from 1.0×10^2 to 4.0×10^3 CFU/100ml.

From the Site 2, Ouaga 2000, the least concentration of 1.0×10^2 to 1.0×10^3 CFU / 100 ml) and those of Ouaga 2000 Site 1 had an intermediate concentration (1.0×10^2 to 3.6×10^3 CFU / 100 ml. As regards *E. coli*, the concentrations varied according to the sites and according to the samples. Thus the highest concentrations were 3. 5.0×10^3 CFU / 100 ml, 9.7×10^2 CFU / 100 ml, 2.3×10^3 CFU / 100 ml for Ouaga 2000 Site 1,Ouaga 2000 Site 2 and the Tanghin dam, respectively.

In addition, the results indicate that for each site, three (3) of eight (8) samples contained *Enterococci*. The concentration of these bacteria varies from 5.0×10^2 to 1.9×10^3 CFU / 100 ml for site 1 of Ouaga2000; from 6.0×10^2 to 1.3×10^3 CFU / 100 ml of Ouaga 2000 Site 2 and from 8.0×10^2 to 3.4×10^3 CFU / 100 ml for the Tanghin dam.

At Site 1, three (3) of eight (8) samples (3/8) (i.e. a rate of 37.5%) had faecal coliforms concentration that did not meet the WHO standard (≤ 1000 CFU / 100 ml) and two out of eight samples (i.e. a rate of 25%) had an *E. coli* concentration that did not meet the WHO standard. At the Tanghin dam, two samples out of eight (a rate of 25%) had concentrations of faecal coliforms and *E. coli* that did not meet the WHO standard.

The presence of faecal coliforms and enterococci in the samples shows that there is faecal contamination of these water bodies. Faecal contamination would be linked to the use of animal excreta as manure and also to domestic water (case of Ouaga 2000) which could contain human faecal matter.

The results of our study are similar to those found in Benin (Djegbe *et al.*, 2018) which reported total and faecal coliform concentrations of 5.0×10^3 CFU / 100 ml and 2.5×10^3 CFU / 100 ml respectively. Similar results have been observed by several authors notably Ndounla (2007) on the quality of spring and well water in the city of Dschang in Cameroon, Hounsounou *et al.*, (2016) on the wells of Grand-Popo in Benin as well as Nguendo (2010) on the bacteriological quality of water in Abomey-Calavi in Benin. Another study carried out on the irrigation waters of the city of Ouagadougou reported concentrations of faecal coliforms and enterococci that were much higher than our results (Thiaw, 2006).

Bacteria such as *Salmonella enterica* and *Pseudomonas aeruginosa* were not detected in our samples. Contrary to our results, Dao *et al.*, (2018); Traoré *et al.*, (2015) previously isolated *Salmonella* in irrigation water in Burkina Faso. In Côte d'Ivoire, Tano *et al.,* (2011) also found *Salmonella* in irrigation water. This difference would be linked to a very low concentration of *Salmonella* in the water used in these water bodies which make their isolation difficult.

Physico-chemical characteristics

The physicochemical results are summarized in Table 2

Ammonium (NH_4^+), nitrites (NO_2^-) and nitrates (NO_3^-) concentrations in water

The average ammonium concentration was higher at the Tanghin dam (0.85 mg/L) more than at Site 2 of Ouaga 2000 (0.45mg/L) and Site 1 of Ouaga 2000 (0. 18 mg/L). The presence of ammonium would be linked to leaching of soils enriched in nitrogenous fertilizers to a process of incomplete degradation of organic matter and to urban discharges. According to Rodier *et al.,* (2009) ammonium may come from the breakdown of nitrogen in urine and faeces. Our results are quite similar to those found in the water of the Boulmiougou dam (average = 0.3 mg/L) and lower than the values obtained in the treated wastewater from Kossodo (average = 9.28 mg/L) by Bougma (2016). This difference would be due to the fact that the treated wastewater would have come from industrial waste which is rich in ammonium due to the use of nitrogenous products.

With regard to nitrites, the minimum concentrations are very low at the three sites with 0.5 mg/Las the highest value (Sites 1 and 2 of Ouaga 2000). Our results are comparable to those of Kamsu (2008). Nitrites can come either from incomplete oxidation of ammonia or from reduction of nitrates by denitrification (Rodier *et al.,* 2009) and the low rate observed is believed to be due to their rapid transformation into nitrates.

Indeed, the results indicate a higher average nitrate concentration at Site 1 of Ouaga 2000 (average: 8.35 mg/L) and low at the Tanghin dam (average: 0.425mg/L) and then for this parameter, our samples complied with the WHO standard (<50mg/L) (Figure 4).

The presence of nitrates at Ouaga 2000 Site 1 could be linked to the excessive use of organic manure at this Site (compared to other sites) as well as to the waste observed around the site. In addition, it could be due to domestic water which may contain human excreta (urine, stool, etc.).

The present study results are comparable to those previously reported at the Boulmiougou dam in Burkina Faso (Kamsu, 2008). On the other hand, values higher than ours (Atidegla *et al.,* 2010) and lower than our values (Tano *et al.,* 2011) have been reported respectively in Benin and Ivory Coast.

These differences in results could be explained by the difference in fertilizer application in these countries. Given that nitrates are nutrients that can be directly used by plants, their low content in certain samples (Site 2 of Ouaga 2000 and the Tanghin dam) could be explained by their direct assimilation or by the cultivation of crops in the case of Site 2 of Ouaga 2000 (market gardening in the dry season and rice growing in the rainy season).

According to Leclerc (2008) water pollution by excess nitrates is one of the major causes of long-term natural water degradation. Their proliferation leads to a decrease in the oxygen content of the environment and consequently to the mortality of aquatic fauna and flora (Ouattara, 2016).

pH of the water

The pH of the samples varied between 6.86 to 7.60, 7.21 to 7.53 and 7.30 to 7.99 respectively for Site 1, Site 2 of Ouaga 2000 and the Tanghin dam. This is conforming to the WHO standard (6.5 <pH <8.5). The present study results corroborate those found in Burkina Faso (Kamsu, 2008; Gampini, 2013; Ouédraogo *et al.,* 2018) and in Côte d'Ivoire (Tano *et al.,* 2011). The low alkalinity (ie 7.35 <pH <7.45) observed in certain cases would be linked to the existence of several aqueous effluents such as washing water, dishes, household toilets which are poured into the gutters which may possibly increase the pH of the water (Djegbé *et al.*, 2018).

The hardness and the concentration of calcium (Ca^{2+}) in water

The results show a higher hardness level of the Tanghin dam (10.4-33 °F) than at the level of Site 1 of Ouaga 2000 (11 to 26 °F) and Site 2 of Ouaga 2000 (7.6 to 12. 2 °F). The values obtained on the Ouaga 2000 sites are similar to those reported in Morocco (Ballouki, 2012). The hardness may be linked to the leaching of the land crossed (Rodier *et al.*, 2009).

As for the calcium concentrations, they varied from 32 to 84 mg/L for Site 1 of Ouaga 2000, 24 to 33.6 mg/L for Site 2 of Ouaga 2000 and 14.4 to 48.8mg/L for the Tanghin dam (Table.2). These values complied with WHO standards (<100mg/L) but much higher than those found by Gampini (2013) and by Bougma (2016).

This difference could be explained by a gradual accumulation of calcium in the water due to the accumulation of waste. In addition, a study carried out on dam water in Algeria showed values much higher than our results (Guerraiche, 2017) which could be explained by a difference in water pollution at the level of the samples sites. Indeed, in organically polluted water courses, the calcium concentration can be increased because the proteins and weak acids resulting from the oxidation of organic matter increase the dissolution of calcium carbonate (Guerraiche, 2017).

Table.1 Microbiological analyses of different sites

	Bacteria	***Total Coliforms***	***Faecal coliforms***	***E. coli***	***Enteroccci***	***P. aeruginosa***	***Salmonella enterica***
Ouaga 20000 site 1	Mean	$3,5.10^3$	$1,2.10^3$	$9,5.10^2$	$4,9.10^2$	00	Absence
	Minimum	$2,1.10^3$	1.10^2	1.10^2	00	00	Absence
	Maximum	$4,8.10^3$	$3,6.10^3$	$3,5.10^3$	$1,9.10^3$	00	Absence
Ouaga 2000 site 2	Mean	$2,8.10^3$	$4,1.\ 10^2$	$4.\ 10^2$	$4.\ 10^2$	00	Absence
	Minimum	$1,6.10^3$	1.10^2	$9.\ 10^2$	00	00	Absence
	Maximum	$4,3.10^3$	1.10^3	$9,7.10^2$	$1,3.10^3$	00	Absence
Tanghin Dam	Mean	$5,5.10^3$	$1,1.10^3$	9.10^2	$7,4.10^2$	00	Absence
	Minimum	$4,4.10^3$	1.10^2	00	00	00	Absence
	Maximum	$6,8.10^3$	$2,4.10^3$	$2,3.10^3$	$3,4.10^3$	00	Absence
WHO standards			$\leq 10^3$	$\leq 10^3$			00

all expressed in (CFU / 100 ml). The detection of *Salmonella enterica* is expressed in the presence or absence

Table.2 Physico-chemical parameters of the waters of the three sites (average and extreme values)

	pH	EC (µS/Cm)	TH (°F)	Ca^{2+} (mgL^{-1})	Mg^{2+} (mgL^{-1})	NH^+_4 (mgL^{-1})	NO_2^- (mgL^{-1})	NO_3^- (mgL^{-1})	Cl^- (mgL^{-1})	F^- (mgL^{-1})	Fe (mgL^{-1})
Ouaga 200 site 1											
Average	7.20	780	20.07	61.50	11.43	0.18	0.18	8.35	76.96	0.26	0.4
Minimun	6.86	481	11.00	32.00	7.30	0.10	00	0.40	46.20	00	00
Maximum	7.60	1174	26.00	84.00	18.00	0.40	0.50	22.40	131.40	1.20	1.30
Ouaga 2000 site 2											
Average	7.34	310.75	9.13	23.90	5.82	0.45	0.06	2.08	24.41	0.46	0.82
Minimum	7.21	279	7.60	24.00	3.40	00	00	0.40	19.90	0.20	0.50
Maximum	7.53	368	12.20	33.60	9.20	1.50	0.50	7.00	42.60	0.70	2.40
Tanghin dam											
Average	7.50	784.75	16.35	38.90	16.10	0.85	0.03	0.43	77.30	0.71	0.48
Minimum	7.30	368	10.40	14.40	3.90	0.10	00	00	30.50	0.40	0.10
Maximum	7.99	1588	33.00	48.80	71.40	1.00	0.10	1.30	191.00	1.70	1.00
WHOG	6.5- 8.5	--	--	<100	<50	--	--	<5	--	≤15	<5

pH= potential Hydrogen ; EC= Electrical Conductivity ; TH = Total hardness ; Ca2+ = Calcium ; Mg2+ = Magnesium ; NH4+ = Ammonium ; NO2- = Nitrites ; NO3- = Nitrates ; Cl- = Chloride ; F = Fluoride; Fe= iron ; WHOG=World Health Organisation Guidelines

Fig.1 Ouaga 2000 site 1

Fig.2 Ouaga 2000 site 2

Fig.3 Tanghin dam

Magnesium (Mg^{2+}), chlorides (Cl^-) and iron (Fe) ions concentrations in water

Regarding magnesium, the highest concentrations (3.9 to 71.4 mg/L) were obtained at the Tanghin dam Site followed by Site 1 in Ouaga 2000 (7.3 to 18 mg/L) and finally from Site 2 of Ouaga 2000 (3.4 to 9.2 mg/L) (Figure 8). In addition, a sample from the Tanghin dam had a magnesium concentration above the WHO standard (<50 mg/L).

This higher or lower concentration of samples from the Tanghin dam may be due to the use of calco-magnesian type amendments. Magnesium in water comes from carbonic acid attack of magnesium rocks and the dissolution of magnesium in the form of carbonates (MgCO3) and bicarbonates (Mg2HCO3) (Guerraiche, 2017).

In addition, the chloride concentrations varied from 46.2 to 131.4 mg/L, 19.9 to 42.6 mg/Land 30.5 to 191 mg/L respectively for Site 1 of Ouaga 2000, Ouaga 2000 Site 2 and the Tanghin dam. The values obtained at Site 2 of Ouaga 2000 are comparable to those found in Morocco on spring waters (Ballouki, 2012). This low concentration of chlorides on Site 2 of Ouaga 2000 could be linked to the low application of fertilizer at this site.

Regarding iron, the different samples had a relatively low content. In fact, in most of the samples from the Tanghin dam, it was less than 1 mg/L while in the samples from Site 1 of Ouaga 2000 and Site 2 of Ouaga 2000, it varied from 00 to 1.3 mg/L and 0.5 to 2.4 mg/L respectively. It is important to specify that all the concentrations obtained complied with the WHO standard (<5 mg/L).

Like other heavy metals, iron could accumulate in vegetables, which consumption may cause serious health problems for consumers. These include renal and hepatic disorders, lead poisoning resulting in biological abnormalities and various histopathological alterations (Degbey *et al.,* 2010).

Water conductivity

The results of this study indicate a conductivity range from 481 to 11174 μScm^{-1} for Site 1 of Ouaga 2000, from 279 to 368 μScm^{-1} for Site 2 of Ouaga 2000 and 368 to 1588 μScm^{-1} for the Tanghin dam. These results differ from those reported in Côte d'Ivoire (Tano *et al.,* 2011) especially with regard to Site 1 in Ouaga 2000 and the Tanghin dam. This difference could be linked to the high concentration of waste at these two sites. The conductivity could be due to an important or even high mineralization.

In conclusion, the use of wastewater in market gardening is a problem often ignored by market gardeners and consumers of products. But increasingly, studies are shedding more light on the health and environmental risks associated with their use. Our study provided information on the quality of water used in market gardening in the city of Ouagadougou. Through this study we were able to evaluate the bacteriological and physico-chemical quality of the water by different methods. From this study, we generally observed that the three sites studied presented physico-chemical quality that were acceptable. Indeed, all the samples from the three sites had concentrations meeting the WHO standard except for one sample from the Tanghin dam which had a magnesium concentration higher than the WHO standard. In addition, the microbiological quality is not entirely satisfactory. Only samples from Site 2 in Ouaga 2000 had faecal coliform concentrations meeting WHO standards. The other sites (Ouaga 2000 Site 1 and the Tanghin dam) do not meet the standards. But more studies of water quality are needed in order to preserve the environment and the health of the population. We recommend the use of simple water purification systems to purify the water before they are used for farming purposes.

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Authors' Contributions

OT had the original idea for the study and with all co-authors carried out the design, sampling, analyses and drafted the manuscript, RD, CK, ON, CKSS, participated in writing the manuscript. NB supervised the analyses and participated in writing the manuscript. All authors read and approved the final version of the manuscript.

Competing interests

None of the authors have any competing financial or other interests that could influence or bias the contents of this paper.

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