HEALTH HAZARDS LINKED TO THE QUALITY OF THE IRRIGATION WATER AND TO THE CONSUMPTION OF THE VEGETABLES GROWN IN THE MARKET GARDENING SITE OF NKOLONDOM, (YAOUNDE - CAMEROON)

Antoine Vikkey Hinson[1] ; Yvonne Mbaduet[1] ; Rousseau Djouaka[2] ; Francis Zeukeng[2,3] ;; Fabien Gounongbe[4]; Mènonli Adjobime[1] ; Benjamin Fayomi[1]

1 : Unity of Teaching and Research in Occupational Health and Environment, Faculty of Sciences and Health of Cotonou (University of Abomey-Calavi Benin) BP 188 Cotonou Benin

2 :AgroEcoHealth Platform, International Institute of Tropical Agriculture (IITA), 08 P.O.Box 0932, Tri-Postal Cotonou, Benin.

3: Faculty of Science, Department of Biochemistry, University of Yaoundé I, P.O.Box 812, Yaoundé, Cameroon

4: Département de Médecine et Spécialités Médicales, Faculté de Médecine, Université de Parakou

Corresponding author: Antoine Vikkey HINSON: vikkey.hinson@gmail.com

ABSTRACT

Background: *The water used for irrigation contains measurable quantities of dissolved substances which, when accumulated in the soil and crops, have serious consequences on the environment and human health. This cross-sectional and descriptive study was carried out on the Nkolondom vegetables production site in order to assess the health risks related to water used for irrigation and thus, improve on the quality of vegetables and the health of consumers.*
Methods: *Thirty structured questionnaires were administered to vegetable producers. Water used for irrigation and the main vegetables produced were carefully collected to determine the degree of contamination in toxic heavy metals (Pb, Cd, As, Cu) and in microbes or fecal and total coliforms. A new advanced and sensitive approach, the Metalyser Pro HM3000 helped us to quantify the heavy metals.*
Results: *Vegetable growing in Nkolondom is a basic activity which is characterised using traditional watering cans for irrigation, the non-use of personal protective equipment and the excessive use of inputs and pesticides. Irrigation is done with water from the river et the main crops produced there are lettuce and celery. The irrigation water as well as the vegetables that were analysed contained non-toxic doses of heavy metals which varied as follows: Cu> Pb> As> Cd. The mean concentrations in fecal coliforms found were not toxic in the water used for irrigation (100 UFC/100 ml) and toxic in the vegetables (2,67 10^4 UFC/100 g). Vegetables grown in Nkolondom are thus dangerous for consumption and could cause many health issues to vegetable producers.*

Conclusion: *The health risks are related to the environment, to the irrigation water, to the chemicals used, (pesticides and fertilisers) and to the physical workload. Vegetables producers mostly suffer from water-borne diseases, skin diseases and musculoskeletal disorders.*

Key words: *Irrigation water, vegetables, heavy metals, fecal coliform, Nkolondom*

INTRODUCTION

Nowadays, urban and suburban market gardening is developing in the big African cities [1] and in the city of Yaoundé together with its suburbs as well. As a matter of fact, market gardening yields on average more than three hundred (300) millions CFA francs as net profit per year for all the market gardeners put together in some African cities [2]. Without this activity, many city-dwellers could not get some vegetables whose regular consumption helps to reduce severe nutritional deficiency [3]. These market garden produces are consumed raw. For this reason, the water used for the market gardening produces irrigation must not be bad quality water. It must therefore meet all the local, regional and/or national quality standards. Indeed, the irrigation of the gardens with bad quality water would seriously endanger the human health. Many studies have shown that in the long-run irrigation with the wastewater can cause a progressive accumulation of poisons in the soil, as well as the transfer of a quantity of poisonous substances (bioavailable fraction) onto the irrigated gardens, and which afterwards, will create some cases of toxicity with man after a certain period of consumption [4, 5, 6]. The presence of those contaminating substances in the water used as well as in the vegetables constitutes a serious hazard for the health of the millions of consumers including the market gardeners themselves. The heavy metals are very hazardous for the human health because of their non-biodegradable nature and their implication in the phenomena of bioaccumulation and bio-amplification in the food chain [4,7]. The ingestion of those heavy metals through contaminated vegetables can lead to various chronic diseases such as nervous system disorders, respiratory affections, affections of the liver or kidneys, cancer, etc. [8]. Concerning pathogenic microorganisms as the coliforms, they are at the origin of many hydric diseases.

In Cameroon, there exists very little information on the quality of the irrigation water and vegetables in the market gardening areas. With the demographic growth observed during the last decade and the occupation of the swampy areas for dwelling, the demand for fresh vegetables doubled in the city [9]. The occupation of the swampy areas often dedicated for market gardening for dwelling causes a reduction of available market gardening areas and the use of different farming techniques. We can possibly mention the use of all kinds of water, often polluted for irrigation of vegetables, and the increasing of the doses of agricultural inputs and pesticides to increase market gardening production. The quality of the produces grown with this type of treatment is often causing of many problems among the consumers. Besides, the market gardener who handles those produces, and remains in contact with wastewater every day, is being exposed to many health hazards. The control of the quality of the irrigation water and that of the market gardening produces turns out therefore to be necessary to assure food security and to protect the market gardeners and consumers' health. It is then in such a context that we decided to study the health hazards linked to the quality of the irrigation water and the consumption of the vegetables grown in the market gardening site of Nkolondom, a suburban area of Yaoundé, Central Cameroon region.

1. METHODOLOGY

It was a cross-sectional study conducted from April 1 to August 30, 2016 in the market gardening site of Nkolondom situated in the city of Yaoundé (3o55'N-11o31'E). Nkolondom is a suburb of the city of Yaoundé, political capital of Cameroon. It is situated at about 800m of altitude.

Samplings:

Sampling of the participants:

A reasoned non-probabilistic sampling enabled us to recruit 50 market gardeners who are very aware of the objectives of the study and who gave their full consent. A well-structured questionnaire structured was then administered to those volunteering market gardeners. The main information collected concerned: sociodemographic information (age, sex, social status and number of children), identification of agricultural practices (types of vegetables cultivated, type of water used for irrigation, watering system, types of pesticides and fertilizers used, frequencies of treatment, etc.), the market gardeners' perceptions on : the quality of the water used for irrigation, the quality of the vegetables produced, the frequency of consumption of the vegetables in households and the potential health hazards linked to the consumption of the vegetables.

Sampling of water and vegetable

- **Sampling of water sources used for irrigation**

Samples from the different sources of the water used for irrigation were aseptically collected in the market gardening sites. Early morning collection of the samples was done every time at the irrigation points (**figure 1**). A composite sample consisting of each irrigation point was constituted and sampled water was transferred in sterile glass bottles for microbial analysis and in clean high-density polyethylene bottles for heavy metal analysis. The polyethylene bottles were washed and soaked in HCl 0.01N overnight, and now washed three times with deionized water following the cleaning method described by Chary et al [10]. All the water sources used for vegetables irrigation were sampled in three replicates, labelled, store at 4°C in appropriate iceboxes containing accumulators of cold and transported to the laboratory for various analyses. Microbiological analysis was always done on the day of the collection of the samples, or within the 24 hours.

- **Sampling of vegetable produces**

Samples of mature vegetable produces were randomly collected in the morning during the different water collection periods in the study site. Composite samples of every type of vegetable (lettuce and celery) were constituted and at least 500g of the edible part of every vegetable produce was sampled in three replicates (**figure 2**). Those samples were put in " zip bag" plastic bags; they were labelled and stored at 4°C in iceboxes containing accumulators of cold, and thereafter transported to the laboratory for analysis.

Figure 1: Irrigation water source (the Ntsa stream) **Figure 2**: Lettuce and celery farm

Analysing heavy metals in the water used for irrigation and in vegetable produces

This analysis was done to determine the level of pollution of the irrigation waters and of vegetable produces with heavy metals. The poisonous heavy metals concerned were Lead (Pb), Cadmium (Cd), Arsenic (As) and Copper (Cu).

- **Pre-treatment and extraction of heavy metals from vegetables**

The analysis of heavy metals in vegetables was preceded by a stage of their extraction. The collected vegetables were first rinsed with sterile deionized water in order to remove particles of soil and all other irrelevant bodies. Afterwards, they were cut up into small slices with a sterile knife, and then dried up in a steam-room to a temperature of 50°C for 12 hours, and to 120°C for 24 hours [11]. The dried vegetables were ground in a mortar and with a sterile pestle (Trace2O, Berkshire, UK) to obtain a powder. This powder was then sieved with a sieve of 2 mm of mesh.

The extraction was done as it has been described by Maleki and al. (2014) [12] . One (01) gram of powder of vegetables was weighed with an electronic balance then put in a beaker made of Pyrex. Then 10 ml of the mixture of three acids (HNO3, H2SO4 and HClO4) according to the ratio 1 :1 :1 and provided by the supplier Trace2O, Berkshire, UK was added. The mixture was kept one night then heated to 95°C until a transparent solution is obtained. After cooling, the digested sample was filtered through a Wattman filter paper (3 mm), then diluted until the volume of 100 ml with deionized water and kept at ambient temperature for the subsequent analyses.

- **Heavy metal dosage in irrigation waters and in vegetables after extraction**

Heavy metals (Cd, Pb, Cu, As) in irrigation waters and extracts of vegetables (lettuce and carrot) were quantized with the Metalyser HM3000 machine (Trace2O, Berkshire, UK) (figure 3). The technique used by this machine was the inverted voltamperometry. This machine helped to quantize 15 heavy metals grouped in 14M groups. The metals to be analysed in this study constituted the M1 groups for Cd and Pb, M3 for As and M4 for the Cu. The process of analysis of the heavy metals by using this technique included three phases: the conditioning of the electrode, the analysis of the sample and the display of the results.

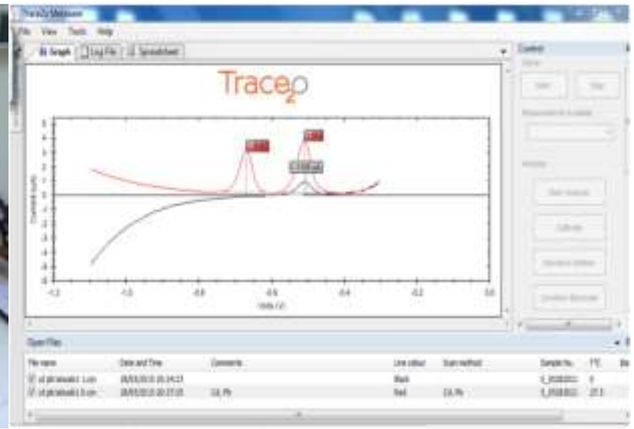

Figure 3: Devices for heavy metals dosage. **Figure 4**: Voltamogramme for metals dosage

1= the digestion probe of the HM4000 metalyzer; 2= the analysis probe of the HM3000 Metalyzer 3= Tablet computer; 4= HM 3000 metalyzer instrument

❖ **Quantization of cadmium and lead**

The reagents of the M1 group (tampon, standard, conditioning solution) and the functioning electrode 1 (WE1) were used to analyse the Cd and the Pb. The WE1 electrode was beforehand polished up with “polishing slurry” so that no abrasions could be noticed. Then, the conditioning of the electrode was done with the "M1; 4; 5 conditioning solution". Thereafter, 70 ml of sample of water or of extract of vegetables were added to 1 sachet of each tampon M1 4.5a and M1 4.5b connected then to the probe of analysis to be analysed. After the first scan of the sample by the device, 280 µl of the standard M1 corresponding to 20 ppb of Cd and Pb were added. At the end the analysis, the results (concentration) in ppb were given automatically together with graphic representations on the tablet of analysis.

❖ **Quantization of the Copper and Arsenic**

Cu (M4 group) and As (M3 group) analysis was done as it was described for the Cd and the Pb by using different electrodes and reagents (tampons and standard). For As quantization, the reagents of the M3 group and the functioning electrode 2 (WE2) were used whereas the reagents of the M4 group and the functioning electrode 1 (WE1) were used for the Cu analysis.

Quantization of the coliforms in irrigation waters and in vegetables

This analysis helped to search for the presence of micro-organisms indicative of faecal pollution in irrigation waters and in vegetables. The aim was to search for total coliforms and for faecal coliforms as well. The method of filtration on membrane was used to count total and faecal coliforms [13]. The Lauryl Sulphate Broth Membrane culture medium obtained from the supplier and selective for the coliforms analysis was used. Two millilitres of the culture medium were added on some sterile absorbing garnishes in a sterile Petri dishes obtained from the same supplier.

Each sample of irrigation water (10 ml) was aseptically taken with a sterile pipette in a sterile glass bottle, and then diluted ten times by addition of 90 ml sterile saline peptone water. Successive decimal dilutions (until 10-9) were then prepared by using the same diluent. As for the samples of vegetables, fifty grams (50g) aseptically taken, ground and diluted by adding 450ml of sterile saline peptone water in a sterile glass bottle, then homogenized for 10mn. Successive decimal dilutions (until à10 -9) were then prepared by using the same diluent. From each dilution, 10ml have been filtered with a filtering membrane of 0.45µm and the membrane was put in Petri dishes containing the culture medium. The Petri dishes were then let at ambient temperature for three (03) hours in a hood for revitalization of stressed bacteria. After this, they were incubated for 24h at 37°C for total coliforms and at 44°C for faecal coliforms. The colonies of coliforms appearing yellowish after the time of incubation were counted and expressed as Colonies Forming Unities /100 ml (CFU/100ml).

Data Analysis

The data were statistically analysed with the SPSS software, version 18.0. The results were expressed in terms of average ± standard deviation. The Khi square test was used to determine the proportions of each matrix, and the non-parametric test (ANOVA) was used to evaluate some cases of difference in concentrations made of heavy metals and of coliforms among the different matrixes. The threshold of significance was 5%

2. RESULT

2.1.Socio-demographic characteristics of the study population

The socioeconomic data collected during this study in the market gardening site of Nkolondom revealed an inequality in the involvement of men and women in market gardening. Out of 30 market gardeners investigated 56.7% (17) were of male sex with a sex ratio of 1.3 in comparison to female sex. Most market gardeners were adults with a high dominance of adults aged from 31-50 years (48.9%) and an average age of 45±10.6 years. A high level of involvement of young adults below 30 years (22.6%) and of people over 50 years (28.5%) was also noticed. Most market gardeners investigated were married (63.3%) and were heads of family with on average 4.5±2.2 children and a secondary school level of education (46.67%). The size of the households is generally big and can reach up to 15 persons all under the market gardener's responsibility. Farming is the main activity of the people investigated (66.67%) and market gardening is only a seasonal and temporary activity for subsistence (table1).

Tableau 1 : Social statut of the market gardener in Nkolondom.

Demographic data of the investigated		Effective	%
Marital status	Married	19	63,33
	Divorced	2	6,70
	Single	5	16,67
	widow	4	13,33
Household size (persons)	≤ 5	17	39,4
	6 -15	12	59,9
	> 15	1	0,7
Main activity	Market gardening	5	16,67
	Agriculture	20	66,67
	Trade	1	3,33
	Other	4	13,33
Level of education	Any education	1	3,33
	Primary	10	33,33
	Secondary	14	46,67
	University	3	10,0
	Professional	2	6,67

2.2.Convenient agricultural practices adopted in the market gardening site of Nkolondom

Types of vegetables grown

Lettuce is grown by all the market gardeners contrarily to produces such as eggplant (Solanumesculentum), mint (Menthaspicata) and watermelon (Citrulluslanatus) which are grown very rarely (Table 2).

Table 2 : Distribution of vegetables in the market gardening site of Nkolondom

Type of vegetable	Sientific name	Number collected	Percentage (%)
Lettuce	*Lactuca sativa*	30	100
Celery	*Apiumgraveolens*	25	83.3
Morelle	*Solanummacrocarpon*	24	80
Parsley	*Petroselinumsativum*	24	80
Amaranth	*Amaranthushybridus*	20	66.7
Basil	*Ocimum basilicum*	17	56.7
Vegetable Corete	*Corchorusolitorius*	11	36.67
Hot pepper	*Capsicumfrutescens*	10	33.3
Vernonia	*Vernonia amygdalina*	6	20
Cabbage	*Brassicaoleracea*	4	13.3
Tomato	*Lycopersiconesculentum*	4	13.3
Cucumber	*Ecballium elaterium*	4	13.3
Leek	*Allium porrum,*	4	13.3
Pepper	*Capsicumannuum*	3	10
Gumbo	*Abelmoschusesculentus*	2	6.7
Watermelon	*Citrulluslanatus*	1	3.3
Minth	*Menthaspicata*	1	3.3
Eggplant	*Solanumesculentum*	1	3.3
Carrot	*Daucus carota*	0	-
Beet	*Beta vulgaris*	0	-
French bean	*Phaseolus vulgaris*	0	-

Types of irrigation waters and irrigation systems

The water used for irrigation of vegetables gardens comes from the Ntsa River (figure 1): a stream which is mainly fed by the runoff.

The water used for the analyses of the quality (heavy metals and coliforms) was sampled from fourteen different points. The physical and chemical analysis of this irrigation water revealed the average values of pH (6.55), temperature (23.73°C), conductivity (54.413 µs) and of TDS (27.207 ppm). Those values were in conformity with the norms corresponding to good irrigation water according to World Health Organization.

Use of inputs and pesticides

All of the market gardeners use some inputs to increase growth and productivity of vegetables. The inputs used are mostly organic and chemical fertilizers. 93.33% of the market gardeners use both types of inputs all along the development cycle of the crops, whereas only 2 of them (6.67%) use organic manures only.

All the market gardeners investigated use pesticides. The pesticides used are, among others, insecticides and fungicides. The frequency of treatment varies from once a week (66.7%), twice a week (23.3%) to twice every other week (10%) (Figure 5).

In general, the pesticides are used without any personal protection equipment, and with a sprayer equipment.

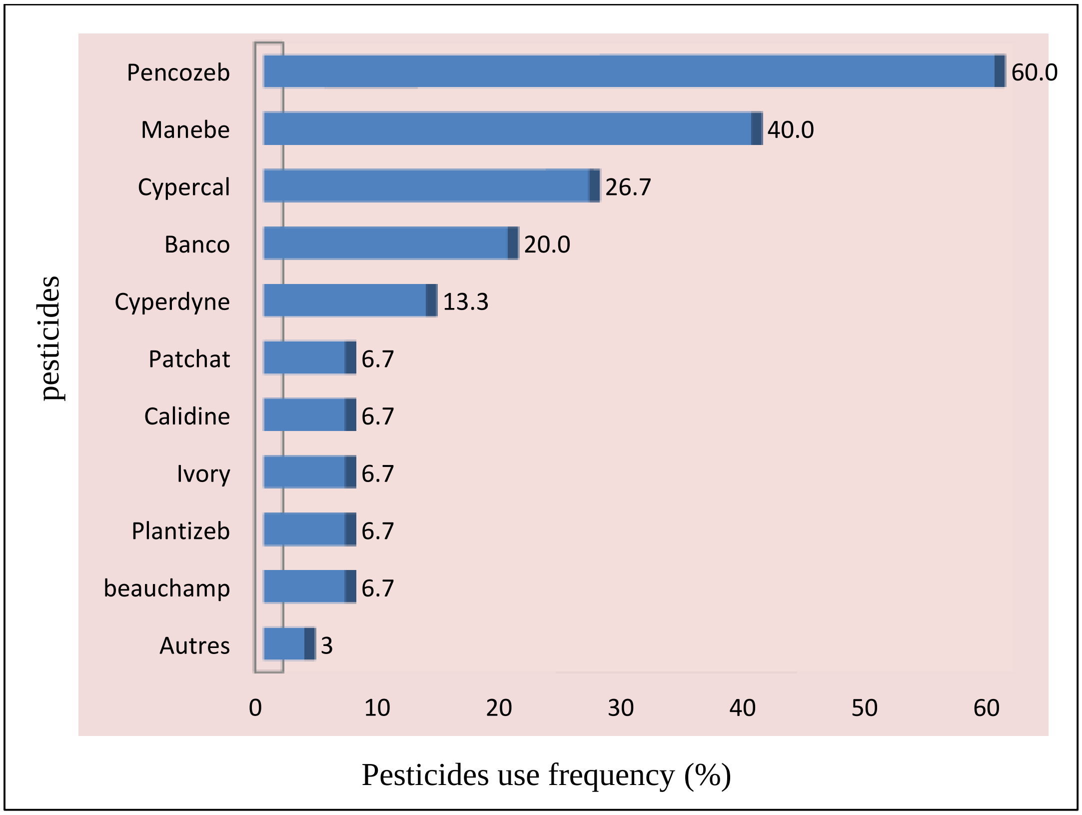

Figure 5 : Distribution of main pesticides listed in the truck-farming site of Nkolondom

2.3.Health hazards linked with the use of irrigation waters and with the consumption of market gardening produces

Market gardeners' views on the irrigation waters' quality

According to the market gardeners, clean water is clear and unclean water is brownish; and because their irrigation water is clear, 73% of them declared that their irrigation water is clean water and of good quality. On the other hand, basing on the presence and the origin of contaminating agents in the irrigation water, 80% of the market gardeners asserted that their irrigation water contains contaminating agents from various origins. The different contaminating agents mentioned were mainly microorganisms and chemicals. The main origins of contamination are the environment (56.7%), the agricultural inputs (33.3%) and pesticides (30%), as well as human and animal faeces (33.3 %).

Distribution of heavy metals in irrigation waters and in market vegetables gardens

Lead (0.422 ppb) was the most concentrated metal in the irrigation water. The concentrations of Cu, Cd and of As on the other hand were very low (<0.001 ppb). The concentration levels of the analysed metals in vegetables (lettuce and celery) were the highest in market gardening produces, corresponding to Cu>Pb>As=Cd (table 3). Three replicates of each vegetable were analysed and the concentrations of Cu (p=0.08) and of Pb (p=0.011) significantly varied for lettuce and for celery.

The dose of metal found in the lettuce were 0.68±15.28 ppb (Cu), 1.119±0.327 ppb (Pb) and<0.001 ppb for the Cd and for As. The Celery contained higher doses of Cu with 111.52±47.19 ppb (Cu), 0.415±0.491 ppb (Pb) and identical concentrations of Cd and of As (table 3)

Table 3: Mean concentrations of heavy metals in the irrigation water and vegetables gardens

		Mean concentration of metals			
		Cu	**Pb**	**Cd**	**As**
Irrigation water and vegetables analysed	**Ntsa River**	0.001	0.422	0.001	0.001
	Lettuce	60.683	1.119	0.001	0.001
	Celery	111.52	0.415	0.001	0.001

Distribution of coliforms in irrigation waters and in market gardening produces

The irrigation water of was not very contaminated, and was less poisonous with faecal coliforms compared to the standard dose set out by WHO (1000 UFC/100ml) (Table 4). The analysed market gardening produces were more concentrated and more poisonous with coliforms than was the water used for their irrigation.

Table 4: Average concentrations of faecal and total coliforms in the irrigation water and in the vegetables grown in the market gardening.

Truck-farming site of Nkolondom			
Coliforms **(Log10** *UFC/100 ml or g***)**	Irrigation water (*Mean±SD*)	Dry Truck (*Mean±SD*)	
	River	Lettuce	Celery
Fecal coliform	2.00 ± 1.914	4.426 ± 4.097	4.176 ± 3.699

Total coliform	3.540 ± 2.230	5.630 ± 4.667	5.538 ± 4.653
Toxicity level of WHO	**> 3.00**	**> 3.00**	**> 3.00**

Health hazards linked with irrigation waters and with market gardening produces

In total, 70% of the market gardeners investigated were regular consumers of their own produces and, nearly 76.2% of them recognized that there exist potential health hazards linked with the consumption of those produces. There is no significant interrelationship between the awareness of the hazards and the consumption of market gardening produces. The hazards mentioned were especially about waterborne diseases such as typhoid, amoebas and Cholera (**Figure 6**). They also mentioned other hazards like: lumbar pains, skin diseases (pimples and feet athletes) and some other symptoms (headaches and fatigue) due to an intense physical activity and to a regular contact with the irrigation water; and symptoms of waterborne infections such as diarrhoea, vomits and cough. Feet athletes very predominant with market gardeners and were characterized by a crackling of the feet in the shape of teeth (**Figure 6**).

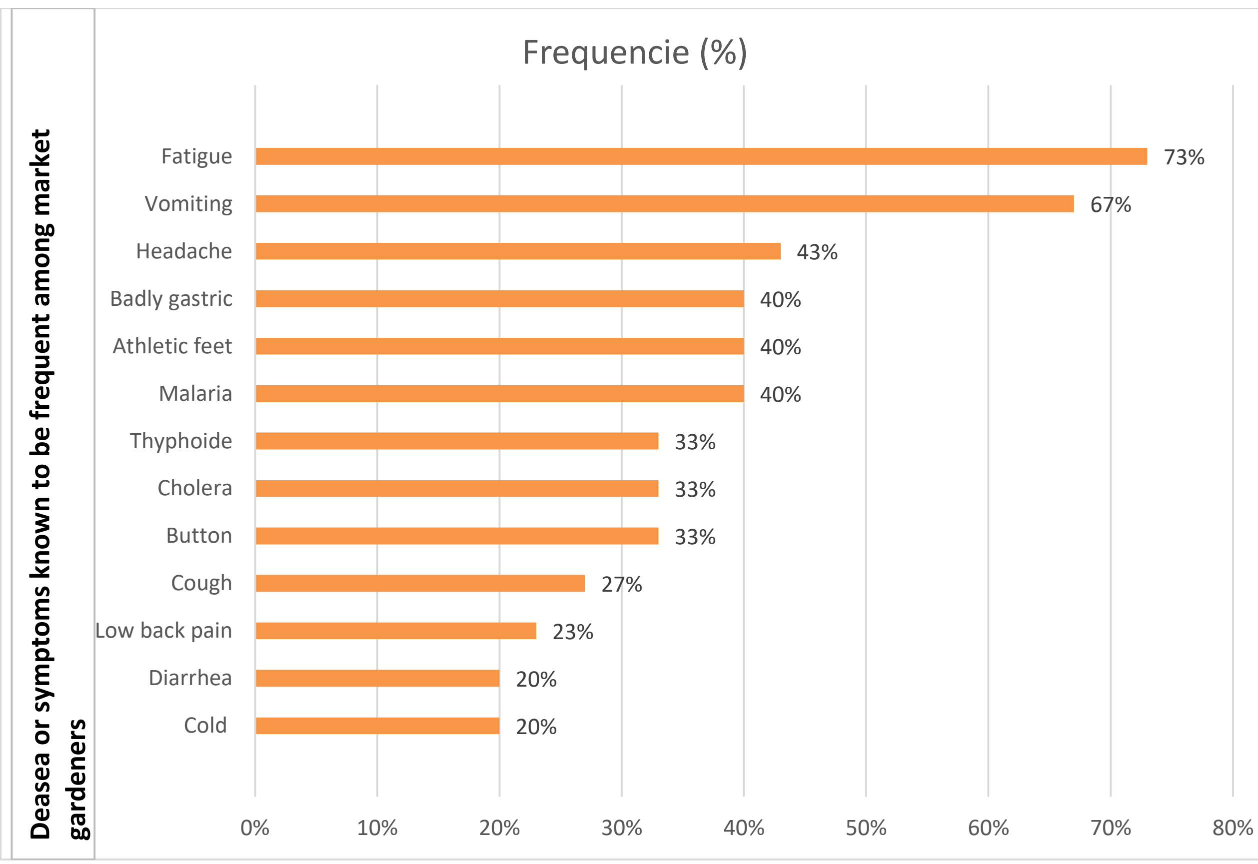

Figure 6: Distribution of the diseases and symptoms noticed among the market gardening populations of Nkolondom.

3. DISCUSSION

3.1.Demographic features of market gardeners

The African population has grown strongly in recent decades, resulting in an increase in the unemployment rate in the continent [14]. To alleviate this scourge, several countries including Cameroon have relied on the strengthening and intensification of agricultural practices as alternatives of employment and as a source of rapid income [1]. Thus urban and peri-urban market gardening has increased in the peripheries of large metropolises and is still a very important source of income for the improvement of the living conditions of several populations. Indeed, it is possible for some market gardeners to increase their family incomes up to 60% only by practicing market gardening. In the case of the market gardening site of Nkolondom, a periphery of the city of Yaoundé, demography shows that men and women share the same interest in market gardening. The majority are adults aged 31-50 years. The practice of market gardening in Yaoundé is thus not an activity of the men as it has often been observed in other market gardening sites [15, 16]. indeed, in some countries and according to different cultures, men as heads of households carry out the most difficult tasks in the chain of market gardening (sometimes from mowing to the maturation of the vegetables) and women who intervene only at the chain ensure the harvesting and the sale of vegetables [9,16]. Unlike adults who are most often owners of the market gardening sites, there is little involvement of young people and adults less than 30 years of age in market gardening in Nkolondom. When they intervene, they work as temporary or manual workers. Indeed, as the most active group in society, these people are school-children or students, or are involved in vocational training and do not have enough time to conduct daily market gardening activities. Market gardening is therefore only a temporary means of subsistence for them, because, they are paid directly to the task. The high level of involvement of adults over 30 years of age in market gardening may be associated with the high rate of unemployment registered in population group and with their position as head of the household, who are responsible for an average of four children.

3.2.Features and quality of irrigation water

Despite its advantages as source of rapid income, urban and peri-urban market gardening is often source of several problems concerning the quality of the waters used for irrigation and the quality of the vegetables produced. Faced with this dilemma, the consumer is often much more sceptical about the consumption of market produces. Therefore, knowledge on the knowledge of market produces needs to be strengthened in order to assure consumers about the potential health hazards associated with the consumption of those produces. A single source of irrigation water has been observed in the market gardening site of Nkolondom as described by [9]. It is river water generally yellowish in rainy season, and is clear in the dry season, and is fed by the runoff from the surrounding mountains. Depending on the geographical position of this site, it is impossible to find the municipal waters in the area. Indeed, located in a swampy area, the market gardening site is off-centre from the households. However, the waters generated in the households near the river are directly dumped into it. Kuitcha et al describe this river water as the best alternative for all people without access to the main sources of drinking water (CamWater, wells and boreholes) in the city of Yaoundé. This is due to the low incomes of the market gardeners who do not have enough resources to supply better quality and improve their system of irrigation. Again according to this characteristic of limited resources, Nkolondom market gardeners preferably use watering-cans for irrigation of vegetables. The motor-pumps are used by the market gardeners who possess large areas and sometimes enough resources. However, the dominance of watering-cans as main irrigation system confirms the low economic level of the market gardeners and sometimes the non-professionalism in the practice of market gardening. Indeed, in sites where practitioners are more skilled, one would note a predominance of advanced irrigation systems like turnstiles and motor-pumps [15]. In addition to the non-professionalism of market gardeners, we observed increased neglect of wearing personal protective equipment (PPE) during the practice of irrigation and the administration of inputs on the crops. Despite the control of the risks associated with this practice, market gardeners are almost insensitive to these dangers, which are known to be mainly related to the application of pesticides and to the frequent contact with irrigation waters. They rarely and almost do not use PPE such as gloves, mask, the closed shoes and blouses or long sleeve shirts. This should call on the public health authorities to reinforce their knowledge of the precautions to be taken during market gardening activities.

The quality of the irrigation water is of paramount importance in order to protect market gardening product consumers’ health and to safe guard the protection of the market gardeners themselves. Since the market value and the consumption of the produces grow from day by day, an export of contaminated vegetables could lead to the dissemination of the contaminating agents into the sites that are still healthy or not having those contaminants at all [18]. Here, we have investigated the quality of the irrigation water and vegetables from Nkolondom market gardening site in heavy metals and in microbial pathogens. In a general, the levels of heavy metal found in the irrigation water were low and below the toxic levels set by World Health Organization (WHO). This irrigation water is therefore not directly toxic in heavy metals for the market gardening produces consumers’ health [19]. As river and surface water, the irrigation water from the Ntsa would therefore be less polluted than that one of the river Ntem which flows in the city of Yaoundé [20]. This difference demonstrates low anthropogenic activities in the market gardening site of Nkolondom [9] and is also due to its geographical position. In fact, the market gardening site is located in a shallow area away from the road axis and is therefore less exposed to the fumes or aerosols of road vehicles; since these are true pollutants because of their high concentration of Copper and Lead [11, 21]. Surface fluvial waters (rivers) would accumulate less contaminating agents than stagnant ones (wells) and, would be contaminated more contaminated than deep waters (boreholes). Indeed, deep waters undergo first a kind of natural filtration by the soil, and are less in contact with the polluted objects of the environment [22]. The small traces of Cadmium and Arsenic found in the irrigation water could be attributed to the absence of mining activities and garbage storage points around this market gardening site. Indeed, these two metals are generally found in the depth of the soil and are of anthropological origin or in the atmosphere from cigarette smoke or damaged batteries [23]. The low rates observed confirm that these metals have not yet reached a critical level of saturation and that the soil continues to play its role of tampon by decreasing the quantity of metals entering the surface waters [24]. Market gardeners must therefore be educated more and more about the precautions to be taken to avoid such levels of saturation. Above all, It will be necessary avoid excessive use of inputs and pesticides, and the accumulation of urban garbage around market gardening sites.

In addition to heavy metals, good quality irrigation water must be free of or must contain minute quantities of pathogenic microbes. In precarious sanitary conditions, these pathogens of faecal origin (faecal coliform) can contaminate all sources of water, including drinking water. Critical concentrations of coliforms in irrigation waters are likely to lead to contamination of vegetables, which would have a negative impact on human health, as these vegetables are often, consumed raw [21]. Nkolondom irrigation waters contain non-toxic proportions of faecal coliforms in compared to the toxic doses set by WHO (>1000 colony forming units or UFC/100 ml). These coliforms in irrigation waters would be derived from the inputs or manures of chickens and oxen used to enhance the growth of vegetables [19]. Nevertheless, some physicochemical parameters of water obtained in this study (pH 6.55) are superior to the optimal growth conditions of the faecal microbes (pH 5.5 - 6.5). It is therefore possible that these have influenced the growth and spread of microorganisms in irrigation waters. The great quantities of total coliforms found show that besides the faecal pathogens, other microorganisms reside in these irrigation waters. It would therefore be wise to investigate the different microbial species present in order to determine the exact nature of the microbial flora of the irrigation water. This will make it possible to better specify the impact of each pathogen on both public health and the environment.

3.3.Features and quality of Nkolondom market gardening produces

We have noted throughout this study that Nkolondom market gardeners cultivate different varieties of vegetables. These are mostly fast-growing vegetables that provide substantial incomes, and the production of which depends on the demand and on the market gardeners' professional experience. About 18 crops were identified and some high commercial demand vegetables such as carrot and green bean were completely absent. According to these market gardeners, they said they do not possess necessary expertise in the cultivation of those produces. In Cameroon, these vegetables come only from the province of the West and more precisely from the departments of Mifi, the Menoua and the Noun. These, in fact; are main supply sites the Cameroonian markets and peripheries in vegetables [25]. Nkolondom productions help only to supply the surrounding populations and the markets of Yaoundé solely. According to Temple and Moustier [1], the interest of the market gardeners for a given produce depends on a number of factors including population culture, cultural practices, market value and the cost of the produces, life cycle of the produce, the sensitivity of the produce to pests, the rate of consumption of the produce in terms of inputs and even the market gardener's health condition. Indeed, this last-mentioned parameter can strongly influence the frequency of irrigation of vegetables which is done manually in the market gardening site of Nkolondom.

Heavy metals excess market gardening produces often cause irreversible damages to consumers of such produces. The vegetables (celery and lettuce) analysed in this study contain different concentrations of metals. The most toxic metals were Copper and Lead, and according to Tom et al. [26], these are generally the most hazardous metals in market gardening produces. As was often observed, the levels of metal in vegetables were higher than they were found in irrigation waters. This shows that in addition to the irrigation water, other factors such as atmospheric and volcanic deposits, erosion, concentration of metals in the soil, use of inputs, and maturity of vegetables during the harvest; which would also be sources of the metals found in market gardening produces [6; 22; 23; 26]. Lettuce was more concentrated in Lead (Pb) than celery, whereas celery was more toxic in Copper (Cu) than celery. Since the two vegetables are of the same class (leafy vegetables), this difference would depend on the bioavailability of the metals in the soil and on the type of cultivation practiced [27]. Nevertheless, the high concentration of those metals in lettuce is also due to intensive use of inputs and pesticides during the cultivation of this vegetable. Indeed, according to the market gardeners themselves, the growing of lettuce is faster and requires a more frequent follow-up and treatment than that of celery. Using organic pesticides as an alternative to chemical pesticides could reduce the accumulation of metals in vegetables. Even though the levels of metals found have not reached their critical condition yet, it is important to report that the small proportions found constitute a potential health risk for the consumers of these produces. Besides, continued consumption of contaminated vegetables results in an accumulation of metals in the organism, disrupting biochemical and metabolic processes, and can lead to cardiovascular, nervous, renal and even bone diseases [7; 8]. If it is difficult to avoid the contamination of vegetables during cultivation due to environmental contaminations, it is however urgent to consider the implementation of techniques of decontamination of vegetables during the post - harvest period and during storage in order to guarantee safety for the consumers.

The vegetables analysed in this study were more concentrated in faecal and total microbes than was the water used for their irrigation. The doses of faecal coliforms found were higher than the standard doses established by WHO (> 1000 UFC/100 g). The vegetables from the market gardening site of Nkolondom are contaminated with faecal microbes and therefore toxic and dangerous for human consumption. Lettuce is more likely to develop those microorganisms than celery. Indeed, with wider leaves, lettuce possesses a large surface of retention of the microorganisms. This rough surface encourages camouflage and development of microorganisms present in the air, soil and surface water [16; 18]. Besides, high use of inputs of animal origin could also contribute to the accumulation of coliforms in market gardening produces. The survival of microorganisms on plants is influenced by several factors including the rate of heat and moisture. In order to better assess the impact of these coliforms on the market gardening produces consumers' health, it would be wise to quantize and specify all types of microbe present, as some faecal pathogens are more virulent than others [19] .since those microbes are of faecal origin mostly, there is need to increase health education of the market gardeners in relation to the maintenance of market gardening sites, the quality of the water used for the cleaning of market gardening produces and the safety of potential consumers. As reported by some market gardeners, cleaning of market gardening produces with good quality water sometimes added to vinegar or salt could reduce the health risks associated with the consumption of those produces.

3.4.Convenient market gardening practice and health risks

The contamination of foods with heavy metals and microbial pathogens is a real public health issue. These contaminating agents are of potential health hazards which accumulate in market gardening produces with negative consequences for the market gardeners themselves and for the consumers [4; 7; 28]. This study demonstrates that irrigation waters and market gardening produces of Nkolondom contain non-toxic heavy metals concentrations. The levels of coliforms found in the vegetables are toxic and harmful for human consumption. Indeed, consumption of the vegetables contaminated by microorganisms has often triggered epidemics due to food poisoning in various countries [29; 30]. However, the feverishness following consumption of contaminated vegetables depends on several factors, including the minimal infectious level the microbe, the level of the consumers' immunity and the pathways of contamination. Thus, high ingestion of heavy metals in vegetables is often associated with colon cancer [31]. In addition to these indirect risks, there exist other health issues resulting from contamination of vegetables or contaminated water which have been recognized by the market gardeners. These include water-borne diseases (diarrhoea, vomiting and typhoid), often caused by a poor hygiene, skin diseases (pimples and feet athletes), and musculoskeletal disorders (lumbar pains). Those disorders can be directly related to the intense physical efforts required throughout the market gardening chain. Skin infections may be associated to the use of poor quality irrigation waters and the ingestion or inhalation of inputs and pesticides at the time of their application on the crops [4; 7; 28]. Indeed, during those long-length activities and despite the knowledge of the risks they run, the market gardeners do not apply any means of protection and do not wear any personal protective equipment (PPE). In a complementary way to this qualitative and descriptive study, analytical studies will establish direct relationship between the occurrence of those diseases and the practice of market gardening. This will enable us to better conclude on the health risk factors that market gardening practices would generate on human health. With the levels of metals found in irrigation waters, this activity alone is enough to cause crackling of the market gardeners' feet and even of their hands. Indeed, the market gardeners bearing these signs have confessed to be the main actors of irrigation of their gardening site. Besides, the crackled areas (feet and hands) are those that are in regular contact with the water. These health risks are identical to those recently described in a study carried out in Benin [15]. This study therefore helped to draw the attention of the market gardeners and potential consumers of market gardening produces to the potential risks associated with market gardening activities, and stressed the need to develop new strategies for removing contaminating agent (heavy metals and coliforms) from market gardening produces in the post - harvest period. First, we are thinking of increasing the use of biological pesticides in market gardening practices and of implementing different strategies of cleaning market gardening produces in the post - harvest period, especially for vegetables to be consumed raw.

CONCLUSION

This study allowed to underline the sanitary risks which run the truck farmers during the irrigation or the pesticides spraying on the cultures, and the consumers of vegetables stemming from this irrigation. It is hydric diseases, skin disorders and musculoskeletal disorders. These risks could be minimized by using a water of good quality irrigation, a not excessive treatment of vegetables and by practising a healthy truck farming.

REFERENCES

1. *Temple, L. and P. Moustier, 2004. Les fonctions et contraintes de l'agriculture périurbaine de quelques villes africaines (Yaoundé, Cotonou, Dakar). Cah. Agric., 13:15-27.*
2. *Allagbé, H., M. Aitchedji and A. Yadouleton, 2014. Genesis and development of urban vegetable farming in Republic of Benin. IJIAS., 7:123-133.*
3. *Gandonou, E., Agbossou, K., Sintondji, L., 2007. Etude de la durabilité environnementale et économique des pratiques d'irrigation en agriculture périurbaine et urbaine (APU) à Cotonou et sa périphérie Volet socio-économie. FSA/UAC Bénin, 39p.*
4. *Lugwisha, E.H. and C.O. Othman, 2014. Levels of Selected Heavy Metals in Soil, Tomatoes and Selected Vegetables from Lushoto District-Tanzania. Int. J. Environ. Monit. Anal.,2:313-319.*
5. *Mustapha, I.H. and B.O. Adeboye, 2014. Heavy metals accumulation in edible part of vegetables irrigated with untreated municipal wastewater in tropical savannah zone, Nigeria. Afr. J. Environ. Sci. Technol., 8:460-463.*

6. *Khan, K., Y. Lu, H. Khan, M. Ishtiaq, S. Khan, M. Waqas, L. Wei and T. Wang, 2013. Heavy metals in agricultural soils and crops and their health risks in Swat District, northern Pakistan. Food. Chem. Toxicol.,58:449–458.*
7. *Lawal, A.O. and A.A. Audu, 2011. Analysis of heavy metals found in vegetables from some cultivated gardens in the Kano metropolis, Nigeria. J. Environ. Chem. Ecotoxicol.,36:142-148.*
8. *Kihampa, C., J.S.W. Mwegoha and S.R. Shemdoe, 2011. Heavy metals concentrations in vegetables grown in the vicinity of the closed dumpsite. Int. J. Environ. Sci., 2:889-895.*
9. *Temple, L., S. Marquis and S. Simon, 2008. Le maraîchage périurbain à Yaoundé est-il un système de production localisé innovant ? Economies et Sociétés, Agroalimentaire., 30:2309-2328.*
10. *Chary, N.S., C.T. Kamala and D.S.S. Raj, 2008. Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. Ecotoxicol. Environ. Saf., 69:513–524.*
11. *Koumoloua, L., P. Edorha, S. Montchoa, K. Aklikokoub, F. Lokoc, M. Bokod and E.E. Creppye, 2013. Health-risk market garden production linked to heavy metals in irrigation water in Benin. Compt. Rend. Biol. 336:278-83.*
12. *Maleki Afshin, Hassan Amini, Shahrokh Nazmara, Shiva Zandi and Amir Hossein Mahvi : Spatial distribution of heavy metals in soil, water and vegetables of farms in Sanandaj, Kurdistan Iran Journal of Environmental Health Science & Engineering 2014, 12:136*
13. *Rompré, A., P. Servais, J. Baudart, deR. Marie-Rene and P. Laurent, 2002. Detection and enumeration of coliforms in drinking water: current methods and emerging approaches. J. Microbiol. Meth., 49: 31–54.*
14. *United Nations Fund for Population (UNFP), 1994. Human development world report. Economica, Paris, 239 p.*
15. *Rousseau Djouaka1, Francis Zeukeng, Murielle Farrelle Eurydice Soglo, Razack Adeoti, Omolacho Merdie Zinsou Ahoukpo, Taïra Sarah Tamou-Tabe et al. Heavy metal contamination and faecal coliforms in peri-urban market gardening sites in Benin and Cameroon ; International Journal of Agriculture and Environmental Research (2016) Volume:02, Issue:05*
16. *Keraita, B., P. Drechsel and F. Konradsen, 2008. Using on farm sedimentation ponds to improve microbial quality of irrigation water in urban vegetable farming in Ghana. Wat. Sci. Tech.,57:519-525.*
17. *Kuitcha, D., K.B.V. Kamgang, N.L. Sigha, G. Lienou and G.E. Ekodeck, 2008. Water supply, sanitation and health risks in Yaounde, Cameroon. Afr. J. Environ. Sci. Technol.,2:379-386.*
18. *Gemmell, E.M. and S. Schmidt, 2010. Potential links between irrigation water quality and microbiological quality of food in subsistence farming in KwaZulu-Natal, South Africa. Current Research, Technology and Education Topics in Applied Microbiology and Microbial Biotechnology, A. Mendèz-Vilas (Ed.), p1190-1195.*
19. *Akrong, O.M., A.J. Ampofo and A.K.S. Danso, 2012. The Quality and Health Implications of Urban Irrigation Water Used for Vegetable Production in the Accra Metropolis. J. Environ. Prot., 3:1509-1518.*
20. *Defo, C., K.P.B. Yerima, K.M.I. Noumsi and N. Bemmo, 2015. Assessment of some heavy metals in soil and groundwater in an urban watershed of Yaoundé (Cameroon-West Africa). Environ. Monit. Assess., 187:DOI 10. 1007/s10661-015-4292-1.*

21. *Scott, C.A., N.I. Faruqui and S.L. Raschid, 2010. Wastewater use in irrigated agriculture: Confronting the Livelihood and Environmental Realities. CABI Publishing; Wallingford, UK.*
22. *Atidegla, C.S., K.E. Agbossou, J. Huat and G.R. Kakai, 2011. Contamination métallique des légumes des périmètres maraîchers urbains et péri urbains: Cas de la commune de Gran-Popo au Bénin. Int. J. Biol. Chem. Sci., 5:2351-2361.*
23. *Farooq, M., F. Anwar and U. Rashid, 2008. Appraisal of heavy metal contents in different vegetables grown in the vicinity of an industrial area. Pak. J. Bot., 40:2099-2106*
24. *Agbossou, K.E., M.S. Sanny, B. Zokpodo, B. Ahamide and H.J. Guedegbe, 2013. Evaluation qualitative de quelques légumes sur le périmètre maraîcher de Houéyiho, à Cotonou au sud-Bénin. BRAB., 42:1-12*
25. *Tarla, D.N., V.M. Bantar, M.Y.C. Mfopou, D. Fotio and D.A. Fontem, 2015. Determination of Heavy Metal Concentration in Surface Waters of the Western Highlands of Cameroon. . JGEESI., 2: 46-53.*
26. *Tom, M., T.D. Fletcher and D.T. McCarthy, 2014. Heavy Metal Contamination of Vegetables Irrigated by urban Stormwater: A Matter of Time? PLoS ONE 9:e112441.*
27. *Islam, Eu., X-e. Yang, Z-l. He and Q. Mahmood, 2007. Assessing potential dietary toxicity of heavy metals in selected vegetables and food crops. J. Zhejiang Univ. Sci. B., 8:1-13.*
28. *Orisakwe, E.O., K.J. Nduka, N.C. Amadi, O.D. Dike and O. Bede, 2012. Heavy metals health risk assessment for population via consumption of food crops and fruits in Owerri, South Eastern, Nigeria. Chem. Cent. J., 6:2-7.*
29. *CDC (Centers for Disease Control and Prevention), 2009. Investigation of an outbreak of Salmonella Saintpaul infections linked to raw Alfalfa sprouts, Update for May 8, 2009. CDC, Atlanta, GA. Available at: http://www.cdc.gov/Salmonella/saintpaul/ (Accessed 14 May 2015).*
30. *Gillespie, I.A., 2004. Outbreak of Salmonella Newport infection associated with lettuce in the UK. Euro surveillance., 8:2562*
31. *Turkdogan, M.K., F. Kilicel, K. Kara and I. Tuncer, 2002. Heavy metals in soil, vegetables and fruits in the endemic upper gastrointestinal cancer region of Turkey.Environ. Toxicol. Phar.,13:175-179.*