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State of the Environment and Its Impacts on the Urban Agriculture of Edible Plants in the City of Lubumbashi

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ABSTRACT

This research looked at the state of the environment in the areas where amaranth urban agriculture is practised in the municipality of Katuba, City of Lubumbashi, the Democratic Republic of Congo. Samples of water used for watering, the soil where urban agriculture is practised, and amaranths have been subjected to characterization analyses to look for chemical and microbiological pollutants. These analyses revealed that water and amaranths are polluted from the mineral and microbial standpoint, unlike soil samples. Indeed, water samples contained *Paramecia, Entamoeba histolytica's* eggs and colonies of faecal contamination germs, mesophilic flora, and other pathogen germs such as *Aeromonas hydrophila* and *Pseudomonas aeruginosa*. As for amaranth samples, their concentrations of cobalt were greater than the value set by the quality standards. The *Paramecia, Entamoeba histolytica's* eggs, *Escherichia coli*, and *Klesiella planticola* contaminate them. For the above, consuming these amaranths poses health risks to the population. Public authorities must take the necessary measures to organize the practice of urban agriculture of edible plants to bring it up to standard and protect the consumers' health.

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1. Introduction

These days, urban agriculture is extensively practised worldwide because of its benefits. Indeed, it ensures food security and is a source of additional income for about 100-200 million urban farmers, to name a few [1]. Moreover, the number of urban dwellers involved in urban agriculture worldwide accounts for 25-30 %. This figure is expected to increase far beyond due to the urban population growth and rural-urban migration [1]. In the Haut-Katanga region of the Democratic Republic of Congo (D.R.C.), the people from the peripheral quarters of urban centres invested themselves for many years in the growing of edible plants, the breeding of poultry, rabbits, pigs, goats, etc. This is seen as a strategy for quickly accessing fresh food and as a means of increasing household incomes [2-9]. The urban population practices growing edible plants on lands located along streams, railways, and big roads and in the vicinity of water bodies [1-4]. In D.R.C., urban and peri-urban horticulture practiced in five cities produces about 150,000 tonnes of vegetables per year and employs approximately 60,000 people. This means that about 30,000 tonnes of vegetables are produced per year in the city of Kinshasa and 2,250 tonnes in that of Lubumbashi [10]. For researchers involved in studies on urbanism and social changes arising in cities found in the Central African Copperbelt region, they view this urban agriculture as a response to the poverty brought about by the industrial mining's collapse at the end of the decennia 90s [1, 2, 4, 10]. From this perspective, the urban agriculture practiced in the Haut-Katanga region constitutes a survival strategy developed as time went on by the urban population confronted with the economic slump. The declining prices of primary commodities caused this social malaise during the 80s. Therefore, the people endured low wages or salaries policy and unemployment, aside from other problems in relationship with rapid population growth and ceaseless wars that together aggravated poverty in the country [2, 4, 11]. For other researchers, urban agriculture can be an opportunity to create new employment, strengthen social bonds, build resilience to climate change, rendering cities greener, and protect their biodiversity [1, 10, 12-14]. In the City of Lubumbashi, it is looked at as a subsistence farming of edible plants and as a source of income [1, 4, 10, 13-15] for a significant part of the population of quarters wherein lands are sufficiently watered by streams or located along water bodies [1, 6]. Indeed, the urban population has organized itself into associations of the market gardeners and operates on public or private lands for growing edible plants. This is done with the agreement of the municipal authorities and the population benefits from the coaching of projects funded by the United Nations specialized agencies such as the Food and Agriculture Organisation (F.A.O) [4, 10-13, 15, 16]. Growing vegetables in lands located within public and private spaces are viewed as a response to different life's problems. Among these is the problematic access to arable lands in urban areas due to the demographic pressure exacerbated by the rural exodus and the high birth rate [4-9, 11-13, 17, 18]. According to [19], cited by [1], 55% of the world population will live in urban centres by 2020, and the figure is expected to surpass 60 and 70% in 2030 and 2050, respectively. According to research by [13], within 18 years, the urban population of sub-Saharan Africa is projected to reach almost 600 million, which is twice what it was in 2010. With this situation, people living in urban areas will have no choice but to invest in informal activities to gain their bread. Among informal paying activities, one finds the growing of edible plants, such as cabbages, carrots, tomatoes, onions, celeries, salads, leeks, amaranths, etc. The last activity is the easiest way to access fresh food in urban areas and earn money [10, 13]. The occupation of public spaces [1, 13], whether legally or not, for growing edible plants has become the striking feature of numerous peripheral quarters of central urban areas in the Haut-Katanga region. This is encouraged by the presence of fertile lands and well watered by a sizeable hydrographical network [1, 4, 15]. Given the easy access to water and arable lands, aside from benefits related to the informal sector paying activities [1, 13, 14, 20], the urban agriculture's practice can be viewed in the Haut-Katanga region as a true godsend for the people living in urban centres [4, 21]. However, according to [22], not all people perceive urban agriculture as a godsend; that is, it can benefit a city and its dwellers [2-9, 11-14]. Instead, some people consider it harmful to farmers, consumers, the environment, and the urban land economy. For other, urban agriculture is a marginal, temporary and archaic activity [12, 13].

To highlight urban agriculture's dark side, that is, its drawbacks, it is essential recalling that the hydrographical network just evocated extends over large tracts of land inside cities such as Lubumbashi, Likasi, and Kipushi and comprises a significant number of watercourses and lakes [16]: Kafubu, Katuba, Kampemba, Kimilolo, Kamisepe, Kalubwe, Kikula, Buluo, Lufira, Mura, Likasi, Tshombe, Tshangalele, Kamerenge, etc. Unfortunately, many serve as spillways for organic and inorganic solid wastes [21-29]. Water from streams irrigates vast tracts of arable land where the urban population grows edible plants, breeds poultry and pigs, etc. Water abstracted from

watercourses also serves for laundry, the houses sanitation human drinking [27]. The drinking of untreated water is widespread in urban centres not yet connected to urban drinking water distribution networks [26-28, 30, 31]. Indeed, nearly 2.3% of households in the city of Lubumbashi consumed untreated water in 2018, mainly in urban centres and peripheral neighbourhoods [31]. The use of untreated water for human drinking, houses sanitation, laundry, growing vegetables, and breeding poultry and pigs [13, 30, 32] endangers the population's health primarily when water is sourced from streams, lakes, ponds, etc. [18, 31]. Indeed, this kind of water contains various pollutants of mineral and organic origins as well as pathogen microorganisms [6, 18, 21, 22, 27-32]. Health problems brought about by using polluted water and soils while growing edible plants have urged government authorities to prohibit urban agriculture in many African cities such as Nairobi, Niamey, Lusaka, Kampala, Lomé, Bamako, etc. [13, 18, 22, 29].

This research aims at contributing to the urban population health protection threatened by mineral origin and biological pollution. To achieve this, it studied the general state of the environment in the municipality of Katuba with a particular focus on the quality of water and soil in areas utilized for the urban agriculture of edible plants. Specifically, fieldwork enabled searching for and measuring the concentrations of pollutants of mineral and biological origin capable of endangering human health. This will help establish a link between the deterioration of the environmental state and disturbances to human health resulting from exposure to pollutants grown in edible plants [33-35]. The findings from this research will help public authorities to make the best decisions for introducing good practices in urban agriculture of edible plants.

2. Materials and Methods

This section describes the research area location, the sampling procedure for water, soil, and amaranths, and the techniques and analytical apparatus used for their characterization.

2.1. Location of the Search Area

The research area is found in the municipality of Katuba, which in turn is located in the city of Lubumbashi (Figure **1**), that is, the capital of the region of Haut-Katanga, in the D.R.C. Lubumbashi is a major city in Africa geographically located at points of Latitude 11°40 12.00' South and Longitude 27°28 12.00' East.

2.2. Sampling Procedure

The sampling was carried out to constitute representative samples of the watering water and the soil used for urban agriculture of the amaranths (Table **1**).

The sampling points have been chosen to allow us to verify, through chemical and microbiological analyses, how the quality of agricultural water, that is, the water abstracted from the river threatened by the pollution as well as water recovered from the wells dug near its banks could affect the soil quality and thus influence the quality of the grown plants for human consumption following a possible pollutants transfer. The samples collection took different amounts of water, soil, and amaranth, as described below, during the period running from 24/8/2020 to 16/04/2021.

2.2.1. Water Sampling

Ten sites were selected along the Katuba River including water wells (Figure **2**) located near gardens, given that they are supplied by water from the river. As will be seen, appropriate sampling equipment was utilized to avoid biasing the sample analysis results. The sampling of water was conducted in during the early hours of the morning between 6 and 7 hours, that is, before the start of the market gardeners work, to avoid the contamination of the sample and before the sampled medium is perturbed. Clean containers, weighted and attached to a clean rope were utilized for collecting samples away from the water surface in wells and along the Katuba River.

In total, thirty samples consisting of 250 mL of water were drawn and placed in sterilized polyethylene bottles: 10 for the mineral analysis and 20 for microbiological testing (Figure **3**).

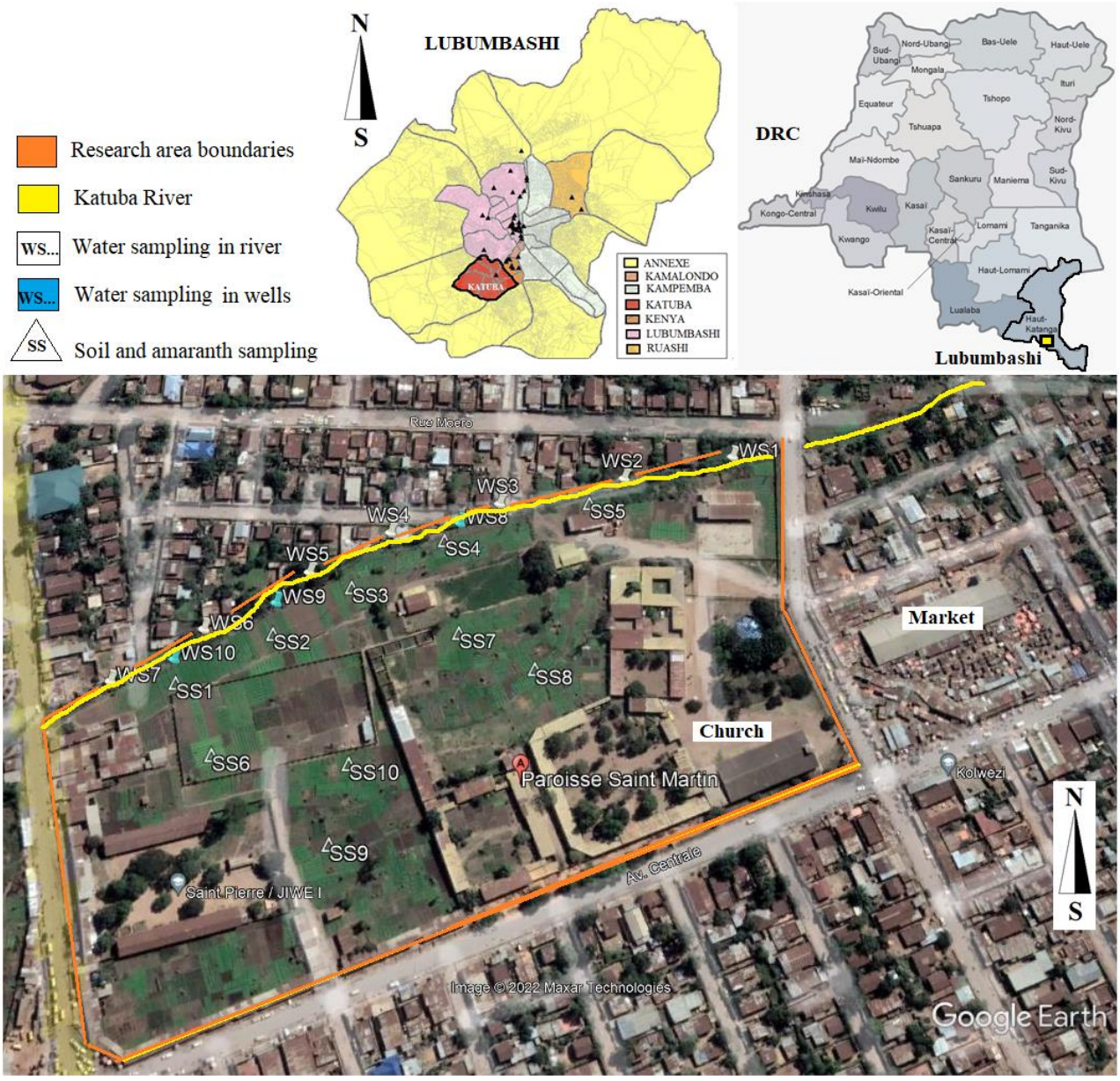

Figure 1: View of the research areas - Katuba municipality.

2.2.2. Soil Sampling

In this case, 10 sampling points were selected from gardens located along the Katuba River to provide 200 g samples each. For each soil sample, 20 g aliquots were put into clean plastic bags for mineral chemical analysis.

2.2.3. Amaranth Sampling

Amaranth samples were taken in different gardens near water wells utilized for watering. Twenty samples weighing 100 g each were taken and placed in sterile plastic bags (Figure **4**). These samples were deposited in the laboratory for analyses, that is, 10 samples for the mineral chemical analysis and 10 other samples for microbiological analysis.

2.3. Samples Characterization

It consisted of analyses to determine the concentration of different chemical elements in various water samples, soil, and amaranth.

Table 1: Sampling point location in the research area.

Sample Naming	Sample Location	
	Latitude	Longitude
WS1	11°42'41.12"S	27°28'2.45"E
WS2	11°42'41.57"S	27°28'0.42"E
WS2	11°42'42.08"S	27°27'58.13"E
WS4	11°42'42.66"S	27°27'56.16"E
WS5	11°42'43.43"S	27°27'54.75"E
WS6	11°42'44.49"S	27°27'52.96"E
WS7	11°42'45.44"S	27°27'51.44"E
WS8	11°42'42.46"S	27°27'57.41"E
WS9	11°42'44.00"S	27°27'54.19"E
WS10	11°42'45.04"S	27°27'52.49"E
SS1	11°42'45.32"S	27°27'52.60"E
SS2	11°42'44.43"S	27°27'54.22"E
SS3	11°42'43.56"S	27°27'55.56"E
SS4	11°42'42.65"S	27°27'57.19"E
SS5	11°42'41.92"S	27°27'59.83"E
SS6	11°42'46.58"S	27°27'53.34"E
SS7	11°42'44.40"S	27°27'57.50"E
SS8	11°42'45.06"S	27°27'58.85"E
SS9	11°42'48.08"S	27°27'55.44"E
SS10	11°42'46.73"S	27°27'55.69"E

Figure 2a: View of the river Katuba.

Figure 2b: View of a well dug near the Katuba River.

Figure 3: Water samples intended for microbiological analyses.

Figure 4a: Amaranths garden in the municipality of Katuba.

Figure 4b: Amaranths samples intended for analyses.

2.3.1. Samples Preparation Procedure

The samples intended for characterization analyses underwent different treatments as described below:

2.3.1.1. Water Samples

Two 50 mL aliquots were prepared for each sample to be submitted to the mineral chemical analysis. Subsequently, they were poured into small sterile plastic bottles. Three drops of concentrated nitric acid of analytic purity, 65%, were added before hermetically closing the bottles and shaking them vigorously to homogenize the contents. The resulting acidified waters were subjected to spectrophotometric measurements of the concentrations of the different elements, which were expressed in ppm or mg/L.

As for water samples intended for pH measurements, they were not acidified. Their analysis was directly conducted using a HASCH-mark pH meter. The water samples intended for microbiological analysis were also not acidified but protected from temperature effects using thermal insulation thanks to transporting them in a cooler box. Their analysis was carried out within a maximum of 48 hours after sampling, that is to say, within 4 hours of their arrival at the laboratory. They were, therefore, refrigerated between 2°C and 6°C until the analysis time.

2.3.1.2. Soil Samples

Aliquots of 20 g each were prepared and placed in a 250 mL beaker before attacking them with aqua regia: 20 mL HCl - 25%, 20 mL HNO_3- 65%, and 8 mL $HClO_4$ - 85%. After the reaction, the resulting mixtures were supplemented to 100 mL by adding double-distilled water and placed on a hot plate for at least 10 minutes. They were then allowed to cool, with the resulting solutions transferred to 250 mL volumetric flasks. The volume of each volumetric flask was completed using double distilled water. Aliquots of 10 mL each were collected and diluted with distilled water before being subjected to spectrophotometric analyses. The dilution used has enabled converting to mg/kg the results from the analysis.

2.3.1.3. Amaranth Samples

Amaranths samples of 200 g were put in the oven at 105°C until complete desiccation. 80 g of dry matter was calcined in an oven. 20 g of ash from each sample was placed in a 250 mL beaker and attacked with an acid mixture of 6 mL H_2SO_4 - 98%, 3 mL HNO_3 - 65%, 4 mL $HClO_4$ - 85%, and 2 mL HCl - 25%. The sample's acid attack was continued on a hot plate until obtaining syrup and the white smoke cleared. The resulting solution was allowed to cool down before collecting aliquots of 10 mL each. These aliquots were diluted with double-distilled water as for previous analyses. Afterward, they were subjected in duplicate to spectrophotometric analyses of the chemical elements of our interest. The same dilution factor and the concentration of each element were expressed in mg per kg of fresh amaranth.

The amaranth samples intended for the microbiological analysis were placed inside sterile plastic bags hermetically closed. They were transported inside an isothermal case to the laboratory and deposited in the refrigerator between 2°C and 6°C. Afterward, the amaranth samples were rinsed with double-distilled water. The rinsing water was collected by either being centrifuged or vacuum filtrated before being subjected to microbiological analyses.

2.3.2. Determination of Chemical Elements in Water, Soil, and Amaranth

The chemical elements were analyzed using a Perkin Elmer-type Plasma Source Atomic Emission Spectrophotometer (Avio® 550/560 Max ICP-OES).

2.3.3. Procedure for Microbiological Analyses of Samples

These analyses consisted of a series of microscopic examinations and the count of microorganisms present in water and on amaranth samples thanks to two complementary analytical processes: physical amplification and biological amplification on a microbial culture:

- Direct microscopic observation of the centrifuged samples without microbial culture;
- Microbial culture on *Mac Conkey* broth and germs isolation on *agar-agar*, with the count in petri dishes [36, 37].

For microbiological analyses, the water samples were centrifuged or vacuum filtrated using a cellulose ester-made filter membrane (0.45µm) [38]. A filtration ramp endowed with sterile filter holders was utilized. The centrifuged sample was examined using the microscope or served as an inoculum for a culture medium contained in a petri dish. As for the filter, the membrane was recovered and deposited on the agar contained in the petri dish. The different culture media were incubated at temperatures matching each microorganism sought [36, 37, 39].

3. Results and Discussion

3.1. Environment State of at Areas Dedicated to the Urban Agriculture

The state of the environment was studied based on the measurement of the concentrations of pollutants present in water and soil and capable of deteriorating their quality compared to well-established standards [29, 40].

3.1.1. Results from the Chemical Analysis of Water Used in Urban Agriculture

Chemical mineral analysis of the water samples used for growing the amaranth in the municipality of Katuba led to the results recorded in Table **2** below.

Table 2: Concentrations of chemical elements contained in water used for the amaranth's watering.

Sample	pH	Concentrations (mg/L)								
		Cu	Co*	Fe	Al	Mn	Pb*	Zn	Ca	Mg
WS1	7.94	0.01	100	0.06	0.01	0.01	10	0.01	1.11	0.17
WS2	7.95	0.1	190	1.09	0.36	0.04	40	0.08	1.03	0.28
WS3	7.95	0.12	60	0.66	0.36	0.01	20	0.01	1.03	0.28
WS4	7.50	0.1	180	1.11	0.38	0.05	50	0.07	0.99	0.17
WS5	7.86	0.07	90	0.09	0.01	0.03	60	0.03	1.07	0.09
WS6	7.45	0.02	170	0.36	0.09	0.06	30	0.03	0.22	0.13
WS7	7.85	0.13	200	1.09	0.23	0.01	40	0.06	0.38	0.20
WS8	7.95	0.11	130	1.00	0.4	0.02	70	0.05	0.88	0.21
WS9	7.56	0.04	10	0.88	0.19	0.01	50	0.02	1.01	0.19
WS10	7.84	0.01	60	0.38	0.33	0.01	20	0.09	1.03	0.11
Mean	7.78	0.07	119	0.67	0.24	0.03	39	0.05	0.88	0.18
standards	6.5-9.5	0.2-1	50	5.00	500	0.20	200	1-5	-	-

*Concentration in µg/L.

The samples submitted to analysis have presented an average pH of 7.78, that is to say, a value ranging between the limits set by the standard used. At first a glance, the obtained results reveal that in 90% of the analyzed samples only the cobalt concentration exceeds the quality standard (50 µg/L). The mean concentration of cobalt in the water samples analyzed is 119 µg/L, a value that is more than twice the maximum limit set by the quality standard. This does not apply to all other analyzed chemical elements, including those reputed toxic to human health, such as lead. Indeed, their concentrations are below the maximum permissible values (200 µg/L Pb) prescribed by the standards for domestic and agricultural use water quality. Based on the results from the chemical analysis, it can be stated that the water used for watering amaranths grown in the municipality of Katuba presents health risks due to its excess concentration of cobalt. The presence of this chemical element in the water used in the culture of amaranths invites caution regarding their consumption owing to a possible intoxication by cobalt [34, 35, 40-42]. Contrary to the conclusion reached in a previous study [43], the use of the same water in urban amaranth agriculture could have great health implications even though the concentrations of the majority of the chemical elements present are lower than the values set by the standards used due to process of biomagnification [42]. However, the origin [42, 44] of cobalt implicated in the deterioration of the water quality used for growing amaranth is difficult to determine because the river it is abstracted from never receives wastewater from the mining industry, but different types of domestic wastewaters [44].

3.1.2. Results of Microbiological Analysis of Water for Urban Agriculture of Amaranth

Microbiological analysis of water utilized in urban amaranth agriculture, before and after microbial cultivation, enabled arriving of the results given in Table **3**.

The microscopic analysis, without microbial culture, of the freshly collected and centrifuged samples has revealed the presence of *Paramecia* and *Entamoeba histolytica* eggs in the water used in the urban agriculture amaranths. Extensive microbiological analysis of these samples revealed the presence of colonies of faecal contamination germs, mesophilic flora, and other germs, including *Aeromonas hydrophila* and *Pseudomonas aeruginosa*. The living organisms observed in the water attest to its poor microbiological quality [37, 44]. Its use for the watering of edible plants should be prohibited because of the health risks for market gardeners and

consumers of amaranth [34, 35]. This water is, therefore, unfit for agricultural use, and its poor microbiological quality has to do with the fact that it is abstracted from a River used as a spillway for domestic sewage [44]. The same river also receives faecal matter that overflows from septic tanks. The presence of *Aeromonas hydrophila* in water can cause Gastroenteritis, septicaemia, infections, cellulitis, and urinary tract infections in people practicing the urban agriculture of edible plants [45].

Table 3: Identification and count of microorganisms observed in the water used for watering amaranths.

Sample	Examination without Culture	Examination of the Sample with Culture and Isolated Germ					
		Germ 1	Colonies	Germ 2	Colonies	Germ 3	Colonies
WS1	*Paramecia*	*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS2		*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS3	*Entamoeba histolytica eggs*	*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS4		*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷	*Aeromonas hydrophila*	< 10 ⁷
WS5		*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS6	*Paramecia*	*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷	*Aeromonas hydrophila*	< 10 ⁷
WS7	*Paramecia*	*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷	*Aeromonas hydrophila*	< 10 ⁷
WS8		*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS9	*Paramecia*	*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷	*Aeromonas hydrophila*	< 10 ⁷
WS10	*Paramecia*	*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS11		*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷	*Aeromonas hydrophila*	< 10 ⁷
WS12		*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS13	*Entamoeba histolytica* eggs	*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷	*Pseudomonas aeruginosa*	< 10 ⁷
WS14		*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS15		*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS16	*Paramecia*	*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS17		*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS18		*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS19	*Paramecia*	*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		
WS20		*Escherichia coli*	< 10 ⁷	Mesophilic flora	< 10 ⁷		

3.1.3. Results of the Chemical Analysis of Soil Used in Urban Agriculture

The mineral chemical characterization of the soil samples used for growing amaranth in areas situated along the Katuba River enabled obtaining the results in Table **4**.

The results obtained from the mineral chemical analysis of soil samples show no evidence of pollution. Indeed, the concentrations of the analyzed chemical elements are equal to or lower than the toxicity thresholds defined by the standards utilized. Therefore, there is no risk of the vegetables being contaminated by heavy metals. Even cobalt, the only pollutant found in water used in urban amaranth agriculture, is observed in the soil at a virtually constant concentration and well below the limit set by standards. This small concentration of cobalt observed in the soil enables considering that only the river water used for watering cultivated plants should be the only source of this pollutant. Indeed, literature states [45] that cobalt concentration in soil generally varies widely, ranging from about 1 to 40 ppm [46], with an average level of 7 ppm. This implies that soils containing less than 3 ppm of cobalt, as the soil samples studied in this research, should be considered cobalt-deficient [42]. Even metals reputed toxic to humans such as lead (5.5 mg/kg) and cadmium (8 mg/kg and an average of 0.4 mg/kg) [7] have average concentrations well below the standard in the studied soils.

Table 4: Concentrations of observed chemical elements in soil used for growing amaranth.

Sample	Concentration (mg/kg)											
	Cu	Co	Fe	Al	Cr	Mn	Ni	Pb	Zn	Cd	Ca	Mg
SS1	20.0	0.2	603.0	159.8	1.0	4.6	0.4	3.2	9.4	0.8	20.0	4.0
SS2	13.6	0.2	398.4	202.6	0.4	5.6	0.2	14.4	12.2	0.2	17.8	3.6
SS3	15.0	0.2	394.2	253.6	0.4	7.4	0.2	2.2	13.2	0.8	18.6	3.8
SS4	16.0	0.2	623.4	197.6	1.0	7.4	0.2	5.8	12.2	0.4	17.6	3.4
SS5	17.6	0.2	507.0	177.8	0.6	5.8	0.2	12.2	14.8	0.6	17.8	4.2
SS6	11.8	0.2	403.6	206.2	1.0	7.0	0.4	5.8	12.0	0.2	19.8	4.6
SS7	18.2	0.2	390.0	237.2	0.8	6.2	0.4	3.4	12.2	0.2	17.4	3.2
SS8	17.2	0.2	442.0	182.6	0.6	5.6	0.2	1.8	11.8	0.2	18.2	3.6
SS9	14.2	0.2	310.0	166.2	0.4	5.4	0.2	2.0	13.0	0.4	19.2	5.0
SS10	13.8	0.2	352.6	160.2	0.4	4.0	0.2	4.6	10.6	0.2	17.8	4.4
Mean	15.7	0.2	442.4	194.4	0.7	5.9	0.3	5.5	12.1	0.4	18.4	4.0
QS	50.0	25.0	-	-	-	-	50.0	50.0	150	0.8	-	-

QS: quality standard.

As far as zinc is concerned, its mean concentration in the soil samples subjected to analysis is equal to 12.1 mg/kg. This value is far less than the mean range of concentrations usually observed in different soils. Indeed, the mean concentrations of total Zn likely to be observed in soils of different groups found around the world generally range between 60 and 89 mg/kg [47]. The above confirms the fact that the different metals sought in the soil under study are at concentrations proper for agricultural use. The obtained results thus highlight that the soil is not yet contaminated from a mineral standpoint in spaces used for growing amaranths consumed by the population in the Katuba municipality. However, the presence of aluminum in the soil deserves more attention, given that its toxicity depends on soil pH [48, 49].

It is important recalling that the concentration of a given metal pollutant in the soil is simply a partial indicator of pollution risk but cannot prevent it from being transferred to plants grown on the soil [34, 42]. Indeed, the transfer depends on the characteristics of a given metal pollutant and soil, that is, its behaviour in a given environment, the acidity and the presence of organic matter in the soil, and other factors [50, 51]. All these may induce or not a lesser or greater bioavailability of a given metal pollutant [34, 50, 51].

3.2. Environment State and Its Impacts on the Urban Agriculture of Edible Plants

3.2.1. Results of Mineral Chemical Analysis of Amaranth Samples

Samples of amaranth, grown on the soil analyzed in the previous section (Table **4**) and watered with water, which features are given in Table **2**, were analyzed to determine the mineral chemical composition (Table **5**).

Cobalt is the chemical element of concern, given that its concentration in sample N°4 is higher than the maximum permissible limit defined for plants intended for human consumption [42]. In the other samples, cobalt is present at acceptable concentrations. However, its concentrations enable considering that toxic metals succeeded in building up in amaranth under study [44] as witnessed by samples N°2, N°3, N°7, and N°8 that can be classified as great accumulators of metals. This applies to the rest of the amaranth samples subjected to the mineral chemical analysis. Overall, the results given by the chemical analysis reveal that amaranths grown in the municipality of Katuba are highly polluted by lead and, to a lesser extent, by cobalt. It is worth recalling that cobalt is also very dangerous to human health because it can bio-magnify in the food chain.

Table 5: Concentration of chemical elements observed in amaranth samples.

Sample No.	Concentration (mg/kg)							
	Cu	Co	Fe	Al	Pb	Zn	Ca	Mg
SS1	2.0	44.0	584.0	326.0	30.0	112.0	200.0	38
SS2	22.0	16.0	850.0	416.0	24.0	214.0	178.0	34
SS3	2.0	22.0	662.0	332.0	20.0	192.0	206.0	50
SS4	2.0	54.0	265.0	736.0	52.0	188.0	198.0	54
SS5	18.0	46.0	132.0	422.0	22.0	94.0	184.0	32
SS6	24.0	34.0	578.0	572.0	36.0	206.0	174.0	40
SS7	20.0	22.0	600.0	340.0	32.0	182.0	178.0	36
SS8	2.0	30.0	820.0	398.0	24.0	156.0	180.0	44
SS9	2.0	40.0	580.0	316.0	38.0	166.0	194.0	38
SS10	2.0	24.0	624.0	624.0	34.0	122.0	208.0	46
Mean	9.6	33.2	569.5	448.2	31.2	163.2	190.0	41.2
MCL	73.3	50.0	425.5-450 [30]	-	0.3	-	-	-
EPC	30-100	15-30	-	-	30-300	-	-	-
TDC	5-10	1	-	-	3-10	95		-
NMCP [52]	10	0.2	150	80	1	50	-	-

MCL = maximum concentration limit for edible plants.
EPC = excessively phytotoxic concentration.
TDC = Thresholds for diagnosing contamination [10].
NMCT = Normal metal content in a plant.

For this reason, vegetables, fruits, fish, and meat need not contain cobalt in high amounts [42]. Cobalt prone to building up in plants is present in the soil in a soluble state or a form weakly attached to soil particles. This implies an environment preferably acidic [42]. In addition, the amaranths are loaded with iron [30] and zinc, of which the measured concentration surpasses the T.D.C. [11]. This should prompt consumers to be more cautious given the toxicity of metals found in the amaranths and especially the presence of lead [11]. The ingestion of lead may result in poisoning, given that it can build up in the bones and other human body tissues [53]. As highlighted by many researches, the presence of the toxic metal affects the quality of amaranths, with the consumers' health endangering [11, 40].

3.2.2. Microbiological Quality of Amaranths Produced by Urban Agriculture

This analysis was motivated by the presence of pathogenic microorganisms in water used for urban amaranth agriculture. Table **6** below shows results from the amaranth samples' microbiological analysis.

It is evidence that living organisms observed in water have contaminated the amaranths. These are especially the *Paramecia*, the eggs of *Entamoeba histolytica*, *Escherichia coli*, and *Klesiella planticola*. The presence on amaranth samples of pathogenic microorganisms among those observed in watering water highlights the role it can play in the exposure of consumers to diseases such as gastroenteritis [18]. *Escherichia coli* reveals faecal origin contamination capable of exposing consumers to pathogenic microorganisms such as enteric viruses, protozoa, or bacteria originating from the human intestines or warm-blooded animals [54]. Given that faecal origin microorganisms were also identified among those observed in the watering water, the presence of *Escherichia coli* might be the outcome of certain agricultural practices such as the spreading of manure or the use of domestic composts as well as animal manure for fertilizing the soil or also from the use of manure from poultry [54].

The presence of *Paramecia* implies that of fermentable organic matters of which the decomposition favours the proliferation of pathogen microorganisms that use *Paramecia* as a food source. It is worth recalling that the

Paramecia is part of a genus composed of unicellular ciliates that cannot usually cause human diseases. Some of their strains enable the elimination of human intracellular pathogen germs such as *Legionella pneumophila* [55]. Strains of *Paramecia* can also serve in water purification technologies [55]. However, *Paramecium* species possess a prodigious capacity for ingesting some bacteria and fungi [56] and can be transmission vectors of bacteria responsible for infectious diseases [56-59]. Besides, *Paramecia* are the members of a group of eukaryotes comprising protists or species capable of causing many diseases. The *Paramecia* are widespread in freshwater, brackish, and marine environments. They are often more abundant in stagnant water basins and ponds, such as the wells from which water is abstracted for watering amaranths grown in the municipality of Katuba.

Table 6: Identification and count of microorganisms observed on amaranth samples.

Sample	Microscopic Examination of the Sample without Microbial Culture	Examination of the Sample after Microbial Culture and Isolated Germ			
		Germ 1	Colonies	Germs	Colonies
WS1	*Paramecia*	*Escherichia coli*	$< 10^7$		
WS2	*Paramecia*	*Escherichia coli*	$< 10^7$		
WS3	*Entamoeba histolytica* eggs	*Escherichia coli*	$< 10^7$	*Klebsiella planticola*	$< 10^7$
WS4	*Paramecia*+ *Entamoeba histolytica* eggs	*Escherichia coli*	$< 10^7$	*Klebsiella planticola*	$< 10^7$
WS5	*Paramecia*	*Escherichia coli*	$< 10^7$	*Klebsiella planticola*	$< 10^7$
WS6	*Paramecia*	*Escherichia coli*	$< 10^7$	*Klebsiella planticola*	$< 10^7$
WS7	*Paramecia*	*Escherichia coli*	$< 10^7$		
WS8	*Entamoeba histolytica* eggs	*Escherichia coli*	$< 10^7$		
WS9	*Paramecia*	*Escherichia coli*	$< 10^7$		
WS10	*Paramecia*	*Escherichia coli*	$< 10^7$		

The presence of eggs of *Entamoeba histolytica* might bring about *amoebiasis*, of which the estimated worldwide prevalence is 500 million infected people. This disease is held responsible for 40,000 - 100,000 deaths each year [60]. According to [61, 62], cited by [59], The *amoebiasis* is viewed today as one of the most concerning health problems that torment people, especially in developing countries [63, 64]. Regarding the presence of *Escherichia coli*, it is revealing contamination of faecal origin, that is, a phenomenon closely related to the poor quality of water used in the urban agriculture practiced in the municipality of Katuba. This microorganism reveals a major health risk for consumers of amaranth through their exposure to diarrheal diseases reputed to cause 1.8 million deaths a year, especially in low-income per inhabitant countries such as the D.R.C. [12, 63-65].

Table 7: Pollutants identified on or in amaranth and their respective diseases and/or symptoms.

Identified Pollutant	Caused Disease and/or Symptoms
Paramecia	• A great number of infectious diseases such as, those involving the *Paramecia* as transmission vectors of pathogen bacteria [56-59].
Entamoeba histolytica eggs	• Amoebic dysentery and abscesses [64].
Escherichia coli	• Bacterial infections [66-68] including cholecystitis, bacteraemia, cholangitis, urinary tract infection, and traveller's diarrhoea as well as clinical infections such as neonatal meningitis and pneumonia; • Signs and symptoms of contamination include [66, 68]: ✓ diarrhoea, which may range from mild and watery to severe and bloody; ✓ stomach cramping, pain or tenderness; ✓ nausea and vomiting.
Klesiella planticola	• different types of healthcare-associated infections, including pneumonia, bloodstream infections, wound or surgical site infections, and meningitis [69];
Cobalt	• Heart failure through effects on muscles with nausea and vomiting as symptoms [42, 70]; • Damage to thyroid gland [70]; • Vision problems and harm to foetal development health in pregnant women [42].

3.2.3. Health Risks Related to the Pollutants Observed on Amaranths

Chemical and microbiological analyses conducted in view characterizing amaranth samples from urban agriculture in the municipality of Katuba revealed the presence of cobalt [42] and pathogenic microorganisms capable of endangering consumers' health. Table **7** below lists and describes the diseases capable of affecting the human health due to amaranths consumption.

It is important to indicate that the main routes through which humans ingest the most cobalt are water and food [42]. Cobalt is beneficial for humans because it is part of vitamin B12, essential to maintain human health. Indeed, it enables fighting against anemia and is very useful for pregnant women [42]. However, as stated by [49], an inadequate or exaggerated supply of cobalt and other micronutrients results in health problems [68, 71].

4. Conclusion

At the end of this research, specifically interested in studying the state of the environment in areas dedicated to urban agriculture practiced in the municipality of Katuba so to determine its impact on the quality of grown edible plants (amaranth), one can retain what follows:

The water used for the amaranths watering has abstracted a river and wells dug at its edges and of inferior chemical and microbiological quality. It contains cobalt at excessive concentrations. The same water contains *Paramecia*, *Entamoeba histolytica* eggs, faecal germs, mesophilic flora, and other pathogenic germs, including *Aeromonas hydrophila* and *Pseudomonas aeruginosa*. As a result, pollutants of mineral and biological origin observed in water might contaminate the grown amaranth;

The soil on which amaranth is grown contains chemical elements at concentrations that do not show any apparent sign of mineral pollution. However, any possibility of the transfer from the soil to edible plants cannot be excluded;

The mineral and microbiological chemical analyses of the amaranths revealed the presence of cobalt and lead at excessive concentrations. They also enabled identifying pathogenic microorganisms also observed while analyzing the water used in the urban agriculture of amaranths. This highlights that those biological pollutants have been also transferred to edible plants.

Ultimately, this research succeeded in establishing a link between the deterioration of the quality of the environment and the poor quality of edible plants produced by urban agriculture practiced in the municipality of Katuba. The obtained results highlight different diseases capable of endangering the population's health due to the consumption of the poor-quality grown plants.

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