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Evaluation of the Physico-Chemical and Bacteriological Quality of Surface Water used for Watering Market Gardening Crops Lutendele Neighborhood in Kinshasa

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Abstract: This study was conducted in the Lutendele neighborhood of Mont-Ngafula Municipality, Kinshasa Province. Its objective was to assess the physicochemical and bacteriological quality of the water used for irrigating market garden crops in order to determine potential contamination risks and their potential impacts on consumer health.

To this end, water samples were manually collected from two sampling points coded E1 and E2 in November 2024. In situ measurements of physicochemical parameters, including temperature, pH, electrical conductivity, and dissolved oxygen, were performed using a WTW multi-parameter probe. Bacteriological analyses consisted of the identification and quantification of Escherichia coli as an indicator bacterium of fecal pollution using the membrane culture method. The results obtained revealed the following average values for the overall parameters measured in situ:

Temperature (in °C): 27.3 °C (E1) and 25.4 °C (E2). These values recorded during this study are slightly higher than the limit value (25 °C) set by the WHO guidelines. This slight thermal pollution can be explained by domestic wastewater discharge.

pH: 4.98 (E1) to 5.42 (E2). All these average pH values recorded demonstrate that the waters studied are all acidic (pH < 7). This could be explained by the contribution of potentially acidic runoff water, which tends to lower the pH of the waters in the study environment.

Dissolved oxygen (in mg/L): 4.52 (E1) to 7.36 (E2). These levels are all below the WHO guideline (≥10 mg/L) for surface water. There is therefore an oxygen deficit in the study environment, linked in part to the organic matter pollution present in these waters.

Electrical conductivity (in µS cm−1): 15.58 (E1) and 28.5 (E2). In both samples, the electrical conductivity values recorded comply with the WHO standard, which sets the maximum conductivity value at 200 µS/cm for surface water.

As for bacteriological analyses, average Escherichia coli concentrations of 23 (E1) and 50 (E2) were recorded in CFU/100 mL. These values, which do not comply with WHO standards for all surface water, whose normative requirement is (0 CFU/100 mL), indicate significant fecal pollution, which may be explained by the contribution of fecal contaminants carried by runoff water and by the insufficient hygiene measures (hygienic facilities) of the surrounding population.

In summary, the results of this study indicate that the irrigation water used for market gardening in the Lutendele neighborhood, Mont-Ngafula Municipality, in the city of Kinshasa, is of poor quality with regard to both the physicochemical and microbiological parameters analyzed, and this is therefore intended as a warning to ensure and protect the health of consumers of market garden products.

Keywords: *Market Gardening, Irrigation, Surface Water, Physicochemical, Bacteriological.*

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I. INTRODUCTION

It should be noted at the outset that market gardening plays a crucial role in food security and livelihoods in many parts of the world (I. Tiamiyou, 1995, p. 4). Local farmers, called market gardeners, cultivate a variety of vegetables and fruits to meet the needs of the local population and nearby urban markets (A.M. Nazal, 2017, p. 2). However, despite its economic and nutritional importance, market gardening faces several challenges, including the quality of the water used for irrigation and crop watering.

For millennia, surface water has been exploited in Africa to water market garden and agricultural products. Thus, water, a source of life, can become a danger to the environment and users if it is not of acceptable quality (Agassounon et al., 2014). This study therefore aims to assess the quality of water used to irrigate market garden crops in the Lutendele neighborhood, in the Mont-Ngafula Commune, in the city of Kinshasa in the Democratic Republic of Congo.

Our research question is: What is the physicochemical and bacteriological quality of the water from the Luteshi River used to irrigate market garden crops in the Lutendele neighborhood?

We anticipate that the water from the Luteshi River used to irrigate market garden crops in Lutendele would be of poor quality, and the physicochemical and bacteriological parameters characterizing this water would not comply with WHO standards.

The theme addressed by this study is a daily reality for the residents of Mont-Ngafula in general and the Lutendele neighborhood in particular. The scientific significance of this study lies in its contribution to a better understanding of the quality of water resources used for irrigating market garden crops, which is a crucial issue for public health and food safety.

On a practical level, the results of this study will aim to raise awareness among market gardeners in the Lutendele neighborhood about the importance of water quality for irrigation. By highlighting the risks associated with using contaminated water, this research will encourage safer and more environmentally friendly agricultural practices, thereby contributing to consumer health and crop sustainability.

II. STUDY ENVIRONMENT, MATERIALS, AND METHODS

➢ *Presentation of the Study Environment*

To better understand a study area, it is necessary to delineate it spatially. This allows us to adequately justify the need to describe the Lutendele neighborhood in the commune of Mont-ngafula, which constitutes our field of research.

➢ *Geographical Location*

The Lutendele neighborhood is located in the commune of Mont-ngafula in the city of Kinshasa at 4°22'56" S latitude and 15°12'09" E longitude. Its average altitude reaches 302 m (Mapcarta) and includes the localities of Kuwait 1, Kuwait 2, Mangoba, Musanga, Lutendele 1, Lutendele 2, and Madila.

- *The Lutendele neighborhood is bordered by*

✓ To the north by the CPA Mushie and Kimbwala neighborhoods;
✓ To the south by the Mitendi and Musangu neighborhoods;
✓ To the east by the commune of Ngaliema;
✓ To the west by the Congo River.

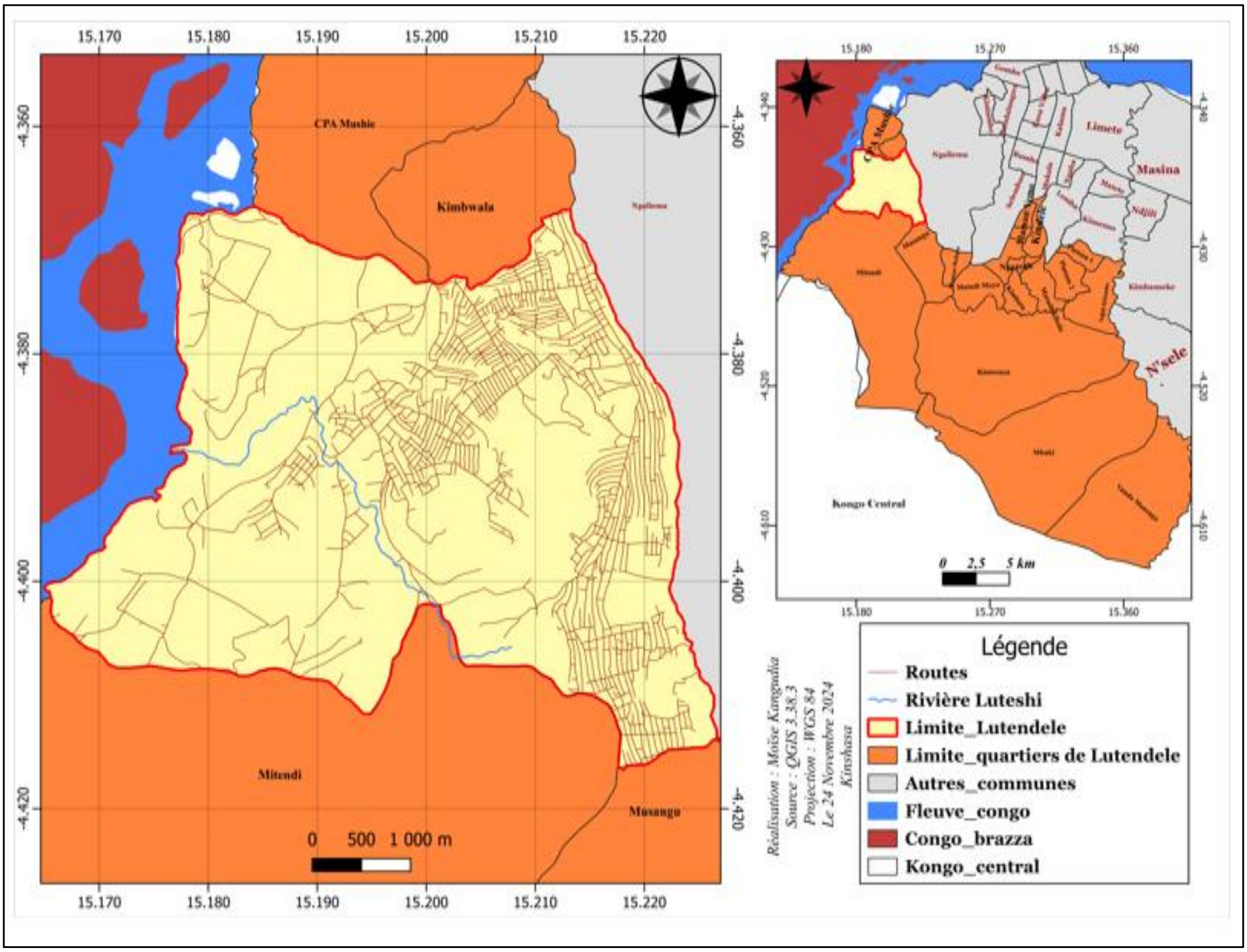

Fig 1 Geographic Location of the Lutendele Neighborhood in the Commune of Mont Ngafula (QGIS 3.38)

III. METHODOLOGICAL APPROACHES

➢ *Sampling Method and Sampling Procedure*

Before analyzing or determining water quality, it is recommended to collect water samples for analytical purposes.

Water samples (500 mL enclosed in sterile plastic bottles) were manually collected in duplicate during the rainy season in November 2024.

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Two sampling points on the Luteshi River, one at the source not far from the watering catchment point and the other on the riverbed, coded E1 and E2 respectively, were chosen based on their high frequency of use for watering market garden crops.

In the field (in situ), we had to determine a total of four (4) parameters, including temperature, hydrogen potential (pH), and Dissolved oxygen and electrical conductivity were measured using a WTW multi-parameter probe.

All samples were stored in a cooler at 4°C and transported to the OCC laboratory the same day for bacteriological analysis

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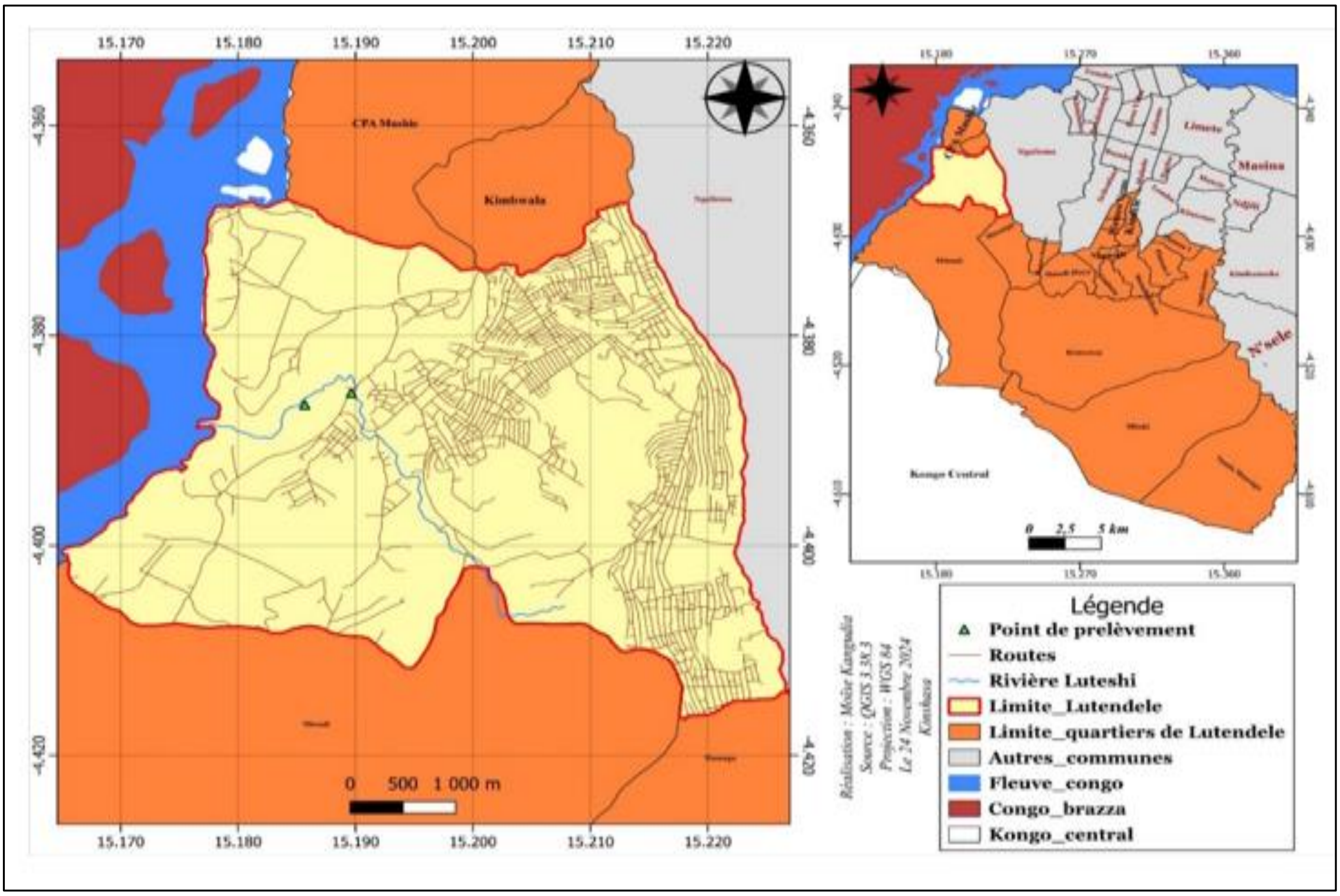

Fig 2 Location of sampling sites

Table 1 Description of the Sampled Sites at the Lutendele Market Garden Site

Code	Code GPS Coordinates		Description
	Latitude	Longitude	
E1	015°11'141'E	04°23'195'S	Slightly tinted water from the spring not far from the irrigation catchment point
E2	015°11'379'E	04°23'126'S	Water from the Luteshi River it carries everyting it finds along its path before flowing into the congo River, which explains the brownish color

IV. ANALYSIS OF PHYSICOCHEMICAL PARAMETERS: In situ MEASUREMENTS

➢ *Hydrogen Potential (pH)*

- *Concept*

Hydrogen potential is a physicochemical measurement that describes the degree of acidity or alkalinity of the aquatic environment. Its scale ranges from 0 to 14. A pH between 6 and 9 allows for relatively normal development of flora and fauna. Living organisms are very sensitive to even limited sudden changes in pH. The influence of pH is also felt through the role it plays on the ionic balances of other elements by increasing or decreasing their toxicity.

pH is also a physicochemical parameter that summarizes the stability of the equilibrium established between the different forms of H_2CO_3. It is linked to the buffer system developed by the CO_3^{2-} and HCO_3^- ions. It depends on the diffusion of CO_2 from the atmosphere, the balance of respiratory and photosynthetic metabolisms, as well as the origin of the water, the geological nature of the environment crossed, wastewater discharge, etc. (Dussart, 1966).

It is inseparable from the values of temperature, salinity, and CO_2 levels. Thus, it has been shown that the mineralization of organic matter causes a drop in pH. It has a direct effect on the availability of metal ions in the marine environment and therefore on the rate of their accumulation by organisms, while also modifying the form of the metal and influencing the physiology of organisms (Bryan, 1979).

Heavy metals can be mobilized when environmental conditions change. There is a pH above which metals are

abruptly released, this pH varies depending on the metal in question (Duchauffour, 1995). For example, this pH is 6.00, 5.00, and 4.00 for cadmium, copper, and lead, respectively.

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- *Principle:*

The potential difference between a glass electrode and a reference electrode immersed in a solution is a linear function of the solution's pH. Potentiometry is based on Nernst's law.

Nernst's law:

$$E = E_o + \frac{0,06}{n} \log \frac{[M']}{[M]}$$

Where

Eo: Standard potential;

E: Normal potential;

n: Number of electrons exchanged;

M: Concentration of the medium;

M': Concentration of the liquid in the electrode.

- *Materials*

- ✓ pH meter with WTW combination electrode;
- ✓ 50 ml beaker;
- ✓ Wash bottle. Reagents
- ✓ pH 4 and 7 buffer solutions
- ✓ Solutions to be analyzed

- *Procedure*

- ✓ Plug the pH meter into the mains;
- ✓ Collect the water to be analyzed in a clean beaker;
- ✓ Clean the electrode with distilled water, rinse with the water to be analyzed;
- ✓ Immerse the electrode in the sample;
- ✓ Read the pH value on the display.

➢ *Dissolved Oxygen*

Dissolved oxygen is an excellent indicator of water quality. Its presence in surface water plays a key role in self-purification and the maintenance of aquatic life.

➢ *Temperature*

- *Concept*

The evolution of a river's temperature remains linked, on the one hand, to local conditions such as regional climate, topography, sunshine duration, flow rate, and depth, and, on the other hand, to potential hot water discharges from factories using water as a cooling medium. Water temperature is a critical parameter in the life of aquatic ecosystems. It influences several physical, chemical, and biological processes (Barbe, 1981).

High temperatures reduce the solubility of gases in water, particularly oxygen levels: If the water temperature varies from 13 to 20°C, the dissolved oxygen concentration drops by 13%. However, the role of oxygen is fundamental for living organisms and for the oxidation of organic and mineral matter. Low temperatures affect the self-purification of rivers because oxidation reactions are slowed. Conversely, a higher temperature accelerates these reactions, but consequently leads to a higher consumption of dissolved oxygen.

- *Equipment*

Thermometer coupled with the WTW brand multi-parameter probe.

- *Procedure*

- ✓ Plug the device into the electrical mains.
- ✓ Clean the electrode with distilled water, then with the sample water.
- ✓ Immerse the electrode in the river.
- ✓ Read the value indicated on the screen after stabilization.

➢ *Electrical Conductivity of Water*

- *Concept*

Electrical conductivity is a measure of water's ability to conduct an electric current, therefore an indirect measure of the ion content of the water. Thus, the more ions such as Ca2+, Mg2+, Na+, K+, HCO3-, Cl-, and SO42- a water contains, the more it is able to conduct an electric current and the higher the measured conductivity.

Electrical conductivity is an indicator of changes in material composition and their overall concentration. It is proportional to the quality of dissolved ionizable salts. It provides information on the overall mineralization level of surface water.

Conductivity is influenced by various natural and anthropogenic factors, including:

- ✓ The geology of the watershed (rock composition).
- ✓ Groundwater input.

Water temperature (high temperatures affect electrical conductivity by affecting salt mobility).

- ✓ Evaporation of lake water (which increases or decreases the ion concentration in the water).
- ✓ Flow variations in the streams and rivers that feed the lake (conductivity increases when the flow is low, due to a higher ion concentration, and decreases when the flow is high).
- ✓ Contaminated water inputs from human activities (road de-icing, agriculture, urban development, industrial activities).

➢ *Principle*

The measurement is based on the use of a galvanometer or cathode method.

- *Equipment*

Digital conductivity meter coupled with a WTW multi-parameter probe.

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✓ *Procedure*

- Plug the device into the electrical outlet
- Clean the electrode with distilled water, then with the sample water
- Immerse the electrode in the river
- Read the value indicated on the display after stabilization.

V. QUANTIFICATION AND CHARACTERIZATION OF INDICATOR BACTERIA OF FECAL CONTAMINATION

➢ *Concepts*

Although many different microorganisms thrive in sewage, a common intestinal bacterium, E. coli, is generally used to indicate the amount of wastewater present in a given water source and to indirectly measure the presence of pathogens. E. coli is ideal for monitoring the presence of wastewater because it is not present in the environment except in human and animal feces, where it proliferates. To detect the presence of E. coli in water, the fecal coliform test is performed. The characterization of fecal indicator bacteria (FIB) is very important for assessing water contamination by human material and preventing human health risks associated with drinking water or during recreational activities (Scott et al., 2005; Converse et al., 2009).

- Safe drinking water should not contain more than one coliform bacterium per 100 mL of water analyzed.
- Safe bathing water should not contain more than 200 units per 100 mL of water analyzed.
- Recreational water features (boats) should not contain more than 2,000 units per 100 mL.

The presence of Escherichia coli (E. coli), fecal coliforms, or enterococci in water indicates that it has been contaminated by feces. Water contaminated in this way can contain microbes (bacteria, viruses, or parasites) that cause health problems.

Water contaminated by microorganisms can cause gastroenteritis, which manifests itself through the following symptoms:

- Diarrhea;
- Abdominal cramps;
- Nausea;
- Vomiting.

Although most strains of coliform bacteria do not cause disease, the fecal coliform test is a good indicator of the likely presence of pathogens or disease vectors in the water.

For this study, a single indicator bacterium of fecal pollution, E. coli, was quantified in the water samples using the culture method. Culture Medium:

Tryptone Soy Agar (TSA): Composed of 15 g/L Tryptone, 5 g/L Peptone, 5 g/L NaCl, and 15 g/L Agar

Tryptone Bile X-Glucuronide (TBX medium): Composed of 20 g/L Tryptone, 1.5 g/L Bile Salts No. 3, 4 g/L K2HPO4, and 10 g/L Agar

➢ *Preparation of the Medium*

Dissolve 20 g of TSA in 500 ml of distilled water and gently bring to a boil to dissolve the powder.
Autoclave at 121°C for 20 minutes.

Cool and dispense 15 ml of medium into a sterile Petri dish. Dissolve 18.5 g of TBX in 500 ml of distilled water and gently bring to a boil to dissolve the powder.

- Autoclave at 121°C for 20 minutes.
- Cool and dispense 15 ml of medium into a sterile Petri dish.
- Analytical Method
- Filter 100 ml of the water to be analyzed through a sterile membrane filter with a diameter of 47 mm and an average pore size of 0.45 µm.

Carefully place the membrane in the culture medium so that it is evenly spread and there are no air bubbles between the membrane and the medium.

Incubate for 2-4 hours at 37°C on TSA, then Transfer for at least 24 hours at 44°C on TBX.

Count the blue colonies on the membrane.

Express the concentration as CFU/100 mL of water.

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VI. SUMMARY OF THE ANALYTICAL SCHEME

The entire methodological approach is summarized in the diagram shown below:

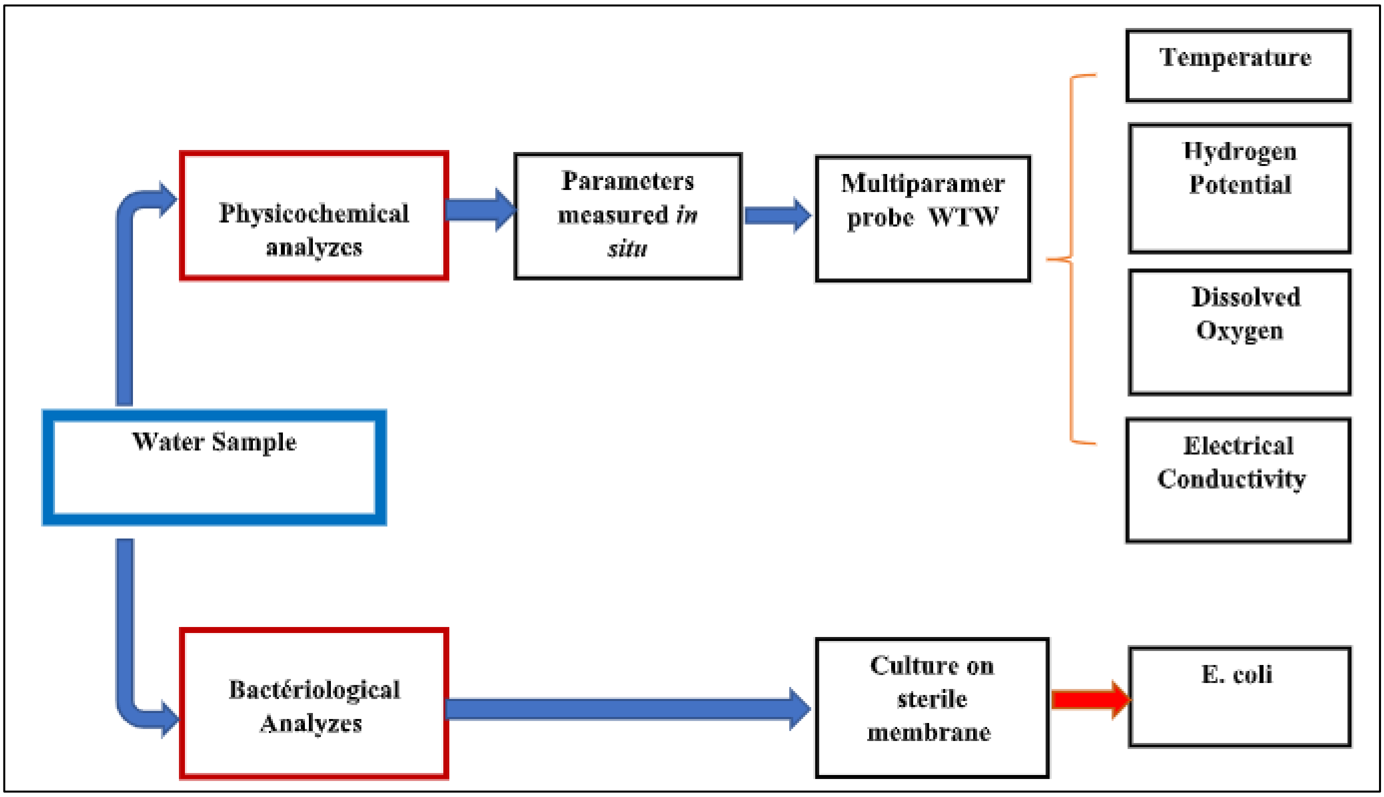

Fig 3 Diagram of the Methodological Approach

VII. PRESENTATION, INTERPRETATION, AND DISCUSSION OF RESULTS

- *Presentation of Results*

The results obtained in this study are grouped according to the two analytical characteristics (physicochemical and bacteriological characteristics) of the irrigation waters studied and recorded in tables clearly visualized by histograms.

- *Results of Physicochemical Parameters Measured in Situ*

The results of the in-situ physicochemical parameters, including temperature, pH, electrical conductivity, and dissolved oxygen, for the samples are presented in Table 2.

Table 2 Mean values of in situ physicochemical parameters

Sampling site	T (en °C)	pH	CE (en µS Cm^{-1})	O_2 (en mg L^{-1})
E 1	27,3	4,98	15,58	4,52
E 2	25,4	5,42	28,5	7,36
Standard*	25	6,5-8,5	≤200	≥10

WHO Guidelines (2017) applicable to surface waters.

Results of microbiological parameters measured in the laboratory

The results of the quantification of fecal pollution indicator bacteria, including E. coli, in the water samples from our study environment are shown in Table 3 below.

Table 3 Mean concentration of E. coli in water samples

Sample code	Concentration (in CFU/100mL)
E1	**23**
E2	**50**
WHO standard	**0**

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VIII. DISCUSSIONS

Examination of the results of the physicochemical and bacteriological analyses of the irrigation water from our study environment allows for various observations, which we discuss in the following lines.

➢ *Physicochemical Parameters*

- *1° Temperature (°C)*

The average temperatures of the irrigation water recorded at the Lutendele site ranged between 27.3°C (E1) and 25.4°C (E2). These values recorded during this study are slightly higher than the limit value (25°C) of the WHO guidelines. This slight thermal pollution can be explained by domestic wastewater discharge.

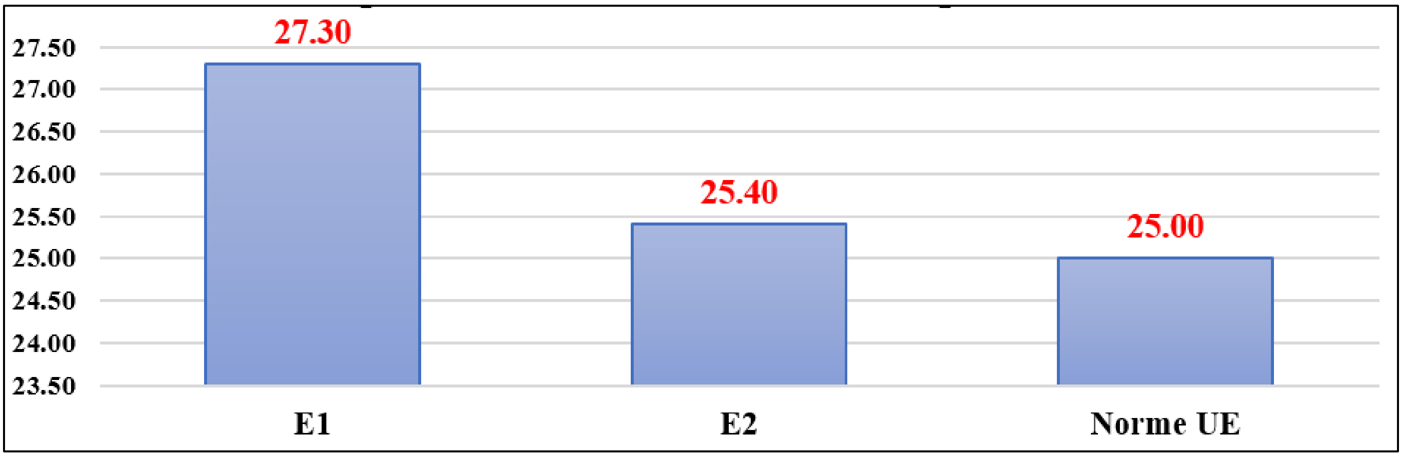

Fig 4 Graphical Representation of the Average Temperature Values in the Simples in ℃

- *2° pH*

The average pH values ranged from 4.98 (E1) to 5.42 (E2). All these average pH values recorded demonstrate that the studied waters are all acidic (pH < 7). This could be explained by the contribution of potentially acidic runoff water, which tends to lower the pH of the waters in the study environment.

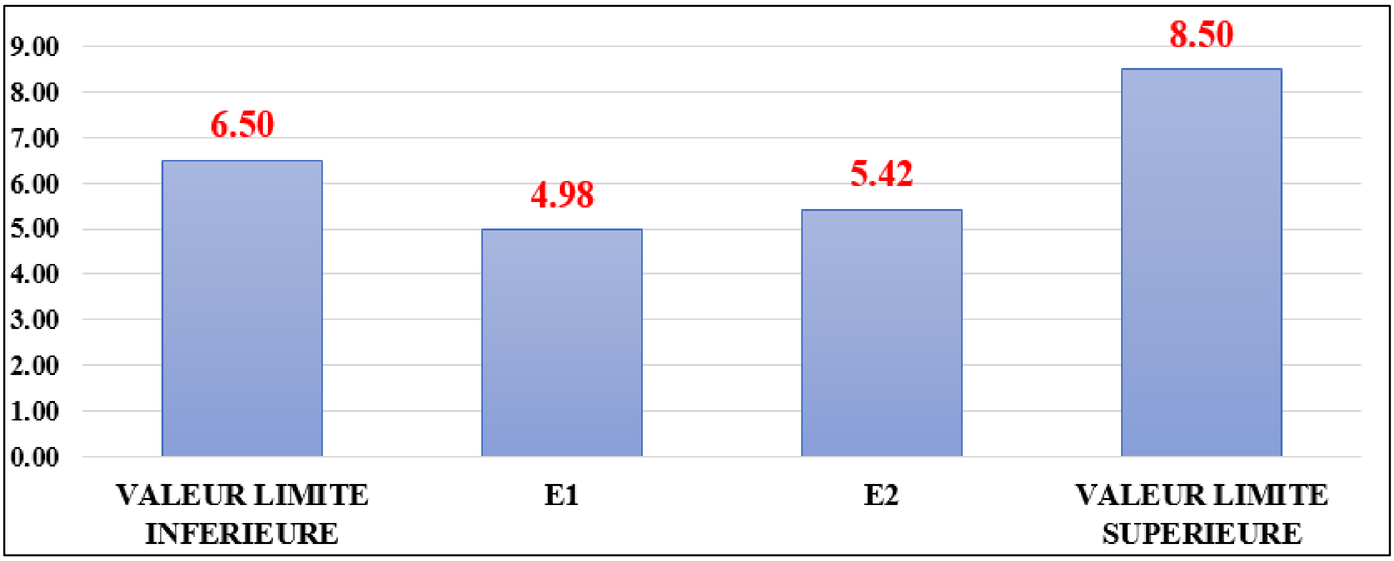

Fig 5 Graphical Representation of the Average Ph Values in the Water Simples

- *3° Electrical Conductivity (EC)*

A low conductivity value is observed in the samples under study. Point 1, for example, recorded a value of 15.58 µs/cm and 28.5 µs/cm for point 2.

The average values of the measured electrical conductivities range from 15.58 µs/cm (E1) to 28.5 µs/cm (E2). In all samples, the recorded electrical conductivity values were consistent with the WHO guideline, which sets the maximum conductivity value at 200 µS/cm for surface water.

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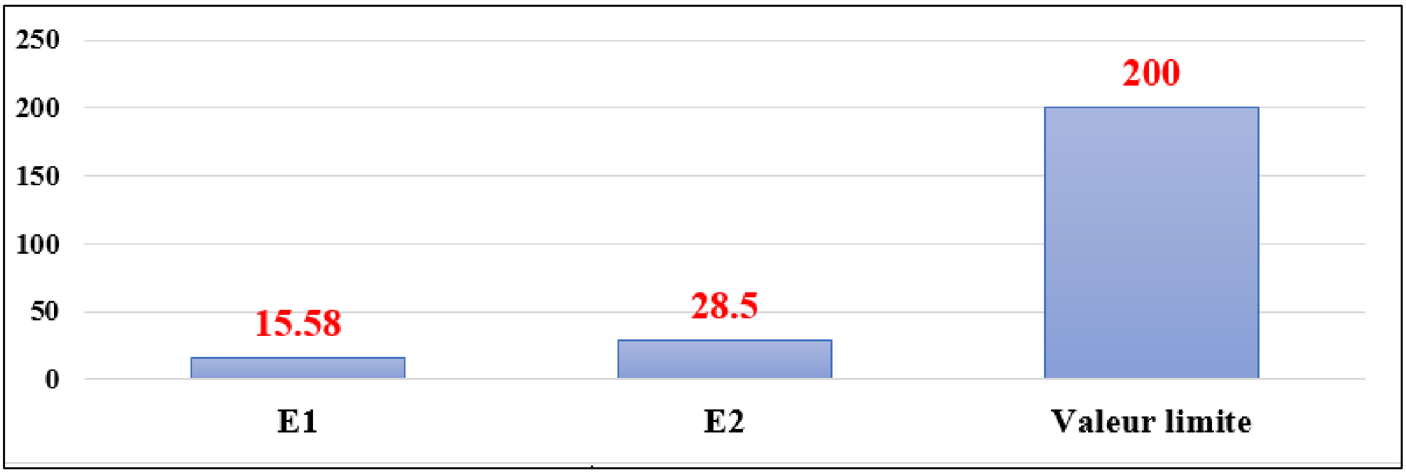

Fig 6 Graphical Representation of Average Electrical Conductivity Values in Water Samples In µs/Cm

➤ *Dissolved Oxygen (Mg/L)*

The dissolved oxygen levels (in mg/L) in the irrigation water under study ranged from 4.52 (E1) to 7.36 (E2).

These levels, all below the WHO guideline, which sets the minimum dissolved oxygen concentration for surface water at 10 mg/L, indicate an oxygen deficiency in the study environment, likely related to the organic matter pollution present in these waters.

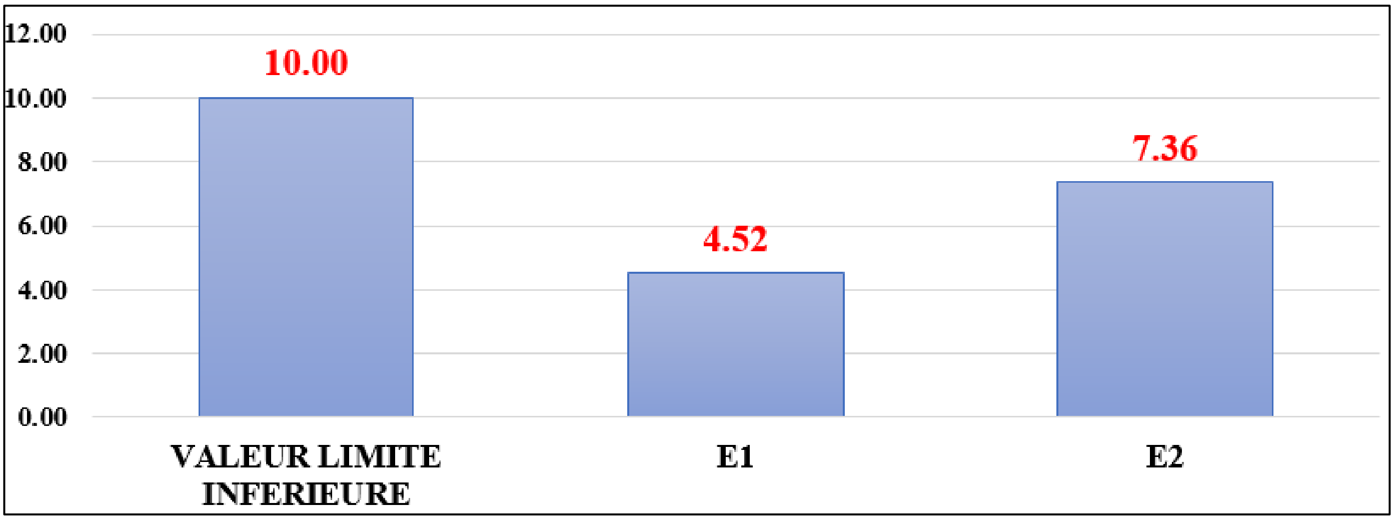

Fig 7 Graphical Representation of Average Dissolved Oxygen Values in Water Samples In Mg/L

IX. BACTERIOLOGICAL PARAMETERS

Examination of the bacteriological analysis results of Lutendele irrigation water samples revealed average E. coli concentrations of 23 CFU/100mL (E1) and 50 CFU/100mL (E2). These values, which do not comply with WHO standards for drinking water (0 CFU/100mL), generally indicate that all of these waters are significantly fecally polluted.

This situation could be explained by the contribution of fecal contaminants carried by runoff water and by the inadequate hygiene measures (hygienic facilities) of the surrounding population.

The higher concentration of BIF in the water indicates the potential presence of pathogenic organisms responsible for waterborne diseases such as gastrointestinal illnesses, typhoid, cholera, and other diarrheal diseases.

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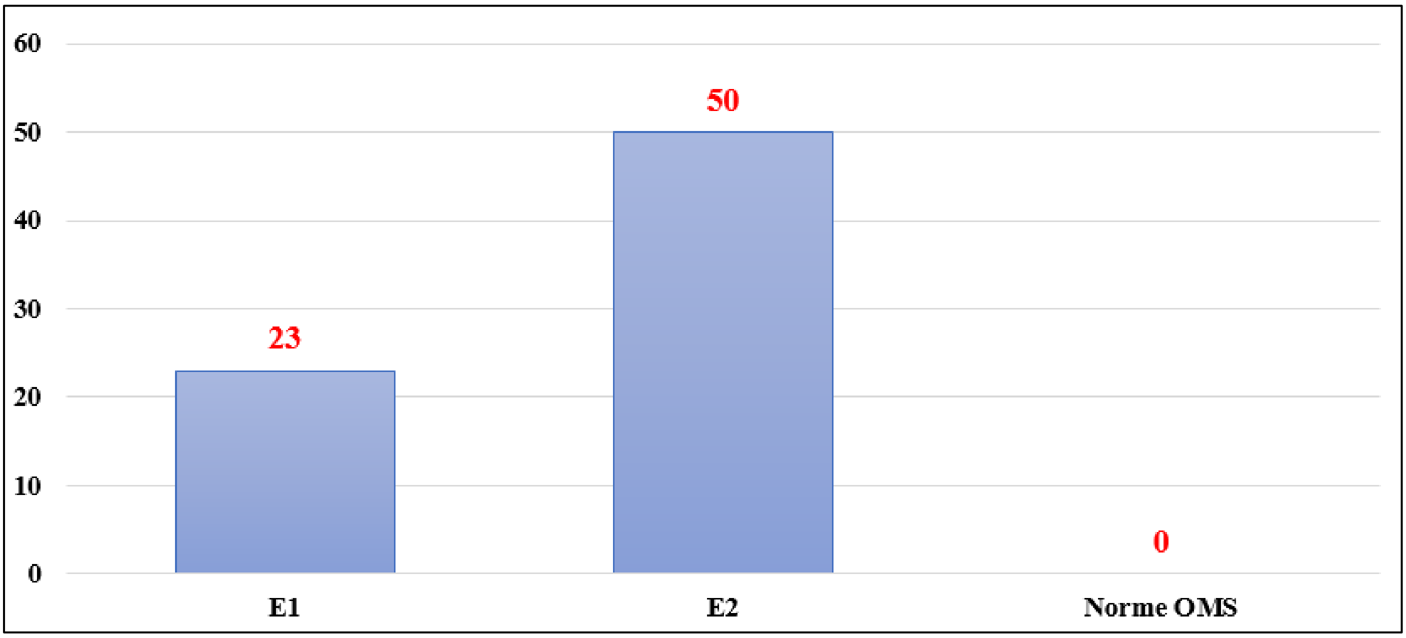

Fig 8 Average Concentration of E.Coli in Water Samples (In UFC/100ml)

X. GENERAL CONCLUSION AND RECOMMENDATIONS

The main objective was to assess the quality of the water used to irrigate market garden crops in the Lutendele neighborhood.

To achieve this objective, the methodology focused on the analysis of physicochemical parameters, including temperature, pH, electrical conductivity, and dissolved oxygen using a multiparameter probe; and bacteriological analysis (identification and quantification of E. coli) using sterile membrane culture.

The results of this research demonstrated that the water used to irrigate market garden crops in the Lutendele neighborhood is of poor quality, characterized primarily by acid and fecal pollution, thus confirming our initial hypothesis.

The proven physicochemical and microbiological quality of this water presents risks to human health, given that the contamination of market garden crops regularly irrigated with this water can only be a logical consequence. The potential causes of the poor physicochemical and bacteriological quality of the Luteshi River waters are potentially urban and agricultural pressures.

To ensure a safe and clean supply of irrigation water, accessible to all market gardeners, to address the problems related to irrigation water pollution and improve its quality, we have suggested the following recommendations:

➢ *To Agricultural Authorities:*

- Ensure proper management of surface water intended for irrigation to minimize the possibility of crop contamination.
- Agricultural sites must be identified, protected, and subject to an environmental monitoring system.
- Provide market gardeners with appropriate methods for disinfecting irrigation water in general and the Luteshi River in particular.

➢ *Regarding the market gardeners on this site:*

- Crop placement should be carefully considered in light of potential sources of contamination.
- Irrigation systems should be located away from latrines and all sources of pollution. A protected perimeter should be established and respected.

- Limit the use of pesticides and fertilizers or use environmentally friendly alternatives to prevent any runoff into irrigation water.
- Treat irrigation water using basic techniques before use.

➢ *To The Local Population And Surrounding Areas*

- Ensure hygiene when preparing food products from the Lutendele site.
- Avoid raw or direct consumption of products from this site.
- Switch supplies between different sites.
- Be aware of any adverse effects after consuming an agricultural product from this area and contact a doctor as soon as possible.

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