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Analysis of agricultural practices' impact on the quality of irrigation water for growing vegetables in the Urban Commune of N'Zérékoré, Republic of Guinea

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Abstract

Irrigation water quality is a crucial factor influencing agricultural productivity and food safety. In the urban commune of N'Zérékoré, vegetable farming is a predominant activity. However, most local growers lack precise information on the quality of the water used for irrigation due to the absence of systematic monitoring by agricultural and public health authorities. This study, conducted in February 2024 in the Nyèn I and Nyèn II districts, aimed to assess the physico-chemical and biological characteristics of irrigation water used for vegetable cultivation.

Water samples were collected weekly from both districts and analyzed using volumetric analysis and molecular absorption spectrophotometry. Data were processed using XLSTAT 2016 software, followed by an ANOVA with NSK's test at a 5% significance level. The results showed that the concentrations of chemical elements, as well as total and fecal coliforms, were statistically similar across both sites. No significant variations were observed between the different sampling weeks. The mean concentrations of potassium (11.15 mg/L), manganese (0.34 mg/L), sulfates (11 mg/L), nitrates (42.02 mg/L), nitrites (1.9 mg/L), and total iron (2.94 mg/L) remained within acceptable levels for agricultural use.

However, microbiological analysis revealed significant contamination, with fecal coliform counts averaging 869.75 CFU/100 mL and total coliform counts reaching 1142.50 CFU/100 mL, indicating potential health risks for crops and the environment. These findings highlight the need for phytoremediation measures, improved water treatment, and better irrigation water management to ensure safer and more sustainable agricultural practices in N'Zérékoré.

Keywords: Water Quality; Market Gardening; Contamination; Physico-Chemical Parameters; Biological Parameter; Irrigation Water Management

1. Introduction

Historically, market gardening in Republic of Guinea was practiced in association with other crops during the rainy season. However, in recent years, this sector has experienced rapid expansion, driven by the need to meet the increasing food demand resulting from population growth. Today, vegetable cultivation is practiced intensively and ubiquitously

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across the country, ensuring a continuous supply of fresh produce throughout the year. According to projections by OECD/FAO [1], agricultural production is expected to increase by 7%, 6%, and 7% over the next decade for oilseeds, leguminous plants, and tuberous crops, respectively. This rise is largely attributed to their perceived health benefits and growing consumer preference for these food sources [1].

To maintain market supply and meet the increasing demand for fresh produce, vegetable crops are cultivated even during the dry season. However, water availability remains a critical limiting factor, varying significantly depending on the season and production zone within Republic of Guinea. Water is not only essential for plant growth but also plays a fundamental role in ecosystem stability, as highlighted by Nyika and Dinka [2]. Beyond availability, water quality is a determining factor in the success of market gardening, as irrigation with contaminated water can introduce pathogens and pollutants, jeopardizing both crop yield and consumer health [3].

Access to clean, unpolluted water for irrigation remains a major challenge in many urban areas in Republic of Guinea, including N'Zérékoré, as reported by several studies [4, 5]. The sources of contamination are diverse and primarily linked to human activities, including the widespread use of pesticides, improper disposal of agrochemical packaging, infiltration of wastewater from domestic and industrial sources, and the decomposition of organic matter and untreated effluents [6, 7]. These polluted water sources contribute to serious public health and environmental concerns, as they can introduce chemical residues, bacteria, fungi, and toxins into vegetable crops [8, 9].

Despite these risks, the increasing degradation of urban environments has forced many farmers in N'Zérékoré to rely on readily available irrigation sources, regardless of their quality. The most commonly used water sources in the urban commune include deep, uncovered wells, which are extensively utilized during the dry season, as well as the “Tilé” River and its tributary “Zaly” [10]. Additionally, shallow pits, often less than 10 meters deep and located near gardens and rivers, serve as an alternative irrigation source. Given that runoff water can transport household waste, industrial effluents, and pesticide residues into these water bodies, the risk of contamination is substantial. Furthermore, because many market gardening products are consumed fresh and unprocessed, ensuring the quality of irrigation water is a public health priority [1]. The direct reuse of untreated irrigation water can serve as a vector for pathogens and pollutants, posing risks not only to crops but also to human and animal health [11].

In response to these concerns, the present study was conducted in N'Zérékoré to evaluate the quality of irrigation water used in urban market gardening. Specifically, it aims to identify pollutants linked to agricultural and human activities, assess the physico-chemical and microbiological properties of irrigation water, and propose recommendations for sustainable water quality management to safeguard both crops and consumers. This research is intended to provide scientific evidence that can guide farmers, policymakers, and stakeholders in the implementation of strategies for the safe and sustainable use of irrigation water in Republic of Guinea.

2. Materials and methods

2.1. Study area

This study was conducted in the Nyèn I and Nyèn II districts of the Urban Commune of N'Zérékoré, Republic of Guinea. In these districts, market gardening areas cover approximately 6 hectares in Nyèn I and 4 hectares in Nyèn II as shown in Figure 1. The administrative region of N'Zérékoré, one of Guinea’s eight regions, comprises six prefectures, including the N'Zérékoré prefecture, which serves as the regional capital. It consists of 64 sub-prefectures, 6 urban communes, and 61 rural communes [12].

Market gardening is practiced intensively in this area, providing a diverse supply of fresh fruits and vegetables for both local consumption and urban markets. The choice of N'Zérékoré for this study was motivated by public health concerns, as reported by the Institut National de la Statistique [12]. According to INS data, the N'Zérékoré region ranks first, second, and third among Republic of Guinea’s administrative regions for neonatal mortality (18 ‰), juvenile mortality (41 ‰), and infant mortality (54 ‰), respectively. These indicators highlight the potential health risks associated with environmental factors, including water quality, justifying the need for an assessment of irrigation water used in market gardening.

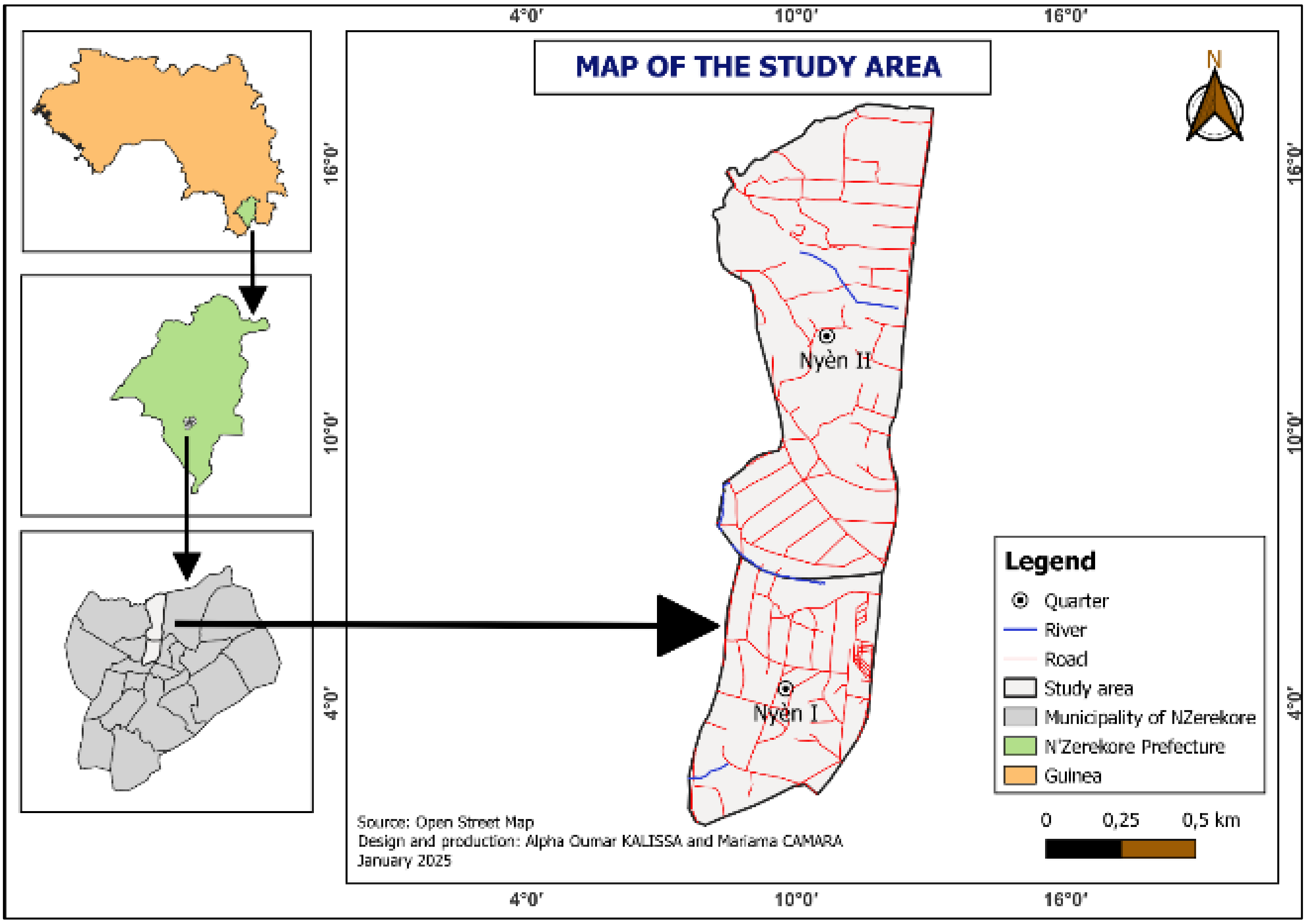

Figure 1 Study area of Nyèn I and Nyèn II districts

2.2. Method of sampling

A total of 49 traditional market gardening wells were surveyed in the Nyèn I and Nyèn II districts, with an average spacing of 5 to 10 meters between wells. In these areas, irrigation is performed manually using 10-liter plastic watering cans.

To assess irrigation water quality, four samples were collected per district, with a one-week interval between each sampling. Water samples were collected in 500 mL polyethylene bottles, following the methodology described by Rodier [13]. Prior to sampling, the bottles were thoroughly cleaned, rinsed with distilled water, and sterilized to prevent contamination. At each sampling site, bottles were immersed aseptically to avoid external contamination, labeled, and stored in a cooler at 4°C before being transported for analysis. The analyses were conducted at the analytical chemistry laboratory of the University of N'Zérékoré and at the biology laboratory of Gamal Abdel Nasser University (UGAN) of Conakry.

2.3. Parameters assessed and analysis method

The study focused on both physico-chemical and microbiological parameters of irrigation water.

2.3.1. Method for determining the chemical composition of the water

Field measurements of pH and temperature were conducted in situ using HANNA HI 98194 (2015 version) instruments. The pH measurement determined the acidity or basicity of the water, while temperature (T) influenced various chemical and biological processes.

Laboratory analyses included the quantification of total iron (Fe), nitrates (NO_3^-), nitrites (NO_2^-), sulfates (SO_4^{2-}), manganese (Mn), and potassium (K). These elements were analyzed due to their relevance in agricultural practices, particularly regarding the intensive use of fertilizers and pesticides [14, 15].

The Analytical Chemistry Laboratory at the University of N'Zérékoré employed volumetric analysis and molecular absorption spectrophotometry for determining mineral element concentrations, using 7500 and AL450 photometers [16, 17, 18].

2.3.2. Method of microbiological analysis of sampled waters

For microbiological assessment, water samples were analyzed at the Biology Department of the Faculty of Science and Technology at University Gamal Abdel Nasser in Conakry. The analysis focused exclusively on total coliforms and fecal coliforms, given the available laboratory resources.

The membrane filtration method described by Rodier [13] was applied. After filtration, portions of the samples were inoculated on bacterial culture media in Petri dishes, which were then incubated. Following the incubation period, bacterial enumeration was performed to estimate the microbial load in irrigation water.

2.4. Statistical analysis

Statistical analyses were conducted using XLSTAT 2016 software. Mean values for chemical elements (expressed in mg/L) and bacteriological parameters (expressed in CFU/100mL) were calculated for each site. Analysis of variance (ANOVA) was performed, followed by a Student-Newman-Keuls (SNK) test at a 5% significance level to determine potential differences between sampling periods.

3. Results

3.1. Temporal variation of chemical and biological compounds in irrigation water from Nyen stations

The analysis revealed that the concentrations of potassium (K), manganese (Mn), sulfates (SO_4^{2-}), nitrates (NO_3^-), nitrites (NO_2^-), and total iron (Fe), as well as water temperature, remained relatively stable across the four sampling weeks. Statistical analysis indicated no significant differences between different sampling weeks and between the week × station interaction (Table 1). Similarly, the bacterial loads of total and fecal coliforms did not exhibit any significant temporal variation (Table 2).

Table 1 Weekly variation in chemical elements in the irrigation water at Nyèn

Week	T (°C)	pH	K	Manganese	Sulfates	Nitrates	Nitrites	Fe total
4	26,01 A	6,38 A	10,45 A	0,30 A	12,00 A	60,52 A	2,87 A	3,35 A
1	21,97 A	6,38 A	12,20 A	0,50 A	10,00 A	36,09 A	1,82 A	3,20 A
3	30,97 A	6,37 A	11,50 A	0,35 A	11,50 A	31,19 A	1,18 A	2,70 A
2	24,38 A	6,32 A	10,45 A	0,20 A	10,50 A	40,25 A	1,72 A	2,50 A
Pr > F	0,099	0,015	0,840	0,539	0,208	0,173	0,250	0,969
Significant	No	Yes	No	No	No	No	No	No
Wk*Sttion Pr > F	0,685	0,647	0,664	0,636	0,734	0,805	0,782	0,714
Significant	No	No	No	No	No	No	No	No

*Wk*Sttion = week*Station*

Table 2 Weekly variation in coliforms in the irrigation water at Nyèn

Week	Faecal coliforms (en UFC/100ml)	Total coliforms (en UFC/100ml)
1	779,50 [A]	1400,00 [A]
2	965,00 [A]	1450,00 [A]
3	790,00 [A]	1150,00 [A]
4	680,00 [A]	835,00 [A]
Pr > F	0,708	0,096
Significant	No	No

3.2. Results of biological parameters of irrigation water from Nyèn I and Nyèn II stations

Table 3 presents the results of the various biological analyses carried out on irrigation water from the Nyèn I and Nyèn II stations in the commune of N'Zérékoré. The statistical analysis shows that there is no significant difference between these two stations for total coliform and fecal coliform values. The maximum values are 869.75 CFU/100ml and 1142.50 CFU/100ml, for fecal coliforms and total coliforms respectively. These values exceed the levels recommended by the World Health Organization / Food and Agriculture Organization of the United Nations (WHO/ FAO). These waters could be a potential risk to crop health and the environment in N'Zérékoré.

Table 3 Values for total and faecal coliforms in irrigation water from Nyèn stations

Stations	Faecal coliforms (en UFC/100ml)	Total coliforms (en UFC/100ml)
Nyèn I	869,75 A	1142,50 A
Nyèn II	737,50 A	1275,00 A
Pr > F	0,708	0,096
Significant	No	No

3.3. Results of chemical parameters of Nyèn I and Nyèn II irrigation water

3.3.1. Results of chemical parameters of Nyèn I and Nyèn II irrigation water

The results of chemical analysis of irrigation water from the Nyèn station are presented in Table 4. Overall, the levels of the various chemical elements present in the irrigation water were statistically equivalent. Thus, the following mean values were obtained for the Nyèn station: the mean value for potassium (K) is 11.15 mg/L, for manganese (Mn) is 0.34 mg/L, for sulfates (SO_4^{2-}) is 11 mg/L, for nitrates (NO_3^-) is 42.02 mg/L, for nitrites (NO_2^-) is 1.9 mg/L, and for total (Fe) iron is 2.94 mg/L.

The results show that the average pH value of the irrigation water is 6.36 at Nyèn. In addition, the results show mean temperatures of 27.77°C and 23.89°C at Nyèn I and Nyèn II respectively. However, these values are not statistically different at the 5% threshold according to the analysis of variance (Table 4). It could be said that the thermal regime of Nyèn irrigation water (in Forest Guinea) follows that of the climate, given that the measurements were taken in February.

Overall, the average levels of total iron (Fe), manganese (Mn), potassium (K), sulfates (SO_4^{2-}), nitrates (NO_3^-) and nitrites (NO_2^-) in the samples were below the permitted standards established by WHO/FAO.

Table 4 Values of chemical elements in irrigation water from Nyèn I and Nyèn II

Stations	T (en °C)	pH	K	Mn	SO_4^{2-}	NO_3^-	NO_2^-	Fe total
Nyèn I	27,77 A	6,29 A	10,60 A	0,20 A	11,75 A	55,02 B	2,85 B	2,95 A
Nyèn II	23,89 A	6,43 A	11,70 A	0,47 A	10,25 A	29,01 A	0,95 A	2,93 A
Pr > F	0,099	0,015	0,840	0,539	0,208	0,173	0,250	0,969
Significant	No	No	No	No	No	Yes	Yes	No

4. Discussion

The analysis of irrigation water at the Nyèn stations in the Urban Commune of N'Zérékoré revealed relative stability in chemical and biological parameters over the four weeks of sampling. This stability suggests minimal variation in water composition, despite exposure to certain local and anthropogenic agricultural practices.

The concentrations of potassium (K), manganese (Mn), sulfates (SO_4^{2-}), nitrites (NO_2^-), and nitrates (NO_3^-) remained stable over time, with no significant differences between the two stations (Nyèn I and Nyèn II) or between sampling weeks. These concentrations were consistently below the thresholds established by WHO/FAO. These findings contrast with those of Ashraf *et al*. [8] in Pakistan, where As, Cd, Pb, Cr, Fe, Hg, and Mn concentrations exceeded WHO/FAO recommendations, and those of Djade [19] in Côte d'Ivoire, who reported values generally in line with WHO drinking water guidelines, except for Fe, which exceeded the recommended limits.

The observed stability in chemical composition suggests that agricultural practices, particularly the use of fertilizers and pesticides, had a limited impact on irrigation water quality at Nyen. This could be attributed to the time required for contaminants to reach water sources. Indeed, the effects of fertilizer and pesticide application on water quality are not necessarily immediate, as certain chemical compounds undergo dilution or retention in the soil before reaching water bodies [20, 21]. Additionally, the stability of nitrate and nitrite levels could be explained by low bacterial activity in nitrification/denitrification processes [22] or by a dynamic equilibrium between nutrient inputs and environmental losses. Furthermore, the frequent renewal of irrigation water may contribute to minimizing fluctuations in chemical concentrations, a phenomenon highlighted by several authors [20].

Regarding biological parameters that exceeded WHO/FAO standards, their stability between sampling stations indicates a relatively constant level of microbiological contamination. This contamination can be attributed to multiple factors, including hydrological conditions (temperature, pH) and environmental sources (atmospheric defecation, use of organic fertilizers, etc.). Water temperature, in particular, plays a crucial role in microbial proliferation [23]. Terei *et al*. [24] demonstrated that temperature influences the growth of *Salmonella* and that the frequency of contamination increases with temperature. The relatively stable temperature observed in this study may thus explain the homogeneity of microbiological contamination across the sites.

More broadly, water quality-particularly microbial load-is influenced by long-term pollution from fertilizers and pesticides used in agricultural practices [25, 26]. However, the absence of significant variations over the study period could be due to the one-week sampling interval, which may not capture long-term fluctuations, as suggested by studies employing longer intervals of two months or more [27, 28].

5. Conclusion

The present study was carried out to analyze the quality of irrigation water used for market gardening in the Nyèn district of the Urban Commune of N'Zérékoré . The results showed a relative stability in the chemical and biological composition of the irrigation water over the period studied. However, these results do not mean that irrigation water is totally risk-free. Prolonged exposure to contaminants (heavy metals, pesticide residues, etc.), even at low concentrations, can have cumulative effects on soil fertility, crop health and consumer food safety. Therefore, for a better understanding of the impact of agricultural practices on water quality, further studies integrating seasonal analyses, bioaccumulation tests and an assessment of soil and crop contamination would be necessary

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there are no conflicts of interest to divulge.

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