JIEPH Journal of Interventional Epidemiology & Public Health

Research

Gardeners' knowledge, practices and associated risk factors for multidrug-resistant bacteria dissemination in environment and humans: A One Health approach in gardens of Ouagadougou, Burkina Faso

KEYWORDS: Gardeners, urban agriculture, multi-resistant bacteria, knowledge, One Health

Fatimata Bintou Josiane Diarra[1], Isidore Juste Ouindgueta Bonkoungou[1,&], Djifahamaï Soma[1], Namwin Siourimè Somda[2], Evariste Bako[3], Souleymane Sore[4], Marguerite Edith Malatala Nikiema[5], Natéwindé Sawadogo[6], Nicolas Barro[1], Daouda Kassié[7,8]

[&]**CORRESPONDING AUTHOR**
Isidore Juste Ouindgueta Bonkoungou, Department of Biochemistry and Microbiology, Université Joseph KI-ZERBO, Ouagadougou, Burkina Faso, Email address: isidore.bonkoungou@ujkz.bf

[1]Department of Biochemistry and Microbiology, Université Joseph KI-ZERBO, Ouagadougou, Burkina Faso, [2]Département Technologie Alimentaire (DTA) / IRSAT / CNRST, Ouagadougou 03, Burkina Faso, [3]Université Thomas SANAKARA/Centre Universitaire de Tenkodogo, 12, Ouagadougou 12, Burkina Faso, [4]Direction des laboratoires de Biologie Médicale, Ministère de la Santé, Ouagadougou 03, Burkina Faso, [5]Laboratoire de Virologie et Biotechnologies Végétales, Institut de l'environnement et de Recherches Agricoles(INERA), CNRST, Burkina Faso, [6]CEFORGRIS/Université Joseph KI-ZERBO, Ouagadougou, Burkina Faso, [7]Centre de coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), UMR ASTRE (Animal, Santé, Territoires, Risques, Ecosystèmes), Montpellier, France, [8]Institut Pasteur de Madagascar (IPM), Unité Epidémiologie et Recherche Clinique, Antananarivo, Madagascar

RECEIVED
10/01/2025

ACCEPTED
12/05/2025

PUBLISHED
19/05/2025

LINK

https://afenet-journal.org/gardeners-knowledge-practices-and-associated-risk-factors-for-multidrug-resistant-bacteria-dissemination-in-environment-and-humans-a-one-health-approach-in-gardens-of-ouagadougou-burkina-faso/

CITATION
Fatimata Bintou Josiane Diarra et al Gardeners' knowledge, practices and associated risk factors for Multidrug-Resistant Bacteria dissemination in environment and humans: A One Health approach in gardens of Ouagadougou, Burkina Faso. Journal of Interventional Epidemiology and Public Health. 2025;8:36
DOI: https://doi.org/10.37432/jieph-d-25-00018

ABSTRACT

Background: Garden products can be contaminated with multidrug-resistant (MDR) bacteria through fecal waste, irrigation water, biosolids, or animal manure used as fertilizer. This study assesses the knowledge and practices of gardeners in Ouagadougou, and identifies risk factors for MDR bacteria spread in humans and the environment using a One Health approach. **Methods:** In April 2023, a questionnaire survey was conducted among 110 consenting gardeners from three sites (Paspanga, Tanghin, and Boulmiougou). Data were collected via face-to-face interviews using Kobo Collect and analyzed using descriptive statistics and logistic regression to identify factors linked to low knowledge and risk. **Results:** Most participants were male (52.7%), 70.9% had no formal education, and 54.6% were aged 41–60 years. The majority used well water for irrigation (99.1%). All used organic fertilizers, but 92.7% did not produce their own, and composting was low (23.6%). Shared latrines were used by 71.8%, and 60.0% did not use personal protective equipment. Knowledge gaps were significant: 72.7% didn't believe irrigation water could contaminate produce, 73.6% were unaware of manure risks, and 67.3% didn't think contaminated produce could infect humans. Logistic regression revealed that perceptions about water contamination were paradoxically linked to higher odds of risky behaviour (odds ratio = 3.48, p = 0.016). **Conclusion:** This study reveals knowledge gaps and risky practices among gardeners, contributing to MDR bacteria spread and posing health risks. Urgent interventions are needed to improve education, infrastructure, and practices in urban farming.

Introduction

Agriculture plays a crucial role in the socio-economic development of communities, providing employment for over 40% of the global workforce, with around 52% of workers in Africa and Asia [1]. Within this sector, market gardening including the fruit and vegetable industries, plays a crucial role in national economies and greatly contributes to improving the dietary and nutritional balance of populations [2,3]. Antimicrobial Resistance (AMR) is the ability of microorganisms to resist the effects of antimicrobial treatments, particularly antibiotics [4]. Humans can acquire antimicrobial-resistant bacteria (ARB) from various sources, including human-to-human transmission, direct contact with animals, food, and the environment [5]. The agricultural ecosystem provides an ideal platform for the development and spread of AMR, driven by the overuse and misuse of antibiotics in the veterinary, agricultural, and medical sectors [6]. Studies have detected the presence of multi-drug-resistant (MDR) bacteria on fresh vegetables [7–9]. Fresh produce can be contaminated with pathogenic bacteria through contact with fecal waste during farming practices, such as using wastewater for irrigation and applying biosolids or animal manure as fertilizer [10,11]. Agricultural soil can also harbor pathogens, with contamination worsened by waste application [12,13]. Leafy and non-leafy vegetables, such as carrots, are particularly vulnerable to contamination by soil-borne bacteria [14]. Untreated animal manure represents a significant source of MDR bacteria contamination prior to harvest [11,15,16].

In sub-Saharan Africa, between 50% and 90% of vegetables consumed by urban residents are produced in urban or peri-urban areas, often using wastewater [17]. The rapid demographic growth in these cities is leading to an increased demand for food, particularly garden products. Market gardening in sub-Saharan Africa frequently involves the intensive and inappropriate use of inputs, including mineral fertilizers, organic waste, phytosanitary products, and wastewater, with significant adverse effects on human health and the environment [18,19]. Due to the limited availability of irrigation water in urban and peri-urban areas, farmers often depend on untreated or poorly treated wastewater, which serves as a potential source of MDR bacteria originating from households, hospitals, and farms [20]. Resistant bacteria have been identified in waterways contaminated by wastewater from hospitals and peri-urban and rural communities [21]. This wastewater is sometimes used to irrigate garden crops [22].

The city of Ouagadougou is largely supplied with garden produce grown with water from dams, wells, and boreholes, but most notably from wastewater, the quality of which remains questionable [22]. Factors contributing to the spread of these MDR bacteria include direct exposure to wastewater and the consumption of contaminated, insufficiently cleaned fresh vegetables by both farmers and consumers [23]. Given that the knowledge and practices of gardeners are critical for raising awareness, informing policy, ensuring consumer access to safe produce, and breaking the chain of MDR bacteria dissemination, this study was essential in understanding these aspects in Burkina Faso. This study aims to assess the knowledge, practices, and associated risk factors contributing to the dissemination of MDR Bacteria in the environment and human health within urban agriculture systems in Ouagadougou, Burkina Faso.

Methods

Study design and location

We administrated questionnaires in April 2023. A total of 110 consenting gardeners participated in this study. The research was conducted at three market gardening sites in Ouagadougou: Paspanga (30 participants), Tanghin (48 participants), and Boulmiougou (32 participants) (Figure 1). The inclusion criterion for these sites was their role in market gardening, where samples were collected in our previous study to determine the presence of antibiotic-resistant bacteria [24].

The gardening site of Paspanga is located next to a city hospital, near a channel conducting municipality wastewater away from the city. The gardening site of Tanghin Dam is close to a medical center and the livestock market. On the contrary, the gardening site of Boulmiougou Dam is located in a less polluted area, far from health facilities.

The sample size was estimated based on the calculation of a proportion by Cochran formula [25].

$$n = \frac{t^2 \cdot p(1-p)}{e^2}$$

n: Expected sample size

t: Confidence level (1.96 for a 95% confidence interval)

p: Expected proportion of the farming population with insufficient knowledge regarding the rational use of antibiotics $p = 42$ % [22]
e: Margin of error set at 10%
By applying the formula, the minimum sample size required to achieve an expected proportion of 42%, with a 10% margin of error at a 95% confidence level, is approximately 94 participants.

Data collection
The questionnaires were designed in French using the online software Kobo Toolbox (Kobo Inc., Cambridge, MA, USA) and administered face-to-face using Kobo Collect (v2023.1.2). The questionnaire was divided into three sections: The first section collected information on the socio-demographic characteristics of the participants; the second section focused on practices that may risk spreading antibiotic resistance in market gardening; and the third section assessed the knowledge of the participants, three questionnaires were asked: human contamination through garden produce, contamination of produce by animal manure, contamination by irrigated water.

Data analysis
Data collected were exported from the Kobo Toolbox application to Microsoft Excel 2016 for cleaning and preliminary organization. Statistical analyses were performed using R software (Version 2024.09.1). Descriptive statistics, including frequencies, means, and proportions, were used to summarize the data. Pearson's Chi-squared test was used to compare categorical variables, with statistical significance set at $p < 0.05$. This test assumes independent observations and expected cell frequencies of at least 5. When expected counts were below 5, we used Fisher's exact test for accuracy. Results with p-values close to this threshold (e.g., $0.05 < p < 0.10$) were described as trends, indicating a potential association. However, these trends were reported descriptively and interpretatively, without being considered statistically significant unless explicitly stated.
The knowledge and practice scores were calculated based on gardeners' responses across three key dimensions: i) Knowledge about Multidrug-Resistant Bacteria dissemination in urban agriculture, ii) Practices at risk of spreading Multidrug-Resistant Bacteria in the environment, and iii) Practices at risk of spreading multidrug-resistant bacteria in human. Each dimension was assessed using binary-coded variables (0 or 1), where 1 indicated a correct response or secure practice. "Good" or "Poor" knowledge or practices were calculated as follows:

1. **Knowledge of multidrug-resistant bacteria dissemination in urban agriculture:** Knowledge scores were derived from three variables, resulting in scores ranging from a minimum of 0 to a maximum of 3 points. The average knowledge score across participants was 0.863 points across all participants.
2. **Practices contributing to the spread of multidrug-resistant bacteria in the environment:** Seven variables were assessed to evaluate gardeners' practices that could contribute to the environmental spread of MDR bacteria. Scores ranged from a minimum of 1 to a maximum of 5 points, with an average score of 3.15 points across all participants.
3. **Practices contributing to the spread of multidrug-resistant bacteria to humans:** Seventeen variables were analyzed to assess the risk of human contamination with MDR bacteria. These variables included water consumption, hygiene practices, food handling, and the use of personal protective equipment (PPE). Scores ranged from a minimum of 5 to a maximum of 13 points, with an average score of 9.14 points across all participants.

For each dimension, participants were categorized as having either "Good" or "Poor" knowledge or practices. Classification thresholds were determined using the mean scores across all participants. Individuals whose scores exceeded the group average were classified as having "Good" knowledge or practices, while those with scores equal to or below the average were classified as having "Poor" knowledge or practices.
Binomial logistic regressions were performed to identify factors associated with knowledge and practices, with predictors included in univariate analyses -regardless of their significance – to explore relationships among the different variables (Table S1). The MASS library in R was used to perform stepwise backwards regressions procedure. The minimal models were selected on the basis of the

lowest AIC values by removing the factors with the highest p value in the model. The goal is to identify the most parsimonious model that explains the data without overfitting and to ensure that only the most relevant predictors are retained, thus improving model interpretability and reducing multicollinearity [26].

Ethics approval of research

This study received approval from the Burkina Faso Health Research Ethics Committee (CERS) (Approval No. 2023-06-132). Written and signed consent was obtained from each participant. For participants who spoke "Mooré", a local language, the consent form was translated and explained before administering the questionnaire. Interviews were conducted in local languages, when participants had difficulty expressing themselves in French. Participants were informed that they could withdraw from the study at any time without penalty by simply suspending the questionnaire.

Results

Socio-demographic characteristics of gardeners

Among the 110 participants, 52.7% were male and 47.3% female. Age distribution was balanced, with 34.5% aged 20–40 years, 30.9% aged 41–50 years, and 34.5% aged 51 or older. The mean age of the participants was 45.02 years ([20-71] years). Most (70.9%) had no formal education, and 59.1% managed gardens with 3–30 plots. The majority (67.3%) grew 1–2 types of vegetables, while 32.7% grew 3–4 types. Over half (51.8%) employed regular workers, while 48.2% worked independently. Most gardeners (54.5%) had 20 years or less of experience, while 45.5% had over 21 years of experience (Table 1).

Knowledge about multidrug-resistant bacteria dissemination in urban agriculture

The majority of respondents (67.3%) did not believe that humans could be contaminated by garden produce, while 32.7% acknowledged this potential risk. Similarly, 73.6% did not recognize animal waste as a source of contamination, while 26.4% were aware of this risk. A similar trend was observed regarding irrigation water, with 72.7% unaware of its contamination potential and 27.3% acknowledging the risk.

Only 40% of the gardeners (n=47) demonstrated good knowledge of multidrug-resistant bacteria dissemination in urban agriculture (Table 1).

Relation between gardeners' socio-demographic characteristics and knowledge levels on contamination risks

A higher proportion of female gardeners (57.4%) had good knowledge compared to males (42.6%), though the difference is not statistically significant (p = 0.098). Gardeners aged 41–50 years showed the highest proportion of good knowledge (42.6%), while those aged 20–40 years exhibited the highest poor knowledge (41.3%), with a p-value of 0.058 suggesting a potential trend. Education level does not significantly affect knowledge (p = 0.230), but unschooled gardeners are overrepresented in the poor knowledge category (76.2%). Garden size, vegetable types grown, number of workers, and work experience did not show significant associations with knowledge levels (Table 1).

Independent factors associated with gardeners' knowledge of contamination risks

To identify factors influencing gardeners' knowledge, a stepwise backward binary logistic regression was performed using socio-demographic variables and knowledge levels. Age was the only significant factor associated with knowledge.

Gardeners aged 41–50 years are 3.2 times more likely to have good knowledge compared to the 20-40 age group (aOR=3.20, 95%CI=1.20-8.96). Although gardeners aged 51 years and older have an odds ratio of 1.646 compared to those aged 20–40 years (aOR=1.65, 95% CI=0.61-4.61), the association was not statistically significant (Table S1).

Practices at risk of spreading multidrug-resistant bacteria in the environment

Among the 110 gardeners, 47.2% (n=52) exhibited risky practices, while 52.7% (n=58) adopted safe practices in relation to the spread of multidrug-resistant bacteria. Gardeners with larger gardens (≥31 plots) were more likely to engage in risky practices (53.8%) compared to those with smaller gardens (3–30 plots), where 70.7% practiced safely (p = 0.002). On the other hand, gardeners growing fewer types of vegetables (1–2 types) tended to engage in riskier practices (53.8%), while those growing more types (3–4) were more likely to adopt safer practices (46.2%) (p = 0.001).

Other variables, such as gender, age, education, experience, and beliefs about contamination (irrigation water, manure, and produce contamination) did not show statistically significant differences in risky or safe practices. Additionally, the presence of additional workers did not significantly influence practice scores (Table 2).

Independent factors associated with practices at risk of spreading multidrug-resistant bacteria in the environment

At multivariable analysis, only the number of vegetable types produced remained in the model. Those who produced 3-4 vegetable types had higher odds of engaging in risky practices compared to those who produced 1-2 vegetable types only, (aOR=4.29, 95%CI=1.81-10.49, p=0.001) (Table S1).

On the other hand, gardeners growing fewer types of vegetables (1–2 types) tended to engage in riskier practices (53.8%), while those growing more types (3–4) were more likely to adopt safer practices

Practices at risk of spreading multidrug-resistant bacteria to humans

The majority of gardeners (57.3%) consume water from external sources, while 42.7% bring their own water. Among those using external sources, 20% drink well water, 9.1% use borehole water, 45.5% prefer store-bought water, and 12% use water from fountains or public taps.

Regarding hygiene practices, 73.6% wash their hands with soap, while 26.4% do not. For dishwashing, 62.7% of gardeners use well water, while only 5.5% prefer borehole water.

As for food, 57.3% of gardeners do not bring food from home, and 42.7% bring their own meals. Only 14.5% prepare meals directly in the garden. Additionally, 51.8% consume raw vegetables, and 82.7% wash vegetables before selling them.

Regarding PPE use, only 23.6% of gardeners wear gloves, and 38.2% use protective masks during gardening activities. Protective boots are even less common, with only 19.1% of gardeners wearing them.

Among the gardeners surveyed, 59.1% (n=65) exhibited risky practices, while 49.9% (n=45) demonstrated secure practices regarding the dissemination of multidrug-resistant bacteria to humans (Table 3).

Distribution of risky and secure practices among gardeners

In bivariate analysis, no sociodemographic variable or risk perception (garden produce, manure, water) was significantly associated with either risky or safe practices. The use of different water sources and sanitation facilities also showed no significant association with the level of risk. However, a trend suggests that the use of compost may be linked to safer practices.

Regarding practices related to the risk of human contamination, participants who used compost were more likely to adopt safe practices (37.8%) compared to those who did not use compost (13.8%) (p = 0.007), indicating a potentially significant relationship (Table 3).

Independent factors associated with gardeners' practices at risk of spreading multidrug-resistant bacteria to humans

Gardeners who had one or more regular workers were significantly less likely to adopt risky practices (aOR = 0.394; 95% CI [0.158–0.933]; p = 0.038). Paradoxically, gardeners who perceived a risk of contamination of garden produce by irrigation water were significantly more likely to engage in risky practices (aOR = 4.674; 95% CI [1.483–16.671]; p = 0.012). The use of compost was strongly associated with an increased likelihood of adopting risky practices (aOR = 5.943; 95% CI [2.075–18.835]; p = 0.001) (Table S1).

Discussion

This study offers valuable insights into the socio-demographic characteristics, practices, and knowledge of market gardeners in Ouagadougou, Burkina Faso, as well as their potential role in the dissemination of multi-drug resistant (MDR) bacteria in both the environment and human populations. Through a One Health perspective, the findings underscore the urgent need for targeted interventions in urban agriculture to mitigate the risks associated with antimicrobial resistance (AMR).

The majority of gardeners were male, in line with previous studies in Burkina Faso and the USA, where male participation was 72% and 54.4%, respectively [27,28].

A significant gap was identified in gardeners' knowledge of contamination risks. Over 70% of participants did not believe that irrigation water, animal manure, or garden produce could serve as contamination sources for humans. This lack of awareness likely stems from limited education and the reliance on traditional practices passed down through experience, without formal training in safe agricultural and hygiene practices. Addressing this gap through targeted training programs is critical for reducing AMR risks.

At the univariate level, limited engagement in diverse gardening (1-2 types) appeared to lead to more risk-prone practices. However, in a multivariable analysis, those cultivating 3-4 types exhibited significantly higher odds of risky behavior, likely due to uncontrolled factors such as production scale and crop management complexity. This contrasts with findings from other regions, where crop diversification is generally associated with safer and more sustainable practices [29,30]. While compost use was linked to safer practices in univariate analysis, multivariable regression showed it was associated with a higher risk of unsafe behaviors. This paradox may reflect improper composting methods, where insufficient decomposition of raw manure increases microbial contamination. Our study underscores the local context, suggesting that while diversification in urban agriculture can be beneficial, it also introduces management challenges exacerbated by the complexities of urban farming. Additionally, gardeners concerned about the potential contamination of their produce from irrigation water were significantly more likely to engage in risky behavior (aOR = 4.67; 95% CI:1.48–16.67; $p = 0.012$). This discrepancy may reflect a gap between risk awareness and available mitigation strategies, illustrating an understanding of vulnerability but a lack of practical avoidance measures.

Several practices among gardeners posed significant risks for the spread of MDR bacteria, particularly those related to water usage, fertilizer application, and sanitation. The majority of participants relied on well water for irrigation, which, due to poor hygiene practices, is likely to contain MDR bacteria. The limited use of surface water and wastewater during the dry season mirrors findings from Jiang et al. (2021), where 38% of farmers used well water for irrigation [23]. However, unlike farmers in Kentucky, who predominantly used municipal water (70.3%), gardeners in Burkina Faso often resort to untreated sources, exacerbating contamination risks [22,27]. A study conducted on treated wastewater used for irrigation of fresh produce in Nsukka, in south-east Nigeria, has revealed the presence of MDR *Escherichia coli* [31]. In Burkina Faso, some healthcare facilities discharge untreated wastewater directly into the environment or municipal channels, which are then used for irrigation [32,33]. It is established that irrigation practices represent a significant source of contamination with antimicrobial-resistant bacteria in fresh produce and the wider environment [34–36].

Animal manure was widely used as an organic fertilizer, consistent with Sawadogo et al. (2023), who reported that nearly 90% of farmers in Burkina Faso applied manure [37]. This practice is concerning, as livestock antibiotics contribute to bacterial resistance, and resistant bacteria are excreted in animal feces, which can then contaminate produce and the environment [38,39]. Composting, although shown to reduce MDR bacteria in manure, was underutilized, with only 23.6% of gardeners incorporating compost into their practices. Educating gardeners on safe composting techniques could mitigate these risks.

Shared latrines near garden plots further exacerbate the risk of contamination with human waste. These facilities, often reservoirs of extended-spectrum β-lactamase (ESBL) producing bacteria, facilitate bidirectional contamination between humans and vegetables, as seen in Dar es Salaam, where communal latrines harbored MDR *E. coli* [40]. Such findings highlight the importance of improving sanitation infrastructure near gardening sites to reduce environmental contamination.

Consumption of contaminated raw vegetables poses a significant threat to human health, as antimicrobial resistance genes can transfer to commensal bacteria in the human gut. Studies in Tunisia, China, and the Netherlands have isolated MDR Enterobacterales from vegetable samples, reinforcing the global nature of this issue [36,41–43]. In Burkina Faso, ESBL-producing bacteria and MDR strains have been detected in lettuce, irrigation water, manure, and soil, further emphasizing the interconnected risks within urban agriculture systems [24,44].

Low use of personal protective equipment (PPE) among gardeners less than 40% use gloves or masks and only 19.1% wear boots exposes them to contaminants like soil, manure, and irrigation water. This lack of protection, driven by limited knowledge and finances, highlights the need for safety interventions.

Unregulated irrigation, untreated manure, and poor sanitation spread antimicrobial resistance (AMR) through agricultural runoff, fecal waste, and untreated hospital wastewater. These pathways contaminate water, produce, and ultimately humans, creating a cycle that spreads multidrug-resistant (MDR) bacteria. Cross-contamination during harvesting by workers colonized with MDR bacteria worsens the issue, complicating treatment, raising healthcare costs, and increasing mortality and morbidity.

Our research highlights the significant role of urban farming in the spread of antimicrobial resistance (AMR) within the One Health framework, emphasizing the interconnectedness of humans, animals, and the environment. Addressing these challenges requires a comprehensive One Health strategy. Key recommendations include developing integrated, multisectoral AMR surveillance systems that encompass human, veterinary, and environmental health; educating farmers and agricultural workers on responsible antimicrobial practices; enforcing stricter regulations on antibiotic use in agriculture and waste management; improving sanitation, waste disposal, and water treatment infrastructure; and fostering collaboration among health, agriculture, and environmental sectors to implement tailored, unified solutions. These measures will be instrumental in limiting the spread of AMR in urban agricultural contexts while safeguarding public health through a cohesive One Health approach.

Our study has limitations: 1) Our study was limited to three market garden sites in the city of Ouagadougou, hence the small number of participants, and our results may differ for other sites, 2) Some questions on knowledge and use of antibiotics would have enabled us to better discuss our results.

Conclusion

This study highlights the multifaceted risks associated with urban agriculture in Ouagadougou and its role in the dissemination of multidrug-resistant (MDR) bacteria. The survey provided valuable insights into the socio-demographic characteristics of gardeners, who were predominantly men with limited formal education but extensive agricultural experience. Despite their expertise, significant gaps in knowledge and risky practices were identified, which contribute to the spread of MDR bacteria.

Risky behaviors included the widespread use of untreated animal manure, chemical fertilizers, and irrigation water from wells, dams, and wastewater sources, as well as the proximity of shared latrines to gardening sites. Many gardeners were unaware that irrigation water and manure could contaminate plant products or that humans could be exposed to MDR bacteria through the consumption of contaminated produce. These findings underscore the necessity for awareness campaigns and training initiatives to address knowledge gaps and promote safer agricultural practices. A One Health approach that integrates environmental, human, and animal health is essential to reduce risks. Key interventions include training on food safety, composting, and personal protective equipment (PPE) use, as well as improving access to clean water and sanitation. Integrating these measures into local and national policies can significantly reduce antimicrobial resistance in urban agriculture, thereby protecting both public health and the environment.

What is already known about the topic

- Excessive antibiotic use, untreated manure, and wastewater irrigation fuel antimicrobial-resistant bacteria (ARB) spread in agriculture, particularly contaminating leafy greens and vegetables.
- Water scarcity in sub-Saharan Africa exacerbates the issue, as urban farmers rely on untreated wastewater, introducing pathogens into the food supply.

What this study adds

- This research offers the first detailed assessment of market gardeners' practices and AMR risks in Burkina Faso's urban agriculture.
- Findings emphasize bidirectional contamination between humans and the environment, underscoring the urgency of sanitation improvements, farmer education, and policy enforcement.

Competing Interest

The authors of this work declare no competing interest

Funding

The study is funded by a doctoral research grant (CEFORGRIS-13-01-2025) provided by the Africa Center of Excellence in Social Risk Management (CEA-CEFORGRIS) at the University Joseph KI-ZERBO, Burkina Faso.

Acknowledgements

The authors are grateful to the Africa Center of Excellence in Social Risk Management (CEA-CEFORGRIS) at the University Joseph KI-ZERBO, Burkina Faso, for providing a doctoral research grant that supported this study (CEFORGRIS-13-01-2025). We thank also all the gardeners at the Paspanga, Tanghin and Boulmiougou sites for their participation and their support to facilitate data collection.

Authors´ contributions

FBJD, IJOB, DS, DK as first, second, third and last authors was responsible for design conception, survey design, data collection, analysis and interpretation of data and write up of the article. NSS, EB, SS, MEMN, NS and NB supervised, reviewed the article at each stage of the write up process. Final approval of the version to be published by all authors.

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Tables & Figures

Table 1: Sociodemographic characteristics of gardeners and their knowledge of the contamination risks

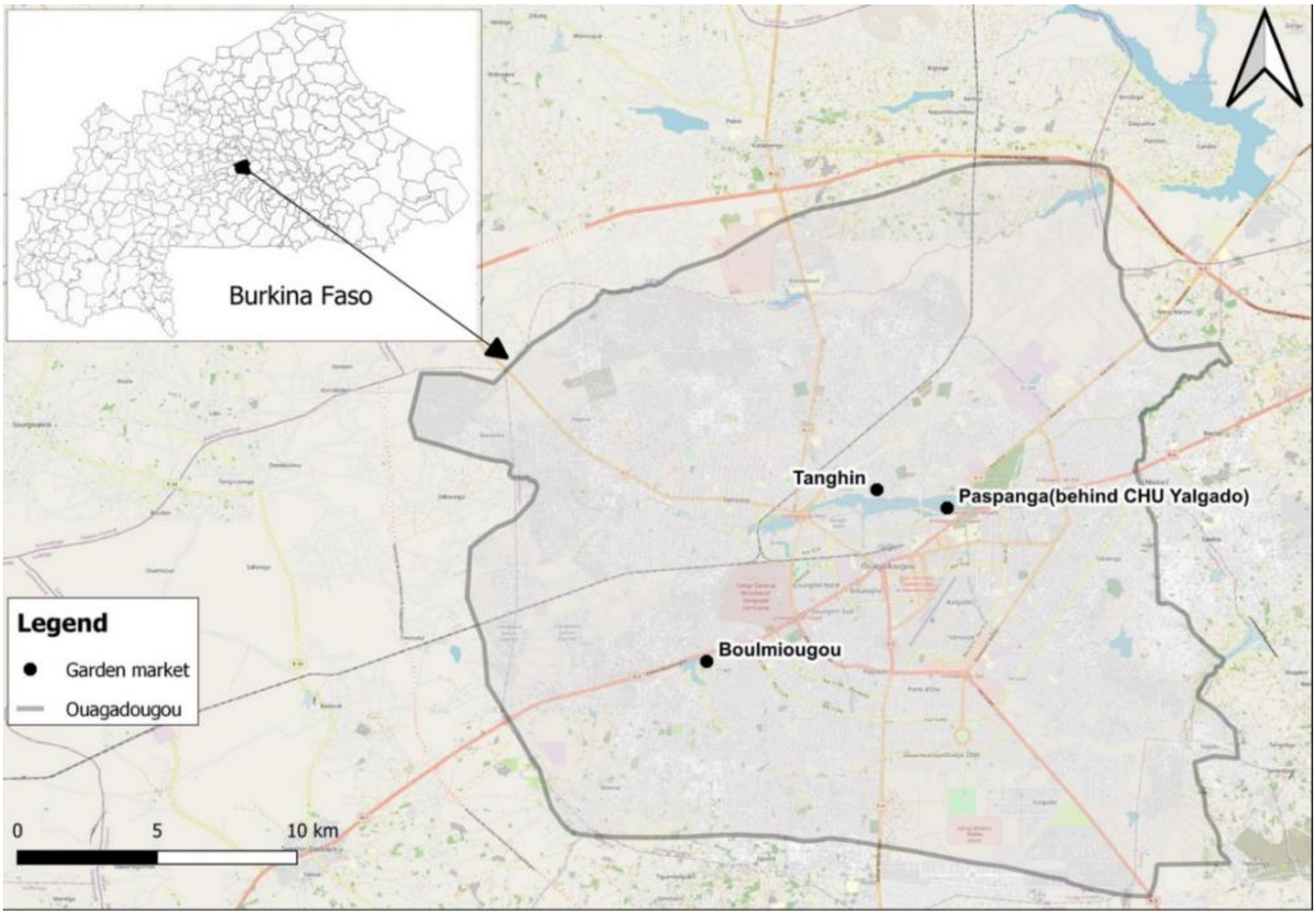
Category	**Variables**	**Number of gardeners 110 (100%)**	**Good Knowledge 47 (40%)**	**Poor Knowledge 63 (60%)**	**p-value from Chi Square**
Gender	Female	52 (47.3%)	27 (57.4%)	25 (39.7%)	0.098
	Male	58 (52.7%)	20 (42.6%)	38 (60.3%)	
Age	20 – 40	38 (34.5%)	12 (25.5%)	26 (41.3%)	0.058
	41 – 50	34 (30.9%)	20 (42.6%)	14 (22.2%)	
	51 and above	38 (34.5%)	15 (31.9%)	23 (36.5%)	
Education	Schooled	32 (29.1%)	17 (36.2%)	15 (23.8%)	0.230
	Unschooled	78 (70.9%)	30 (63.8%)	48 (76.2%)	
Garden Size (Number of plots)	3 – 30	65 (59.1%)	30 (63.8%)	35 (55.6%)	0.498
	31 and more	45 (40.9%)	17 (36.2%)	28 (44.4%)	
Number of vegetable types produced	1 – 2	74 (67.3%)	31 (66%)	43 (68.3%)	0.961
	3 – 4	36 (32.7%)	16 (34%)	20 (31.7%)	
Number of additional regular workers	None	53 (48.2%)	23 (48.9%)	30 (47.6%)	1
	One or more	57 (51.8%)	24 (51.1%)	33 (52.4%)	
Site working experience	20 or less	60 (54.5%)	24 (51.1%)	36 (57.1%)	0.660
	21 or more	50 (45.5%)	23 (48.9%)	27 (42.9%)	

Table 2: Sociodemographic characteristics, knowledge of gardeners about the contamination risks and gardeners' practices at risk of spreading multidrug-resistant bacteria in the environment				
Category	**Variables**	**Risky Practices 52 (47.2%)**	**Secure Practices 58 (52.7%)**	**p-value (Chi Square)**
Gender	Female	22 (42.3%)	30 (51.7%)	0.219
	Male	30 (57.7%)	28 (48.3%)	
Age	20 – 40	16 (30.8%)	22 (37.9%)	0.649
	41 – 50	19 (36.5%)	15 (25.9%)	
	51 and above	17 (32.7%)	21 (36.2%)	
Education	Schooled	18 (34.6%)	14 (24.1%)	0.134
	Unschooled	34 (65.4%)	44 (75.9%)	
Garden Size (Number of plots)	3 – 30	24 (46.2%)	41 (70.7%)	0.002
	31 and more	28 (53.8%)	17 (29.3%)	
Number of vegetable types produced	1 – 2	28 (53.8%)	46 (79.3%)	0.001
	3 – 4	24 (46.2%)	12 (20.7%)	
Number of additional regular workers	None	24 (46.2%)	29 (50.0%)	0.312
	One or more	28 (53.8%)	29 (50.0%)	
Site working experience	20 or less	26 (50.0%)	34 (58.6%)	0.516
	21 or more	26 (50.0%)	24 (41.4%)	
Belief: humans can be contaminated by garden produce	No	35 (67.3%)	39 (67.2%)	0.932
	Yes	17 (32.7%)	19 (32.8%)	
Belief: animal manure can contaminate garden produce	No	39 (75.0%)	42 (72.4%)	0.946
	Yes	13 (25.0%)	16 (27.6%)	
Belief: garden produce can be contaminated by irrigate water	No	40 (76.9%)	40 (69.0%)	0.263
	Yes	12 (23.1%)	18 (31.0%)	

Table 3: Sociodemographic characteristics and knowledge of gardeners about the contamination risks, gardeners' practices at risk of spreading multidrug-resistant bacteria in the environment and in humans				
Category	**Variables**	**Risky Practices 65 (59.1%)**	**Secure Practices 45 (40.9%)**	**p-value (Chi square / Fisher's Exact)**
Gender	Female	32 (49.2%)	20 (44.4%)	0.764
	Male	33 (50.8%)	25 (55.6%)	
Age	20 – 40	24 (36.9%)	14 (31.1%)	0.808
	41 – 50	19 (29.2%)	15 (33.3%)	
	51 and more	22 (33.9%)	16 (35.6%)	
Education	Schooled	20 (30.7%)	12 (26.7%)	0.801
	Unschooled	45 (69.3%)	33 (73.3%)	
Garden size (Number of plots)	3 – 30	40 (61.5%)	25 (55.6%)	0.667
	31 and more	25 (38.5%)	20 (44.4%)	
Number of vegetable types produced	1 – 2	48 (73.8%)	26 (57.8%)	0.119
	3 – 4	17 (26.2%)	19 (42.2%)	
Number of additional regular workers	None	27 (41.5%)	26 (57.8%)	0.138
	One or more	38 (58.5%)	19 (42.2%)	
Site working experience	20 or less	37 (56.9%)	23 (51.1%)	0.684
	21 or more	28 (43.1%)	22 (48.9%)	
Belief: humans can be contaminated by garden produce	No	45 (69.2%)	29 (64.4%)	0.749
	Yes	20 (30.8%)	16 (35.6%)	
Belief: animal manure can contaminate garden produce	No	49 (75.4%)	32 (71.1%)	0.779
	Yes	16 (24.6%)	13 (28.9%)	
Belief: garden produce can be contaminated by irrigate water	No	51 (78.5%)	29 (64.4%)	0.160
	Yes	14 (21.5%)	16 (35.6%)	
Drilling water for irrigation	No	65 (100%)	45 (100%)	NA
	Yes	0 (0%)	0 (0%)	
Use well water for irrigation	No	1 (1.5%)	0 (0%)	1
	Yes	64 (98.5%)	45 (100%)	
Use dams water	No	47 (72.3%)	40 (88.9%)	0.062
	Yes	18 (27.7%)	5 (11.1%)	
Use waste water	No	62 (95.4%)	44 (97.8%)	0.643
	Yes	3 (5.5%)	1 (2.2%)	

Table 3: Sociodemographic characteristics and knowledge of gardeners about the contamination risks, gardeners' practices at risk of spreading multidrug-resistant bacteria in the environment and in humans				
Category	**Variables**	**Risky Practices 65 (59.1%)**	**Secure Practices 45 (40.9%)**	**p-value (Chi square / Fisher's Exact)**
Use organic fertilizer	No	0 (0%)	0 (0%)	NA
	Yes	65 (100%)	45 (100%)	
Use chemical fertilizer	No	4 (6.2%)	0 (0%)	0.143
	Yes	61 (93.8%)	45 (100%)	
Produce own fertilizer	No	61 (93.8%)	41 (91.1%)	0.865
	Yes	4 (6.2%)	4 (8.9%)	
Use compost	No	56 (86.2%)	28 (62.2%)	0.007
	Yes	9 (13.8%)	17 (37.8%)	
Sanitary facilities used	Clean Latrine	5 (7.7%)	2 (4.4%)	0.310
	Open/Fields	11 (16.9%)	13 (28.9%)	
	Shared latrines	49 (75.3%)	30 (66.7%)	

Table S1: Factors associated with gardeners' knowledge on contamination risks, practices at risk of spreading multidrug-resistant bacteria in the environment, plants and humans			
Variable	**Adjusted Odds Ratio**	**95% CI**	**p-value**
LEVEL 1: Gardeners knowledgeable about contamination risks			
Gender – Female	Reference		
Gender – Male	0.475	[0.210 – 1.050]	0.069
Age – 20–40	Reference		
Age – 41–50	3.202	[1.202 – 8.957]	0.022
Age – 51 and more	1.646	[0.605 – 4.618]	0.333
Education – Schooled	Reference		
Education – Unschooled	0.491	[0.194 – 1.211]	0.126
LEVEL 2: Practices that risk plant and environmental contamination			
Vegetable types – 1–2	Reference		
Vegetable types – 3–4	4.286	[1.807 – 10.487]	0.001
LEVEL 3: Risk of human contamination			
Gender – Female	Reference		
Gender – Male	0.364	[0.148 – 0.852]	0.023
Regular workers – None	Reference		
Regular workers – One or more	0.353	[0.143 – 0.830]	0.020
Water contamination belief – No	Reference		
Water contamination belief – Yes	3.483	[1.310 – 10.120]	0.016
Use of compost – No	Reference		
Use of compost – Yes	5.537	[1.912 – 18.457]	0.003



Source : institut Géographique du Bukina, 2020

Figure 1: Map showing the survey sites