Tanzania Journal of Science 50(1): 48-61, 2024
ISSN 0856-1761, e-ISSN 2507-7961

Microbiological Quality of Irrigation Water and Leafy Vegetables in Dar es Salaam, Tanzania

Bubelwa L. Kamara[1,], Godwill D. Mrema[1] and Thomas J. Lyimo[2*]
[1]*Department of Chemical and Process Engineering, University of Dar es Salaam, Tanzania*
[2]*Department of Molecular Biology and Biotechnology, College of Natural and Applied Sciences, University of Dar es Salaam, P.O. Box* 35179, *Dar es Salaam, Tanzania*
Email addresses: b4kamaz@gmail.com; gdmrema@yahoo.com
**Corresponding author: E-mail*: tjlyimo@udsm.ac.tz. Telephone: +255 754 375 924
Received 14 Dec 2023, Revised 22 Feb 2024, Accepted 25 Mar 2024, Published 30 Apr 2024
https://dx.doi.org/10.4314/tjs.v50i1.4

Abstract

The quality of water used for the irrigation of leafy vegetables in urban settings is in doubt due to contamination associated with poor hygiene and water pollution. This study examined the microbiological quality of irrigation water and leafy vegetables at Chang'ombe in Dar es Salaam, Tanzania as well as the perceptions and level of awareness of nearby consumers. Water and leafy vegetable samples were analysed for faecal coliform (FC) using standard techniques. Perception and awareness of consumers were collected using a questionnaire survey. The results showed an average FC count of 406.1 ± 16.40 MPN/100 ml for the irrigation water. The sweet potato leaves and amaranth had FC counts of 11.40 ± 5.220 CFU/g and 17.60 ± 11.98 CFU/g respectively. The levels of FC in irrigation water and leafy vegetables were within the allowed limits by WHO and NAS-USA standards respectively but fall short of some stricter European standards for irrigation water. The household survey showed that consumers perceive irrigation water at Chang'ombe as polluted and may be one of the main sources of food contamination. They minimize associated health risks in various ways such as using clean storage, washing and cooking. It was concluded that the microbial quality of water used for irrigation of leafy vegetables at Chang'ombe poses no risk to public health, but based on tighter standards, improved public awareness of hygienic practices is crucial to address potential risks.

Keywords: Water pollution; wastewater irrigation; faecal coliform; Msimbazi River; public health risk

Introduction

The rise of population due to urbanization in developing countries has led to a high demand for food and water for both drinking and agricultural activities. This rise combined with negative impacts of climate change has resulted in a scarcity of freshwater resources and degradation of water quality due to increased socio-economic activities and pollution (Machiwa 2010, Liu et al. 2024). As alternative water resource, streams of freshwater in urban areas, be it from wastewater discharges or rain waters have widely been used for agriculture, especially for vegetable farming (Game and Primus 2015, Kayombo and Mayo 2018). The reuse of wastewater merits consideration in light of scientific advancement and the escalating water crisis because it has the potential to reduce water pollution and water scarcity problems (Jaramillo and Restrepo 2017). Worldwide, treated wastewater that has reached recommended standards is ideal for agricultural irrigation (WHO 2006). Direct wastewater reuse involves irrigation water sourced from a treatment plant, while indirect reuse involves collecting untreated wastewater downstream for irrigation purposes whose quality varies based on effluent quality, natural purification processes and pollution levels (Jeong et al. 2016).

Ramya and Patel (2019) suggest that most people in contemporary society have developed an affinity for leafy vegetables especially due to nutritional purposes. Generally, leafy vegetables refer to those that possess addible leaves that can be eaten raw, fully, or partially cooked (Welbaum 2019). Leafy vegetables are important sources of essential trace elements, vitamins and other growth factors for communities and are normally obtained at relatively low prices in developing countries (Bishoge and Suntu 2018). Urban horticulture is the main source of leafy vegetables in urban settings and generally offers a means of income for producers and distributors as well as the dietary life of many households' livelihoods (Game and Primus 2015, Bishoge and Suntu 2018). However, in developing countries, the quality of most vegetables obtained from urban horticulture is in doubt due to the quality of water used for farming and the poor hygiene and infrastructures at the selling point (Thomas et al. 2013). For instance, in unplanned urban areas like Dar es Salaam most people neglect to empty pits regularly and adequately (Jenkins et al. 2015). Hence, during the rainy season they flush out (de-sludge) their toilets into surface water sources which pollute the surrounding water sources (Yao et al. 2023). Some of these sources are used for farming.

The use of various freshwater sources such as rivers streams and short wells for farming in Dar es Salaam is very common, especially with leafy vegetables (Chanzi 2018). Among leafy vegetable farming areas in Dar es Salaam is along the Msimbazi River including Chang'ombe Police area at Temeke Municipal Council. The farmers in Chang'ombe use water from a stream which is a tributary of the Msimbazi River whose pollution status has been documented by various researchers to be physically, chemically, and microbiologically polluted (Chanzi 2018, Kayombo and Mayo 2018). The situation puts the farmers and vegetable users at a high health risk.

Awareness and perceptions play a huge role in maximizing or minimizing risks due to poor water quality. According to a study conducted by Anderson et al. (2007), the level of education was a determinant factor in whether or not people perceive water pollution as a problem. The poor who depend on unclean water supplies view water pollution as a community problem contrary to those whose access to clean water is guaranteed. Studies by Leonard et al. (2012) and Lyimo et al. (2008) on awareness levels of the community members in Dar es Salaam showed that there is a link between water pollution, health problems and development. A study by Mayilla et al. (2016) highlights a notable lack of awareness among vegetables farmers, traders and consumers regarding health risk reduction measures associated with the use of low-quality irrigation water (wastewater), particularly in the context of areas of unplanned settlements. While there is some level of acceptance and willingness to use wastewater when treated for various purposes including irrigation, there exists a significant gap in understanding the technologies involved and the potential health risks associated with such practices in Tanzania (Msaki et al. 2022). Both studies indicate a complex relationship between risks related with wastewater reuse practices and knowledge, awareness, and perceptions. Likewise, Leonard et al. (2012) concluded that the health risks of using polluted water in Msimbazi River water were high due to the low level of awareness of the respondents. To corroborate the above findings, this study assessed the microbiological quality of irrigation water and leafy vegetables at Chang'ombe in Dar es Salaam, Tanzania as well as the perceptions and level of awareness of nearby consumers.

Materials and Methods

Study area and sampling

This study was conducted at Chang'ombe division in Temeke Municipality, Dar es Salaam Tanzania. The water samples for microbial analysis were collected from two study stations; Station 1 (sampling point 1 and 2) and Station 2 (sampling point 3-5) in tributaries of the Msimbazi River at Chang'ombe Street in an area famously known as Serengeti where Nelson Mandela Road intersects with Chang'ombe road (Figure 1). Locations of the sampling points (GPS coordinates) are given in Table 1. The streams pass through vegetable farms and the sampling points are established where farmers obtain their irrigation water. Duplicate surface water samples were collected using pre-labeled 250 ml sterile bottles between 08.00–10.00 am (when most farmers irrigate their vegetables) at a weekly interval for five weeks from 26th August to 23rd September 2019. The samples kept in cool box (with ice pellets) at low temperature during transportation. The inoculation of samples took place the same day and the remaining samples were stored in refrigerator in the laboratory.

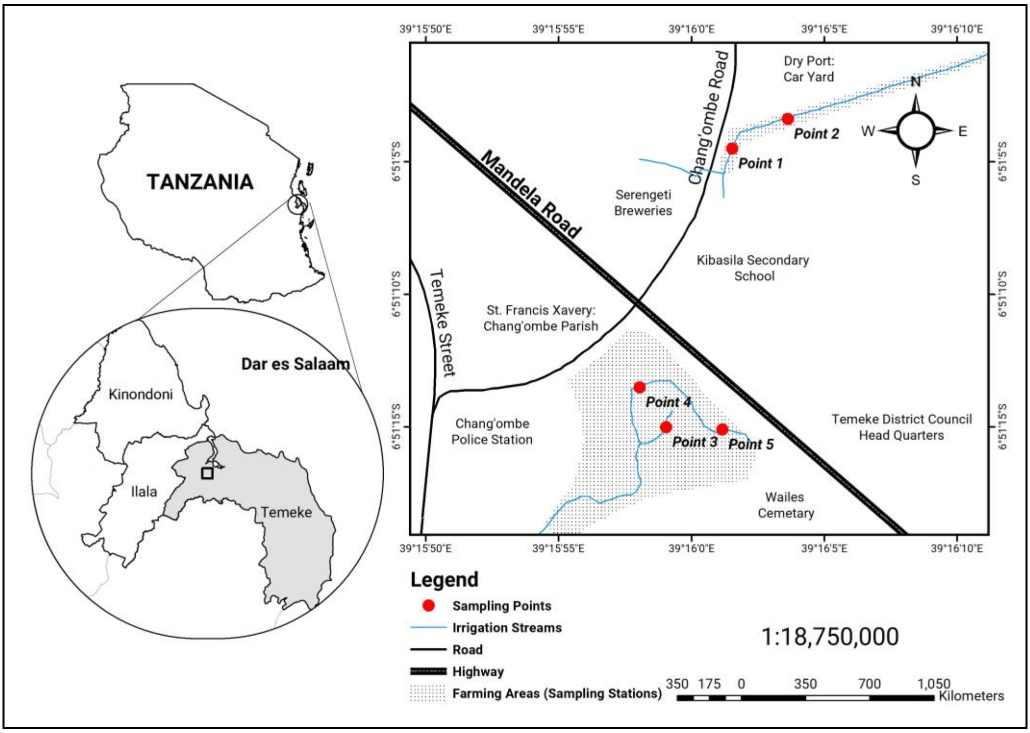


Figure 1: A map showing location of the sampling points in Dar es Salaam, Tanzania.

Table 1: Locations (GPS coordinates) of the sampling points.

Name	Longitude	Latitude	Altitude
Point 1	39.2670938757	-6.8512551566	23.3356584346
Point 2	39.2676757882	-6.8509441328	23.5805679866
Point 3	39.2664019912	-6.8541691534	22.3702370209
Point 4	39.2661258939	-6.8537519281	22.6721386264
Point 5	39.2669911620	-6.8541933232	22.4634677779

Microbial analysis of the water samples

The collected water samples were immediately (within 6 hrs) analysed for faecal indicator bacteria using the Most Probable Number (MPN) method. The choice of the MPN method was based on the fact that the sampled water was considerably turbid. Two-step tests (presumptive test and confirmatory test) were performed as described in APHA 2017. In the presumptive test, a single-strength concentration of MacConkey broth medium was prepared as described by the manufacturer (HiMedia Laboratories Ltd, Mumbai, India). The medium was dispensed in test tubes at aliquots of 9 ml each and sterilized at 121 °C by autoclave. The sterilized tubes were inoculated with 1 ml of water samples and serially diluted up to 10^{-6} folds using 3 tube series as described by de Man (1983). Thereafter they were incubated (Memmert incubator model BE 400) for 24 hours at 44.5 ºC to allow faecal coliform (FC) bacteria growth. For the confirmatory tests, a few positive tubes were tested using Eosin methyl blue agar using the streaking technique and incubated in the same conditions. The FC colonies were identified by a distinctive greenish metallic sheen that signified the presence of thermotolerant *Escherichia coli* in the sample. The MPN chart as suggested by de Man (1983) was used to calculate the number of bacteria in the original samples.

Microbial analysis of vegetable samples

Prior to commencement of the collection of vegetable samples, a reconnaissance visit was conducted at the market to determine sellers who get their supply from Chang'ombe farms. Samples of two species of vegetables namely *Ipomoea batatas* (Sweet Potato leaves; locally known as *Matembele*) and *Amaranthus cruentus* (Amaranth; locally known as *Mchicha*) freshly harvested and ready to be sold were randomly collected from Keko Magurumbasi and Keko Toroli markets. The vegetable samples were concurrently collected with water samples. The samples were stored in a sterile zipper plastic bag, transported to the laboratory and immediately tested for FC using the Membrane Filtration (MF) technique. In the laboratory, 100 g of fresh vegetables were soaked in 100 ml of sterile water and thoroughly mixed. Thereafter, 1 ml of the water was diluted into 100 ml of sterile water (dilution factor 10^{-2}) followed by filtration using a disinfected stainless filtration assembly (Sartorius AG, Göttingen, Germany) containing a sterile membrane filter (pore size 0.45 µm). The filters were then transferred to confirmatory m-FC Agar Base medium in a Petri dish and incubated at 44.5 ºC for 24 hours. Visually identifiable *E. coli* colonies with light blue colour were counted and computed to find the number of Colony Forming Units (CFU) per gram of the original sample (APHA, 2017).

Assessment of community perceptions and awareness

Assessment of community awareness of water quality was conducted in households adjacent to the Keko Magurumbasi market. This was selected because most of farmers from the sampling points supply their leafy vegetables to Keko Magurumbasi A market. Data on perception and awareness issues relevant to the quality of water used for irrigation of leafy vegetation was obtained using a questionnaire from the sampled population. Structured mixed-method questionnaires (with open-ended and closed-ended questions) were distributed to the sampled population of 50 respondents and administered using the digital platform Kobo toolbox (Kobo collect mobile application). A purposive sampling method was deployed to obtain households with the highest probability of purchasing vegetables from the Keko Magurumbasi market. A reconnaissance survey was performed and identified 60 households that were located in the most immediate block (locally known as *shina*) where the Keko Magurumbasi A marketplace is located. The formula below was applied to narrow down the representative sample size to 52 which rounded off to 50 households that were eventually surveyed. The survey started close and moved further from the marketplace's location until the sample size was complete. Sample size was calculated using Slovin or Yamane formula bellow (Adam 2020)

$$\text{Sample Size} = \frac{N}{1 + Ne^2}$$

Where: N is the population size (for this case 60 households), and *e* is the margin of error (for this case was 0.05).

Data analysis

Microsoft Excel was used in recording and arranging data and making graphs for the obtained data obtained from the laboratory experiments and questionnaires. GraphPad Prism 8 was used in performing statistical analysis. A parametric *t*-test and one-way ANOVA with its Post-Hoc were performed for data that passed normality test. Data from different collection points was analysed using a non-parametric Kruskal-Wallis (KW) test followed by the Dunn's Multiple Comparison Test. To test the difference counts obtained between the two sampling stations Mann-Whitney U test was applied. Additional data from observations were analysed qualitatively using thematic analysis of notes taken. Significance difference was determined at the 95% confidence level in all cases.

Results

Microbial quality of the irrigation waters

All tested irrigation water samples were positive for faecal coliform (FC) bacteria and the average counts at different sampling stations are shown in Figure 2. The positive tubes were confirmed following the confirmatory tests procedure where greenish metallic sheen colonies signified thermotolerant *E. coli*. In some tests, pink colonies without metallic sheen and colorless colonies were revealed, indicating presence of strains of *Enterobacter* sp., *Proteus* sp., or *Salmonella* sp. as described by the medium manufacturer (HiMedia Laboratories Ltd, Mumbai, India). The numbers of FC ranged from an average minimum value of 265.4 ± 107.9 to a maximum of 743.3 ± 143.3 MPN/100 ml. On combining data from all stations, the FC counts averaged 430.5 ± 116.1 MPN/100 ml. Statistical analyses showed that there were no significant differences between sampling station 1 and 2 (Mann-Whitney U = 12; P> 0.9999).

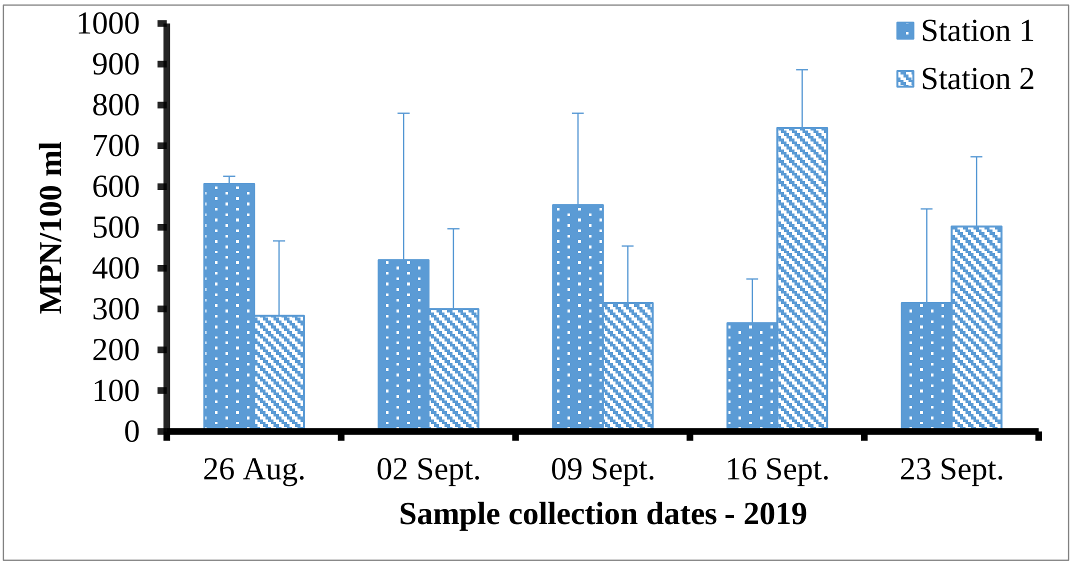


Figure 2: Average number of faecal coliforms counts at different sampling stations (Error bars= Standard Error of mean).

Microbial quality of the fresh leafy vegetables

The assessment of the microbial quality of fresh leafy vegetables and the average number of *E. coli* colonies was done instead of a general FC count since a confirmatory m-FC Agar base medium was used. In this case, *E. coli* were identified as they were light blue colonies (Appendix 1). On average, the numbers of *E. coli* ranged from a minimum of 4.00 ± 4.73 CFU/g to a maximum of 31.00 ± 13.87 CFU/g of fresh vegetables. The variations with sampling dates and different vegetable species are shown in Figure 3. Statistical analysis shows that there was no significant difference between the *E. coli* count for Sweet Potato leaves and amaranth (Mann-Whitney U = 7.50; P = 0.33 two tailed).

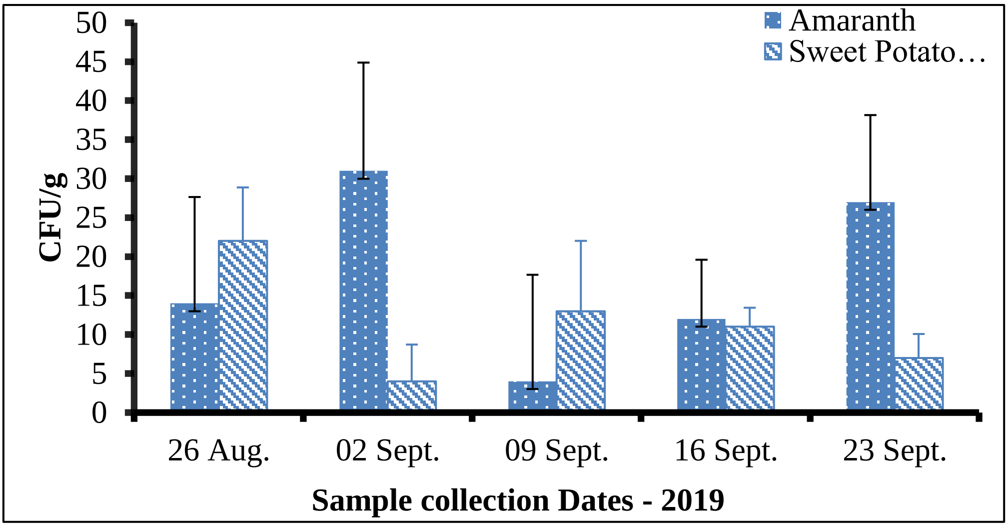


Figure 3: Average number of *E. coli* per gram of amaranth and sweet potato leaves Error bars= Standard Error of mean).

Perceptions and awareness of irrigation water quality

On the demographic characteristics of respondents, among the 50 interviewed households, 66% were female and 34% were male household heads (Appendix 2). Most of the respondents, 36% and 32% were in the age groups 24–34 and 35–50 years, respectively. The results also show that 52% of the respondents had attained at least primary education, whereas 30% had had secondary education and few (16%) had tertiary education i.e., University or college (certificate or diploma after form 4 or 6 education). Furthermore, most of the respondents (66%) were businessmen/women followed by 20% who were involved in the informal sector/works and the remaining 14% were employees in the private sector. None of the respondents was employed by the government (Appendix 2). The results indicate that the respondent demographics is dominated by young adults (youth) and middle-aged female with educational achievements varying with the majority having primary education. The majority of respondents are entrepreneurs or self-employed in the informal economy and none work for the government.

Respondents' characteristics on consumption of leafy vegetables

The results on habits of use of leafy vegetables are summarized in Table 2. It was found that all respondents use leafy vegetables and the majority (42%) consume them regularly, 32% daily and 26% use them rarely as an option to their diet. Almost all (96%) of respondents consume cooked or semi-cooked vegetables. The remaining 4% switch between cooked and uncooked leafy vegetables that can be consumed raw. The most noteworthy reason that motivated the consumption of leafy vegetables was healthy benefits (80%) followed by availability (10%) and affordability (6%). Furthermore, the findings show that most (80%) of the leafy vegetables' preparations are done at home where they wash the vegetables before cooking (90%). The remaining 20% of the respondents purchase their vegetables already prepared (cut/sliced and washed) on the market ready for cooking.

On the other hand, the majority of the households (72%) are well aware of where the vegetables they consume come from with 40% consuming vegetables from the study site, Chang'ombe (Table 2).

Awareness and perceptions on irrigation water and leafy vegetable quality

Table 3 presents results on awareness and perceptions of respondents on vegetable quality. The majority (76%) of the respondents perceive Irrigation water to be the main source of contamination of leafy vegetables. The remaining respondents believe that contamination of leafy vegetables occurs due to handling at the marketplace (12%) which includes the usage of unsafe water, splash from the ground, storage of vegetables and transporting containers (Table 3).

When asked about the quality of irrigation water in Chang'ombe streams, 64% of the respondents perceive the Chang'ombe water source for irrigation of leafy vegetables as polluted water (with bad quality). Most respondents judged water quality based on its appearance (56%) while others judged based on the location of the water source (24%) and the activities on the site (16%). If the water appears clear, it was considered of good quality and when colored in appearance it was considered of poor quality.

Table 2: Habits of use of vegetables by the respondents.

Variables	**Female (n=33)**	**Male (n=17)**	**Total (n=50)**	
	%	**%**	**n**	**%**
Consumption of leafy vegetables				
Never	0	0	0	0
Rarely	24	29	13	26
Regularly	39	47	21	42
Daily	36	24	16	32
If consume vegetables raw				
Yes	3	6	2	4
No	97	94	48	96
Reasons for leafy vegetable consumption				
Healthy benefits	82	76	40	80
Easily available	9	12	5	10
Affordable	6	6	3	6
Other reasons (e.g., taste)	3	6	2	4
If wash leafy vegetables before cooking				

Every time	94	82	45	90
Never	0	12	2	4
Sometimes	6	6	3	6
Source of leafy vegetables				
Gongolamboto	6.1	0	2	4
Keko Magereza	6.1	17.6	5	10
Chang'ombe	42.4	35.3	20	40
Kiluvya	3.0	11.8	3	6
Msimbazi River Valley	15.2	5.9	6	12
Don’t know	27.2	29.4	14	28

When asked about possible sources of water pollution at Chang’ombe, the majority (80%) of the respondents suggested that the industrial effluents from Serengeti Breweries contribute to the deterioration of water quality. Poor waste disposal and domestic effluents were also pointed out as sources of contamination by 16% and 4% of the respondents, respectively.

Table 3: Awareness and perceptions of respondents on the quality of vegetables.

Variables	**Female (n=33)**	**Male (n=17)**	**Total (n=50)**	
	%	**%**	**n**	**%**
Sources of leafy vegetable contamination				
Irrigation water	76	76	38	76
Transporting containers	6	0	2	4
Handling at the Market	12	12	6	12
Other sources	3	0	1	2
Cleaning water	3	12	3	6
Perceived irrigation water quality at Chang’ombe				
Bad	64	65	32	64
Average	9	12	5	10
Good	3	6	2	4
I don’t know/Not sure	24	18	11	22
Sources of pollution of irrigation water				
Industrial Effluents	78	86	20	80
Domestic Effluents	6	0	1	4
Poor Waste Disposal	17	14	4	16
The basis for judging water quality				
Location of water source	30	12	12	24
Its appearance	52	65	28	56
Activities on site	12	24	8	16

Other	6	0	2	4

Awareness of contamination prevention techniques and health risks

Most respondents (62%) were aware of various methods used for prevention of contamination of leafy vegetables. They mentioned prevention methods, such as storing vegetables in a clean environment, washing with clean water as well as keeping the environment (on the source and market) clean and proper cooking.

When asked about health risks, the majority of the respondents (82%) said that every once in a while, one of the households has its members diagnosed and/or exhibiting symptoms of stomach sickness or infection of a bacterial nature. Most of the respondents (42%) were not sure if stomach infections are due to contaminated leafy vegetables or other foods. However, they strongly perceive food contamination as the leading cause of frequent illnesses. Furthermore, 28% associated various stomach problems with drinking and cooking water.

Discussion

Microbial quality of the vegetable irrigation water

The microbial quality of the studied irrigation water was contaminated due to the presence of faecal coliform (FC) in all collected samples. The WHO standards prescribed FC count per 100 ml to be ≤ 1000 for unrestricted irrigation of food crops (Jeong et al. 2016, Havelaar et al. 2001) therefore the obtained numbers were below the allowed limit and hence not alarming. However, when compared to other standards especially those used by many developed countries, the microbial quality of the assessed irrigation water for leafy vegetables was unacceptable. For instance, in France the acceptable level is ≤ 250 CFU per 100 ml for *E. coli* for unrestricted irrigation of food crops while in Spain and Italy the allowed level is ≤ 100 CFU/100 ml (Jeong et al. 2016). Based on this fact it may be concluded that the studied irrigation water is considered permissible under WHO guidelines since they do not exceed the specified limit. But compared to other standards, especially those used by the European countries, the quality is unacceptable for irrigation of food crops such as leafy vegetables. Hence, the use of vegetables from these farms must be taken consciously with proper treatment before consumption. It was also noted that contrary to the European countries, most African countries including Tanzania have not put in place microbial quality standards for irrigation water.

The obtained low values of FC may also be because sampling was done during the dry season. Several reports show that the concentration of FC and other forms of pollutants in streams or rivers are usually attributed to surface runoff and are very low in the dry seasons. For example, Tornevi et al. (2014) reported that the concentration of *E. coli* was elevated three-ford from the initial concentration 2 to 3 days after rainfall events. In the studied area, the sources of the irrigation water were mainly from the Serengeti Breweries industry situated close to the sample collection site (point source), while others may be from nearby residential areas. The water may also be contaminated by other sources of solid and liquid pollutants probably washed (by water or wind) into the stream or directly introduced (disposed) from a variety of activities (Viman et al. 2010).

Microbial quality of the leafy vegetables

Leafy vegetables produced at Chang'ombe were found to be safe as the number of faecal indicator bacteria in both vegetable species was at acceptable and satisfactory levels based on the criterion for acceptable levels of *E. coli* in fresh food (vegetables inclusive) at point-of-sale according to the National Academy of Science of USA (2003). The National Academy of Science of USA has set a level greater than 100 CFU/g as unsatisfactory and the maximum CFU/g observed in this study falls under the acceptable category, which is between 20 and 100 CFU/g (National Academy of Sciences of USA 2003). In Tanzania, the TBS has only set the standard (TZS 730/ISO 16649-1) for ready-to-eat raw vegetables that there should be no FC detected in ready-to-eat foods. The results were comparable to the study by Kimaro (2017) who reported different types of vegetables samples collected from markets and farms in Morogoro to be microbiologically contaminated with multiple strains including *E. coli* bacteria. The study by Kayombo and Mayo (2018) reported higher FC in the markets than samples obtained from gardens and associated this with poor handling in the market including contaminated hands and sprinkling of vegetables with polluted water. The results came up with similar conclusions to Kimaro (2017) that water used for irrigating vegetables as well as handling in the market may have resulted in contaminated leafy vegetables. Likewise, Hajjami et al. (2013) support these findings that the irrigation water was a major route of direct microbial contamination of fruits and vegetables in Casablanca City (Morocco). This places the consumers at high risk of catching a variety of intestinal infections like diarrhea as already suggested by many other reports (e.g. Kayombo and Mayo 2018, Gurtler, and Gibson 2022).

Perceptions and awareness on irrigation water and leaf vegetable quality

Results showed that all households from the studied area use vegetables as part of their diet signifying the high use of vegetables in Dar es Salaam city. The most important reason that motivates the consumption of leafy vegetables is nutritional benefits (80% of the respondents). This is a fact that has already been shown by previous studies such as Ramya and Patel (2019) where leafy vegetables in general were found to have nutraceutical properties that help in reducing the risk of getting diseases of chronic nature such as diabetes, cancer, gastric ulcers, heart disorders and anemia as well as improving vision.

The findings show that the majority of the community had complete knowledge of where the vegetables were coming from and believed that the vegetables might be microbially contaminated. Thus, most of them washed vegetables from the market before cooking. However, some leafy vegetables such as cabbage and Amaranth were consumed raw or shallowly cooked. Thorough washing or other locally available sanitizing methods to disinfect surfaces that come into contact with food such as hands and serving utensils are suggested as one of the methods of reducing bacteria in raw vegetables for eating (Bolton et al. 2020, Røssvoll et al. 2013). However, these methods are not a 100% effective way of removing bacteria in vegetables but help in reducing the bacterial load depending on the type of water and cleaning techniques (Khalil et al. 2016). Cooking vegetables at temperatures higher than 70°C kills infectious bacteria and ensures safety from bacterial infections (FAO and PAHO 2017).

Furthermore, in this study majority of the respondents knew the sources and poor quality of the irrigation water source where their vegetable comes from. Despite perceiving the water as polluted and a contributor to leafy vegetable contamination the respondents still consume vegetables from Chang'ombe. This was contributed by the low socioeconomic status of most society members whereby more than 15.5% of Tanzanians living in urban areas were reported to live below the poverty line in 2019 (World Bank 2022). Low socioeconomic status (poverty) can be attributed to this risky tendency that leads to people being exposed to bacterial infections (Cesar 2018, Liu 2020, Newman et al. 2015). Furthermore, Yuan et al. (2015) suggest that factors such as age, level of education, relative proximity to medical facilities and level of income may be considered motivators for ignorance and disregard of different health concerns and risks since these factors may also contribute to lack of knowledge and awareness in such matters.

Awareness of contamination prevention techniques and health risks

The majority of respondents at Chang'ombe were aware of various methods for prevention of contamination of leafy vegetables such as storing vegetables in a clean environment, washing them with clean water as well as keeping the environment on the source and market clean and proper cooking. A similar study conducted among food vendors in Ilala (Tanzania) indicated a wide gap between their awareness towards food safety and actual practice (Mlay 2018). Hence, while awareness among respondents is high, implementation might be lacking leading to associated risks. Another study revealed a gap in the knowledge, attitude, and practices related to food safety among street food vendors in low and/or middle-income countries attributed to factors such as limited formal education, inadequate training in food safety, low income, and poor understanding of food handling (Desye et al. 2023) which may also be the case in the current study. In Tanzania, there are still no detailed guidelines on the quality of water for the irrigation of vegetables. However, there are guidelines for food safety at point-of-sale that most informal traditional food markets don't implement effectively compared to large establishments such as supermarkets (Faße et al. 2015). Most of the farmers and consumers belong to low economic and academic classes and display ignorance of these safety standards a situation which puts them at high health risks (Cesar 2018, Liu 2020, Newman, et al. 2015).

Conclusions and recommendations

This study revealed that the microbial quality of water used for irrigation of leafy vegetables at Chang'ombe poses no risk based on WHO standards. However, stricter European standards show potential risks. Notably, vegetables from Chang'ombe sold at marketplace appear safe based on the acceptable *E. coli* levels in fresh produce at point of sale. Hence, these findings highlight the need for more strict safety standards as well as proper consumer awareness on handling vegetables to minimize associated health risks. It is recommended that both public and private institutions should engage in different projects that will help in improving the safety of society from polluted water through proper treatment as well as improvement of wastewater management infrastructure. Societal hygiene enhancement initiatives should be implemented focusing on improvement of knowledge, awareness and perceptions regarding appropriate practices including but not limited to waste and sewage management as well as food safety.

References

Adam AM 2020 Sample Size Determination in Survey Research. *Journal of Scientific Research and Reports,* **26**(5): 90-97. doi:https://doi.org/10.9734/jsrr/2020/v26i530263

Anderson BA, Romani JH, Phillips HE, Wentzel M and Tlabela K 2007 Exploring environmental perceptions, behaviors and awareness: Water and water pollution in South Africa. *Popul. Environ.* **28**:133-161.

APHA (2017). Standard Methods for Examination of Water and Wastewater. (23rd edition). American Public Health Association. www.standardmethods.org.

Bishoge OK and Suntu SL 2018 Opportunies of Urban Horticulture for Poverty Alleviation in Dar es Salaam city, Tanzania - A Case study of Ubungo Municipality. *J. Food, Nutr. Agric.*, **1**(1):12-16. doi:10.21839/jfna.2018.v1i1.123

Bolton J, Bushway A, Crowe K, and El-Begearmi M 2020 *Food Safety Facts*. Retrieved September 30, 2020, from University of Maine: https://extension.umaine.edu/publications/4336e/#:~:text=According%20to%20the%20FDA%20(Food,be%20present%20on%20fresh%20produce.

Cesar MJ 2018 *Poverty Rate and Occurrence of Foodborne Illness Risk Factors in Retail Facilities.* Minneapolis, Minnesota: Walden University.

Chanzi G 2018 Heavy Metal Pollution Assessment along Msimbazi River, Tanzania. *J. Sci. Res. Rep.* **17**(5): 1-8. http://www.journalrepository.org/media/journals/JSRR_22/2018/Feb/Chanzi1752017JSRR38526.pdf

de Man JC 1983 MPN tables, corrected. *Eurz. J. Appl. Microb. and Biotech.* **17**:301–305.

Desye B, Tesfaye AH, Daba C and Berihun G 2023 Food safety knowledge, attitude, and practice of street food vendors and associated factors in low-and middle-income countries: A Systematic review and Meta-analysis. *PLoS One*, **18**(7): 1-18.

Faße A, Oelze N and Grote U 2015 *The Role of Food Safety Standards in Tanzania and their Implications for Food Security*. Hannover, Germany: Institute for Environmental Economics and World Trade, Leibniz University of Hannover.

FAO and PAHO (i.e. Food &Agriculture Organization and Pan American Health Organization) 2017 *Food Handlers Manual*. Instructor.Washington, DC.

Game I and Primus R 2015 GSDR 2015 Brief: Urban Agriculture. New York: State University of New York College of Forestry and Environmental Science. pp 1-2.

Gurtler JB and Gibson KE 2022 Irrigation water and contamination of fresh produce with bacterial foodborne pathogens. *Food Science*, **47**. doi:https://doi.org/10.1016/j.cofs.2022.100889

Hajjami K, Ennaji M, Amdiouni H, Fouad S, and Cohen N 2013 Parasitic Contamination on Fresh Vegetable Consumed in Casablanca City (Morocco) and Risk for consumer. *Int. J. Sci.Technol.***2**(7): 543-549.

Havelaar A, Blumenthal UJ, Strauss M, Kay D and Bartram J 2001 Guidelines: the current position. In World Health Organization, *Water Quality: Guidelines, Standards and Health* (pp. 18-42). Geneva, Switzerland: World Health Organization.

Jaramillo MF and Restrepo I 2017 Wastewater Reuse in Agriculture: A Review about Its Limitations and Benefits. *Sustainability* **9**(1734): 1-19.

Jenkins WM, Cumming O, and Cairncross S 2015 Pit Latrine Emptying Behavior and Demand for Sanitation Services in Dar Es Salaam, Tanzania. *Int. J. Environ. Res. Public Health* **12**(3): 2588-2611.

Jeong H, Kim H, and Jang T 2016 Irrigation Water Quality Standards for Indirect Wastewater Reuse in Agriculture: A Contribution toward Sustainable Wastewater Reuse in South Korea. *Water* 8**:** 169.

Kayombo MC and Mayo AW 2018 Assessment of Microbial Quality of Vegetables Irrigated with Polluted Waters in Dar es Salaam City, Tanzania. *Environ. Ecol. Res.* **6**(4): 229-239.

Khalil MR, Das AK, Hossain I, Jahedi E, Lijon B and Kumar R 2016 Efficacy of Different Washing Protocols in Reducing Bacterial Load in Comon Vegetables Sold in Dhaka City. *Eur. J. Biomol. Pharm. Sci.***3**(6): 149-155.

Kimaro EN 2017 *Bacterial Contaminants of African Indigenous Leafy Vegetables and Their Antibiotic Sensitivity Characteristics: A Case Study of Morogoro Municipality, Tanzania.* Morogoro: Sokoine University of Agriculture. Retrieved from https://www.suaire.sua.ac.tz/handle/123456789/1999

Leonard S, Kihampa, C, and Mwegoha W2012 Heavy metals pollution and urban agriculture in Msimbazi River valley: Health risks and public awareness. *Inter. J.Plant Anim. Environ. Sci.***2**:107-118.

Liu P 2020 Food Safety Knowledge and Practice in Low-income Families in the United States: An Exploratory Study. *Food Prot. Trends* **40**(2): 80-94.

Liu Z, Ying J, He C, Guan D, Pan X, Dai Y, Gong B, He K, Lv C, Wang X, Lin J and Bryan BA 2024 Scarcity and quality risks for future global urban water supply. *Landscape Ecol.* **39**(10): 1-17.

Lyimo CW, Shayo R and Lyimo TJ 2008 Community Awareness on Microbial

Water Pollution and its Effects on Health Development in Urban Tanzania: A case study of Tabata and Kiwalani Wards in Ilala District in Dar es Salaam Region.*Tanz. J. Devel. Stud.* **7**(2): 64-75.

Machiwa JF 2010 Coastal Marine Pollution in Dar es Salaam (Tanzania) relative to Recommended Environmental Quality Targets for the Western Indian Ocean. *West. Ind. Ocean J. Mar. Sci.,* **9**(1):17-30.

Mayilla W, Magayane F, Konradsen F, Keraita B, and Ngowi H 2016 Awareness of Measures for Reducing Health Risk of Using Low-Quality Irrigation Water in Morogoro, Tanzania. *Exposure Health* **8**: 475–485.

Mlay RS 2018 Assessment of Knowledge, Attitude and Practice of Street Food Vendors Towards Food Safety and Hygiene in Ilala Municipality. Dar es Salaam: Open University of Tanzania.

Msaki GL, Njau KN, Treydte AC, and Lyimo TJ 2022 Social knowledge, attitudes, and perceptions on wastewater treatment, technologies, and reuse in Tanzania. *Water Reuse*, **12**(2): 223–241.

National Academy of Sciences 2003 *Scientific Criteria to Ensure Safe Food.* Washington, D.C.: The National Academies Press.

Newman KL, Leon JS, Rebolledo PA and Scallan E 2015 The impact of socioeconomic status on foodborne illness in high-income countries: a systematic review. *Epidem. Infect.*,**143**: 2473–2485.

Ramya V and Patel P 2019 Health benefits of vegetables. *Int. J. Chem. Stud.*7(2):82-87.

Røssvoll EH, Lavik R, Ueland Ø, Jacobsen E, Hagtvedt T and Langsrud S 2013 Food safety practices among Norwegian consumers. *J. Food Protect.***76**(11):1939–1947.

Thomas J, Holbro N and Young D 2013A Review of Sanitation and Hygiene in Tanzania. Dar es Salaam, Tanzania: Maji Safi kwa Afya Bora Ifakara (MSABI).

Tornevi A, Bergstedt O and Forsberg B 2014 Precipitation Effects on Microbial Pollution in a River: Lag Structures and Seasonal Effect Modification. *PLoS One*, **9**(5):1-10.

Viman OV, Oroian I, and Fleșeriu A 2010 Types of water pollution: point source and non-point source. *AACL Bioflux* **3**(5):393-397.

Welbaum GE 2019 *Vegetable Production and Practices*, Wallingford, Oxfordshire, United Kingdom: CABI.

World Bank 2022 *Tanzania Economic Update - Clean Water, Bright Future:* TheTransformative Impact of Investing in WASH (English). Washington, D.C.:World Bank Group.

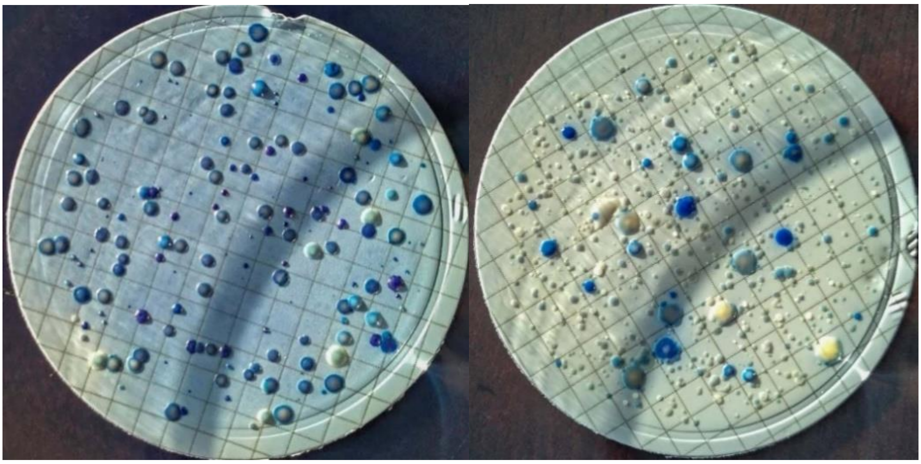
WHO 2006 Guidelines for the Safe Use of Wastewater, Excreta and Greywater; World Health Organization: Geneva, Switzerland.

Yao C, Han C, Wang Z, Wang Y, Zuo S, Kimirei IA, Kishe MA, Gao Q, Xiong C, Guo Z, Yuan Y, Zhang J, Zhang L, Chen SS and Shen Q 2023 Water Quality Degradation in Urban Rivers of Dar es Salaam, Tanzania: Changes, Status, and Causes. *Water Air Soil Pollut.***234**(224).

Yuan F, Qian D, Huang C, Tian M, Xiang Y, He Z and Feng Z 2015 Analysis of awareness of health knowledge among rural residents in Western China. *BMC Public Health*, **15**(55).

Appendices

Appendix 1: An example of m-FC agar plate with blue colonies representing *E. coli* strains.



Appendix 2: A table showing demographic characteristics of respondents.

Demographic variables	Female (n=33)	Male (n=17)	Total (n=50)	
	%	%	n	%
Sex	66	34	50	100
Age				
Below_25	21	18	10	20
25-34	37	35	18	36
35-50	24	47	16	32
Above50	18	0	6	12
Level of education				
Primary Education	55	47	26	52
Secondary School	30	35	16	32
University/College	15	18	8	16
Occupation				
Business	58	82	33	66
Private sector employee	15	12	7	14
Government employee	0	0	0	0
Others (Daily worker)	27	6	10	20