Microbial Risk Assessment of Vegetables Irrigated with Akaki River Water in Addis Ababa.

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Abstract

Background: Consumption of vegetable plays important role in human health. Above 60% of Addis Ababa, vegetable demand is covered by smallholder farmers who grow various vegetables by using the Akaki River as their main water source for irrigation. However, applying faecally contaminated water for irrigation could expose fresh vegetable consumers to many health problems. Therefore, this study aimed to evaluate the microbial contamination of irrigation water and freshly produced vegetables. The study assessed the quality of Akaki river water and vegetables. Fresh vegetables including Ethiopian Kale, Lettuce, Cabbage, and Spinach were collected from 14 farmlands, irrigated with Akaki River water, in the dry and wet seasons. Using standard methods, analysis of E.coli, Non-E.coli, Total coliform, fecal coliform, and Total Aerobic Plate Count were done among the Akaki River water and vegetables.

Result: The finding of the study indicated that all fresh vegetables were contaminated with total coliforms, fecal coliforms, and Total aerobic in the dry and wet seasons. The overall mean count of E. coli and Non-E. Coli from water samples were 2.09 and >3.48 $\log_{10}$ CFU 10 mL^{-1}. The mean count of TC, FC, and TAC on sampled vegetables were 3.22, 1.37, and 4.72 in the dry season, and 3.87, 2.57, and 5.09 $\log_{10}$ CFU per gram in the wet season, respectively.

Conclusion: The Akaki River has been contaminated with non-E. Coli & E. coli coliforms and did not meet the WHO guideline criteria for safe irrigation. The microbial contamination of vegetables was found high and exceeded the HACCPTQM and ICMSF limit values for safe consumption. This calls for farmers and the consumer has to insist on properly processed/stored/sliced fresh vegetables needs to be aware.

Background

Consumption of vegetables play important role in human health (Henning et al., 2017; Sanlier & Guler, 2018). They provide required minerals and vitamins for better health (Conner et al., 2017; Wallace et al., 2020). Moreover, vegetables supply dietary fiber, and fiber intake is linked to a lower incidence of cardiovascular disease and obesity (Slavin & Lloyd, 2012). Besides, they are essential factors for the prevention and control of other non-communicable diseases including cancer (Farvid et al., 2020; Kerschbaum & Nüssler, 2019; Marmot, 2018; Valcke et al., 2017). However, Ethiopia is one of the developing countries with limited access and consumption of fresh and healthy vegetables (Haji, 2008; Hunde, 2017). In this regard, the urban community has better access and consumption than the rural (Demissie, Ali, & Zerfu, 2009). About sixty percent of Addis Ababa vegetable demand met by urban farmers since the early 1940s (Van Rooijen, Biggs, Smout, & Drechsel, 2010; Alebel Bayrau Weldesilassie, 2008).

In and near Addis Ababa, varieties of vegetables are growing by smallholder farmers. These farmers use the Akaki River as their main water source for irrigation without established modern irrigation mechanisms (Van Rooijen et al., 2010). Due to scarcity of freshwater, partially treated and untreated effluent of wastewater from numerous industries and other gray water from the habitat of the Addis Ababa city is currently used for irrigation purpose as other developing urban areas practiced (Gashaye, 2020; Janeiro, Arsénio, Brito, & van Lier, 2020; Ungureanu, Vlăduț, & Voicu, 2020). As all streams of Addis Ababa, the Akaki River is enormously polluted by anthropogenic impacts from upstream to down (Alemu, 2017; Alebel B Weldesilassie, Boelee, Drechsel, & Dabbert, 2011; Woldetsadik, Drechsel, Keraita, Itanna, & Gebrekidan, 2017). Although the Akaki River water is suspected to be the source of contamination to vegetables and the environment, nearly 1,300 smallholder farmers are engaging to cultivate and irrigate different vegetables consumed by the residents of Addis Ababa (Van Rooijen et al., 2010).

Water quality is one of the important criteria to determine the intended purposes of a river (Misaghi, Delgosha, Razzaghmanesh, & Myers, 2017; Şener, Şener, & Davraz, 2017). The quality of river water is explained by its physical, chemical, and biological constitutes (Kebede et al., 2020; Zhang, Meng, Xia, Wu, & She, 2018). The bacteriological quality of river water is a good indication to monitor irrigation water. As a result, many countries have set microbial quality standards based on their contexts. For instance, World Health Organization set the limit of fecal coliform bacteria for unrestricted irrigation as less than 1000 per 100 ml but for restricted irrigation, the recommended limit is about 10^5 fecal coliform bacteria per 100 ml (U. J. Blumenthal, Mara, Peasey, Ruiz-Palacios, & Stott, 2000; WHO, 2006). However, the irrigation practice of smallholder farmers in the urban area of Addis Ababa is traditional and a flooding type(Van Rooijen et al., 2010). So that, in this study the cut-off point for the status of contamination level was taken according to the guideline limit of 10^3 fecal coliform bacteria/100 ml to monitor the irrigation water quality. A study conducted in the Akaki River indicated that the fecal coliform bacteria level of irrigation water is above the WHO recommended limit for unrestricted irrigation (Woldetsadik, Drechsel, Keraita, Itanna, Erko, et al., 2017).

Growing evidence suggests that vegetable consumption is getting attraction by many people particularly in the urban community (Raaijmakers, Snoek, Maziya-Dixon, & Achterbosch, 2018; Raymond, Diduck, Buijs, Boerchers, & Moquin, 2019; Roberts & Shackleton, 2018). The recent popularity of vegetables could be its health advantage and low energy density (Hölzel, Tetens, & Schwaiger, 2018; Shrestha, Haramoto, & Shindo, 2017). However, most urban farmers use untreated or partially treated wastewaters along with high-polluted river like Akaki River (Gashaye, 2020; Gutierrez et al., 2019; Wang et al., 2018; Woldetsadik, Drechsel, Keraita, Itanna, Erko, et al., 2017), which received both liquid and solid wastes from the nearby dwellers and industries operating near to its watershed (Amare, 2019; Yilma, Kiflie, Windsperger, & Gessese, 2019). Hence, microbiologically contaminated rivers could affect the health of farmers on the one hand and consumers of fresh vegetables that are irrigated with contaminated water on the other hand. For instance, the prevalence of perceived illness like intestinal nematodes, diarrhea, and skin disease among farmers working on irrigation farms within and around Addis Ababa were varied significantly between the wastewater and freshwater areas and the prevalence was higher for farmers who are working in downstream than upstream wastewater farm areas (Alebel B Weldesilassie et al., 2011).

Among diarrheal-causing pathogens, Salmonella, Shigella, Escherichia coli, and Cryptosporidium are mentioned (Kundu, Wuertz, & Smith, 2018; Luna-Guevara, Arenas-Hernandez, Martínez de la Peña, Silva, & Luna-Guevara, 2019). Pathogenic Escherichia coli strain causes diarrhea, hemorrhagic colitis, and hemolytic uremic syndrome in humans (Luna-Guevara et al., 2019). Overall, consumption of freshly produced vegetables particularly those eaten raw is caused by foodborne illness (Carstens, Salazar, & Darkoh, 2019; Mun, 2020; Shrestha et al., 2017).

There have been well-documented evidence on freshly produced vegetables related foodborne illness internationally (Luna-Guevara et al., 2019; Mritunjay & Kumar, 2017) and different remedial approaches have been designed to mitigate the effect of wastewater use in urban farming globally (Banach & van der Fels-Klerx, 2020; Woldetsadik, Drechsel, Keraita, Itanna, & Gebrekidan, 2018; Yao et al., 2019). Besides, limited researches in the current study area conducted specifically on fecal coliform distribution on Lettuce and river water (Woldetsadik, Drechsel, Keraita, Itanna, Erko, et al., 2017). However, there is no adequate information about the microbial quality of Akaki River water and different fresh produced vegetables in and near Addis Ababa; particularly, concerning the effect of the wet and dry period, the incidence of Total coliform, Faecal coliform, Aerobic Plate Count of vegetable, E.coli, and non-E.coli of irrigated water. Therefore, this study is aimed to evaluate the microbial contamination of irrigation water and freshly produced vegetables and their perceived health risk.

Methods

Study areas

The study was conducted in vegetable farmlands irrigated with Akaki River water in Addis Ababa, Ethiopia. During our reconnaissance survey, we have identified 14 farmlands in and near Addis Ababa for this study. These farmlands include (figure 1) Burayu Kera, Burayu Gefersa, Lome Meda, Koka, Mekanissa Teklehaymanot, Mekanissa, Kera, Bihere Tsige, and Shitu along the Little Akaki River and Peacock1, Peacock2, Akaki Tirunesh Beijing, and Akaki Beseka in the catchment of Great Akaki River. The Aba Samuel farmland is located downstream of the Akaki Rivers and used water from the manmade dam. The description of each sampling point is summarized in Table 1.

Research Design

A laboratory-based cross-sectional study was conducted on vegetables that are irrigated with Akaki River water during dry and wet seasons.

Sample collection and analysis

Fresh vegetables such as Ethiopian Kale, Lettuce, cabbage, and spinach were collected from farms irrigated by the Akaki River in the dry and wet seasons. During the dry month of February 2017, and in the wet season of August 2016, 38 and 15 vegetable samples were collected, respectively. The Vegetable samples were taken from every corner of the plots to make sampling representative. 500 gm of vegetables were collected from each sampling site in sterilized plastic bags. Besides, 500 ml water samples were collected from the Akaki River irrigation area using sterilized bottles. Collected vegetables and water samples were stored in a refrigerator at 4^{O}C to prevent lysis of microorganisms and subjected to analysis within 24 hours.

Microbial analyses of vegetables and water samples were done at Ethiopian Public Health Institute (EPHI) microbiology laboratory. The membrane filtration method was used for microbiological analysis of water samples following Ethiopian standard agency method number ES ISO 4833 (ESA, 2013) as mentioned by (Alemayehu et al., 2020). Enumeration of Total coliform, fecal coliform, and *E. coli* was done from vegetable samples using standard methods (Refai, 1979). 25 g of vegetable samples were taken from each vegetable sample, rinsed with 225 ml of peptone water, and shake with a stomacher to wash the bacteria from the vegetables and get into the solution. E-coli and non-E-Coli coliform count were done from the water samples using the standard method (U. J. Blumenthal et al., 2000). 1 ml, 10 ml, and 50 ml of the water samples were filtered using 0.45 whole membrane filtration for each water sample and the membranes were incubated at 44 ^{O}c in different Petri-dishes that have appropriate culture media for coliforms. The growth bacterial colonies were counted from those Petri-dishes that are convenient to count. Confirmation for E-coli was done using an indol test from the counted bacterial colonies. For vegetables, the number of bacterial colonies count was reported per gram of vegetables after calculating with the dilution factors and for water samples, it was reported per 10 ml of a water sample. Quality controls for analysis were done using standard organisms as a positive control and blank to check contamination during analysis. Tests that did not pass the quality control were repeated.

Data Analysis

The microbial load of vegetables and average of microbial population per gram of vegetable is calculated after normalized by log transformation except fecal coliforms. Also, descriptive statistics were conducted for Escherichia coli and non-E.Coli coliforms.

Results

Microbial Contamination of Water and fresh vegetables

The present study attempted to determine the level of vegetable contamination with Total Aerobic plate Count (TAC), Total coliform bacteria and fecal coliforms (FC) as well as their microbial loads through Total Aerobic Count (TAC), Total Coliform Counts (TCC), and fecal coliforms (FC). This study also showed the percentage of Akaki River water contamination with E. coli and non-E. Coli coliforms.

Microbial contamination of River water

In the dry period, 14 water samples were collected from the inlet of irrigation water at Akaki River. The result is summarized by each sampling point and the average count of Escherichia Coli and non-Escherichia Coli coliform populations.

Table 2 shows the distribution of E. coli and Non-E.coli coliform in the Akaki River that is used for irrigation of farmland in Adds Ababa. The minimum E.coli population of 10 CFU per 10 ml was measured in Aba Samuel and the maximum E.coli population with 320 CFU/10 ml was found in Akaki Beseka and Mekanissa. On the other hand, the non-E. Coli population was found above 300 CFU/1ml in all water sampling points.

As indicated in Table 3, the study revealed that the overall mean of E.coli and Non-E.coli were 2.09 and >3.48 $\log_{10}$ Colony Forming Unit (CFU) 10 m L^{-1} respectively.

Microbial Contamination of Vegetable in Dry period

During the dry period, 35 vegetable samples from the 14 farmlands were included for analysis. During this time, farmers were entirely dependent on river water for irrigation since less rainwater is presented.

Ethiopian Kale is one of the dominant vegetables in the Ethiopian food menu regardless of the household incomes. Based on the study, the bacteriological quality of Ethiopian Kale is varied among the sampling points and had different microbial quality indicators (Table 4). The total coliform count in Ethiopian Kale varies from 1 $\log_{10}$ CFU g^{-1} in Mekanissa and Shito to approximately 5 $\log_{10}$ CFU g^{-1} in Peacock 2. While the minimum fecal coliform pollution (10 CFU/100 ml) was found in the majority of sampling farms and the maximum, 2800 CFU/100ml was from Peacock2 farm. Contrarily, the total aerobic plate count population was relatively high in all sampling points with the range of 3.3 $\log_{10}$ CFU g^{-1} in Bihere Tsige farm to 6.8 $\log_{10}$ CFU g^{-1} in Akaki Tirunesh Beijing area (Table 4).

Table 5 presents the bacteriological quality of lettuce irrigated with the Akaki River. The population of total coliform in Lettuce ranges from 3.27-log10 CFU g^{-1} in Mekanissa to 4.8 $\log_{10}$ CFU g^{-1} in Burayu Kera. The fecal coliform population is below or equal to 60 CFU/100 ml in all sampling points except in Koka and Bihere Tsige where the FC population was about 240 and 400 CFU/100 ml, respectively. While the total aerobic plate count population varies from 3.6 $\log_{10}$ CFU g^{-1} in Mekanissa to 5.8 $\log_{10}$ CFU g^{-1} in Peacock 1.

The microbial load of Swiss chard during the dry period shows variation based on location and type of microbial indicators (Table 6). The total coliform in Swiss chard ranged from 2 $\log_{10}$ CFU g^{-1} in Burayu Kera to a maximum population of 3.8 $\log_{10}$ CFU g^{-1} in Akaki Tirurnesh Beijing. Similarly, the minimum population of total aerobic plate count was found in Burayu Kera (3.9 $\log_{10}$ CFU g^{-1}) while the maximum population of total aerobic plate count was found in the Koka farm area (5.5 $\log_{10}$ CFU g^{-1}).

Microbial contamination of vegetables in Wet Season

During the rainy season, 18 vegetable samples were taken from the nine small farmlands. This number is lower than what we sampled during the dry season. In this season, most of the sampled vegetables were Ethiopian Kale and Lettuce.

Table 7 presents microbial contamination of Ethiopian Kale during the rainy season. The population of Total coliform, Fecal coliform, and Total aerobic plate count ranges from 19 log_{10} CFU g^{-1}, 0 CFU, and 3.9 log_{10} CFU g^{-1} in Burayu Gefersa to 5.5 log_{10} CFU g^{-1}, 1400 CFU/100 ml, and 5.9 log_{10} CFU g^{-1} in Mekanissa, respectively.

During the rainy season, microbial contamination of Lettuce was very high compared to other vegetables. Here the total coliform, fecal coliform, and total aerobic plat count contamination level were ranged from 4.0 log_{10} CFU g^{-1}, <10 CFU, and 5.3 log_{10} CFU g^{-1} in Mekanissa Teklehaimanot and (>1000), 30 CFU and 6.3 log_{10} CFU g^{-1} in Mekanissa (Table 8).

Average microbial load by season

To measure the level of microbial contamination of fresh vegetables, which cultivated from the Akaki River, the authors calculated the mean value of each microbiological indicator and concerning the type of vegetables.

The mean count of TC, FC, and TAC on collected vegetables irrigated with Akaki River were 3.22, 1.37, and 4.72 in the dry season, and 3.87, 2.57, and 5.09-log10 CFU per gram in the wet season, respectively (Table 9). All fresh Table 10 present the mean microbial count of fresh vegetables irrigated with Akaki River in wet and dry seasons. The mean Total coliform count, Fecal coliform, and total aerobic count of Ethiopian Kale were 3.22, 1.39, and 4.72 log_{10} CFU g^{-1} in the dry season; and 3.49, 2.86, and 4.97 log_{10} CFU g^{-1} in wet season respectively. Also, on Lettuce, the mean of Total coliform, Fecal coliform, and Total aerobic plate count was 3.15, 1.32, and 4.75 log_{10} CFU g^{-1} in the dry season and 4.01, 1.02, and 5.49-log_{10} CFU g^{-1} in the wet season. While the mean of Total coliform, Fecal coliform, and Total aerobic plate count of Swish chard were 3.17, 1.31, and 4.69 log10 CFU g^{-1} in the dry period. However, in the wet season only Total coliform (4.72 log_{10} CFU g^{-1}), and Total aerobic plate count (5.49 log_{10} CFU g^{-1}) were identified.

Discussion

The findings of the study revealed that most of the water samples used for irrigation were highly contaminated and above the permissible level. This could be due to the absence of legal instruments that prevent the discharge of untreated wastewater from nearby factories and the residents of the city.

Furthermore, the mean value of E.coli and Non-E.coli of the sampled water was 2.09 and > 3.48 log10 CFU 10 mL − 1, which is higher than the WHO recommended standard (WHO, 2006). This could be due to the poor attention of government and other concerned bodies that they forget the health impact of wastewater on public health and the biotic environment. According to WHO standard, the Fecal coliforms level must not exceed 1000 counts 100 mL − 1 for the safe use of wastewater for irrigation of vegetables (WHO, 2006). Of those Fecal coliforms, E.coli is recommended as a good indicator to determine the hygiene condition at primary production of leafy vegetables and to validate and verify the application of good agriculture practice (Allende & Monaghan, 2015). However, in this study, most of the water samples were found to be above WHO standard for irrigation. Besides, this finding is also in agreement with previously conducted studies in the Akaki River (Alebel B Weldesilassie et al., 2011; Woldetsadik, Drechsel, Keraita, Itanna, Erko, et al., 2017). The high population of E. coli and other non-E.coli coliforms in all sampling points of irrigation water could be due to practice of open defecation, linkage of toilets from nearby dwellers, the release of poorly treated human excreta from Kality wastewater treatment plant, animal carcass, and blood waste from abattoirs, and other uncontrolled wastes from industries and institutions. As established shreds of evidence suggest, many study findings revealed that such human-induced pollution is contributed to poor bacteriological quality in surface water (Lenart-Boroń, Wolanin, Jelonkiewicz, & Żelazny, 2017; Okullo, Moturi, & Ogendi, 2017; Seiyaboh & Izah, 2017; Tariq et al., 2020).

As contemplated by the irrigation water quality, also the microbial quality of Ethiopian Kale, Lettuce, and Swiss chard from all farms had high Total coliform, Fecal coliform, and Total aerobic plate count population. Almost all sampled farmlands microbial contamination level exceeds the maximum allowable limits set by the various organization including the World Health Organization(WHO, 2006). Among 14 sampling sites, Ethiopian Kale collected from Peacock 2 form land, Lettuce from Bihere Tsige, and Swiss chard from Mekanissa Teklehaimanot sites had high Fecal coliform counts in the dry season. However, Ethiopian Kale and Lettuce in Mekanissa had high Fecal coliform counts in the wet season. The difference could be due to the geographical location of the sampling sites in addition to the rain-off effects in the wet season. The overall mean aerobic mesophilic count observed in this study ranged from 3–7 in the dry season, and 3.75–6.3 $\log_{10}$ CFU g^{-1} in the wet season, which was consistent with other similar studies conducted in Awash River and Awetu stream in Jimma (Benti, Kebede, & Menkir, 2014; Weldezgina & Muleta, 2016).

Though the authors try to present the level of microbial contaminates among the vegetables, there is no specification placed for the permissible level of microbes for raw food being served in Ethiopia. However, Hazard Analysis and Critical Control Points-Total Quality Management (HACCPTQM) Technical Guidelines lay down the microbial quality for raw foods, where the food containing less than 4.4– 6.69, 6.69–7.69 and greater than 7.69 log CFU g − 1 (aerobic plate count) is rated as good, average, poor and spoiled food, respectively (Aycicek, Oguz, & Karci, 2006). Based on these criteria, the findings of the study indicated that most of the vegetables irrigated with Akaki River particularly in the dry season fall under poor categories. This may be due to a lack of dilution in the dry period and farmers are not use river water during the wet season.

Bacteriological quality indicator organisms including Aerobic Plate Count, Total Coliform, and Fecal Coliforms are good indicators of sanitary conditions of fresh vegetables (G. Zhang et al., 2018). In this study, the mean count of total coliform, fecal coliform, and Aerobic Plate Count ranged from 1–5, 1-3.45 and 3–7 $\log_{10}$ CFU g^{-1} in the dry season, and 1.9–5.71, 1.3–3.15 and 3.75–6.3 $\log_{10}$ CFU g^{-1} in the wet season respectively. However, more than 72% of vegetables collected during the wet season (n = 13) were not contaminated with fecal coliform. This may be related to river water dilution and most of the farmers were used natural rainwater for their cultivation. The occurrence of such indicator microorganisms is an indication of the contamination of the vegetables with fecal matter derived from humans and other animals (Cornish, Mensah, & Ghesquire, 1999; Korajkic, McMinn, & Harwood, 2018; Ordaz, Merino-Mascorro, García, & Heredia, 2019).

The total coliform level recorded in this study was higher in all types of vegetables analyzed in both wet and dry seasons. The mean value of TC of Ethiopian kale, Lettuce, and Swish chard ranged from 1-4.83, 3.28–4.84, and 2-3.85 in the dry season and 1.9–5.52, 3-4.64, and 3.64–5.46 $\log_{10}$ CFU g^{-1} in the wet season, respectively. The high percentage of vegetables contaminated with coliform bacteria and fecal coliforms may suggest a high risk of acquiring infectious diseases through the consumption of these vegetables. This idea is supported by a study done by Quansah et al. (Gashaye, 2020; Quansah, Kunadu, Saalia, Díaz-Pérez, & Chen, 2018)

Similarly, the mean of a fecal coliform count of Ethiopian Kale, lettuce, and Swish Chard ranged from 1-3.45, 1-2.72, and 1-2.04 $\log_{10}$ CFU g^{-1} in the dry season respectively; and in the wet season Fecal coliform were identified in Ethiopian Kale (2.57–3.15 $\log_{10}$ CFU g^{-1}), and Lettuce ((< 1-1.48 $\log_{10}$ CFU g^{-1}). However, Fecal coliforms were < 10 log10 CFU g-1 in Swish charge, cabbage, and spinach during the wet season. Except for swish Chard, cabbage, and spinach, in the wet season, the mean fecal coliform values of all the vegetable samples exceed the World Health Organization (WHO) and International Commission on Microbiological Specifications for Food (ICMSF) recommended level of 10^3 Fecal coliforms g-1 fresh weights in both the dry and wet season (U. J. Blumenthal, Mara, D.D., Peasey, A., Ruiz-Palacios, G. and Stott, R, 2000; ICMSF, 1998). This may be due to the location of the river in the metropolitan city that owns the presence of many industries, commercial activities, and residential raw wastewater effluents that may be cause many communicable and non-communicable diseases to the residents.

Conclusion

The Akaki River was heavily contaminated with non-E. Coli & E. coli coliforms and did not meet the WHO guideline criteria for safe irrigation. In this study, target microorganisms commonly used as indicators for the hygiene status of foods frequently exceeded the HACCPTQM and ICMSF limit values for safe consumption. Freshly produced vegetables (especially Ethiopian Kale, lettuce, cabbage, and Swiss chard) had high contamination and they might contain pathogenic microorganisms and represent a risk for consumers regarding the foodborne disease. Therefore, this calls for farmer's and consumer's awareness of the dangers of contacting with Akaki River water and consuming pathogen-contaminated vegetables, and the need to insist on properly processed/stored sliced produce needs to be reawakened. Besides, to minimize potential risks associated with river water irrigation, the proper use of river water, as well as cheap and efficient methods to reduce microbial loads in microbiologically contaminated water used for irrigation, needs to be implemented.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

All authors have read the manuscript carefully and agreed to submit for publication.

Availability of data and material

The current study datasets are part of the Akaki River research project, which is not publicly available. The data can be accessed by fulfilling the data sharing policy of the Ethiopian Public Health Institute.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contribution:

SDM: the corresponding author, analyzed data, designed and drafted manuscript. YBA: data analysis and edit manuscript. AWK, KTT, MGS, MAK, DAD, MGW, TAA, and AMG contributed to the writing of the manuscript and given critical comments on the draft manuscript.

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Tables

Table 1: Summary of land use characteristics

Sampling site	Land use characteristics
Burayu Kera	Upstream land use includes abattoir, dense residential area, municipal wastes, and open defecation of the riverbanks.
Burayu Gefersa	This site is located after the Geferessa dam and there is no known point source pollution. The area is dominated by residential and agricultural activity. In addition, there is a practice of animal grazing and community wash closes in the stream.
Lomimeda	Upstream land use includes vegetable farming, residential areas including condominiums with waste treatment ponds, and glass factory. There is a sign of a release of household and factory wastes.
Coca-cola area	On this site, streams from the Winget side with known point sources such as marble factory, tannery industry jointly pass with the Gefersa stream. On the right sides of the river are houses and on the left are garages. Farming practices a few meters from the riverbanks.
Mekanissa-Teklehaymanot	Upstream land uses are residential houses, Alert hospital, Fistula hospital, Torhayloche hospital, and people bathing in the river. To the right, there are residential areas, animal farming unit and landslide, houses, and vegetable farming dominated the left side. Besides, during our visit to this site, we noticed that open defecation is hugely practiced on both sides of the river.
Mekanisa area	Upstream land use includes an Alcohol factory, which is discharged to the Akaki River, to the left there is vegetable farming and residential houses to the right there is the practice of open defecation. Also, a stream from the Kera side joined this site with abattoir wastes.
Kera	Upstream land use includes the disposal of all the potential pollutants discharged from the upper stream such as the alcohol factory. The right side of the river is irrigated with vegetables and the left side of the river is the Addis Ababa abattoir. At downstream on the other side of the road just near to Japanese restaurant, there is also vegetable farming irrigating with the diverted river. Besides, the upper catchment is dominated by both residential and commercial activities.
Bihere Beheretsige	The upper catchment of this site is predominantly used as a residential area, and several automotive Garages have dominated the area.
Shitu behind Kality WWTP	“Shitu” is indicated the bad odour from the wastewater treatment plant located in the area. The upper catchment of the area is used for a residential area on top of the waste treatment plant. During our site visit, we noted that farmers directly irrigated their farmlands with overflow wastewater from lagoons and discharge wastewater after treatment.
Akaki Beseka	The upper stream is domesticated with animal raring units and the right side is adjoined by a condominium wastewater treatment station and to the left, there is farmland irrigated to produce vegetables.
Akaki Turneshi Beijing	The upper stream is domesticated with a hospital, beer factory road, and the right and left side is inhabited with vegetable farming by uses water pumpers. Besides, the second open market of Addis Ababa next to Merkato is found upstream of this site.
Peacock 1	upstream are situated with hotels, residential areas and the right side is the

	diversion of the river for irrigation and the left side is associated with construction material production and residential houses 100-200 meters away. Moreover, healthcare provider facilities are located above the farmland.
Peacock 2	Upstream are situated with hotels, residential areas on both sides of the sampling sites.
Aba Samuel	This site is located the downstream of Akaki River. Intensive agricultural practice is carried out and animal grazing is common.

Table 2: Microbial contamination of irrigated water, Akaki River, Addis Ababa, Ethiopia, 2017.

Site name	Sample ID	E-COLI/10ML	Non-E.coli/ml coliform
Burayu Gefersa	LA04	170	300+
Lome Meda	LA05	200	300+
Koka	LA06	80	300+
Mekanissa Teklehaymanot	LA07	240	300+
Mekanissa	LA08	320	300+
Kera	LA09	140	300+
Bihere Tsige	LA10	90	300+
Shitu	LA11	180	300+
Peacock1	GA08	220	300+
Peacock2	GA09	320	300+
Akaki Tirunesh Beijing	GA14	110	300+
Akaki Beseka	GA15	280	300+
Aba Samual	ASR	10	300+

Table 3: Microbial quality of river water during the dry season, Akaki River, Addis Ababa Ethiopia, 2017.

Test	N	Count/10ml	Log
E-coli	26	148.85(0-320)	2.09(1-2.51)
Non-E-coli coliforms	26	>3000/ml	>3.48

Table 4: Bacteriological quality of Ethiopian Kale during dry period Akaki River, Addis Ababa Ethiopia, 2017.

Bacteriological quality of Ethiopian Kale during the dry period

Site name	Area code	Total coliform (log 10)	Fecal coliform CFU	Total Aerobic plat count (log 10)
Burayu Gefersa	LA04	2	10	4.209515
Lome Meda	LA05	2.672098	10	4.875061
Koka	LA06	3.633468	520	5.146128
Mekanissa Teklehaymanot	LA07	4.033424	10	5.487845
Mekanissa	LA08	1	10	3.643453
Kera	LA09	2.544068	10	3.897627
Bihere Tsige	LA10	1.60206	10	3.322219
Shitu	LA11	1	10	3.568202
Peacock1	GA08	3.681241	10	5.190892
Peacock2	GA09	4.826075	2800	4.365488
Akaki Tirunesh Beijing	Ga14	1.90309	10	6.826075
Akaki Beseka	GA15	2.041393	10	4.120574
Aba Samual	ASR	4.440909	80	4.959995

Table 5: Bacteriological quality of Lettuce during dry period Akaki River, Addis Ababa Ethiopia, 2017.

Site name	Area code	Total coliform (log 10)	Fecal coliform CFU	Total Aerobic plat count (log 10)
Burayu Kera	LA03	4.837588	10	5.591065
Burayu Gefersa	LA04	4.748188	10	5.540329
Koka	LA06	4.536558	240	5.423901
Mekanissa Teklehaymanot	LA07	4.39794	10	5.658965
Mekanissa	LA08	3.278754	50	3.681241
Bihere Tsige	LA10	4.260071	400	5.172603
Peacock1	GA08	3.380211	30	5.838219
Peacock2	GA09	4.396199	60	5.40002
Aba Samual	ASR	4.068186	10	4.255273

Table 6: Bacteriological quality of Swiss chard during dry period Akaki River, Addis Ababa Ethiopia, 2017.

Site name	Area code	Total coliform (log 10)	Fecal coliform CFU	Total Aerobic plat count (log 10)
Burayu Kera	LA03	2	10	3.913814
Burayu Gefersa	LA04	3.681241	10	4.951338
Lome Meda	LA05	3.041393	10	4.021189
Koka	LA06	3.623249	20	5.468347
Mekanissa Teklehaymanot	LA07	3.716003	110	5.369216
Mekanissa	LA08	3.278754	20	5.283301
Kera	LA09	2.342423	10	4.017033
Bihere Tsige	LA10	2.176091	10	4.064458
Peacock1	GA08	3.255273	60	4.719331
Peacock2	GA09	2.672098	10	3.857332
Akaki Tirunesh Beijing	GA14	3.845098	10	3.908485

Table 7: Microbial quality of Ethiopian Kale during wet season Akaki River, Addis Ababa Ethiopia, 2017.

Site name	Sample ID	Total Coliform (Log 10)	Fecal Coliform	Total Aerobic Plate Count (Log 10)
Burayu Geferesa	LA04	1.90309	0	3.991226
Lome Meda	LA05	1.954243	0	4.149219
Koka	LA06	3.591065	<10	5.922206
Mekanissa Teklehaymanot	LA07	4.326336	<10	5.378398
Mekanissa	LA08	5.523226	1400	5.967548
Kera	LA09	3.447158	<10	5.240549
Bihere Tsige	LA10	3	<10	4.562293
Shitu	LA11	3.653213	370	4.521138
Peacock	GA08	4.017033	<10	5.0086

Table 8: Microbial Quality Lettuce during wet season Akaki River, Addis Ababa Ethiopia, 2017.

Site name	Sample ID	Total Coliform (Log)	Fecal Coliform	Total Aerobic Plate Count (Log)
Koka	LA06	4.643453	20	5.40824
Mekanissa Teklehaymanot	LA07	4.021189	<10	5.392697
Mekanissa	LA08	TMC (>1000)	30	6.304491
Peacock	GA08	4.361728	20	4.869232

Table 9: Average microbial load of vegetables by Season, Akaki River, Addis Ababa Ethiopia, 2017

Test	Dry season			Wet season		
	N	Mean(min-max)	Log (min-max)	N	Mean colony forming unit ml (min-max)	Log (min-max)
Total coliform	35	11088.86(10-68800)	3.22(1-5)	18	70592.78	3.87(1.9-5.71)
Fecal coliform count *	35	132.57(10-2800)	1.37(1-3.45)	5	368(20-1400)	2.57(1.3-3.15)
Total Aerobic count	35	318640(2100-6700000)	4.72(3-7)	18	347066.7 (5600-2016000)	5.09(3.75-6.3)

*13 samples FC population in the wet season were <10 CFU

Table 10: Microbial load in different types of vegetables by season, Akaki River, Addis Ababa Ethiopia, 2017.

	Dry season				Wet Season			
type of sample	**N**	**Total coliform count Log (min-max)**	**Fecal coliform count Log (min-Max)**	**Total Aerobic plat count Log (min-max)**	**N**	**Total coliform count Log (min-max)**	**Fecal coliform count Log (min-Max)**	**Total Aerobic plat count Log (min-max)**
Ethiopian Kale	13	3.22 (1-4.83)	1.39 (1-3.45)	4.72 (3.32-6.83)	9	3.49 (1.9-5.52)	2.86 (2.57-3.15)	4.97 (3.99-5.97)
Lettuce	9	3.15 (3.28-4.84)	1.32 (1-2.72)	4.75 (3.68-5.84)	4	4.01 (3-4.64)	1.02 (<1-1.48)	5.49 (4.87-6.3)
Swiss Chard	11	3.17 (2-3.85)	1.31 (1-2.04)	4.69 (3.86-5.49)	2	4.72 (3.73-5.71)	-	5.49 (5.38-5.61)
Cabbage &spinach	2	2.96(2.7-3.23)	1.24(1-1.48)	4.73 (4.9-4.97)	3	4.29 (3.64-5.46)	-	4.56 (3.75-5.78)

Figures

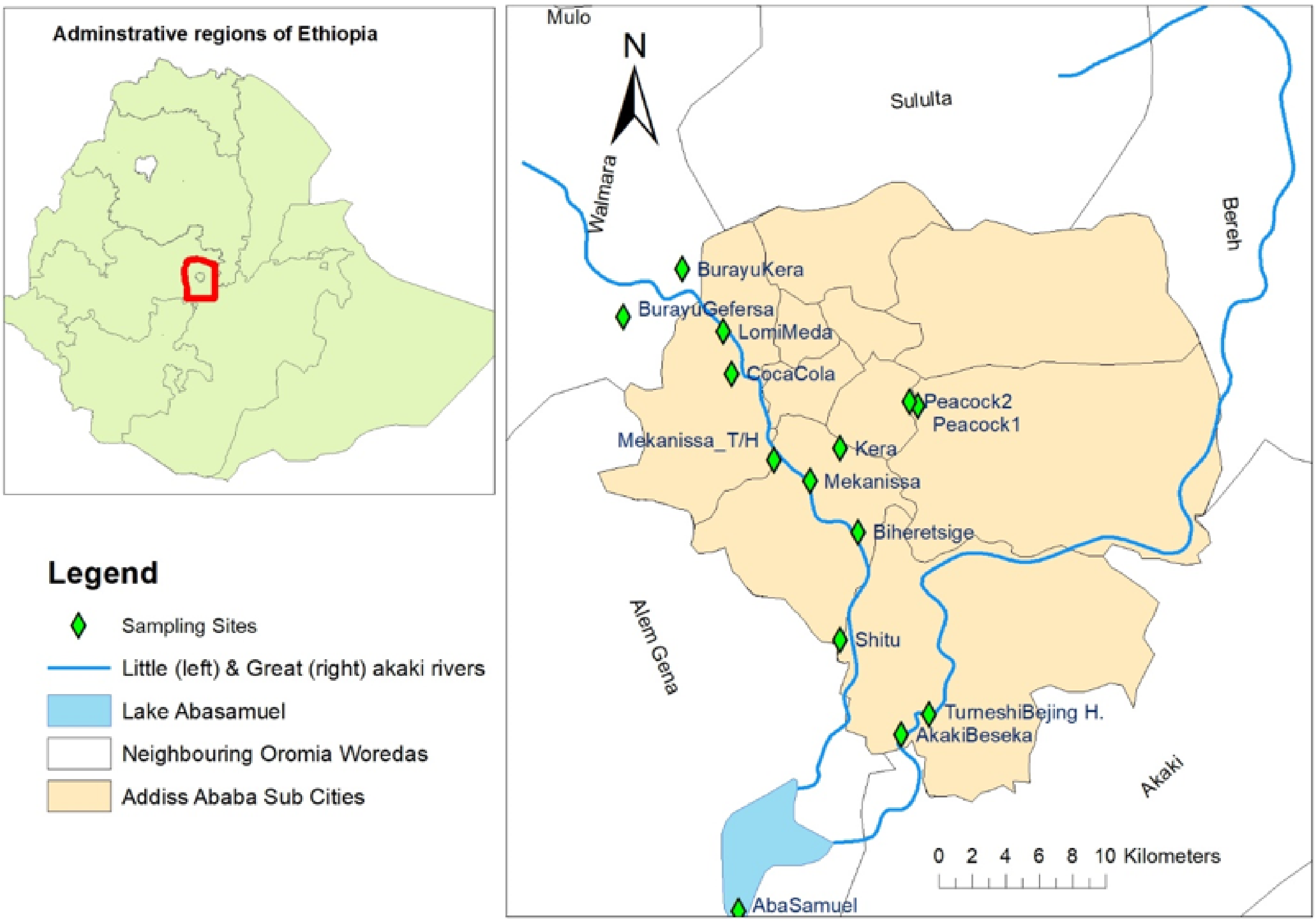

Figure 1

Map of study sites Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.