Wastewater-irrigated urban vegetable farming in Ethiopia: A review on their potential contamination and health effects

Dejen Gashaye

Abstract: In response to rapid urbanization and increase in population, there is water scarcity and growing demand for water for irrigation. Nowadays, use of wastewater in agriculture for production of vegetables is controversial due to its benefits and negative health impacts. Thus, the objective of this paper is to review the benefits and potential health risks in wastewater-irrigated vegetables. Urban vegetable farming by using wastewater can contribute a wide range of benefits to improved livelihoods. In Ethiopia, the wastewater is the only means of survival. The average income from wastewater farming has a vital role, and majority of the wastewater farm households report that they benefit from the wastewater. Despite the great importance of irrigating vegetable crops with wastewater, as a food source for the urban community and as income generation, it is subject to numerous constraints and is causing high health risks like cholera, typhoid, etc., among consumers of wastewater-irrigated produce. Depending on reviewed documents, about potential contamination and health effects of wastewater-irrigated vegetables.

ABOUT THE AUTHOR
Dejen Gashaye is a full-time lecturer and researcher in Institute of Technology, Hydraulic and Water Resources Engineering, Debre Markos University, Ethiopia. He has taught several courses such as Hydraulics I, Hydraulics II, Principles of Irrigation, Waste Water Treatment, Solid Waste Management, Hydraulic Structure I, Hydraulic Structure II, Hydro Power Engineering I, Hydro Power Engineering II, Small Scale Hydro Power and Alternative Energy Sources and Hydraulic Machines for engineering students. The author has also engaged in training and advising students in seminar and research activities, community service programs and other curricular and extracurricular activities. The author has also ample experience in teaching and research development in the field of irrigation water management and related discipline. His research interest focuses on conducting research on irrigation water management and research works related to environmental protection.

PUBLIC INTEREST STATEMENT
The study was designed for better documentation of wastewater utilization for irrigated vegetable crops which will supply important information for further health risk management. Widely produced commodities in urban and peri-urban agriculture are vegetables. Vegetables require a sufficient amount of water for better growth. However, due to low access to adequate clean water, the major sources of irrigation water in urban areas are heavily contaminated and untreated wastewater. Various undesirable microorganisms can be present at the time of growth on the surface of vegetables and their tissue.

The use of wastewater in vegetable crop production has both positive and negative impacts on crop production, public health, soil resources and ecosystems. Currently, using untreated wastewater in agriculture is a controversial issue due to its combination of benefits and negative health impacts. Therefore, conducting a review on the benefits and potential health risks in wastewater-irrigated vegetable farming in urban and peri-urban areas of Ethiopia is important to take remedy for existing problems.
vegetables in urban areas in Ethiopia, irrigation water requirement has been growing in rapidly growing urban centers, and water has become a fragile and scarce resource in a competing environment. Management of water resources and proper utilization of vegetables grown in wastewater irrigation has become one option in developing countries for farmers as well as consumers in urban areas in order to ensure food and nutritional security. Wastewater should be managed properly by the application of different wastewater treatment techniques and proper handling of vegetables to reduce contamination.

**Subjects:** Agriculture & Environmental Sciences; Soil Sciences; Environmental Management; Environment & Health

**Keywords:** Wastewater irrigation; urban areas; contamination; health effect; vegetables

1. Introduction

Urbanization is occurring rapidly throughout Ethiopia, as populations are increasingly migrating from rural areas to major cities, and hence, the country has a high rate of urbanization. Even if the country is one of the least urbanized countries in sub-Saharan Africa, urbanization has recently been accelerated, and it is expected to further accelerate with a mean rate of 3.9% between 2015 and 2020 compared to an estimated average growth rate of 3.1 for Africa (UN Population Division, 2009; USAID, 2010). Such a situation led to widespread food insecurity, which is mainly the result of a lack of availability of food, lack of purchasing power and increase in unemployment. On the other hand, such a trend has resulted in a rising market demand, which paved the way for urban agriculture or horticulture to be emerged as a mechanism to reduce the level of poverty and provide adequate and regular access to food supplies. Urban agricultural activities are being recognized as an important source of food, nutrition and income for the urban poor.

In response to rapid urbanization, water supply has outpaced sanitation coverage and wastewater management, and pollution of natural waterbodies and the use of wastewater in irrigated agriculture have become common realities (Van Rooijen et al., 2010). Wastewater is a combination of liquid wastes discharged from domestic households, farms, institutions and commercial and industrial establishments eventually mixed with groundwater, surface water and stormwater. Wastewater may contain pathogens (bacteria, viruses, protozoa and parasitic worms); organic particles (faeces, hairs, food, paper fibres and plant material); inorganic particles (salts, sand, grit, heavy metals, metal particles and ceramics); and pesticides and other toxins (FAO, 2012).

Untreated wastewater has been widely used for agriculture in most urban and peri-urban areas of developing countries (Scott, Faruqui, et al., 2004). The major benefits of urban area crop production are market proximity, high opportunities for income generation and minimum artificial fertilizer requirement (Qadir et al., 2010). The cultivation of crops for human consumption on wastewater-irrigated soil can potentially lead to the uptake and accumulation of trace metals in the edible plant parts, resulting in potential risk to humans (Ahmad et al., 2016; Zia et al., 2016). Moreover, in urban cities of Ethiopia, a large volume of untreated water is released to waterbodies which farmers use for irrigation (Weldesilassie et al., 2011).

Widely produced commodities in urban and peri-urban agriculture are horticultural crops, predominantly vegetables (cabbage, cauliflower, onion, Swiss chard, pepper, tomato, lettuce and garlic); fruits (avocado, banana, papaya, lemon, coffee and orange); and root and tuber crops (carrot, beetroot and Enset) (Ashebir et al., 2007). Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, vitamins, minerals and fibers required for human health. They also act as neutralizing agents for acidic substances formed during digestion. They are very important protective food and useful for the maintenance of health and the prevention and treatment of various diseases.
vegetables are heavily contaminated and untreated wastewater. Furthermore, there is an increasing trend in wastewater irrigation practice for vegetable farms (Ashebir et al., 2007; Buechler et al., 2014). For this reason, various undesirable microorganisms can be present at the time of growth on the surface of vegetables and their tissue. This becomes particularly important in salad vegetables which are prepared and consumed without heat treatment (Geyid et al., 1991).

In recent years, consumption of fruits and vegetables is increasing gradually, particularly among the urban communities (Yeshiwas & Tadele, 2017). According to Desta et al. (2017a), about 60% of the city’s vegetable consumption, particularly leafy vegetables, is supplied by urban farmers who irrigate their crops using polluted water source. This has a potential adverse effect on human health. The use of wastewater in agriculture, particularly in vegetable crop production, has both positive and negative potential impacts on crop production, public health, soil resources and ecosystems (Hussain et al., 2002; Scott, Faruqui et al., 2004). Currently, use of untreated wastewater in agriculture is a controversial issue due to its combination of benefits and negative health impacts. Thus, the objective of this paper is to review the benefits and potential health risks in wastewater-irrigated vegetable farming in urban and peri-urban areas of Ethiopia and to assess the level of contamination for vegetable farms irrigated by wastewater.

2. Sources of wastewater and irrigated vegetable farming

Due to water scarcity and the growing demand for water for irrigation have produced a marked increase in the use of treated and untreated wastewater for irrigation of vegetables worldwide. The use of industrial or municipal wastewater in agriculture is a common practice in many parts of the world, including Ethiopia (Blumenthal et al., 2000; Tomass & Kidane, 2012; WHO, 2006). Asano et al. (2007) reported that a large amount of freshwater is diverted to domestic, commercial and industrial sectors, which generate greater volumes of wastewater. However, there is lack of investment capacity worldwide for construction and operation of adequate treatment facilities which threatens the quality of surface water, soils and groundwater to which wastewater is discharged (Girmaye, 2014).

In Ethiopia, in 2030, the urban population is expected to reach 37 million (UN, 2018). The main sources of pollution that enters urban surface waterbodies are industries, municipal solid waste and oily wastes from garages and fuel stations and kitchen or domestic wastewater. Van Rooijen (2009), Mengesha et al. (2017) and Yohannes & Elias (2017) reported that there are over 2,000 registered industries in Addis Ababa which is 65% of all industries in the country. Most of these industries are located along the river banks. According to the Addis Ababa Environmental Pollution Authority (2007, unpublished), 90% of all industries lack facilities for some degree of onsite treatment plant and subsequently discharge any effluents into an adjacent stream. Additionally, in Adiss Ababa city, a total of 2,256 m$^3$ or 851 tonnes of solid waste is being generated daily of which 65% is collected and disposed into Repi dump site, about 10% of the waste is composted and recycled, while the remaining 25% is dumped into open spaces, ditches and waterbodies (Van Rooijen, 2009). In addition to solid waste, domestic wastewater is a major contributor to water pollution in Ethiopia. World Bank (2007) estimated that one-quarter of the households in Addis Ababa lack any form of sanitation facility and reported that as a consequence of this they use open spaces, shrubs and river banks to relieve themselves.

Girmaye (2014) stated that, among the major rivers in Ethiopia, Awash river flows from central highlands through Ethiopia’s major industrial and agro-industrial belt, taking in a whole burden of all types of raw effluent stands as one of the Ethiopian river streams in urban areas of developed
rivers. Most of the existing industries and major towns within the upper watershed have no treatment plants for the discharge of their wastes and are seriously polluting the watercourse. In addition, the Modjo river is highly polluted by discharging effluents. From Modjo tannery industry and waste disposed from the town, is the main tributary of Awash River. Further, more food and beverage industries in Ethiopia tend to discharge heavy organic pollutants and dyes from textile factories are also released waste material.

The vegetable farms at Akaki and the peacock park are among the biggest farms in the capital, where a substantial amount of vegetables is being produced seasonally. These farms are irrigated with the wastewater from rivers Akaki and Bulbula. Before several decades, the water from the rivers in the capital was clean. However, with the increase in the urban population and industrialization, the water has now become contaminated with various pollutants, among which are heavy metals (Fisseha, 1998, 2002).

3. Status of vegetable crop production by irrigating wastewater

The use of polluted water in agriculture is a common practice around the world. Studies indicate that at least 20 million hectares of land are irrigated with untreated or partially treated wastewater in developing countries (Scott, Faruqui et al., 2004; Keraita et al., 2008; Ruma & Sheikh, 2010). The reasons for using wastewater vary depending on the situation and local context. Survey results from 53 cities in developing countries indicated that the main reasons for wastewater reuse in agriculture are increasing urban water demand, urban food demand, market incentives and lack of alternative water sources (BW et al., 2010; Sally & Jayakody, 2008).

According to Ruma and Sheikh (2010) in Addis Ababa, smallholder vegetable farmers are commonly irrigated by using heavily polluted water. This is due to the reason of water scarcity and widespread pollution of existing irrigation sources.

Tekeste (2017) conducted a study to assess and analyze major on-farm wastewater hazard reduction approaches in the Akaki River. The result indicated that farmers are challenged with deteriorating water quality of the Akaki River in the past 40 years. Similar results were also reported by Van Rooijen et al., (2010), and a variety of vegetables have been produced within and around the city, mainly using heavily polluted irrigation water from the Akaki River which receives most of the wastewater. The percentage of wastewater that is eventually used for irrigation varies thus between seasons.

According to Minbale et al. (2019) and Desta et al. (2017a), urban farmers in Addis Ababa have been growing vegetables for the last 60 years, using the Akaki River as the main source of irrigation water. Today, around 60% of the city’s vegetables are irrigated with contaminated river water. Because of an increasing population, urban farming, industrial expansion and lack of sewage treatment, the city of Addis Ababa is suffering from serious surface water pollution (Eriksson & Sigvant, 2019; Yohannes & Elias, 2017). BW et al. (2010) also reported that 1,260 urban farmers in Addis Ababa were producing vegetables (lettuce, Swiss chard, cabbage, carrot, beetroot and potatoes) with wastewater irrigation of little Akaki River on about 1,240 hectares. The wastewater used farmers mainly grow cash crops like about 61% of all vegetables and 90% of leafy vegetables in the city market come from urban farms. In Mekelle city, urban vegetable producers were using irrigation water from wastewater generated from hotels, hospital and slaughterhouse (Tomass & Kidane, 2012).

Girmaye (2014) conducted a study to assess the level of some heavy metal contaminates on vegetables such as lettuce, spinach and cabbage irrigated with Awash river water in Melka Hida and Wonji Gefersa farms in Adama town. The result indicated that cadmium and lead concentration in all vegetables was found above the tolerable limit of 0.2 and 0.3 mg/kg dry weight. According to Tomass and Kidane (2012), more than 60% of the farmers in the Mekelle city and “Mariam Dahan” village are irrigating their vegetables once a week by using wastewater from the city drainage canal.
4. Wastewater use in urban and peri-urban agriculture and its contribution to livelihoods and food security

Fifty percent of all children in developing countries (10.4 million children) under the age of five die per year due to malnutrition (Rice et al., 2000; WHO, 2000). Healthy individuals make healthy communities. Wastewater, if well managed, can help alleviate malnutrition, especially for children of poor households. According to the World Health Organization (2005), wastewater use in agriculture may have important economic benefits for households and communities that can improve the health of families through better access to health care education, nutritious food and improved access to both water and sanitation in the household (Van Rooijen et al., 2010).

Migration from rural to urban areas is increasing in sub-Saharan Africa. An estimated 54% of the sub-Saharan Africa population will inhabit urban areas by 2030 (UN, 2002). According to Haddad et al. (1999), unless urban poverty and malnutrition are reduced at the same rate as the urban population increases, food and nutrition insecurity will increase. The practice of producing crops within urban and peri-urban areas is one strategy to contribute to improving the food and nutritional security status of individuals and populations (Boischio et al., 2006; Ruel et al., 1998).

Janssen et al. (2005) and Roschid-Sally et al. (2005) revealed that wastewater use can contribute to improved livelihoods at the household level, particularly through recycling of water for irrigation and specifically with additional direct benefits of nutrients for plant use. It has the potential to address the problems of local water shortages (Jimenez, 2005).

Urban and peri-urban agriculture can offer wide-ranging benefits (Pasquini, 2006). It can contribute substantial amounts to the proportion of food consumed in the city (Table 1). Urban and peri-urban agriculture increases quantity and quality of food available for consumption and provides nutrition and income which improves the urban environment by using the organic solid and liquid wastes of the city, provides aesthetic value to these areas and helps to achieve optimum land utilization (Boischio et al., 2006; Buechler et al., 2014; Lynch et al., 2001; Ruma & Sheikh, 2010). Studies indicated that a significant proportion of a city’s food requirements in developing countries are supplied from within the urban boundaries because within those areas the substantial amount of wastewater (mainly from homes and industries) is available in urban drains for irrigating lands along the urban drainage courses (Ruma & Sheikh, 2010).

| Vegetable      | Plot size (ha) | Market price (birr/kg) | Net income (Birr/ha) | Total net income (birr/year) | Av. farmer income (birr/month) |
|----------------|---------------|------------------------|----------------------|-------------------------------|--------------------------------|
| Lettuce        | 55            | 2                      | 24,279               | 2,666,805                     | 141.2                          |
| Swiss chard    | 49            | 2.00                   | 21,810               | 1,060,620                     | 56.2                           |
| Carrot         | 46            | 1.00                   | 14,854               | 1,363,597                     | 72.2                           |
| Cabbage        | 33            | 1                      | 24,425               | 1,591,045                     | 84.2                           |
| Kale           | 39            | 2                      | 9,269                | 724,094                       | 38.3                           |
| Potato         | 49            | 1.00                   | 11,915               | 1,160,521                     | 61.4                           |
| Beetroot       | 25            | 1.00                   | 22,010               | 1,113,706                     | 59.0                           |
| Tomato         | 15            | 1.25                   | 14,735               | 442,919                       | 23.5                           |
| Onion          | 7             | 2.00                   | 12,960               | 181,440                       | 9.6                            |
| Cucumber (Zukuni) | 10            | 2.00                   | 65,660               | 1,353,909                     | 71.7                           |
| Cauliflower    | 27            | 3.00                   | 14,070               | 747,398                       | 39.6                           |

Source: Bureau of Agriculture Addis Ababa, (2003).
Wastewater is a reliable supply of water that allows farmers to grow crops throughout the year. It also contains nutrients that can improve crop growth. Furthermore, it is often the only water available, so farmers, especially in urban areas, have no choice but to use this wastewater to irrigate their crops (FAO, 2012).

The practice of wastewater utilization in crop production is also common in Ethiopia, the second most populous country in sub-Saharan Africa. It is essential for the livelihoods of many poor farm households and supplies fresh vegetables at low prices to the nearby cities (Alebel B. Weldesilassie et al., 2009). Tekete (2017) reported that informal wastewater irrigation contributes 60% of major and 90% of leafy vegetables to Addis Ababa’s food basket. According to Alebel B. Weldesilassie et al. (2009), the wastewater is the only means of survival, and the average income from wastewater farming accounts for 62% of the total annual household income, with this value ranging from a low of 27% to a high of 97%. Accordingly, 88% of the wastewater farm households report that they benefit from the wastewater.

According to Boischio et al. (2006), production of vegetables with wastewater serves as a means of supplementary income for small businesses through the vegetable marketing channels. Alebel B. Weldesilassie et al. (2009) also reported a similar result as irrigated agricultural activity is the main source of income for the farm households. Ruma and Sheikh (2010) also reported a similar result, and none of the vegetable cultivators produced vegetables purposely for home consumption rather for market supply.

Alebel B. Weldesilassie et al. (2009) conducted a study on the economic value of wastewater irrigation in Addis Ababa (Table 2). The result indicated that each wastewater farmer has 0.72 hectares of average irrigated farmland and wastewater farm income accounts for 62% of the annual total household income, ranging from 27% to 97%. Alebel B. Weldesilassie et al. (2009) also reported that even if irrigation water poses potential health risks to both farmers and consumers, farmers perceive that its benefits be more important than the health hazards. They also stated that nearly 85% and 88% of respondents state that they benefited a lot from the use of irrigation water and it is their only means of survival, respectively. Moreover, income from wastewater farming was the largest share in the total annual income of the farm households, and only 3% of the wastewater farmers indicate that they benefited only a little, though they still work on the farm for lack of livelihood alternatives. On the other hand, about 21% of the wastewater farmers perceive that their health is affected by the irrigation water and they also accept the notion that working on wastewater farm areas and consumption of vegetables produced using the wastewater has health risks which are as expected. This implies that the importance of producing vegetables by irrigating wastewater has a positive significance on the livelihood of the farmers. Furthermore, reports also indicated that wastewater irrigation practices in the Akaki River at Addis Ababa have gotten the attention of researchers due to its high economic benefit (Van Rooijen et al., 2010).

4. Health risk of wastewater-irrigated and contaminated vegetables

Despite the great importance of the urban and peri-urban vegetable production in Ethiopia, as informal agriculture as a food source for the urban community and as income generation means for the poor dwellers, it is subject to numerous constraints and is causing high health risks (Delesa, 2017).

| Farmers’ level of benefit | Name wastewater irrigation area | Akaki Oromia | Akaki Addis | Lafto | Kolfe |
|--------------------------|---------------------------------|------------|-------------|-------|-------|
| Highly benefited          |                                 | 95.9       | 71.4        | 95.7  | 82.5  |
| Somewhat benefited        |                                 | 2          | 21.4        | 4.3   | 15    |
| Little benefited          |                                 | 2.1        | 7.2         | 0.0   | 2.5   |

Source: Alebel B. Weldesilassie et al. (2009).
Heavy metals such as cadmium, copper, lead, chromium and mercury are important environmental pollutants, particularly in areas irrigated with wastewater (Girmaye, 2014). According to Dmello (2000) and Sharma et al. (2006), contamination of vegetables with heavy metals and pesticides poses a threat to consumers. Health risks associated with urban agriculture vary according to the specific activity. Without adequate safeguards, however, wastewater irrigation can cause serious drawbacks to public health and the environment (Boischio et al., 2006; Habbari et al., 2000).

The high concentrations of cadmium, chromium, copper, mercury, nickel and zinc give evidence of industrial pollution traced back to agricultural crops. Long-term exposure to low levels of chemical pollutants can lead to chronic health effects and enhance the risk of adverse pregnancy outcomes. Empirical evidence shows a strong association between drinking water pollution and cancer incidence and mortality. Even though all of these metals have not yet reached the phytotoxic levels, some of the vegetables have surpassed the naturally expected levels. This is particularly true for Cd, Cr, Cu, Hg, Ni and Zn in potato and Cr in onion and red beet. For a long time, it has been known that intake of food that contains high levels of heavy metals poses risks to human health (Pendias & Pendias, 1984; Gebre Van Rooijen, 2009).

The use of wastewater for irrigation is associated with adverse effects on farmers, public health and the environment (Hussain et al., 2001, 2002). Farmers are affected by direct contact with contaminated wastewater, and its use in agriculture causes negative externalities both to public health through the consumption of agricultural produce irrigated with wastewater and to the environment by constantly polluting the groundwater and soils (Alebel B. Weldesilassie et al., 2009; Bond, 1999; Rashed et al., 1995).

The practice of using untreated municipal wastewater for irrigation and raw manure as fertilizer and habit of eating vegetables raw or undercooked are reported to result in risk of infection with intestinal parasites in developing countries (Blumenthal et al., 2000). Infection with vegetable-transmitted parasites and pathogenic bacteria can occur due to occupational exposure or through consumption of vegetables that are contaminated with human or animal excreta without proper washing and disinfection (Beuchat, 1998; WHO, 2006). Unhygienic sewage disposal and absence of its treatment facilities pose potential health hazards through contaminating irrigated food crops with parasites in urban areas of African countries including Ethiopia (Srikanth and Naik, 2004a; Damen et al., 2007; Nyarango et al., 2008; Weldesilassie Fror et al., 2009; Tomass & Kidane, 2012).

Beyene (2015) assessed the potential health risk to Addis Ababa residents associated with vegetable consumption. The result indicated that of the three heavy metals, Pb posed the greatest health risk to both adult and children consumers of vegetables grown in study areas, especially Swiss chard, followed by Ethiopian kale. For both adults and children, heavy metal content in the three leafy vegetables was less than 1.0, indicating that the residents in the Addis Ababa are not exposed to significant health risks associated with consumption of green leafy vegetables.

The study conducted by Van Rooijen et al. (2010) in Addis Ababa, Ethiopia, assessed water quality from urban surface waterbodies and their microbiological contamination. The result indicated that for the use of wastewater in irrigated agriculture, the presence of excreta-related pathogens gives particular reason for caution, especially where irrigated vegetables are grown and consumed uncooked as it is the case in particular in both African cities.

Delesa (2017) conducted an experiment to determine the extent of raw vegetable contamination with parasites that could be transmitted to humans in Nekemte, Oromiya Region, on samples collected from markets. The result indicated a high risk of human infection since parasites which exist in association with these vegetables are capable of infecting humans, especially Cryptosporidium and Giardia cysts are highly prevalent from both farms and markets. The result also shows that there is contamination of pathogenic intestinal parasites from both vegetable farms, Ascaris eggs being the most prevalent in cabbage (41.6%). The results also indicated that cabbage was found to be the most heavily contaminated vegetable by aerobic bacteria (Table 3). Therefore, great attention should be given in using contaminated
Additionally, there is heavy metal contamination of fresh leafy vegetables (lettuce, cabbage and carrots) grown in Nekemte town vegetable farms irrigated with wastewater. Leafy vegetables are often eaten raw or with minimal processing and, if contaminated with pathogenic bacteria, may lead to health hazards.

Poorly handled vegetables are reported to harbor different intestinal parasites such as *Ascaris lumbricoides*, *Taenia* spp, *Fasciola hepatica*, *Hymenolepis nana*, *Echinococcus* spp, *Enterobius vermicularis*, *Trichuris* spp, *Toxocara* spp, *Strongyloides stercoralis*, *Giardia lamblia*, *Entamoeba* spp, *Iodamoeba butschlii*, *Blastocystis hominis* and *Cryptosporidium parvum* (Abougrain et al., 2009; Gharavi et al., 2002; Gupta et al., 2009; Uga et al., 2009). Several studies indicated the prevalence of intestinal parasites in different parts of Ethiopia through microscopic examination of stool samples collected from the suspected human population (Dejenie & Petros, 2009; Legesse & Erko, 2004; Tadesse, 2005). However, research activities to detect parasites from environmental sources such as vegetables are scarce in Ethiopia (Rosa, 2009; Tomass & Kidane, 2012).

Tomass and Kidane (2012) conducted a study to determine the rate of parasitological contamination of vegetables associated with the use of municipal wastewater for irrigation and raw manure as fertilizer on pre-harvest vegetables in Mekelle city and a suburban village by collecting samples of pre-harvest on leafy, fruit and root vegetables and reported that *S. stercoralis* was the most common parasitic contaminant detected in most of the vegetables examined 28 (63.63%) followed by *Taenia* and *Entamoebasp*. However, in “Mariam Dahan” village, the distribution of parasites among the vegetables is different, with *S. stercoralis* being the most frequent contaminant (Table 4).

| Site          | Types of vegetable | Total aerobic mesophilic count | Total coliform count | Fecal coliform count | Total yeast and molds count |
|--------------|-------------------|-------------------------------|----------------------|----------------------|-----------------------------|
| Bordi        | Cabbage           | 4.17                          | 4.04                 | 3.98                 | 4.03                        |
|              | Lettuce           | 4.4                           | 4.04                 | 3.98                 | 3.44                        |
|              | Carrot            | 4.26                          | 4.35                 | 3.59                 | 3.83                        |
| Darge        | Cabbage           | 4.43                          | 4.23                 | 4.12                 | 4.04                        |
|              | Lettuce           | 4.52                          | 4.36                 | 4.33                 | 3.33                        |
|              | Carrot            | 4.4                           | 4.5                  | 4.41                 | 4.3                         |
| M/Sefere     | Cabbage           | 4.12                          | 4.23                 | 4.4                  | 4.26                        |
|              | Lettuce           | 4.05                          | 3.66                 | 3.65                 | 3.88                        |
|              | Carrot            | 3.76                          | 4.54                 | 4.10                 | 4.28                        |
| Bl/Jama      | Cabbage           | 4.05                          | 3.32                 | 4.24                 | 4.35                        |
|              | Lettuce           | 4.05                          | 3.05                 | 4.13                 | 4.35                        |
|              | Carrot            | 4.10                          | 4.31                 | 4.12                 | 4.31                        |
| Bako         | Cabbage           | 4.4                           | 4.04                 | 3.99                 | 3.44                        |
|              | Lettuce           | 4.18                          | 4.26                 | 3.73                 | 3.82                        |
|              | Carrot            | 4.32                          | 4.04                 | 4.06                 | 3.36                        |
| Sibu sire    | Cabbage           | 4.24                          | 4.25                 | 3.69                 | 3.95                        |
|              | Lettuce           | 4.24                          | 4.04                 | 4.02                 | 3.68                        |
|              | Carrot            | 4.35                          | 4.15                 | 3.84                 | 3.44                        |
| Arjo Gudatu  | Cabbage           | 4.1                           | 4.13                 | 3.84                 | 4.18                        |
|              | Lettuce           | 4.4                           | 4.04                 | 3.99                 | 3.44                        |
|              | Carrot            | 4.16                          | 4.31                 | 3.82                 | 4.04                        |

Source: Delesa (2017).
Srikanth and Naik (2004b) reported the health hazards of usage of untreated wastewater in agriculture through the detection of *Giardia spp* and fecal coliforms from pre-harvest vegetables in suburbs of Asmara, Eritrea. Weldesilassie et al. (2009) surveyed the prevalence of intestinal illness among households in relation to the use of wastewater for vegetable production in peri-urban areas of Addis Ababa, Ethiopia; however, these authors did not carry out microscopic detection of intestinal parasites from wastewater-grown vegetables.

A study on parasitological quality of pre-harvest vegetables in Arba Minch, southern Ethiopia, reported that several helminth parasites including *A. lumbricoides*, *H. nana*, *F. hepatica*, *E. vermicularis* and hook worm were recorded on vegetables produced by wastewater (Rosa, 2009).

The use of wastewater to produce food crops, particularly vegetables, is very prevalent in Addis Ababa, Ethiopia. This practice may pose health risks to farmworkers and consumers. Woldetsadik et al. (2017b) conducted a study to evaluate farmers’ perceptions on irrigation water quality, health risks and health risk mitigation measures in four wastewater-irrigated urban vegetable farming sites in Addis Ababa (Table 5). Results indicated that farmers appear informed about the contamination of their irrigation water. Among the perceived health risks, skin problems were the top-rated health risk, while eye burn, sore feet and abdominal pains were rated low across the four farming sites.

According to Woldetsadik et al. (2017b), the highest faecal coliform concentration was exhibited in irrigation water from Lekunda farming site in Addis Ababa. At Lekunda, the proximity of farmlands to resident and cattle houses coupled with almost null proper sanitation service potentially imposes an effect on faecal coliform levels in the irrigation water which potentially affects human health.

The studies that examined the impact of untreated wastewater on health, environment and income in Pakistan indicated higher hookworm infections in farmers and farmworkers who use wastewater for irrigation than those who do not (Ensink et al., 2003). The main risk for the public arises when vegetable or salad crops grown with untreated wastewater are consumed raw. This

| Table 4. Pre-harvest parasitic contamination of vegetables in Mekelle City and Mariam Dahan village, Tigray, northern Ethiopia |
| --- |
| **No.** | **Mekelle Town** | | | **Mariam Dahan village** | |
| Vegetable type | Examined (No.) | Positive No. (%) | Examined (No.) | Positive No. (%) |
| 1 | Lettuce | 21 | 6 (28.57) | - | - |
| 2 | Swiss chard | 59 | 18 (30.51) | 56 | 11 (19.64) |
| 3 | Onion | 10 | 5 (50) | 19 | 12 (63.16) |
| 4 | Cabbage | 15 | 5 (33.33) | 4 | 1 (25) |
| 5 | Tomato | 3 | 1 (33.33) | 3 | 1 (33.33) |

Source: Tomass and Kidane (2012).

| Table 5. Percentage of farmer’s awareness regarding the health effect of wastewater irrigation |
| --- |
| **Farmers awareness on** | **Name wastewater irrigation area** |
| | Akaki Oromia | Akaki Addis | Lafto | Kolfe |
| Effect on producers’ health | 37.8 | 21.4 | 0 | 0 |
| Effect on consumers’ health | 21.4 | 16.4 | 2.2 | 0 |

Source: Alebel B. Weldesilassie et al. (2009).
can be linked to cholera and typhoid as well as to faecal bacterial diseases, bacterial diarrhoea and dysentery among consumers of wastewater-irrigated produce. Municipal and industrial wastewater is a major source of chemical pollutants that could affect human health.

According to Van Rooijen et al. (2010), the health risk occurred by consuming lettuce produced with polluted water is lower in Addis Ababa than in Accra due to less frequent watering and lower faecal coliform counts (Table 6).

Minbale et al. (2019) explained the sequence of hazard index for vegetables grown in wastewater irrigation in Addis Ababa. The result indicated that hazard index was in the order of Swiss chard > lettuce > cabbage > Ethiopian kale > carrot > potato for both adults and children. The relative contributions of Ethiopia kale, lettuce, cabbage, Swiss chard, carrot and potato to the aggregate health risk were 15.20%, 21.44%, 15.56%, 31.09%, 11.16% and 5.56%. The contributions of lettuce and Swiss chard were higher than other vegetables. The hazard index values of carrot and potato indicated a low potential health risk to consumers.

Roro et al. (2019) conducted a study to evaluate the amount and type of heavy metal accumulated in soil and plant tissue through irrigation of untreated, semi-treated and treated wastewater from Lake Hawassa in sweet potato. The result indicated that irrigation of sweet potato with untreated textile wastewater increased the chance of getting higher level of Zn and Cu than Cr.

Desta and Diriba (2016) conducted a study to determine the bacteriological load and safety of some fresh vegetables irrigated with Awetu River water in Jimma town, southwestern Ethiopia, and reported that all the respondents were used Awetu River water without any treatment for irrigation of vegetables that may be eaten raw. They also reported that the prevalence of S. aureus (20.0%) in Jimma in all vegetables was lower than what is mentioned in the study of Halablab et al. (2011) who reported a higher prevalence of S. aureus (51.5%) from Lebanon.

5. Strategies for managing contaminations and ways to reduce health risks
Water use has been growing at more than twice the rate of the population increases during the last century. In rapidly growing urban centers, water has become a fragile and scarce resource in a competing environment. Management of water resources and proper utilization of vegetables

| Kind of risk                      | Health risk                                      | Who is at risk       | How                                      |
|----------------------------------|--------------------------------------------------|----------------------|------------------------------------------|
| Work-related risk (contact)      | Parasitic worms (ascaris and hookworm)           | Farmers/fieldworkers | Contact with irrigation water and contaminated soil |
|                                   | Diarrhea in children                              | Children playing in the farm | Contact with irrigation water and contaminated soil |
|                                   | • Skin infection (itching and blisters on the hand and feet) | Market vendors | Washing vegetables with wastewater |
|                                   | • Nail problems (spoon-formed nails)              |                      |                                          |
| Consumption related              | • Mainly bacterial and viral infections (cholera, typhoid, hepatitis A, diarrhea) | Vegetable consumers | Eating contaminated vegetables in raw |
|                                   | • Ascaris                                         | Children playing in the farm | Licking soil |

Source: FAO (2012).
grown in wastewater has become an urgent issue for urban and peri-urban farmers in order to reduce the risk for illnesses to farmers and consumers.

5.1. Wastewater treatment

As competition for water increases, recycled water is likely to become more important. Recycled water can be used to produce food if properly treated (Van Rooijen et al., 2010). In Addis Ababa, there are two secondary treatment plants that are in operation. According to NEDECO (2002), the wastewater treatment fraction will increase from the present 30% to 53% by 2020. The wastewater treatment capacity of 50–70% of the wastewater flow in the cases of Addis Ababa to reduce the risk for farmers or consumers given the high absolute pollution load (WHO, 2006; Van Rooijen, 2010).

5.2. Washing and boiling/cooking vegetables before consumption

Intestinal parasitic infections are widely distributed throughout the world causing substantial intimidation to the public health, economy and physical and cognitive development, particularly among children in developing countries like Ethiopia. The consumption of fruits and vegetables helps in protecting the human body from a number of diseases. However, eating unclean, raw or undercooked fruits and vegetables is one of the means by which the transmission of intestinal parasitic infections is propagated. Despite the fact that intestinal parasitosis is common in Jimma Town (Fanos & Belew, 2015).

Yusuf and Oluwole (2009) and Beyene (2015) reported that variations in the magnitude of reductions in microorganisms and heavy metals due to washing of vegetables are observed. They further suggested that to reduce the health risk, vegetables should be washed properly before consumption as washing can remove a significant amount of aerial contamination from the vegetable surfaces (Table 7).

In boiled vegetables, heavy metal contents reduced significantly. According to Banerjee et al. (2011), Cu content in unwashed brinjal exceeds the safe limit. However, in boiled vegetables, Cu content did not exceed the safe limit.

Control measures aimed at protecting agricultural fieldworkers in wastewater irrigation and crop handlers include the provision (and insistence on the wearing) of protective clothing, the maintenance of high levels of hygiene and immunization against (or chemotherapeutic control of) selected infections (IWMI, 2006; WHO, 1989).

According to FAO (2006, 1992), risks to consumers can be reduced through cooking the agricultural product before consumption and by high standards of food hygiene, including water availability, which should be emphasized in the health education associated with wastewater use schemes. Local residents should be kept fully informed on the use of wastewater in agriculture so that they and their children can avoid these areas.

| Indicator organism       | Washing method                                      |
|--------------------------|-----------------------------------------------------|
|                          | Unwashed                                            |
|                          | Washed with portable tap water and rinsing for 2 min |
| Feacal coliform (log10MPN/100 g) | 4.23<sup>a</sup>                                   | 3.43<sup>b</sup>          |
| Helminth egg (egg/100 g) | 2.2                                                 | 0.8                       |
| Actual egg count (range) | 0–6                                                 | 0–3                       |

Source: Woldetsadik et al. (2017).
Tekeste (2017) conducted a study to assess and analyze major on-farm wastewater hazard reduction adoptions in Addis Ababa and reported that about 41.67% of the interviewed farmers use on-farm wastewater hazard intervention measures. The major on-farm adoption measures in the study area are simple filtration (15%), safer application (less contaminating irrigation methods) (10%), crop restriction (8.33%) and irrigation cessation (8.33%).

5.3. Filtration techniques
Filtration systems remove disease-causing microorganisms from polluted water by trapping them in the filtration media. Once they have been trapped, they die or are removed by exposing them to heat or predators. Large pathogenic microorganisms such as parasites are generally trapped mainly by straining, while smaller organisms such as bacteria and viruses are trapped by adsorption (FAO, 2012). There is a wide range of filtration systems, but slow sand filters are probably the most appropriate to treat irrigation water. Sand filters remove pathogenic microorganisms from polluted water by first retaining them in the filtration media before they are eliminated.

5.4. Irrigation methods
The use of appropriate irrigation methods has also been outlined as one of the health protection measures in wastewater-irrigated agriculture (FAO, 1992, 2002). Based on health impacts from wastewater, the WHO has classified irrigation methods into three categories: flood and furrow, spray and sprinkler and controlled irrigation methods (FAO, 1992, 2002). Flood and furrow irrigation methods apply water on the surface and pose the highest risks to fieldworkers and more so when protective clothing is not used (Blumenthal et al., 2000). Spray and sprinkler are overhead irrigation methods and have the highest potential to transfer pathogens to crop surfaces, as water is applied on edible parts of most crops and aerosols also result in a wider movement of pathogens.

Furrow irrigation method also minimizes contact between the irrigation water and edible parts of high growing vegetables such as green pepper but uses much more water (FAO, 1992, 2012).

Controlled irrigation techniques such as drip irrigation offer farmworkers the most health protection and also result in minimal pathogen transfer to crop surfaces because water is applied directly to the root (FAO, 1992). However, controlled irrigation techniques are comparatively the most expensive and are also prone to clogging as polluted water has high turbidity levels. They can reduce contamination on crops by 2 to 4 log units (WHO, 2006). Irrigated by using watering cans should be also reduced in order to decrease splashing of contaminated soils onto the surface of vegetables.

5.5. Cessation of irrigation before harvesting
Most pathogens are easily killed by harsh environmental conditions such as heat, sunlight and lack of water. So, even if these pathogens get on vegetable crop’s leaves from contaminated water, they will die off by ceasing irrigating for vegetables a few days before you harvest them. Generally, more days of withholding irrigation before harvesting leads to a higher decrease in vegetable contamination. However, withholding water also leads to poor crop growth and therefore reduction in yields where the climate is hot. In the cooler Addis Ababa, for example, it is easier to stop irrigation for a few days than in the hotter areas (Van Rooijen, 2010).

Correct water management during application can minimize soil and crop contamination. The timing of irrigation, including frequency, is important not only for pathogen reduction but also for other toxicities (FAO, 1992). For reducing pathogens, one of the most widely documented field water management measures is cessation of irrigation. Farmers cease irrigation a few days before crops are harvested to allow for pathogens to die off due to exposure to unfavorable weather conditions such as sunlight (Shuval et al., 1986). About 99% of detectable viruses have been reported eliminated after two days’ exposure to sunlight, supporting regulations that a suitable time interval should be maintained between irrigation and crop handling or grazing time (Feigin et al., 1991).
Keraita et al. (2007; 2012) reported that the experiment in Ghana showed an average daily reduction of 0.65 log units of thermo-tolerant coliforms on lettuce with yield losses.

Studies by Van Rooijen (2010) indicate that for water-sensitive crops that need daily irrigation such as lettuce, you can withhold irrigation for 2–4 days before harvesting to reduce contamination with little loss of yield. Vegetables that are less water sensitive, such as green pepper, onions and cabbage, can do without irrigation for longer without significant losses of yields. For such crops, escape irrigating for more than four days before harvest to minimize contamination.

5.6. Crop selection

Some crops are more prone to contamination from pathogens, salinity and toxicity than others. Proper crop selection will lead to decreased human health risks. For instance, crops with their edible parts more exposed to contaminated soils and irrigation water, like low-growing crops and root and tubers, will be more prone to pathogen contamination (Keraita et al., 2012).

However, Sisay Teklu (2010) indicated the main constraints related to wastewater irrigation agriculture in Ethiopia. Among the constraints, the major ones are lack of policy and strategy on the safe use of wastewater in agriculture, insufficient access to non-contaminated or clean water, health problems resulting from the usage of contaminated and polluted water, poor water use efficiency and lack of skilled technicians for promoting and training urban agriculture skills. Moreover, Delesa (2017) also suggest that, due to the potential microbiological risks of vegetables, it should be treated directly with certain disinfectant before consumption and to develop highly effective treatments for removing pathogens from a wide range of raw produce.

6. Conclusion

Untreated, partially treated or diluted wastewater has been widely used for agriculture in most urban and peri-urban areas of developing countries. Widely produced commodities in urban and peri-urban agriculture are horticultural crops, predominantly vegetables. Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, vitamins, minerals and fibers required for human health.

Vegetables require a constantly available and a high amount of water for better growth and yield. They need to be irrigated on everyday. Due to low access to adequate clean water, the major sources of irrigation water in urban areas are heavily contaminated and untreated (Ashebir et al., 2007). Since conventional treatment is very costly, most wastewater is allowed to be dumped, untreated, into waterbodies or onto the land and use as source of irrigation to cultivate vegetable crops. However, for this reason, various undesirable microorganisms may be present at the time of growth on the surface of vegetables and their tissue. About 60% of the city’s vegetable consumption, particularly leafy vegetables, is supplied by urban farmers who irrigate their crops using the polluted river. This has a potential adverse effect on human health. The use of wastewater in agriculture has both positive and negative potential impacts on crop production, public health, soil resources and ecosystems (Hussain et al., 2002; Scott et al., 2004). Currently, using untreated wastewater in agriculture is controversial due to its combination of benefits and negative health impacts. Thus, the objective of this paper is to review the benefits and potential health risks in wastewater-irrigated vegetables in urban and peri-urban areas in Ethiopia and to assess the level of contamination for vegetable farms irrigated by wastewater.

Urban and peri-urban agriculture can offer wide-ranging benefits. It can contribute substantial amounts to the proportion of food consumed in the city. Urban and peri-urban agriculture increases the quantity and quality of food available for consumption and provides nutrition and income which improves the urban environment by using the organic solid and liquid wastes of the city, provides aesthetic value to these areas and helps to achieve optimum land. Studies indicated that a significant
In conclusion, in Ethiopia, the wastewater is the only means of survival and the average income of the households. Despite the great importance of irrigating vegetables with wastewater, as a food source for the urban community and as income generation means for the poor dwellers, it is subject to numerous constraints and is causing high health risks. However, depending on reviewed documents, to assess the potential contamination and health effects of wastewater-irrigated vegetables in urban areas in Ethiopia, the present review recommends that. Currently, with increasing population and rapid urbanization, irrigation water requirement has been growing in rapidly growing urban centers, and water has become a fragile and scarce resource in a competing environment. Management of water resources and proper utilization of vegetables grown in wastewater irrigation has become one option in developing countries for farmers as well as consumers in urban areas in order to ensure food and nutritional security. Wastewater should be managed properly (by application of different wastewater treatment techniques, washing and boiling/cooking vegetables before consumption and proper handling of vegetables) to reduce contamination by frequently occurred parasites and their health impact, can help alleviate malnutrition especially for children of poor households. In addition, maintaining the hygiene of the worker and the vegetables too has the most significant effect in reducing worker and consumer health hazards. To minimize the risk of health risk and to be more benefited from wastewater irrigation in Ethiopia, wastewater treatment technologies should be properly applied and policies and strategies should be desirable for proper domestic and industrial wastewater disposal and utilization technique.

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Author details
Dejen Gashaye 1
E-mail: dejengashaye@gmail.com

1 Institute of Technology, Hydraulic and Water Resources Engineering Academic Program, Debre Markos University, Debre Markos, Ethiopia.

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