Chapter

# Microbial and Chemical Contamination of Vegetables in Urban and Peri-Urban Areas of Sub-Sahara Africa

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## Abstract

Most farmers in urban and peri-urban areas in West Africa have limited land, so practice farming systems targeted at the production of high-value crops used in urban diets, especially exotic vegetables. Moreover, rapid urban population growth and adverse climate change are causing increased demand for food and water, leading to water scarcity in those cities. The intense pressure of increasing food demand in cities pushes small farmers to depend on untreated wastewater, undecomposed manure, and pesticides for their production, which negatively affect the health of the population. This chapter presents an overview of the identification of pathway and levels of vegetables contamination in SSA and the identification of interventions employed to reduce public health risk. The microbiological and chemical assessment of irrigation water, fertiliser and vegetable samples collected from farms and markets in SSA revealed their contamination with pathogenic bacteria above the recommended standard of WHO and ICMSF. They were also contaminated by heavy metal above the safe limits by FAO/WHO and pesticide residues. The treatment of irrigation water, proper composting of manure and appropriate use of pesticides could be complement disinfection of vegetables before consumption to reduce public health risk.

**Keywords:** West Africa, vegetables, water scarcity, fertiliser, pesticides

## 1. Introduction

Agriculture is becoming less beneficial to rural farmers in the Sahelian region of West Africa (WA) because of the population explosion, severity and persistence of climate change, scarcity of irrigation infrastructure, degradation of the environment and slow pace of technology change amongst other factors. These challenges have resulted in a large number of rural farmers migrating to cities in search of social and economic opportunities and its accompanying increase in urban food demand [1, 2]. Most farmers in urban and peri-urban areas have limited land, and so practice farming systems targeted at the production of high-value crops used in urban diets, especially exotic vegetables. These farming systems, known as urban and peri-urban agriculture (UPA), have evolved in different African cities, and in WA involves 20 million people essentially farming for subsistence and/or income generation [3–5]. The contribution of urban agriculture (UA) in strengthening the living conditions of urban Africans is unknown or is seen as a small role in the fight against chronic hunger [6, 7]. The urban population involved in urban UA in Africa is estimated at 50% in Ghana [8, 9], 46% in big cities in Mali [10], 80% of families in Brazzaville, 68% in six Tanzanian cities, 45% in Lusaka, 37% in Maputo, 36% in Ouagadougou and 35% in Yaoundé [11, 12].

In Mali, agriculture contributes about 23% of export earnings and 40% of gross domestic product (GDP) [13], with 5.1% growth rate in 2019 [14]. Vegetable production in Malian cities is usually done on open lands along streams, rivers and roadsides. Due to the inaccessibility of clean irrigation water and the high cost of chemical fertiliser, urban and peri-urban farmers use drainage water and untreated animal waste for production. They are also involved in unselective use of pesticides [15, 16] . These indiscriminate practices negatively affect the health of the population [17–19].

The primary public health problem associated with the consumption of vegetables produced using untreated irrigation water in WA include contamination with pathogenic microorganisms such as *Escherichia coli* [20]. Helminths transmitted to crops through soil are also responsible for some parasitic diseases prevalent in sub-Saharan Africa (SSA) [18, 21, 22]. Studies in West African countries have generally revealed high levels of harmful microorganisms, heavy metals and pesticide residue in irrigation water and vegetables [23–25] far exceed recommended levels set by World Health Organisation (WHO) [26] and International Commission of Microbiological Specifications for Foods (ICMSF) [27]. Many authors [16, 19, 28] also reported high contamination levels of lettuce with pesticide residue and *Salmonella* species in WA. Other biological and chemical contaminants of water for UPA in WA include dye effluents from textile dyeing activities and industrial and domestic waste. The effective wastewater treatment published by WHO [26] is impracticable in most parts of SSA due to high cost. Wastewater treatment for urban vegetable production is therefore currently not a realistic option for WA, and banning the use of untreated irrigation water will also threaten many livelihoods, affect urban vegetable supply, and will therefore be-contrary to poverty alleviation. In order to mitigate these problems, the characteristic of UPA has been reviewed for major cities in SSA countries such as Ghana [29], Burkina Faso [30], Kenya [31], Nigeria [32] etc. The present chapter reviews the identification of pathway and levels of vegetables contamination and also the identification of interventions employed to reduce public health risk without compelling farmers to change their cropping system or water sources.

## 2. Material and methods

For this study, research was conducted using scientific papers, books, reports and statistical data from WHO to quantify the level of vegetable contamination and determine key points where necessary interventions could be applied to reduce public health risks in SSA. The concept is based on the biological and chemical identification of irrigation waters, fertilisers and vegetables, pre- and post-harvest risk management strategies for pathogens. Microbiological analysis and helminth eggs were done using standard methods of ISO and standard morphological characteristics, respectively. Heavy metals and pesticide residues were quantifying by atomic absorption spectrophotometry and Gas Chromatography, respectively.

## 3. Contribution of urban and peri-urban agriculture to food security and livelihoods in African cities

Food insecurity is a significant problem in Africa due to rapid urbanisation as urban needy people spend 60–80% of their income on food which, is of low quality and quantity [5, 33]. This food insecurity pushes the rural population to migrate to cities in search of better living conditions. UPA is very beneficial in Africa as it supplies vegetables to urban areas within 30 km radius and this contribute about 70% of their food's needs [34]. In the short term, it increases food security, diversification, food self-sufficiency, earnings, job creation and encourage the use of municipal waste as composts [35, 36].

## 4. Challenges of vegetables production in SSA

The lack of training of farmers in West Africa on education on innovative agricultural practices and agricultural extension affects vegetable production by causing the yield loss. The yield loss negatively impacts the incomes of farmers and their means of subsistence. Some agricultural practices such as irrigation of vegetable farms with contaminated water, the use of animal or human wastes, pre and post-harvest handling practices, transportation, storage and processing are factors that contribute to bacterial and fungal contamination of vegetables [25, 28, 37–40]. In addition, contaminated water (irrigation water) used to wash vegetable from the farm before they are put on sale are probable factors contributing to parasitic contamination on soil and transmission to vegetables [37].

## 5. Quality of organic fertilisers and irrigation water used for vegetable production

### 5.1 Quality of organic fertilisers

One of the good agricultural practices is the use of organic and inorganic fertilisers that increase soil fertility and plant quality [41]. These two fertilisers provide essential food components for the development of the plant [42]. Similar to other African countries, fresh organic manure and compost are the commonly used soil fertility improvement materials in Malian cities [43]. However, the application of organic manures promotes microbiological contamination of soil and vegetables [15, 37, 44, 45].

### 5.2 Quality of irrigation water used for vegetable production

Rapid urban population growth and adverse climate change in Africa are causing increased demand for food and water, leading to water scarcity in cities. The intense pressure of increasing food demand in cities is pushing small farmers to depend on untreated wastewater for their production [46]. Wastewater, rich in organic matter, is available, freely (because it comes from stagnant streams or lakes), and is beneficial for soil fertility [47]. However, wastewater has a high level of contamination with microbial pathogens and chemicals. African cities do not have adequate sewage facilities, pushing the population to dump waste directly into waterways [48]. Small urban farmers find it difficult, often impossible to get good quality water (visually clear water), and eventually use this water (of poor quality) for their production. Studies in WA have shown high levels of contamination of irrigation water with foodborne pathogens (faecal coliforms) above WHO [26] recommended standard [49–51]. Akinde et al. [28] found total coliforms (1.27 $10^4$ CFU/ml), *Klebsiella pneumoniae* (27.9%), *Pseudomonas aeruginosa* (26.2%), *E. coli* (8.2%), *Citrobacter*, *Enterobacter* and *Salmonella* spp.) in Nigeria. These pathogens are from the faeces of animals or humans or domestic and industrial waste [52, 53]. They cause public health problems because they can be a source of disease amongst consumers of these vegetables (especially those consumed raw) [54]. These diseases can be infectious and are amongst the leading causes of death in the world [55]. In developing countries, 80% of death are from water-related diseases [56]. Several epidemiological studies have shown links between the use of wastewater in agriculture and the risk of infections (viral, protozoan, intestinal and bacterial) amongst farmers, their families, and consumers [38, 39, 57]. Several studies conducted in WA over the last decade have linked vegetable contaminations with helminth eggs such as *Ascaris lumbricoides*, *Hymenolepis diminuta, Trichuris trichiura, Fasciola hepatica* and *Strongyloides larvae* to use of untreated irrigation water [49, 51, 58]. At-risk groups are farmers, consumers, children, especially the general population living in the vicinity of an unsuitable irrigated water field [59]. Amoah et al. [18] found higher prevalence of soil-transmitted helminth (6–16.$10^3$ eggs/L) in wastewater irrigation areas in developing countries.

Heavy metals pollution in agricultural soils and water are mainly from anthropogenic sources such as fertilisers, waste disposal, mining, smelting, sewage sludge, urban effluent and vehicle exhausts [60]. Heavy metals such as lead, cadmium and mercury, have been found in irrigation water in many countries in WA and their concentration varies depending on the region of crop as well the type of metals [24, 51, 61, 62]. The source of heavy metal contamination in water in Mali include industrial and domestic waste and dye effluents from textile dyeing activities (which are poured directly into rivers or drains (that flow directly into rivers) without receiving suitable treatment).

Many pesticides are not easily degradable, some persist in the soil, penetrate surface and groundwater and contaminate the environment. They often penetrate the organism according to their chemical properties and cause bioaccumulation. The duration of pesticides in the soil varies from a few hours to several years in the case of organochlorine pesticides [63]. The aerial drift of pesticides, the wind erosion of treated soil and the volatilisation of applications in terrestrial environments are mostly responsible for pesticide contamination of aquatic ecosystems [19]. Farmers in Africa generally do not follow safety measures in the formulation and application of pesticides and ignore the environmental impacts [64, 65]. In general, pesticides found in water in Africa are organochlorines [66].

## 6. Quality of fresh vegetables in farms and markets in SSA

Enteric bacteria can contaminate vegetables during cultivation, harvesting, transportation and processing. A study by Alemu et al. [67] in Ethiopia showed the contamination of 48.7% of the vegetables sold (cabbage predominated with 71.9%) in Arba Minch Town (Southern Ethiopia) by bacteria. The most frequently detected contaminant amongst vegetables was *E. coli* (31.4%). Microbiological analysis of endives, tomatoes, and ready-to-eat raw produce sold on the market in Côte d'Ivoire revealed a high level of contamination by faecal coliforms, *Enterococcus* and *Pseudomonas*. Washing of vegetables reduced microbial load [68]. Cabbage, lettuce, and scallions sold in Abura and Kotokuraba markets in Ghana were found to be contaminated by *E. coli*, *Enterobacter* spp., *Klebsiella* spp., *Salmonella* spp., *Serratia marcescens*, and *Staphylococcus* [40]. The resistance of infectious stages (cysts, oocysts, and eggs) of helminth parasites on irrigated vegetables to chemicals disinfectants, high temperatures and desiccation is responsible for their high prevalence in developing countries [69]. Alemu et al. [67] reported that vegetables sold in markets in Ethiopia contained in a bucket with water and without prior washing had a high risk of being contaminated by parasites. The level of produce contamination depends on people's health habits as well as sanitation in a particular environment, such as the location of market as an example and the water (mainly pipe borne water which contained low parasites) used to wash vegetables [70]. Adamu et al. [71] reported that helminth parasite contamination of vegetables sold in Maiduguri (Nigeria) market was due to irrigation water. Illiteracy and insufficient public health awareness lead residents to indiscriminate defecation resulting in helminth contamination of water bodies and agricultural land. Animal and human waste used as manure to supplement fertilisers and contaminated water used to wash produce such as lettuce and carrots from the farm before they are put on sale also promote parasitic contamination [37]. Lettuce, which is a crop positioned close to the ground, easily become contaminated by geohelminths during heavy rains and floods [70]. Unhygienic harvesting methods, as well as hands contaminated with faeces, and sprinkling of water on vegetables to make them fresh, can also contaminate vegetables, as is the case with tomatoes [72]. Helminth infection in SSA, results in skin irritation, blood and nervous disorders, tumours, infertility problems, breathing difficulties, nausea, vomiting and endocrine disruption amongst others [73, 74]. The risks linked to the consumption of vegetables irrigated with untreated water were described in the study of epidemics. Studies on the risks of typhoid, gastroenteric, cholera, shigellosis, hepatitis and amebiasis due to the consumption of vegetables irrigated with untreated wastewater have been reported [75, 76]. In South Africa, several food-borne disease outbreaks partly attributed to vegetable contamination have been reported particularly for school children [77–79]. Newell et al. [80] reported many cases of food-borne disease outbreaks from 1990 to 2010 in Ghana, Nigeria and Sudan due to the consumption of untreated irrigated vegetables. *Salmonella* spp., *Campylobacter* spp., *E. coli* and *Listeria monocytogenes* were identified as the major bacterial pathogens in the aforementioned outbreaks. In Mali, outbreak of foodborne diseases sometimes occurs, but there are not official records on them.

The content of heavy metals in plants depends on their ability to absorb them selectively and on the characteristics of the soil [81]. Heavy metals can also be absorbed by the aerial parts of plant leaves from dust and atmospheric precipitation in polluted areas, or from the fossil fuels used for heating, traffic density, fertilisers, and protective agents [82, 83]. Vegetables may also be contaminated with trace metals from the water used by farmers to wash vegetables before they are placed on the market [84]. Vegetables grown in urban and peri-urban areas are more likely to be contaminated with high levels of heavy metals. However, the levels of heavy metals in vegetables grown in Ghana were below the recommended dietary thresholds [85]. Plant roots and leaves accumulate high concentration of metals (from soil and irrigation water) relative to other crops and parts of plants [86, 87]. The closer the plant is to the soil, the higher the transfer of heavy metals from the soil to the plant. Ali et al. [88] reported high levels of heavy metal contamination on ready-to-eat lettuce and spinach in Nigeria, which were above the safe limits by FAO/WHO [89]. Some of these metals are toxic to humans, even at low concentrations. Ogunkunle et al. [90] found high concentrations of lead in cabbage and lettuce (1.840 and 1.930 mg/kg respectively) that were above the WHO maximum value or the level authorised by the FAO. Meanwhile the concentrations of cadmium, zinc, copper, cobalt, manganese, and nickel were below the standards recommended by WHO. Aber et al. [84] revealed that cadmium, lead, and mercury were major contaminants in vegetables sold on the streets of Nigeria. Lente et al. [61] reported lead (1.8–3.5 mg/kg), contamination of vegetables irrigated with waste and ground water above the safe limits in Ghana. Taghipour & Mosaferi [90] also found high level of contamination of kurrat, onion, and tomatoes by heavy metals, which was higher than the standard levels. Excess lead and cadmium in food can be responsible for many diseases, especially nerve, bone, kidney and cardiovascular disease that can lead to death [92, 93]. The rapid growth of industries is of concern to the population regarding the potential accumulation of heavy metals in plants, water and soil [94, 95]. Studies have shown that excessive assimilation of heavy metals by plants gives them toxic effects which could enter food chains, biomagnify and be a source of potential threat to the health of the population [96–98].

In controlling pests, smallholders rely heavily on pesticides in the production of vegetables [65]. Bertrand [99] reported the use of 50% herbicides in horticulture in Africa, more than 20 active ingredients are used in Benin and Senegal [101]. According to Kariathi et al. [101], the largest consumers of tomatoes contaminated by pesticides are the most exposed. The intense application of pesticides has also affected the environment, water and air [102, 103]. Fresh produces contain high levels of pesticides compared to other types of food, and their consumption poses a high risk to human health [19, 103, 104]. The most widely used synthetic insecticides active ingredients are organophosphates, carbamates, pyrethroids, and organochlorines and their toxicity can be very high in the short term or the long term [105]. The misuse of pesticides in SSA is due to the high level of illiteracy, lack of training, ignorance, maladjustment to the product and insufficient knowledge of the pests and diseases [106]. The level of toxicity of pesticides varies depending on the toxicity class [100]. Factors such as type of pesticide, location of pesticide deposition, temperature, pH, duration of pesticide sprayed during growth, duration of treatment and nature of the vegetable influence the stability of the pesticide [107]. The health effects of pesticides appearing on the body of users after contamination, depend on the duration and extent of the exposure. These effects can range from mild skin irritation to congenital disabilities, tumours, genetic changes, blood and nervous disorders, endocrine disruption and even coma or death [108, 109]. Pesticides also affect the reproductive, endocrine, and immune systems [110] and symptoms such as headache, stomach and chest pain, skin and eye irritation, breathing difficulties and vomiting amongst farmers in Tanzania have been reported [74]. Better education on handling practices and sometimes stricter controls on the distribution of pesticides is necessary to minimise their effects on the health of sprayers and vegetable consumers.

## 7. Health risk management strategies

### 7.1 Pre-harvest risk management measures for pathogens

Risk management strategies in agriculture include biological control, integrated pest management and the use of physical barriers such as greenhouses or plastic tunnels [111]. Guideline procedures have been published by WHO [26] for the management of health risks in wastewater irrigation. These instructions are described in eight methods: wastewater treatment; crop restriction; wastewater application techniques that minimise contamination; withholding periods to allow pathogen die off between last irrigation and consumption; hygienic practices at food markets and food preparation measures; health and hygiene promotion; produce washing, disinfection and cooking; and chemotherapy and immunisation. The methods to identify and quantify the public health risks and decisions by risk managers to determine appropriate control measure strategies are as follows: "(1) quantitative microbial risk assessment (QMRA) to determine the overall reduction of essential pathogens to achieve the health objective for different routes of exposure; (2) determination of the necessary degree of reduction of pathogens to achieve the health objective (3) knowledge of the number of pathogens in untreated wastewater is essential; (4) choice of control measures or intervention methods to achieve a safe level of reduction of pathogens; and (5) establishing the level of monitoring of treatment verification according to the pathogen or an indicator e.g. *E. coli* in the cultures or the final effluent from the treatment plant". Amongst all these methodologies, the implementation of QMRA is perhaps the most important. It provides a scientific basis for comparing the types of risks and solutions. Studies on QMRA in the health field are difficult to adopt due to insufficient information provided by stakeholders and limited resources [112]. Public health and wastewater treatment can be improved through the provision of adequate sanitation and wastewater treatment infrastructure like waste stabilisation ponds. This infrastructure will allow better management of wastewater while improving its quality; evaluate control during and after harvest as well as human exposure [113]. The quality of water used for irrigation can be improved after the first treatment. Primary treatment of wastewater involves different options such as sedimentation or clarification of solid waste within the water; chemically-enhanced sedimentation and up flow anaerobic sludge blanket reactors [114, 115]. Secondary treatment is necessary for complete elimination of biological and chemical contamination. It is possible to do the secondary treatment by various methods, including artificial wetlands, seepage-percolation, and anaerobic upwelling reactors [116]. Hygienic measures can also be applied by farmers to minimise the risk of contamination and the spread of sewage infections. These measures constitute farmers' awareness of the dangers; wearing gloves and boots, a vaccination campaign against diseases transmitted by wastewater; changing irrigation methods, and washing the arms and legs after using wastewater [117]. On-farm risk management measures for pathogens are only possible with the implementation of appropriate practices at the farm level, such as the use of good quality water and appropriate methods for irrigation, wearing gloves and boots by farmers, regular disinfection of work tools after use.

Fertiliser application measures, fundamental amendments, as well as sanitary measures, must be applied to the soil [117]. The fundamental amendments are not to produce edible plants, especially if inorganic contaminants contaminate the soil. The application of limestone is useful for soils contaminated by a high level of sodium. Fertiliser should not be used on acid soils to avoid chemical reactions. In this case, specific management of acidic soil treatment is necessary while selecting crops that do not accumulate hard metals. For calcareous soils, there is no appropriate treatment. Soil treatment time varies depending on the type and degree of contamination [118]. Drip irrigation with treated wastewater and appropriate planting area is also an effective way to reduce pathogen contamination of crops [119]. The type of fertiliser used in urban vegetable production in Africa is dependent on the crop cultivated. Fresh organic manure and compost are commonly used for vegetables production in African countries compared to synthetic fertilisers. Fallow system in SSA, important in agriculture, contributes to improve soil fertility [43, 120].

### 7.2 Post-harvest risk management measures for pathogens

Measures used for post-harvest risk management of pathogens include improving the harvesting process, cleaning harvested vegetables, good sanitary measures during transportation, selling and disinfecting before consumption. Vegetables should be cut above a certain height of soil (greater than 10 cm) and washed in the field to reduce contamination by pathogens. Transport vehicles must be well equipped for the specific produce and disinfected before and after transport. In this case, the vegetables must be put in hermetically sealed sterile boxes. Vegetables once on the market should be cleaned, put on clean shelves while being covered by clean covers for sale. Wash rim at the market must be changed regularly. In the kitchen, vegetables should be kept in a well cleaned place and disinfected before consumption, especially those consumed raw. Cooking can also result in about 5–6 log reductions in pathogen loads on vegetable consumed uncooked as lettuce [26]. However, there are a combination of food preparation measures that have small reductions of pathogens of leafy vegetables like lettuce consumed uncooked. This whole process helps reduce biological contamination. Chemical contaminants (heavy metals and pesticide residue) are impossible to remove once absorbed [121], hence all potential sources of contaminations must be addressed.

#### *7.2.1 Sanitisers used to decontaminate harvested vegetable produce*

Disinfection of vegetables before consumption is necessary to reduce microbial numbers. Several factors affect the effectiveness of disinfection including the type of disinfectant, the susceptibility of pathogens to antimicrobials and their topographic characteristics. For example, the skin of vegetables made of a multi-layer hydrophobic cuticle of cutin, makes their surfaces highly water-repellent [122]. Nonetheless disinfection remains important in reducing microbial contaminations.

##### *7.2.1.1 Tap water*

For centuries, tap water has been used to decontaminate vegetables. A survey in Lomé on the use of disinfectants in households revealed that 8% of consumers cleaned vegetables with water [123]. Coulibaly-Kalpy et al. [63] in Côte d'Ivoire showed that washing tomatoes and endives with tap water for 10 min reduced the rate of faecal coliforms, *Enterococci* and *Pseudomonas* by more than 70%. However, Subramanya et al. [124] showed a small reduction (one log CFU/ml) of the bacterial load on the coriander leaves washed with tap water. Traoré et al. [125] also have showed that tap water was not effective in reducing faecal coliforms on lettuce (1.3, 1.6 and 1.9 log CFU/100 g at 5, 10 and 15 minutes, respectively). In addition, Bhilwadikar et al. [122] signalise that tap water was not very effective (11.1% to

23.7%) in reducing the residue of dimethoate, pirimiphosmethyl and malathion in potatoes. Amoah [126] demonstrated that water is not very effective for removing helminth eggs.

*7.2.1.2 Bleach (sodium hypochlorite: NaClO)*

Bleach is used as a disinfectant of choice because of its moderate cost, ease of use and safe and environmentally friendly nature [127]. Eighteen percent of families in Lomé used NaClO to disinfect vegetables. Washing tomatoes and endives with NaClO (17.8 mg/l) solution for 10 min reduced the rate of faecal coliforms, *Enterococci* and *Pseudomonas* by more than 95% [68]. Disinfection of lettuces leaves in Mali for 5(0.00855 ppm), 10(0.00570 ppm) and 15 min (0.00285 ppm) in NaClO solution led to 2.5, 2.8 and 3.5 log reduction in faecal coliforms and complete elimination of *Salmonella* spp. [125]. However, the same authors [128] previously obtained complete disinfection of lettuce by using 2.6 mg/l of bleach for 15 min, which did not affect its quality and the chlorine residues on the produce was less than the maximum acceptable value (5 mg/l) in drinking water [129]. Using sodium hypochlorite at higher concentrations may give much better results, but have toxic effect on the human body cells [51].

*7.2.1.3 Potassium permanganate ($KMnO_4$)*

Potassium permanganate is a powerful oxidant. In Lomé, 22% of consumers washed vegetables with potassium permanganate solution [123]. Traoré et al. [125] reported complete disinfection of *Salmonella* spp. and 3.3 log reductions of faecal coliforms on lettuce with potassium permaganante solution at 170 ppm for 15 min. Cleaning coriander leaves for 10 min in $KMnO_4$ solution (0.1%) eliminated 4 logs CFU of pathogenic bacteria [124]. Subramanya et al. [124] reported 4.1 log reductions of bacterial bioload on raw *Coriandrum sativum* with $KMnO_4$ solution at 0.1% for 10 min. Bhilwadikar et al. [122] revealed the efficacy of $KMnO_4$ (0.001%) in removing residue of carbaryl (93.50%) and methomyl (47.57%) on Chinese cabbage at 15 min. Potassium permanganate at the highest concentration caused purpled discoloration on vegetables (e.g. lettuce leaves) [125].

*7.2.1.4 Vinegar*

A study by [125] showed the effectiveness of 3.2 log CFU/100 g 0.00285 ppm vinegar solution applied for 15 min in reducing the faecal coliforms present in lettuce. Amoah [126] in Ghana reported that dipping lettuce leaves in vinegar 12,500 ppm for 10 min reduced faecal coliforms populations by 3.5 log units. Disinfecting of vegetables with vinegar have sometime negative sensory effects on vegetables [125, 126].

*7.2.1.5 Common salt (NaCl)*

Adjrah et al. [123] point out that 22% of consumers used saline water to disinfect vegetables in Lomé. Traoré et al. [125] demonstrated the efficacy of salt in reducing faecal coliforms and eliminate *Salmonella* spp. populations on vegetables. Amoah [126] in Ghana reported that washing lettuce with salt 35 ppm for 10 min reduced faecal coliforms populations by 2.1 log units. High concentrations of salt, however, deteriorate the external quality of some vegetables such as lettuce [126].

*7.2.1.6 Electrolysed water (EOW)*

It is a powerful bactericide [130, 131]. Studies have shown the use of different types of EOW in disinfection of fresh produce [132–134]. A study by Chen et al. [135] showed the reduction of cyanidine, pelargonidine and 2,2-diphenyl-1-picrylhydrazyle (DPPH) radicals in red cabbage treated with EOW. Many studies demonstrated the effectiveness of EOW against aerobic mesophiles, enterobacteria, mould and yeast contaminating the surface of vegetables [136–138]. The acidic EOW is very effective, but its corrosive and unstable characteristics limit its application [139].

## 8. Conclusions

This chapter has provided a comprehensive discussion of the sources of vegetables contamination in SSA and health reduction intervention approach that can be employed in preventing vegetable contamination. Many farming practices impacted positively and negatively on the health risk of vegetables produced in SSA, particularly in Mali. Generally, vegetables produced are contaminated by pathogenic bacteria, helminth eggs, heavy metals and pesticides. In addition to irrigation water and soil, possible sources of vegetables contaminations include the use of untreated organic manure. It is important to sensitise and train farmers to improve their knowledge in good agronomic practices in order to reduce microbial and chemical contamination of vegetables in the farm. Some of these practices could be the treatment of irrigation water, proper composting of manure and appropriate use of pesticides. These farm contamination reduction measures could complement disinfection of vegetables before consumption to save the health of vegetable consumers.

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