Bacterial and heavy metals contaminations of some vegetables in Mali

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ABSTRACT

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| **Abstract**  Fresh vegetables eaten raw can be agents of transmission of microbes and heavy metals. The frequency and variability of microbes and heavy metals on 96 vegetables from some large production sites in Mali were evaluated. These sites were Bamako, Kati, Baguineda, Samanko, Sikasso and Niono. Among all sites, lettuce, tomato and cucumber from Sikasso were the least contaminated, and the concentrations of total microflora, total and faecal coliforms and *Staphylococcus aureus* on lettuce were respectively 19.88 × 104 CFU/g; 0.85 × 104 CFU/g; 0.73 × 104 CFU/g and 0.48 × 104 CFU/g. The concentrations of microorganisms on tomato following the order of the previous line were respectively 12.48 × 104 CFU/g; 0.24 × 104 CFU/g; 0.00 CFU/g and 0.97 × 104 CFU/g. The contamination of cucumber, still following the same order were 51.15 × 104 CFU/g; 13.33 × 104 CFU/g; 4.24 × 104 CFU/g and 11.03 × 104 CFU/g. However, vegetables from Bamako, Baguineda, Samanko, Niono. Vegetables from Kati were the most contaminated and the concentrations of lettuce were 145,58.104 CFU/g for the total microflora; 56.36 ×104 CFU/g for total coliforms; 23.03 × 104 CFU/g for faecal coliforms, 27.88 × 104 CFU/g for *Staphylococcus aureus*, 0.87 × 104 for *Clostridium* *perfringens* and 31.15 × 104 for *Listeria monocytogenes*. The concentrations of tomato were respectively 85.33 × 104 CFU/g; 12.48 × 104 CFU/g; 9.58 × 104 CFU/g; 17.94 ×104 CFU/g; 0.24 × 104 and 18.67 × 104 CFU/g. And the concentrations of cucumber were 67.64 × 104 CFU/g; 13.70 × 104 CFU/g; 9.82 × 104 CFU/g; 0.61 × 104 CFU/g; 1.28 × 104 and 14.42 × 104 CFU/g, respectively. Among vegetables, lettuce was the most contaminated at all sites except Sikasso and Baguineda where cucumber was the most contaminated.  **Keywords:** Microbial load, Heavy metals, Lettuce, Tomato, Cucumber, Health risk. |

1. **INTRODUCTION**

The United Nations estimates that the global population will reach 9.7 billion in 2050 and the majority of which will be in urban areas in less developed regions (UN DESA, 2017). Sub-Saharan Africa in particular constitutes a large portion of this growth as the urban population is growing rapidly compared to any other region and the urban population is projected to increase rapidly and double over the next 25 years (Saghir & Santoro, 2018). Population growth is resulting in increased urban food demand and changes in diets that serve the emerging middle-class market. In response, many farmers in urban and peri-urban areas practice agricultural methods targeted at production of crops used in urban food especially exotic vegetables.

In Mali, agriculture plays an important role in the provision of employment and foreign trade and engage two-thirds of the country's labor force (IMF, 2015). It contributes about 23% of export earnings and 40% of gross domestic product (GDP) (Sanogo *et al.*, 2019) with 5.1% growth rate in 2019 (World Bank, 2019). Irrigated smallholder vegetable production is usually done on open lands along streams, rivers and roadsides on private or public spaces in the UPAs of Bamako.

In Bamako, urban and peri-urban agriculture focuses on easily perishable vegetables with a short shelf life such as lettuce, tomato, cucumber and cabbage. Among the vegetables consumed raw in Mali, lettuce is one of the most cultivated with a percentage of 69.4 of leafy vegetables (DRA, 2018) and 30.4 of all plants (DRA, 2018). In addition, the increase in urban food demand and increasing urban populations have far exceeded sanitation infrastructure and service delivery. Inadequate and inappropriate urban sanitation infrastructure in Mali has led to untreated wastewater ending up in water bodies used as source of irrigation water for urban and peri-urban agriculture. Due to the inaccessibility of drinking water sources and the search of manure to increase yield, urban and peri-urban farmers end up using drainage water, which negatively affects the health of the population.

Studies conducted in Mali and other parts of West Africa have shown high levels of microorganisms, heavy metals, and pesticide residues in irrigation water and vegetables (Antwi-Agyei *et al.*, 2015, Salawu *et al*., 2015; Dia, 2017; Dao *et al.*, 2018) which far exceed the recommended standards (ICMSF, 2011). Pathogenic bacterias cause public health problems because they can be a source of disease amongst consumers of some vegetables (especially those consumed raw) (Alegbeleye *et al.*, 2018). Heavy metals are toxic to humans, even at low concentrations. Excess lead and cadmium in food can be responsible for many diseases, especially nerve, bone, kidney and cardiovascular disease that can lead to death (Rahimzadeh *et al.*, 2017; Rai *et al.*, 2019). In Mali, very few studies have been carried out on the health risks associated with the consumption and production of irrigated vegetables by small urban and peri-urban farmers. It is therefore important to assess the health risks of irrigated vegetables produced on some large vegetables production sites in Mali. The purpose of this study is to determine the microbiological and physicochemical contaminants of lettuce, cucumber and tomato from large market garden production sites in Mali, in order to assess the health risk associated with their consumption.

1. **MATERIAL AND METHODS**

Samples of lettuce, tomato and cucumber were collected randomly in 2015 from vegetables production sites irrigated with untreated water in Bamako, Baguineda, Kati, Niono, Samanko and Sikasso. Six samples of lettuce were taken per site, for all of the sites selected for the study. Also, six samples of tomato and cucumber were taken at all sites except Bamako (where vegetable farmers produced them less). The sites were chosen based on their accessibility and the presence of active farmers. Thirty heads of lettuce, thirty tomatoes and ten cucumbers were taken from each farm and put in a sterile plastic bag. All samples were labeled, put in a sterile plastic bag, placed in polythene bags and transported on ice to the laboratory where they were analysed immediately or stored at 4ºC within 24 hours before analysis. Lettuce leaves were removed from each head and combined to obtain a composite sample. For the various laboratory analysis, each sample was carefully cutting and mixed to obtain a composite sample. The analysis of the lettuce, cucumber and tomato samples consisted of identifying and quantifying key foodborne pathogens and heavy metals. Pathogenic bacteria identified were total microflora, total and faecal coliforms (CF), *Clostridium perfringens*, *Staphylococcus aureus*, *Salmonella* spp. and *Shigella* spp. and *Listeria monocytogenes*. Total microflora was determined by the method ISO 4833-1 (2013), total coliforms by NF V08-050 (2009), faecal coliforms by NFV 08 060 (2009), *Salmonella* spp and *Shigella* spp. by ISO 6579-1 (2007), *Staphylococcus aureus* by NF V08-057-1 (2004), *Clostridium perfringens* by NF V08-061 (2009) and *Listeria monocytogenes* by ISO 11290 (1997).

Total microflora and coliforms (total and faecal) analysis of lettuce, tomato and cucumber consisted of weighing 25 g of lettuce, tomato or cucumber in 225 ml of sterile buffered saline solution and shaken vigorously for two minutes. A serial dilution was performed in tubes containing the buffered solution and two copies of the broth (one millilitre) inoculated from each dilution. Petri dish was incubated at 37°C for total microflora (on plate count agar (PCA) media), total coliforms (eosin methylene blue (EMB) media), *Salmonella* spp and *Shigella* spp. (salmonella-shigella agar), *Staphylococcus aureus* (mannitol salt agar) and *Listeria monocytogenes* (listeria agar) and 44.5°C for faecal coliforms (EMB media) for 24–48 hours. For the identification of *Clostridium* *perfringens*, the main suspension was incubated for 24 hours at 37ºC to allow the multiplication of bacteria. Following incubation, the suspension was heated at 80ºC for three minutes to eliminate the presence of all bacteria, except *Clostridium* *perfringens*. After cooling, one milliliter of the suspension was inoculated on tryptone sulfite neomycin (TSN) media and incubated at 37°C for 24–48 hours. The number of colonies were counted in each Petri dish and the number of bacteria evaluated in colony forming unit (CFU)/g of sample. The physicochemical analysis of lettuce samples consisted of detecting and measuring lead (Pb), cadmium (Cd) and chromium (cr) by spectrophotometry (photometric flame detector) with an atomic absorption spectrophotometer (Perkin Elmer Analyst 200) after digestion. The level of heavy metals was determined in the irrigation water and the dried samples of lettuce, tomato and cucumber. Vegetable samples were dried in oven for 24 hours at 105°C and one gram of each sample reacted with 10 ml of concentrated sulfuric acid (H2SO4) and nitric acid (HNO3) into a volume ratio of 1:1 and five millilitres of oxygenated water, then mineralised for two hours at 120°C until fumes of sulfur trioxide (SO3) appeared. The sample was cooled and transferred to a 100 ml volumetric flask and then filtrated in another volumetric flask, and the filtrate completed to 100 ml. Lead and cadmium concentrations were determined in the final solution.

**Data analysis**

Each bacteria populations were log transformed before F-test to compare their levels. Where significant difference was found, means were separated using Tukey’s HSD test (P < 0.05). All analysis was accomplished using Genstat 11th Edition.

**3. RESULTS**

**3.1. Bacterial contamination levels on lettuce, tomato and cucumber**

Lettuce, tomato and cucumber showed a large variation in bacterial contamination in Bamako, Kati, Samanko, Sikasso, Baguineda and Niono (Figure 1). Lettuce (48%), tomato and cucumber (32% each) of Kati had the highest frequency of contamination, while vegetables from Sikasso (lettuce (0%), tomato (3%) and cucumber (4%)) had the lowest.

**Figure 1. Frequency of bacterial contamination of lettuce, tomato and cucumber per site**

**3.2. Bacterial contamination levels of lettuce, tomato and cucumber at the six study sites**

Total microflora population on lettuce from Kati was significantly higher (P = 0.013) than Sikasso, but were similar on lettuce from Niono, Samanko, Baguineda and Bamako. *Listeria monocytogenes* population was significantly higher (P = 0.010) than Baguineda and Sikasso, but was similar on lettuce from other sites. Also, *Salmonella-Shigella* on lettuce from Kati and Niono (78.55 × 104 CFU/g, 40.48 × 104 CFU/g, respectively) was significantly higher (P < 0.001) than Bamako, Samanko, Baguineda and Sikasso (31.15 × 104 CFU/g, 21.33 × 104 CFU/g, 6.55 × 104 CFU/g and 0.48 × 104 CFU/g). Total coliform, faecal coliform, *Staphylococcus aureus* and *Clostridium perfringens* levels on lettuce were similar at all sites (Table 1).

**Table 1. Bacterial contamination level of lettuce, tomato and cucumber in all study sites**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Vegetables (104 CFU/g)** | **Bamako** | **Kati** | **Baguineda** | **Samanko** | **Sikasso** | **Niono** |
| **Lettuce** | | | | | | |
| Total microflora | 42.55 (21.15)1 | 145.58 (60.10) | 45.82 (36.80) | 87.27 (49.30) | 19.88 (15.01) | 123.04 (46.8) |
| Total coliforms | 16.61 (14.72) | 60.00 (25.00) | 10.55 (6.17) | 33.10 (26.50) | 0.85 (0.74) | 54.06 (43.30) |
| Faecal coliforms | 8.85 (7.23) | 22.55 (15.01) | 7.52 (4.08) | 15.88 (17.91) | 0.73 (0.60) | 25.58 (26.60) |
| *Staphylococcus aureus*  *Salmonella-Shigella* | 3.64 (1.92)  31.15 (15.10) | 27.88 (5.44)  78.55 (34.20) | 1.09 (1.84)  6.55 (3.54) | 6.42 (4.50)  21.33 (5.94) | 0.48 (0.41)  0.48 (0.41) | 5.94 (4.97)  40.48 (20.48) |
| *Clostridium perfringens* | 4.58 (5.57) | 15.92 (14.06) | 10.58 (14.08) | 17.00 (11.06) | 0.0012 (0.00) | 2.08 (2.65) |
| *Listeria monocytogenes* | 7.52 (6.81) | 31.15 (14.89) | 6.42 (3.38) | 14.79 (5.14) | 1.58 (1.77) | 15.76 (12.75) |
| **Tomato** | | | | | | |
| Total microflora | - | 85.33 (35.00) | 4.48 (4.27) | 31.88 (26.80) | 12.48 (10.74) | 41.45 (23.5) |
| Total coliforms | - | 35.39 (24.19) | 0.36 (0.22) | 10.18 (8.23) | 5.58 (5.28) | 5.58 (4.94) |
| Faecal coliforms | - | 12.85 (10.33) | 0.24 (0.04) | 1.82 (0.86) | 0.00 (0.00) | 2.30 (2.01) |
| *Staphylococcus aureus*  *Salmonella-Shigella* | -  - | 13.21 (10.36)  32.85 (31.00) | 0.00 (0.00)  0.24 (0.03) | 0.12 (0.03)  9.94 (4.86) | 0.97 (0.00)  3.27 (2.16) | 0.12 (0.02)  4.00 (2.52) |
| *Clostridium perfringens* | - | 0.24 (0.05) | 0.002 (0.001) | 0.73 (0.12) | 0.27 (0.17) | 0.21 (0.03) |
| *Listeria monocytogenes* | - | 17.58 (10.42) | 0.24 (0.12) | 7.88 (5.05) | 0.73 (0.50) | 7.52 (5.51) |
| **Cucumber** | | | | | | |
| Total microflora | - | 67.64 (29.7) | 57.82 (32.05) | 23.27 (20.09) | 51.15 (23.82) | 7.03 (5.81) |
| Total coliforms | - | 24.36 (13.94) | 11.76 (10.00) | 5.58 (3.31) | 13.33 (8.29) | 0.61 (0.58) |
| Faecal coliforms | - | 9.82 (5.15) | 8.24 (7.45) | 0.97 (0.51) | 4.24 (4.09) | 0.48 (0.31) |
| *Staphylococcus aureus*  *Salmonella-Shigella* | -  - | 0.61 (0.36)  13.09 (8.11) | 1.21 (1.12)  6.67 (4.73) | 2.18 (2.00)  5.82 (2.38) | 11.03 (10.22)  7.27 (3.87) | 0.36 (0.22)  0.48 (0.40) |
| *Clostridium perfringens* | - | 1.28 (0.20) | 0.00 (0.00) | 0.00 (0.00) | 0.04 (0.04) | 0.60 (0.00) |
| *Listeria monocytogenes* | - | 14.42 (7.10) | 16.85 (11.03) | 4.24 (3.46) | 8.73 (4.85) | 0.24 (0.03) |

1Values in parenthesis are standard deviations.

Total microflora, faecal coliform, *Staphylococcus aureus*, *Salmonella-Shigella Clostridium perfringens, Listeria monocytogenes* populations were however similar for all samples of tomato at all sites. However, total coliform populations of tomato from Kati (35.39 × 104 CFU/g) were significantly higher (P = 0.027) compared to tomato from Sikasso (5.58 × 104 CFU/g), but were similar to tomato from Samanko (10.18 × 104 CFU/g), Niono (5.58 × 104 CFU/g) and Baguineda (0.36 × 104 CFU/g). Significantly higher *Salmonella-Shigella* level (P = 0.017) was observed on cucumber from Kati (13.09 × 104 CFU/g) compared to Samanko and Niono (5.82 × 104 and 0.48 × 104 CFU/g), but was similar to cucumber from Sikasso and Baguineda (7.27 × 104 and 6.67 × 104 CFU/g). Nonetheless, total microflora, total and faecal coliforms, *Staphylococcus aureus*, *Clostridium perfringens, Listeria monocytogenes* populations on cucumber were similar at all sites.

**3.3. Type of bacteria obtained per site**

Lettuce, tomato and cucumber were contaminated with bacteria in all sites. Among bacteria, total microflora (54%) had the highest rate, followed by total coliforms (15%), *Listeria monocytogenes* (13%), faecal coliforms (7%), *Staphylococcus aureus* (5%), and *Clostridium perfringens* (3%) (Figure 2).

**Figure 2.** **Frequency of bacteria in vegetables**

**3.4. Determination of heavy metals in lettuce, tomato and cucumber**

**3.4.1. Heavy metals (Pb, Cr and Cd) concentration levels in lettuce samples**

The mean lead concentrations were higher than the FAO/WHO recommended standard in lettuce (1.46–2.07 mg/kg) at all study sites. Mean chromium concentrations was also higher than the recommended maximum level for production in Bamako, Kati, Baguineda and Samanko (0.20–0.50 mg/kg). There was no trace of cadmium in lettuce from farms at all sites (Table 2).

**Table 2: Concentration (mg l-1) of selected heavy metals in lettuce from farms at all study sites.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sites | Heavy metal | Mean | Range | FAO/WHO recommended maximum concentration for leafy vegetables (mg/kg)1 |
| Bamako | Lead | 2.00 (0.38) | 1.52–2.52 | 0.3 |
| Chromium | 0.50 (0.06) | 0.40–0.59 | 0.2 |
| Cadmium | 0.00 (0.00) | - | 0.2 |
| Kati | Lead | 2.07 (0.95) | 1.27–3.66 | 0.3 |
| Chromium | 0.20 (0.03) | 0.16–0.23 | 0.2 |
| Cadmium | 0.00 (0.00) | - | 0.2 |
| Baguineda | Lead | 1.49 (0.76) | 0.78–2.83 | 0.3 |
| Chromium | 0.30 (0.06) | 0.22–0.36 | 0.2 |
| Cadmium | 0.00 (0.00) | - | 0.2 |
| Samanko | Lead | 1.62 (0.46) | 1.22–2.4 | 0.3 |
| Chromium | 0.42 (0.03) | 0.35–0.43 | 0.2 |
| Cadmium | 0.00 (0.00) | - | 0.2 |
| Sikasso | Lead | 1.48 (0.60) | 0.93–2.59 | 0.3 |
| Chromium | 0.00 (0.04) | -0.03–0.07 | 0.2 |
| Cadmium | 0.00 (0.00) | - | 0.2 |
| Niono | Lead | 1.46 (0.51) | 0.56–1.95 | 0.3 |
| Chromium | 0.10 (0.04) | 0.01–0.07 | 0.2 |
| Cadmium | 0.00 (0.00) | - | 0.2 |

1FAO/WHO (2011).

2Values in parenthesis are standard deviations.

**3.4.2. Heavy metals (Pb, Cr and Cd) concentration levels in tomatoes samples**

The mean lead concentrations were higher than the recommended maximum level for production in tomato from farms at all five study sites. The mean chromium concentrations in tomato samples were also lower than the recommended maximum level for production at Sikasso and Niono. There was no trace of cadmium in tomato from farms at all sites (Table 3).

**Table 3: Concentration (mg/kg) of selected heavy metals in tomatoes from farms at all study sites.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Heavy metal | Mean | Range | FAO/WHO recommended maximum  concentration for leafy vegetables (mg/kg)1 |
| Kati | Lead | 1.55 (0.48) | 0.91–2.29 | 0.1 |
| Chromium | 0.13 (0.05) | 0.04–0.18 | 0.05 |
| Cadmium | 0.00 (0.00) | - | 0.05 |
| Baguineda | Lead | 1.58 (0.58) | 0.76–2.21 | 0.1 |
| Chromium | 0.24 (0.03) | 0.19–0.27 | 0.05 |
| Cadmium | 0.00 (0.00) | - | 0.05 |
| Samanko | Lead | 1.83 (0.90) | 0.24–2.98 | 0.1 |
| Chromium | 0.32 (0.03) | 0.28–0.36 | 0.05 |
| Cadmium | 0.00 (0.00) | - | 0.05 |
| Sikasso | Lead | 1.63 (0.62) | 1.17–2.60 | 0.1 |
| Chromium | 0.04 (0.04) | 0.02–0.10 | 0.05 |
| Cadmium | 0.00 (0.00) | - | 0.05 |
| Niono | Lead | 1.77 (0.39) | 1.11–2.13 | 0.1 |
| Chromium | 0.03 (0.03) | -0.01–0.07 | 0.05 |
| Cadmium | 0.00 (0.00) | - | 0.05 |

**3.4.3. Heavy metals (Pb, Cr and Cd) concentration levels in cucumber samples**

Lead (1.01–1.02 mg/kg) and chromium (0.21–0.43 mg/kg) concentration levels in cucumber samples were mostly above the recommended maximum for crop production cited by FAO/WHO (2011) at all study sites except Sikasso (0.05 mg/kg) where chromium concentration was below (Table 4). There was no trace of cadmium cucumber samples at all study sites.

**3.4.4. Frequency of heavy metals per specimen and per site (mg/kg)**

The percentage of contamination of lettuce, tomato and cucumber samples by lead and cadmium varies depending on the sites. This percentage was 0.00–14.00% in Bamako, 5.10–8.32% in Kati, 5.10–8.00% in Baguineda, 5.20–12.00% in Samanko, 0.00–5.20% in Sikasso and 0.00–10.00% at Niono.

**Table 4: Concentration (mg/kg) of selected heavy metals in cucumber from farms at all study sites.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Heavy metal | Mean | Range | FAO/WHO recommended maximum concentration for leafy vegetables (mg/kg)1 |
| Kati | Lead | 1.01 (0.01) | 1.00–1.03 | 0.10 |
| Chromium | 0.21 (0.04) | 0.15–0.25 | 0.05 |
| Cadmium | 0.00 (0.00) | - | 0.05 |
| Baguineda | Lead | 1.01 (0.00) | 1.01–1.01 | 0.10 |
| Chromium | 0.29 (0.03) | 0.25–0.32 | 0.05 |
| Cadmium | 0.00 (0.00) | - | 0.05 |
| Samanko | Lead | 1.01 (0.01) | 1.00–1.01 | 0.10 |
| Chromium | 0.43 (0.02) | 0.42–0.47 | 0.05 |
| Cadmium | 0.00 (0.00) | - | 0.05 |
| Sikasso | Lead | 1.02 (0.02) | 1.00–1.05 | 0.10 |
| Chromium | 0.04 (0.02) | 0.00–0.07 | 0.05 |
| Cadmium | 0.00 (0.00) | - | 0.05 |
| Niono | Lead | 1.01 (0.01) | 1.00–1.02 | 0.10 |
| Chromium | 0.35 (0.10) | 0.04–1.79 | 0.05 |
| Cadmium | 0.00 (0.00) | - | 0.05 |

**Figure 3. Frequency of lead, chromium and cadmium per site and per vegetable**

1. **DISCUSSION**

The levels of faecal coliforms in lettuce, tomato and cucumber samples at all study sites exceeded the ‘undesirable’ 103 faecal coliforms per 100 g (wet weight) for vegetables by ICSMF (2011). Other pathogenic bacteria such as *Salmonella* spp, *Shigella* spp (0.24–78.55 × 104), *Staphylococcus aureus* (0.00–27.88 × 104), *Clostridium perfringens* (0.00–17.00 × 104) and *Listeria monocytogenes* (0.24–31.15 × 104)were also found. These findings corroborate a previous study done by Samaké *et al.* (2011), who reported similar ‘undesirable’ faecal coliforms levels and *Salmonella* spp. on lettuce in farms from Bamako, Kati and Baguineda. Similar results have also been reported by other authors in West Africa (Abass *et al.*, 2016; Dao *et al.*, 2018; Erhirhie *et al.*, 2020) and elsewhere (Dallal *et al.*, 2015; Mritunjay & Kumar, 2017; Kapeleka *et al.*, 2020). The high faecal coliform contaminations of all vegetable samples and the presence of *Salmonella* spp, *Shigella* spp, *Staphylococcus aureus*, *Clostridium perfringens* and *Listeria monocytogenes* could be due to some practices done by farmers on the study sites. These practices are mainly the irrigation of vegetables with untreated water via overhead irrigation, even on the day of harvest, the application of undecomposed organic manure directly on crops and vegetables production on contaminated soils for several years.

High lead and chromium concentrations (> FAO/WHO (2011) above the acceptable limit for leafy vegetables) were detected in lettuce and tomato (excepting Sikasso and Niono) and cucumber (excluding Sikasso) samples at all study sites. Cadmium was absent in all vegetables. These results agree with other results of Lente *et al.* (2014) and Malan *et al.* (2015), who reported high contamination of lead and chromium in lettuce in Ghana and South Africa. These findings however contradict previous report (< FAO/WHO limits) of Samaké *et al*. (2011), who found acceptable concentrations of lead in composite lettuce samples from Bamako, Kati and Baguineda. The possible sources of heavy metal contaminations on lettuce, tomato and cucumber in the present study include, increasing atmospheric sources (e.g. smoke emissions from industries and vehicles), the increasing textile dyeing activities and the use of sifted garbage soils (which could enclose contaminated waste of lead and chromium).

Contamination of vegetables by pathogenic bacteria and heavy metals (lead and chromium) can constitute a risk to the health of the population. Local health and environmental authorities should educate the public about the health hazards of fresh vegetables and the importance of washing and disinfecting them before consumption. In addition, adequate wastewater treatment and the ban on the use of untreated wastewater for irrigation of plants for human consumption, among others, should be implemented. In short, it is therefore necessary to improve the sanitary conditions of these types of food.

1. **CONCLUSION**

* Lettuce, tomato and cucumber collected from farms at Bamako, Kati, baguineda, Samanko, Sikasso and Niono contained high levels of bacterias (total microflora, total and faecal coliforms, *Salmonella* spp, *Shigella* spp, *Staphylococcus aureus*, *Clostridium perfringens* and *Listeria monocytogenes*). Faecal coliform populations in lettue, tomato and cucumber were above the undesirable level of ICMSF (2011) at all study sites. Lead and chromium concentrations in all vegetables were above the recommended safe limit by FAO/WHO (2011) at all study sites excepting Sikasso (Chromium level in all vegetables) and Niono (Chromium level in lettuce and tomato). There was no trace of cadmium in tomato from farms at all sites. Futher works should investigate the microbiological quality of raw-eaten vegetables in markets and other sales outlets to determine if the postharvest handling process increase or decrease contamination levels in Mali. Quantitative risk assessment to measure level of public health risk on the Malian population that consume vegetables (eaten raw) contaminated with pathogens and chemical contaminants should be considered.

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References

Abass, K., Ganle, J. K. & Adaborna, E. (2016). Coliform Contamination of peri-urban grown vegetables and potential public health risks: Evidence from Kumasi, Ghana. Journal of Community Health, 41, 392–397. https://doi.org/10.1007/s10900-015-0109-y

Alegbeleye, O. O., Singleton, I., Anderson, S., & Sant’Ana, A. S. (2018). Sources and contamination routes of microbial pathogens to fresh produce during field cultivation: A review. *Food Microbiology*, *73*, 177–208. https://doi.org/[10.1016/j.fm.2018.01.003](https://dx.doi.org/10.1016%2Fj.fm.2018.01.003)

Antwi-Agyei, P., Cairncross S., Peasey A., Price V., Bruce J., Baker, K., Moe, C., Ampofo, J., Armah, G., & Ensink, J. (2015). A farm to fork risk assessment for the use of wastewater in agriculture in Accra, Ghana. PLOS One, 10(11), e0142346. https://doi.org/10.1371/journal.pone.0142346

Dallal, M. M. S., Shojaei, M., Yazdi, M. K. S., Vahedi, S. (2015). Microbial Contamination of Fresh Vegetable and Salad Samples Consumed in Tehran, Iran. Journal of Food Quality and Hazards Control, 2, 139-143.

Dao, J., Stenchly, K., Traoré, O., Amoah, P., & Buerkert, A. (2018). Effects of water quality and post-harvest handling on microbiological contamination of lettuce at urban and peri-urban locations of Ouagadougou, Burkina Faso. Foods, 7(12), 206–218. https://doi.org/10.3390/foods7120206

Dia, S. (2017). Control of the bacteriological and toxicological quality of lettuce sold in commune I of the District of Bamako, Mali [Unpublished Master’s thesis]. University of Science, Techniques and Technologies of Bamako.

DRA (Direction Régionale de l’Agriculture du District de Bamako), (2018). Projet plan de campagne agricole (Rapport interne).

Erhirhie, E. O., Omoirri, M. A., Chikodiri, S. C., Ujam, T. N., Emmanuel, K. E., Oseyomon, J. O. (2020). Evaluation of microbial quality of vegetables and fruits in Nigeria: A review. International Journal of Nutrition Sciences, 5(3), 99-108. https://doi.org/10.30476/IJNS.2020.86034.1065

FAO (Food and Agricultural Organization) / WHO (World Health Organization), (2011). The place of urban and peri-urban agriculture (UPA) in national food security programmes. http://www.fao.org/3/i2177e/i2177e00.pdf

FAO (Food and Agriculture Organization), (2012). Growing greener cities in Africa: First status report on urban and peri-urban horticulture in Africa. www.fao.org/ag/agp/greenercities/pdf/GGC-Africa.pdf

ICMSF (International Commission on Microbiological Specifications for Foods), (2011). Microorganisms in foods 8: Use of data for assessing process control and product acceptance. Springer. https://link.springer.com/book/10.1007%2F978-1-4419-9374-8

IMF (International Monetary Fund), (2015). Mali selected issues. (Report No. 15/340). https://www.imf.org/external/pubs/ft/scr/2015/cr15340.pdf

International Organization for Standardization (ISO 11290), (1997). Horizontal method for the detection and enumeration of Listeria monocytogenes - Part 1: Detection method. International Organization for Standardization.

International Organization for Standardization (ISO 4833-1), (2013). Microbiology of the food chain — Horizontal method for the enumeration of microorganisms — Part 1: Colony count at 30ºC by the pour plate technique. International Organization for Standardization.

International Organization for Standardization (ISO 6579-1), (2007). Microbiology of the food chain: Horizontal method for the detection, enumeration and serotyping of Salmonella—Part 1: Detection of Salmonella spp. International Organization for Standardization.

Kapeleka, J. A., Sauli, E., Sadik, O., Ndakidemi, P. A. (2020). Co-exposure risks of pesticides residues and bacterial contamination in fresh fruits and vegetables under smallholder horticultural production systems in Tanzania. PLoS ONE, 15(7), e0235345. https://doi.org/10.1371/journal. pone.0235345

Lente, I., Ofosu-Anim, J., Brimah, A. K., & Atiemo, S. (2014). Heavy metal pollution of vegetable crops irrigated with wastewater in Accra, Ghana. West African Journal of Applied Ecology, 22(1), 41–58.

Malan, M., Müller, F., Cyster, L., Raitt, L., & Aalbers, J. (2015). Heavy metals in the irrigation water, soils and vegetables in the Philippi horticultural area in the Western Cape Province of South Africa. Environmental Monitoring and Assessment, 187, 4085. https://doi.org/10.1007/s10661-014-4085-y

Mritunjay, S. K., & Kumar, V. (2017). A study on prevalence of microbial contamination on the surface of raw salad vegetables. 3 Biotech, 7, 13. https://doi.org/10.1007/s13205-016-0585-5

NF V08-057-1 (2004). Routine method for the enumeration of coagulase-positive staphylococci by colony count at 37°C - Part 1: technique with confirmation of colonies Association Francaise de Normalisation.

NF V08-061 (2009). Microbiology of food and animal feeding stuffs - Anaerobic enumeration of sulfito-reducing bacteria by colony count technique at 46°C. Association Française de Normalisation.

NFV 08 060, (2009). Microbiology of food and animal feeding stuffs: Enumeration of thermotolerant coliforms by colony count technique at 44°C. Association Francaise de Normalisation.

NFV 08–050, (2009). Microbiology of food and animal feeding stuffs - Enumeration of presumptive coliforms by colony-count technique at 30 °C. Association Francaise de Normalisation.

Rahimzadeh, M. R., Rahimzadeh, M. R., Kazemi, S., & Moghadamnia, A. A. (2017). Cadmium toxicity and treatment: An update. *Caspian Journal of Internal Medicine,* *8*(3), 135–145. <https://doi.org/10.22088/cjim.8.3.135>

Rai, P. K., Lee, S. S., Zhang, M., Tsang, Y. F., & Kim, K. H. (2019). Heavy metals in food crops: Health risks, fate, mechanisms, and management. *Environment International 125,* 365–385. <http://doi.org/10.1016/j.envint.2019.01.067>

Saghir, J., & Santoro, J. (2018). Urbanization in Sub-Saharan Africa: Meeting challenges by bridging stakeholders (Report 2018). Center for Strategic & International Studies. public/publication/180411\_Saghir\_UrbanizationAfrica\_Web.pdf

Salawu, K., Barau, M. M., Mohammed, D., Mikailu, D. A., Abdullahi, B. H., & Uroko, R. I. (2015). Determination of some selected heavy metals in spinach and irrigated water from Samaru area within Gusau Metropolis in Zamfara State, Nigeria. Journal of Toxicology and Environmental Health Sciences, 7(8), 76–80. https://doi.org/10.5897/JTEHS2015.0339

Samaké, F., Babana, A. H., Yaro, F., Cissé, D., Traoré, I., Kanté, F., Koné, S., Diallo, S., Touré, O., Sako, M., & Iknane, A. G. (2011). Health risks associated with the consumption of market garden products grown in the urban and peri-urban area of ​​Bamako. Mali Public Health, 1(001), 27–31.

Sanogo, O. M., Doumbia, S., & Descheemaeker, K. (2019). Supplementation of dairy cattle to improve milk and manure production in rural areas in the Koutiala district. Malian Review of Science and Technology, 0(22), 134–143.

UN DESA (United Nations, Department of Economic and Social Affairs), (2017). World population prospects 2019: Key findings and advance table (Report No. ESA/P/WP/248. Microsoft Word - Key Findings WPP 2017\_Final EMBARGOED (un.org)

World Bank, (2015). The World Bank in Mali. https://www.worldbank.org/en/country/mali/overview

World Bank, (2019). Agriculture, forestry, and fishing, value added (annual % growth). https://data.worldbank.org/indicator/NV.AGR.TOTL.KD.ZG