SAFETY OF FRESH PRODUCE: BACTERIAL RISK ASSESSMENT OF IRRIGATION WATER AND SOIL

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ABSTRACT

Irrigating fresh produce with contaminated water may increase the bacterial load and subsequently introduce hazards of food poisoning. Bacterial risk assessment through possible pathogenic cross-contamination of soil and river water used for the irrigation of fresh produce was investigated. Various sites on Berdawny and Ghzayel Rivers in Beka'a Valley were selected to determine the quality of their water (based on microbial contamination) for irrigation and then bacterial load and type. Berdawny river sites were heavily contaminated with faecal coliforms and E. coli (average of 4.7 and 2.5 Log 10 cfu/g respectively). Ghzayel sites (Chamsine and Darzanun) were found to be clear of any contamination indicators. Rawda and Hawsh El Harimeh sites, however, were contaminated with bacteria of faecal origin. The microbial analysis of soil samples taken from nearby farms which were irrigated with water from these rivers indicated that the growing fields were contaminated with the same microbial organisms found in the irrigation water. The contamination level of soil obtained from Rawda and El Hawsh sites (average 4 Log 10 cfu/g) were lower than that of Berdawny sites (average 8 Log 10 cfu/g). The overall findings suggest that the growing crops in these areas are likely to be contaminated and thereby evaluating the health risk of these crops is needed.

Key words: fresh produce, food safety, irrigation water, soil

INTRODUCTION

The concern about pathogens in fresh foods has increased triggered by an increase in numbers of outbreaks of food borne illness and complicated by consumer desire for less processed foods. Fresh, whole, cut, and minimally processed fruits and vegetables are recognized as nutritional foods. Continuing advances in worldwide agronomic practices, processing, preservation, distribution and marketing has enabled agricultural and food industries to supply fresh products of high quality to consumers throughout the year. Unfortunately, along with improved availability of fresh food comes increased opportunities for growing incidence of human illness from pathogenic microorganisms (Beuchat, 1998; Al Tekruse *et al*., 1997). In Lebanon for example, waste and sewage water are used in the irrigation of fresh produce. Measures must be taken to control contamination of produce on the farm and during handling, transporting, processing, marketing and preparation to assure food safety. What is not clearly known is how contamination occurs along these "farm – to – fork" paths. Means to address this issue must include the entire system before prevention and decontamination measures can be fully implemented. The consumer expects high quality agricultural products in the market place. The variations in sizes, shapes, surface topography – rough, highly textured, smooth, availability of entrances to internal issues, fragility and perishability among produce presents a challenge to those working on maintaining safe foods. Environmental components, soil, moisture, animal feces, and spoilage can contribute in many ways to contamination. Several chemicals are utilized and others are being researched for their ability to kill or remove microorganisms (Kim *et al*., 1999; Sapers *et al*., 1999a,b; Sapers and Simmons, 1998; Elphick, 1998; Winniczuk and Parish, 1997, Beuchat *et al*., 1998; Eckert and Ogawa, 1988). Still, determining how contamination occurs and ways to prevent it or decontaminate fruits or vegetables, while maintaining the visual and olfactory qualities, is a challenge. This article partially addresses this challenge and provides some answers to major problems of vegetable safety.

MATERIALS AND METHODS

Bacterial risk assessment of fresh produce (vegetables) was investigated according to the schematic flow chart in Fig. 1.

Irrigation-water and growing field-soil

Six different locations at Berdawny and Ghzayel Rivers were chosen as shown in Chart1 for sampling water, soil, and vegetables during the growing season (May-June). These rivers are the main water sources for irrigation in middle and west Beka'a. The sprinkle irrigation is mainly used in these areas; so any pollutants in water are expected to transfer to the land and growing crops. The water in Berdawny River is contaminated at different sites by sewage and wastewater, whereas two sites (Chamsine and Darzanun sites) at Ghzayel River do not appear to be exposed to any source of contamination. However, Rawda and Hawsh sites along the same river are exposed to contamination sources about 3 km before Rawda.

Sampling of water and soil (25 samples each) were taken simultaneously in sterile bottles or bags from each site according to international standards (IFST, 1999). The samples were then packed in cooled containers and transported to the laboratory for immediate analysis, or within less than 24 hrs, after storage at $4^{o}C$. Water samples from the selected sites were collected aseptically into 1l. sterile bottles that were opened 5 – 10 cm below the water surface. The samples were transported into the laboratory for immediate assessment of biological risk. Soil samples were taken from vegetable growing areas which are irrigated with water from Berdawny or Ghzayel River. The samples were collected with sterile spatula into sterile bags at two depths (5-10 cm and 10 - 30 cm). The samples were transported in cooled containers and stored for less than 24 hrs at less than $4^{o}C$ for the assessment of biological risk of transporting pathogenic bacteria from used irrigation-water into soils at different depths.

Figure 1. Schematic flow chart of the experimental design and actual execution of the research project.

Bacteriological counting and identification

The bacterial population and type in irrigation water and soils irrigated with this water were investigated following different known methods as shown below. The dilution of water or soil samples were done when it was necessary and the total number of each bacterium was taken as per ml water or gram soil.

Bacteria	Media	Incubation/ Hrs
Total coliform	Mackonkey Broth and Agar	37^{O}C, 48
Faecal coliform and E. coli	Mackonkey Broth and Mackenzie Test	44^{O}C, 48
Staphylococcus	Mannitol salt agar	37^{O}C, 24
Clostridium	Trypton Soya agar	44^{O}C, 72
Salmonella	Filtration and Salmonella Shegella agar	37^{O}C, 24

RESULTS AND DISCUSSION

Bacterial Risk Assessment of Water

1-Berdawny River

Figure 2 illustrates the level of contamination in river water at Ma'alaka and Fayda sites, respectively. The bacterial load of water at Ma'alaka site was much greater than international standards (1 log10 cfu/g) (IFST, 1999). Bacterial presence has increased progressively from end of April to the end of June. This is probably due to the increase in ambient temperature in this time of the year. Counts of total coliforms, faecal coliforms and *E. coli* were similar, which may suggest that the latter bacterial strains represent the major part. The heavy presence of *Esherishia* indicates a faecal origin of contamination which could be waste and/or sewage dumping. *Clostridium* showed no growth during the first 10 days, then an average of 2.6 Log10 cfu /g was detected throughout the remaining period. The major source of *Clostridium* strains is soil (Zhao *et al*., 2000); thus, its presence may be related to the level in soil and dumping in the river.

In comparison, Faida site showed a lower microbial load of total *coliforms* and slightly higher presence of *Clostridium* strains. This is probably due to the fact that the Faida site is situated in a less populated area. The higher presence of *Clostridium* strains may be due to the nature of the soil of this site or to another contamination source. *Clostridium* detection was also negative during the first 10 days. These strains are known to be spore-forming anaerobes commonly found in mammalian faeces and soil. The spores persist in the environment and often contaminate raw food materials. Spores may survive cooking and rapid growth may occur if the food is not cooled promptly. Coliforms, however, were one of the first groups of bacterial indicators used in the water and food industries. These organisms are not exclusively of faecal origin. Thermo-tolerant coliforms are those that can multiply at 44^{O}C. Most faecal coliforms are also able to multiply at this temperature and in practice the term "faecal" and "thermo-tolerant" are used synonymously. It is important to note that

Salmonella and *Staphylococcus* strains were not detected in both sites throughout the study period. The absence of these pathogenic strains might be fortunate but it does not imply safety. The presence of faecal coliforms commonly implies the occurrence of various pathogenic strains of *Salmonella, Shigella, Yersinia* and pathogenic *E. coli*.

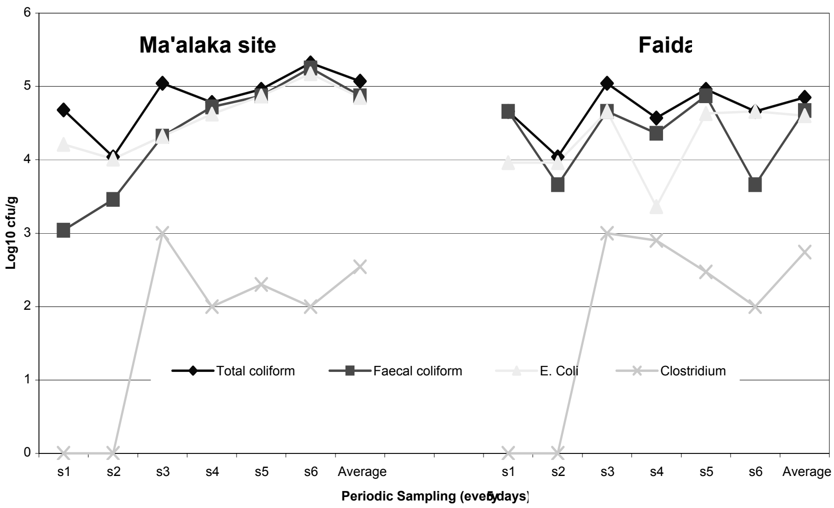

Figure 2. Bacterial count of Berdawny water used for the irrigation of fresh produce. Ma'alaka and Faida are two water sampling sites on the river.

2- Ghzayel River

In line with Berdawny, biological risk assessment was conducted at four different sites along the Ghzayel river within the same period of time. These sites are Chamsine (source), Darzanun, Rawda, and Hawsh El Harimeh. The sites cover most of the area irrigated by this river. The first two sites (Chamsine and Darzanun) were biologically the cleanest (Fig. 3).

The Chamsine site is the actual source of the river, which is also used for drinking. Darzanun is a nearby site and passes through a non-populated area, where dumping is as its minimum. *Clostridium, Salmonella, Staphylococcus* and *E. coli* were not detected at these two sites. On the other hand, total coliforms and faecal coliforms were within acceptable standards. Surprisingly, bacterial load level was decreasing throughout the study period (end April to end June) with a particular drop in faecal microbe levels. This would imply that these microbes are not necessarily of faecal origin. Furthermore, water gets cleaner on running unless re-contaminated (Adams *et al.*, 1989).

These findings project the negative effect of human interference on the safety of the environment and subsequently food. This statement is well illustrated and clarified in Figure 4. Again off-standard levels of contamination by coliforms and *Clostridium* were found in both Rawda and Hawsh El Harimeh sites. The level of contamination was almost within the same range throughout the study season.

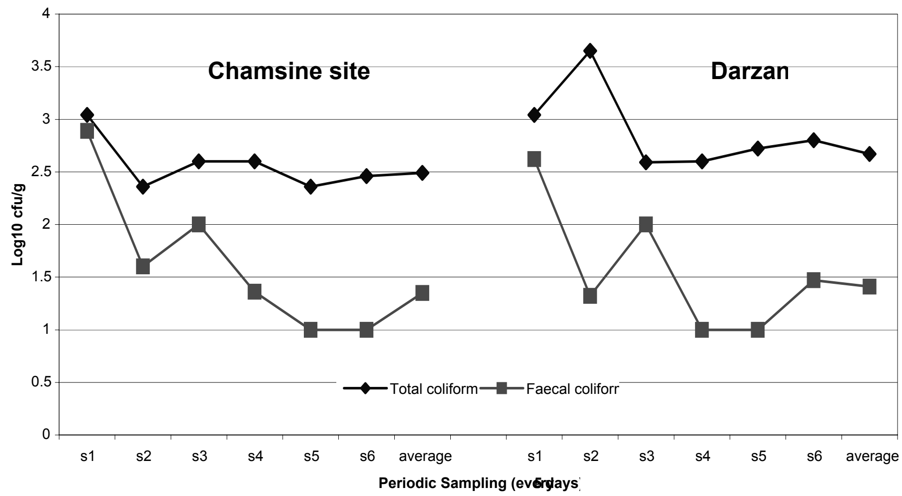

Figure 3. Bacterial count of Ghzayel water used for the irrigation of fresh produce. Chamsine and Darzanun are two water sampling sites along the river.

Contamination increased with the progress of the river along its course. Water starts being polluted directly after Darzanun site, then heavier loads were added after Rawda site. The level of *E.coli* contamination was highest at Hawsh El Harmeh site, implying a very risky situation. Stable range of contamination at these two sites may suggest a stable or continuous dumping of waste, sewage, and other contaminants. As seen in Fig. 4, there was a close association between *E. coli* and faecal coliforms, which may imply an association of contamination origin. Subsequently, this river shows a typical example of contamination by human activities, thus increasing the risk level to health.

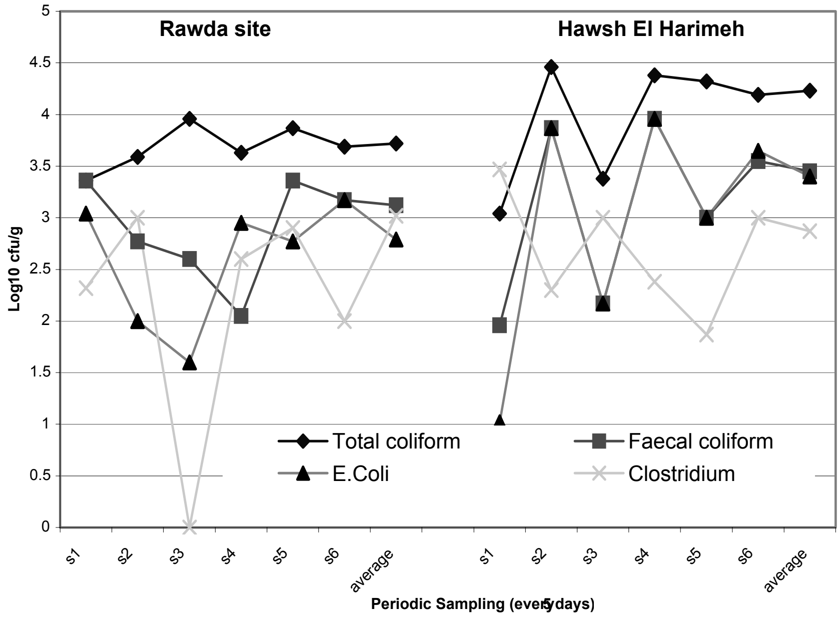

Figure 4. Bacterial count of Ghzayel water used for the irrigation of fresh produce. Rawda and Hawsh El Harimeh are two water sampling sites along the river.

A comparison between both rivers and their respective sampling sites is shown in Fig.5. Because Berdawny river always passes through populated areas, a higher load of contamination was observed. A lower contamination level was also noticed along Ghzayel river at Rawda and Hawsh sites due to waste water discharges. The other two sites at Ghzayel river were very slightly polluted and may not present any biological risk.

Bacterial risk assessment of soil

Results obtained for soil bacterial analysis was in line with those of river water, with only *Clostridium* counts being higher. Faecal coliforms showed highest level in Berdawny sites at both depths (5 – 10 cm and above 10 cm). This was followed by Rawda and Hawsh area. The variation in the number of bacteria between sites is likely related to the microbial conditions of the used water and the presence of contamination sources. This is clearly observed along Ghzayel River, in which very few bacterial colonies were detected in the soils irrigated at Chamsine and Darzanun sites. It should be noted here that the results of the microbial analysis of soils that were not irrigated with water from both rivers showed nil or less than 100 colonies/ g soil of either bacteria studied here, indicating that the soils along both rivers were polluted by their water.

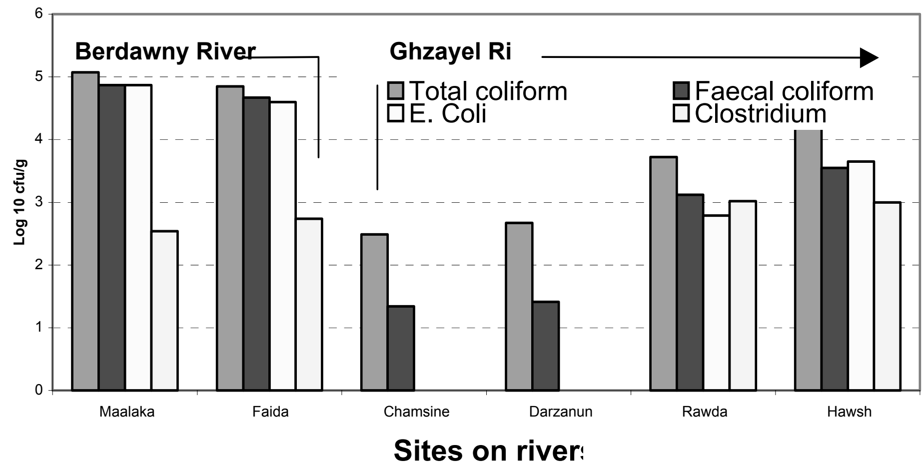

Figure 5. Comparison between water contamination levels of Berdawny and Ghzayel Rivers.

Results reported here indicate that these 2 rivers show a high degree of contamination by organic waste. These results suggest that the irrigation of crops with water from these 2 rivers makes the reuse of this water economically impractical and more importantly may also pose a threat to human health especially if the harmful bacteria are biofilmed onto the fresh produce even after washing. Thus, the wastewater should be treated prior to its use in irrigation. In this respect the health risks associated with the consumption of eating raw vegetables (a common local custom) must be properly assessed.

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