12

Applying the Multiple-Barrier Approach for Microbial Risk Reduction in the Post-Harvest Sector of Wastewater-Irrigated Vegetables

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Abstract

Post-harvest interventions are an important component of a multiple-barrier approach for health-risk reduction of wastewater-irrigated crops as recommended by the 2006 edition of the WHO Guidelines for safe wastewater irrigation. This approach draws on principles of other risk-management approaches, in particular the hazard analysis and critical control point (HACCP) concept. Post-harvest measures are of particular importance as they can address possible on-farm pre-contamination, and also contamination that may occur after the crops leave the farm. Key factors influencing microbial contamination along the farm to fork pathway are basic hygiene and temperature management. Both factors are, however, hardly under control in most developing countries where microbial contamination and proliferation are supported by low education, limited risk awareness, rudimentary technical infrastructure and unenforced regulations. In the face of these challenges, the most successful strategies to enhance food safety will involve interventions at multiple control points along the production chain, with emphasis on local safety targets and innovative educational programmes fitting

local knowledge, culture and risk perceptions. The WHO (2006) recommended health-based targets for risk reduction in wastewater irrigation provide the required flexibility for risk mitigation in line with the concept of food-safety objectives (FSO).

Introduction

Microbial infections of foodborne origin are a major public-health problem internationally and a significant cause of death in developing countries (WHO, 1996, 2006). Underlying problems of food safety differ considerably between developing countries and the more developed part of the world (Nicolas et al., 2007). Food safety in developing countries is influenced by a number of factors. In the context of wastewater irrigation, the main concern is the increasing environmental pollution in urban areas, which does not support the changing behaviour of urban consumers towards more international diets, in particular fruits and salads that are eaten raw. There is a high risk of contamination (not only affecting fruits and vegetables) at all stages of production, processing and distribution which is very difficult to control through regulations given the common constraints in supporting infrastructure (cool chain) and institutional capacities.

Approaches to address this challenge have been discussed over many years in different divisions of the WHO and FAO dealing with food quality and health. The WHO Guidelines (2006) for safe wastewater irrigation present only one of several concepts. However, although different terminologies are used, there is considerable agreement on the best way forward.

The best known initiative is the *Codex Alimentarius* which calls upon countries to work towards international food safety and quality standards. Related recommendations, also for vegetables eaten raw, are outlined in international codes of best practices (CAC, 2003a, 2003b). Acknowledging the complexity of the current food-safety situation within and across many countries, the WHO and FAO advocate targeted interventions using microbiological risk analysis as the basis for building food-safety control programmes. Partly through the activities of *Codex Alimentarius* and expert consultations, both organizations have developed a series of guidelines and reports that detail the various steps in risk analysis and management (FAO/WHO, 2008; Gorris, 2005).

Quantitative microbial risk assessment can help in identifying critical control points (Seidu et al., 2008). However, in many countries the results are predictable given the general substandard situation. The critical control point concept is similar to the multiple-barrier approach recommended by different national and international agencies for drinking-water safety and also by WHO (2006) in view of wastewater-related food-safety issues. The approach recognizes that while each individual barrier may be not be able to completely remove or prevent contamination, and therefore protect public health, implemented together, the barriers work to provide greater assurance that the water or food will be safe at the point of consumption.

Where a quantitative risk assessment is not available, it is still possible to set local food-safety objectives (FSO) (Box 12.1) which relate operational food-safety management to public-health goals (FAO/WHO, 2002). Health-based FSO relate to the time/point of consumption, which gives flexibility to the individual contribution of different control points to the overall risk reduction target. This flexibility also acknowledges that food chains can be very different, but nevertheless should comply with a common health-based target (Gorris, 2005). In the context of health-based targets, the ultimate goal is to have a measurable impact on specific health outcomes, such as diarrhoeal diseases. Whereas metrics and threshold targets for ‘upstream’ parameters (irrigation water quality, for example) may vary from

Box 12.1 Terms and definitions for the key concepts in risk-based food control

Appropriate Level of Protection (ALOP)

Level of protection deemed appropriate by the country establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory (WTO, 1995).

Food-Safety Objective (FSO)

The maximum frequency and/or concentration of a hazard in a food at the time of consumption that provides or contributes to the appropriate level of protection (ALOP) (CAC, 2004).

Health-based targets

Health-based targets are set by national authorities as a defined level of health protection for a given exposure. This can be based on a measure of disease or the absence of a specific disease related to that exposure (WHO 2004, 2006).

Control measures (CM)

Any action and activity that can be used to prevent or eliminate a food-safety hazard or to reduce it to an acceptable level (it can be microbiological specifications, guidelines on pathogen control, hygiene codes, microbiological criteria, specific information, e.g. labelling, training, education, and others (ICMSF, 2002).

Multiple-barrier approach

Protection against contaminants occurs at each step along the water to food pathway, beginning at the wastewater source, continuing at the treatment facility and extending through the farm and market chain to the kitchen where the food is prepared and eventually served (WHO, 2006; modified).

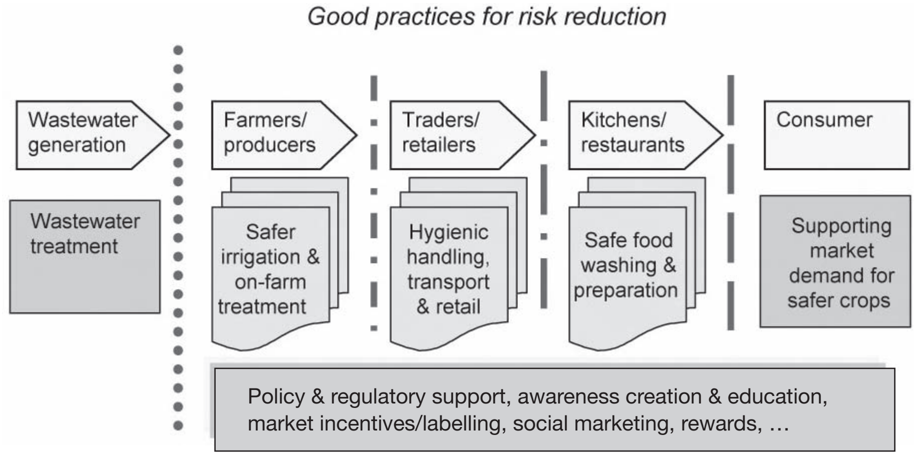

Figure 12.1 *Multiple-barrier approach in the wastewater food chain where treatment alone is an insufficient pathogen barrier*

Source: Based on the HACCP concept, IWMI (unpublished)

system to system, and are often unattainable, the FSO approach is viewed as a success as long as the end result of improved health is achieved through one or more control points (barriers) before the food gets served.

The 2006 edition of the WHO Guidelines for safe wastewater irrigation (WHO, 2006) mirrors this philosophy and recommends a 'multiple-barrier' approach for health-risk reduction, especially where conventional wastewater treatment is not effective (Figure 12.1). Health-based targets are expressed in averted DALYs (see Chapter 2). The Guidelines draw on the hazard analysis and critical control point (HACCP) system and its prerequisites: good agricultural practices (GAP), good manufacturing practices (GMP) and good hygiene practices (GHP) which are recognized by the *Codex Alimentarius* Commission as a cost-effective way to enhance food safety at all stages of the food supply chain (WHO, 1996).

Although microbiologically polluted irrigation water is a major contributor to on-farm contamination of vegetable crops, it is only one of many risk factors in the farm to fork continuum. There are other pathogen sources and non-pathogenic threats. Looking only at pathogens, they can contaminate the edible tissues of plants at any stage from production to consumption via soilborne, seedborne, airborne or waterborne routes. Considering the differences in existing food-production chains, with an enormous variety in structures, logistics and stakeholders, and that they will undoubtedly change rapidly, scale-up and diversify continuously, food-safety management at any scale (regional, national, local, factory) is a challenge (Gorris, 2005). This shows the crucial need for multiple precautions at various pathogen barriers or critical control points. In Chapter 10, the authors introduced farm-based measures, while this chapter focuses on barriers in the post-harvest sector. These address two important objectives: minimizing any existing contamination during primary production (i.e. on farm); and avoiding any additional contamination that may occur through cross-contamination and suboptimal hygiene practices during harvesting, transport, processing, marketing/handling and food preparation.

Biophysical factors affecting risk reduction

Contaminants originating from wastewater may attach to the plant surface, may be taken up by roots or may be internalized into the plant tissue elsewhere. From a food-safety standpoint, the latter route is debatably less significant given the low concentrations of pathogens which can enter the tissue of healthy plants compared to what can be deposited on the surface. Although it has been shown that some human pathogens, such as *Salmonella* spp., can survive and grow within certain vegetables, their replication is generally limited under these conditions (Jablasone et al., 2004; Serani et al., 2008; Shi et al., 2007; Solomon et al., 2002; Tsai and Ingham, 1997; Zhuang et al. 1995). It is more likely for pathogens to enter plants that are wounded or damaged (Aruscavage et al., 2008; Fatemi et al., 2006).[1] The greater risk factor, in terms of quantitative pathogen exposure, is the contamination of the crop surface, especially where the surface is large, like on leafy vegetables.

Understanding the ecology of bacterial pathogens on plant surfaces can lead to the development of intervention strategies to prevent, reduce or remove contamination. Virtually any fruit or vegetable can serve as a vehicle for any pathogen, providing that the pathogen survives in high enough numbers on the product until such time as it is consumed. Common factors influencing pathogen survival include initial dose of contamination, time and environmental conditions (Table 12.1). Table 12.2 shows the die-off rate of different pathogen groups on the crop surface.

Environmental conditions play a key role in the survival of micro-organisms on plant surfaces which are subject to extreme fluctuations in temperature and moisture (Bunster et al., 1989) and related bacterial numbers and diversity (Ailes et al., 2008; Ilic et al., 2008). This offers opportunities for interventions. Natural die-off of bacteria has been described as an important method to minimize safety risks by increasing the interval between the last irrigation (and contamination) and harvest to several days (Aruscavage et al., 2006; Keraita et al., 2007). Unfortunately, the same does not apply to the interval between harvest and consumption: once harvested, (leafy) vegetables begin to decay rapidly and cannot be kept on the shelf to facilitate natural die-off.

It can get even worse. As crops are transported from the farm to the table, contamination, recontamination and cross-contamination issues are gaining in importance. Consequently, instead of naturally decreasing contamination levels

Table 12.1 *Factors affecting pathogen survival in the environment*

Factor	Comment
Humidity/precipitation	Humid environments favour pathogen survival. Dry environments facilitate pathogen die-off. Rainfall can result in splashing of contaminated soil on crops.
Temperature	Most important factor in pathogen die-off. The impact of temperature varies for different pathogens. High temperatures lead to rapid die-off, normal temperatures lead to prolonged survival. Freezing temperatures can also cause pathogen die-off.
Acidity/alkalinity (pH)	Some viruses survive longer in more acid, i. e. lower pH soils, while alkaline soils are associated with more rapid die-off of viruses. Neutral to slightly alkaline soils favour bacterial survival.
Sunlight (UV radiation)	Direct sunlight leads to rapid pathogen inactivation through desiccation and exposure to UV radiation.
Foliage/plant type	Certain vegetables have sticky surfaces (e.g. zucchini) or can absorb pathogens from the environment (e.g. lettuce, sprouts) leading to prolonged pathogen survival. Root crops are more prone to contamination and facilitate pathogen survival.
Competition with native flora and fauna	Antagonistic effects from bacteria or algae may enhance die-off. Bacteria may be preyed upon by protozoa.

Source: Strauss (1985); modified

Table 12.2 *Survival times of selected excreted pathogens in soil and on crop surfaces at 20–30°C*

Pathogens	Survival time	
	In Soil	On crops
Viruses:		
Enteroviruses[a]	<100 but usually <20 days	<60 but usually <15 days
Bacteria:		
Faecal coliform	<70 but usually <20 days	<30 but usually <15 days
Salmonella spp.	<70 but usually <20 days	<30 but usually <15 days
Vibrio cholera	<20 but usually <10 days	<5 but usually <2 days
Protozoa:		
Entamoeba histolytica cysts	<20 but usually <10 days	<10 but usually < 2 days
Helminths:		
Ascaris lumbricoides eggs	Many months	<60 but usually <30 days
Hookworm larvae	<90 but usually <30 days	<30 but usually <10 days
Taenia saginata eggs	Many months	<60 but usually <30 days
Trichuris trichiura eggs	Many months	<60 but usually <30 days

[a]Includes polio-, echo- and coxsackie-viruses.
Source: Feachem et al. (1983)

after harvest, several studies have shown an increase in microbial load as vegetables move from the farm to the consumer (Ailes et al., 2008; Ensink et al., 2007; Ilic et al., 2008). Only when the temperature can be controlled and kept low can longer intervals allow for bacterial die-off; but where temperature cannot be controlled, extended time between harvest and consumption may support an increase in bacterial population numbers rather than a decrease (Box 12.2).

Box 12.2 Methodological challenges

There are many challenges in the detection and removal of pathogenic threats which demand some notes of caution when it comes to recommendations for risk reduction. A few are mentioned here:

- Test conditions: studies that have examined the survival of foodborne pathogens on plants have been mostly conducted under experimental conditions (Aruscavage et al., 2008; Jablasone et al., 2005; Stine et al., 2005). Serious limitations to the extrapolation of these experiments to real-life situations include the large initial inoculums often used and the unnatural (i.e. greenhouse/laboratory) conditions in which the plants are grown.
- Indicator quality: a general challenge is the use of indicator micro-organisms. The detection of specific pathogens such as *Shigella* spp., *E. coli* O157:H7 or *Salmonella* spp. (see Box 12.1) is both expensive and time-consuming. Therefore, many researchers, especially in developing countries, measure thermotolerant coliform contamination frequency and magnitude as a surrogate of pathogen survival and vegetable safety (Ailes et al., 2008). However, the use of coliforms as indicators of pathogen contamination is debatable as many coliforms are naturally present in the environment and on plant surfaces and therefore their presence might not indicate recent pathogen contamination. Moreover, this group of organisms may not exhibit the same survival or attachment behaviour as the pathogens. This is particularly important when considering or assessing their removal (Ilic et al., 2008).
- Tracing contamination: studies trying to trace the source of contamination often tend to compare independent sample sets taken, for example, at the farm gate and in markets (e.g. Armar-Klemesu et al., 1998). However, where markets receive their produce from different farms, it will require significant efforts and sample numbers to confirm the origin of any analysed difference in coliform counts. Amoah et al. (2007a) tried to bypass this problem by following vegetables from various farms – using wastewater or tap water for irrigation – to the final retail points. In this way, it was possible to identify the crucial points at which most contamination occurred in the farm to fork chain of activities.

OPTIONS FOR RISK REDUCTION ALONG THE CONTAMINATION PATHWAY

Harvest

Different paths of contamination are possible during the harvest of leafy green vegetables (Franz and van Bruggen, 2008; Hope et al., 2008; McEvoy et al., 2009). While in more developed countries most concerns are addressed through standardized protocols and mechanized field operations, in developing countries basic hygiene is often violated due to the high dependency on manual labour combined with the lack of clean water or other resources and/or education.

Harvest is a key step along the contamination pathway as it involves the injury of plant tissues. As discussed above, cut surfaces are ideal sites for pathogen attachment and may also serve as an entryway of pathogens into the deeper tissues of the plant where they cannot be disinfected or washed away (Aruscavage et al., 2008). The cleaning and sanitization of equipment used during harvest is an important requirement (McEvoy et al., 2009), but of limited applicability in smallholder farms in developing countries where water for cleaning might not be available and tools are permanently in contact with hands, crops and soil. However, as mentioned above, plant injury and internalization of pathogens at harvest are only noteworthy where surface contamination is not a larger risk factor.

During harvesting and immediately after, fresh vegetables are also exposed to potential cross-contamination from the soil surface, other agricultural inputs (e.g. fresh manure) and handlers. It is important to implement basic sanitary practices to prevent contamination at this level. Using baskets or plastic sheets to avoid contact between utensils and produce and the ground or other potentially unsafe sources of contaminants can greatly contribute to the reduction of the risks of contamination during harvest.

In both northern and southern vegetable production systems, emphasis is often placed on performing parts of the processing while the crop is still on the farm. For example, in-field coring and packaging of lettuce heads in the USA has become a common industry practice (McEvoy et al., 2009). Likewise, in West Africa, it is common practice for vegetable sellers to buy their crops on the farm. This allows them to choose the best-looking ones. Still on the farm, they remove soil particles from freshly harvested vegetables (e.g. carrots, salad greens and cucumbers) by washing them in the streams or ponds usually used for irrigation, as reported, for example, in Niger, Benin, Burkina Faso and Senegal (Klutse et al., 2005). These water sources are often highly contaminated, which undermines growers' efforts to avoid contamination and poses a significant risk to the consumer as well as all stakeholders involved in subsequent crop handling (Hope et al., 2008). Raising awareness about microbial hazards among traders is required, as is the provision of acceptable alternative water sources in which to wash vegetables.

Transport and storage

The main risk factor for increased microbial loads on fresh vegetables during transportation and storage is elevated temperatures over extended periods of time. In many developing countries, there is, however, still a general lack of cool transport and storage. This explains why some crops, especially the most perishable such as lettuce, are often grown in the city close to the point of sale. This urban vicinity, on the other hand usually results in irrigation with contaminated surface water (Drechsel et al., 2008).

The lack of cool storage requires fast transport from farm to retail and exact prediction of quantities to be sold to avoid leftovers. In some countries, intermediate traders are gaining ground to supply to large outlets such as supermarkets. A common bottleneck in this situation is the heat exposure of vegetables already packed in closed plastic bags during transport and intermediate storage, i.e. before the supermarket is reached.

The rate and extent of microbial growth in fresh produce depend mainly on the initial microbial load and time/temperature exposures. In general, lower storage temperatures ensure a longer post-harvest life for fresh fruits and vegetables (Nunes, 2008). Storing produce in the shade is one of the few methods available to keep produce cooler where refrigeration in not feasible.

Another risk factor typical for developing countries is the lack of dedicated transport vehicles. Usually, market traders or farmers hire taxis or mini-vans which are used at other times for the transport of commuters, small livestock or other goods, which increases the general risk of cross-contamination.

In northeastern India, farmers often transport their produce from the field to the market by bullock/buffalo cart, as it is the cheapest available transport. While on-farm packaging practices are almost non-existent, some farmers use straw for crops such as tomatoes as a cushioning material to reduce mechanical damage. Traders further pack the tomatoes in smaller paper cartons with no ventilation and send them to distant markets, with a large proportion of the products damaged and decayed by the time they reach the consumer, which increases food-safety risks (Directorate of Research (Agri) Assam Agricultural University, 2005).

Processing and marketing

Handling, processing and packaging of leafy green vegetables is carried out differently in diverse environments throughout the world. International standards as supported by the *Codex Alimentarius* remain in many developing countries only a long-term target as local conditions, education, regulations and infrastructure (cooling, transport means, etc.) including monitoring cannot yet match what is possible in more developed countries.

The first processing step of fresh vegetables in local African and Asian market chains is often the removal of soil particles and dust to improve their general appearance and market value. In Ghana, for example, the simple removal of ('bad-looking') outer vegetable leaves in markets reduced the coliform counts by 0.5 log unit (lettuce) to 1 unit (cabbage) (M. Akple, pers. communication). Cutting the cabbage into smaller units, on the other hand, increased the surface area and coliform counts, which shows that every manipulation of fresh vegetables down the processing chain may be a source of contamination if prevention measures, such as cleanliness of processing equipment and the surroundings, including hygiene, health and adequate training of the involved staff, are lacking.

As in all stages of production and processing, workers may be the key sources of produce-contamination with pathogens, primarily viruses (norovirus, hepatitis A) and bacteria (*Shigella, Salmonella*, etc.). The two main and most basic steps for risk reduction would be to provide sufficient handwashing facilities and to avoid having ill individuals harvest or handle produce. However, both recommendations face significant challenges in developing countries. On the one hand, labour associations covering the health protection of formal and informal restaurant, vendor and catering staff are usually non-existent. On the other hand, the urbanization rate has outpaced development of sanitary infrastructure. For example, a market survey in Ghana's capital, Accra, found that only 31 per cent of the urban markets have a drainage system, 26 per cent have toilet facilities and 34 per cent are connected to pipe-borne water (Nyanteng, 1998). These data are very similar to those reported from a global survey on street-vended food (WHO, 1996).

Final point of sale

Where the lack of local infrastructure constrains the provision of acceptable hygienic conditions, as described in the previous section, relocation of markets or food stalls is often discussed, especially those that are informal. However, the WHO (1996) noted correctly that street-food vendors are, in many countries, part of the social and cultural fabric of their communities and, therefore, an effort should be made to keep them as close to their current business sites as possible, even though some sanitary facilities may not be available. The reasons are at least twofold:

1 The provision of new sites away from traditional locations often results in business disadvantages, thus there is low adoption and/or an informal reappearance of the stands near the former location.
2 Although better sanitary conditions might reduce the number of risk factors, they may not automatically impact on raw material contamination, cross-contamination, personnel hygiene behaviour, poor food preparation practices or hot and cold holding capacity.

Consequently, relocation should not be seen as a panacea for resolving the problems of low food safety. Indeed, risk mitigation has to start on farm (see Chapter 10) and continue during harvest.

The last point of sale can be a street-market, a supermarket or a restaurant offering, for example, a fresh salad. Although the standards of these entities vary greatly in developing countries, general food-safety considerations are similar and again are much dependent on the ability to keep the produce under low temperatures and well protected from contamination. Especially in hot climates, it is often impossible to conserve unsold leafy vegetables for the next day because of product quality deterioration. Even during the day, water is often used for refreshing or rehydrating (crisping) fruits and vegetables on display. Changing this water once during the day can already decrease the average faecal coliform counts on lettuce by up to 1 log unit, as a comparative analysis has indicated (Drechsel et al., 2000). However, in many developing countries where it is not easy to change water, vegetables are refreshed and washed over the day with the same water, which can lead to severe cross-contamination (Amoah et al., 2007a).

In theory, the use of chlorine tablets could help, but if solutions used for decontamination are not regularly changed, such processing water may itself become a source of contamination. Therefore, clear instructions on dosages and frequencies of water replenishment and disinfectants should be provided and followed. More important is the need to address the motivation for washing or refreshing vegetables in retail. The most obvious motivation is to display 'fresh' produce, which reflects customers' preferences and criteria for purchase; this does not automatically translate into 'safe' products but could be a starting point for awareness campaigns. Such campaigns should be based on local perception studies. In Kumasi, Ghana, public-health students worked as interns over several weeks in eating places of various types (street kiosks, canteens, restaurants), observing behaviour and trying to understand limitation and opportunities to increase food safety (Rheinländer et al., 2008). According to their findings, consumers avoided food-safety risk by assessing the neatness and trustworthiness of vendors. Vendors were also found to emphasize these attributes while ignoring basic food-safety practices.

Consumption at home and in restaurants

Diets vary and the consumption of raw salads is not common in every country or region. However, fresh leafy greens are increasingly eaten in urban centres, e.g. in sub-Saharan Africa, as a modern complement to rice-based fast food. In Ghana, for example, more than 90 per cent of the lettuce produced enters the street-food sector; in Accra alone, at least 200,000 residents of various socio-economic classes consume lettuce or cabbage every day. Most of this produce is grown in urban and peri-urban agricultural plots irrigated with polluted water (Amoah et al., 2005, 2007a; Obuobie et al., 2006).

While markets, transport and retail can be influenced (and, in some countries, also regulated) by governmental guidelines and control measures, consumer behaviour can hardly be controlled through formal regulations (Fischer et al., 2007). On the other hand, if risk awareness is provided, consumers should have a high incentive to practise safe food-handling behaviours because of the direct and immediate impacts on their own health. The challenge is to understand if this awareness is actually influencing behaviour and on what kind of information it is based. Surveys of 210 restaurants and 950 households in seven countries across West Africa showed, for example, that vegetable-washing is common in 56–90 per cent of the urban households and 80–100 per cent of the restaurants (Amoah et al., 2007b; Klutse et al., 2005).

The reasons for washing varied between cities and countries, broadly depending on educational and economic standards, the availability of certain disinfectants and local traditions. In some households, vegetables were washed primarily to remove dirt, sand, dust and, more seldom, chemical farming residues. In other households and restaurants it was performed explicitly to reduce the risk of pathogens and diarrhoeal diseases (Amoah et al., 2007b; Klutse et al., 2005). The most common disinfectants used in the restaurants throughout Francophone West Africa were bleach (Eau de Javel®) (55 per cent of cases) and potassium (K) permanganate (31 per cent), followed by salt, lemon or soap. In Anglophone Ghana, the use of bleach was unknown and the general awareness level related to pathogen contamination appeared to be much lower (Amoah et al., 2007b). Amongst the lower classes in the selected Francophone cities, there was a clear tendency for only water or water with salt, soap or lemon juice to be used, while in middle and upper class households and restaurants the use of bleach or permanganate appeared to be prevalent (Figure 12.2).

In Ghana, various salt and vinegar solutions are dominantly used besides cleaning in water only. Salt is preferred to vinegar for cost reasons, but both appeared highly ineffective in the low concentrations or contact times commonly used (Amoah et al., 2007b). Also Rosas et al. (1984) stressed that common washing practices very often do not reduce the coliform counts to safe levels. There can be large differences depending on contact time and sanitizer (Table 12.3). The observed differences in the knowledge of appropriate sanitizers between Francophone and Anglophone countries in West Africa call for an engagement of the private sector in food-safety campaigns.

Washing can also remove helminth eggs especially with good agitation and rubbing of the leaves. When washing in a bowl was compared to washing under running water (independent of sanitizing solution used) the latter was more effective in egg reduction. Washing in a bowl reduced the helminth egg population by half and sometimes more, while running water reduced the contamination level from the usual eight to nine eggs to one egg per 100g lettuce wet weight (Amoah et al., 2007b).

When it comes to internalized pathogens or pesticides on vegetable surfaces even thorough washing has its limitations (Box 12.3).

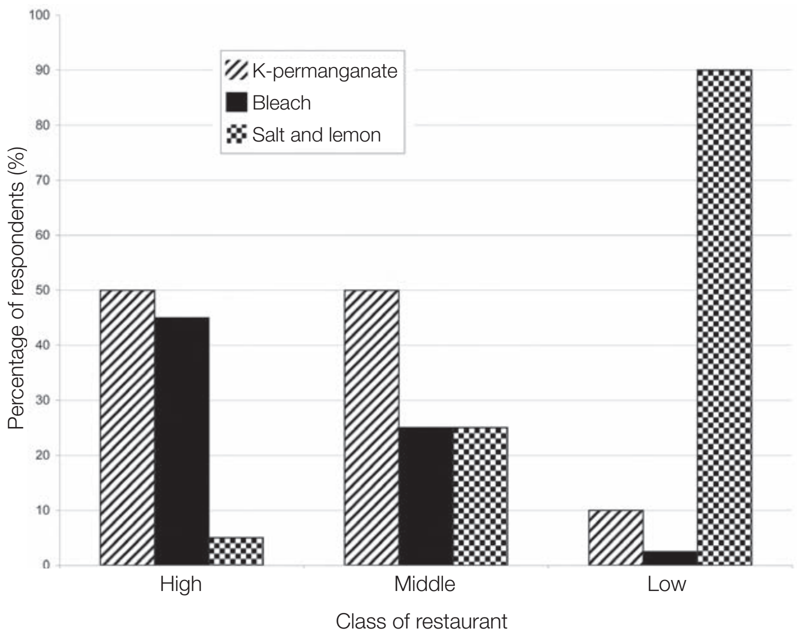

Figure 12.2 *Types of disinfectants used according to the category of restaurants in Cotonou, Benin*

Source: Amoah et al. (2007b)

Box 12.3 Limitations in view of internalized pathogens and pesticides

Surface treatments with sanitizers may substantially reduce surface contamination but are significantly less effective in reducing microbial populations that have been internalized in produce (Pao and Davis, 1999). Zhuang and Beuchat (1996) demonstrated that a 15 per cent solution of trisodium phosphate completely inactivated *Salmonella* on the surface of tomatoes while only resulting in a 2 log reduction of internal populations. Moreover, some pathogens, including bacteria and some viruses, adhere to fruits and vegetables in such a fashion that they cannot be easily removed or killed with conventional washing and disinfection procedures. The exact mechanisms are not yet fully understood.

In addition to microbial contamination, washing vegetables can effectively also reduce levels of pesticide contamination. Special care is, however, required for hydrophobic pesticides which cannot easily be removed with water, unless soap is used. For some fruits and vegetables, such as tomatoes, it is best to remove the skin when boiling cannot eliminate the threat. Cooking vegetables can be contra-effective when the melting point of the pesticide is over 100°C, like in the case of Lindane analysed on tomatoes in Ghana. In this case, the tomato skin cracks when boiled and the pesticide can enter the fruit body (Obuobie et al., 2006). Amoah et al. (2006) compared the general threat of microbial and pesticide contamination of green vegetables in Ghana's urban markets.

Table 12.3 *Effect of selected disinfection methods on faecal coliform levels on lettuce in West Africa*

Method	Log unit reductions[a]	Comments
Dipping in a bowl of water	1.0–1.4	• Increased contact time from a few seconds to 2 minutes improves the efficacy from 1–1.4 logs. • Not very efficient compared to washing with other sanitizers. • Not very effective for helminth eggs if washing has to be done in the same bowl of water. • Warming the water did not result in different counts.
Running tap water	0.3–2.2	• Effective compared with washing in a bowl, also for helminth egg removal. • Increased efficacy only with increased contact time from a few seconds to 2 minutes. • Limited application potential due to absence of tap water in poor households.
Dipping in a bowl with a salt solution	0.5–2.1	• Salt solution is a better sanitizer compared to dipping in water if the contact time is long enough (1–2 mins). • Efficacy improves with increasing temperature and increasing concentration, but high concentrations have a deteriorating effect on the appearance of some crops like lettuce.
Dipping in a bowl with a vinegar solution	0.2–4.7	• Very effective at high concentration (>20ml/l) but this could have possible negative effects on taste and palatability of the washed vegetables. • To achieve best efficacy and keep the sensory quality of product the contact time should be increased to 5–10 mins. • Efficacy is improved even at low concentration if carried out with a temperature over 30°C.
Dipping in a bowl with potassium permanganate solution	0.6–3.0	• Most effective at higher concentrations (200ppm), a temperature of 30°C or higher and a contact time of 5–10 mins. • Higher concentration colours washed vegetables purple which requires more water for rinsing or may raise questions of a negative health impact.
Dipping in a bowl with a solution containing a washing detergent (OMO™)	1.6–2.6	• Significant reductions could be achieved with 5–10 mins' contact time. • Residual perfumes and soap taste might affect consumer's sensory perception. • As OMO contains surfactants which could affect health, thorough rinsing is required
Dipping in a bowl of water with added household bleach	2.2–3.0	• Tested dosages (commercial bleach) resulted in 165–248μS/cm salinity (= concentration indicator). • Effective with 5–10 mins' contact time, and widely used in Francophone West Africa. • May pose a health risk if dosage is not well explained.
Dipping in a bowl of water containing chlorine tablets	2.3–2.7	• Effective at 100ppm but tablets not commonly available in some West African countries. • Effect of higher concentrations on efficacy not tested.

Source: Amoah et al. (2007b); modified; [a] ranges are due to different concentrations or contact times of disinfectant (see next column)

Education of stakeholders in post-harvest risk reduction

Education in food safety is critical for implementation of risk reduction and mitigation measures during post-harvest production of fresh produce in both developed and developing countries. In general, stakeholders at every level need to be included in food-safety education, including policy-makers. In the developing world there is a special need to improve both processors' and consumers' understanding of food safety. Educational campaigns should target the following three groups:

- Processors: in regions where cost is the main barrier to implementing safe practices, education efforts should aim to inform the stakeholders about available low-cost alternatives that can be successfully implemented locally. Educational programmes should also include cost–benefit comparisons and take into account cultural preferences and patterns of behaviour. Aside from conventional training workshops, there are also other educational approaches which try, for example, to show the invisible risk moving along the pathogen pathway (Box 12.4).
- Policy-makers: at the national and international level, the *Codex Alimentarius*, supported by the FAO and WHO, probably has the best potential and network to foster awareness and influence decision-making. Care has to be taken to support countries with appropriate steps towards achieving the international standards.
- Consumers: the educational activities may target the general consumer audience on various levels of society, such as schoolchildren, women, households, etc. As the main considerations differ from country to country, it is crucial to understand the barriers in each region and possible opportunities in order to implement a successful food-safety educational campaign. As the West African example showed, sometimes certain easy-to-buy disinfectants might simply not be known.

However, the step from increased awareness to actual behaviour-change is not an easy one and might require certain triggers and incentives as described in Chapter 16.

Conclusions

Due to poverty-related poor sanitary conditions in most developing countries, it is difficult to maintain appropriate hygienic standards in support of food safety. The enforcement of unrealistic standards, on the other hand, would neither be effective nor address the core of the problem, which is often the lack of understanding of hazards and safe practices (Nicolas et al., 2007). Therefore, regulations based on

Box 12.4 Road shows

Supported by the Knowledge Sharing in Research (KSinR) project of the Consultative Group on International Agricultural Research (CGIAR), alternative methods of awareness creation and education on wastewater irrigation and food safety were tried in Ghana. Instead of conventional training events, farmers, food caterers, market women, retailers and representatives from authorities met in their city for an urban road trip along the contamination pathway.

The participants were taken in a bus to one of their typical urban vegetable production sites with wastewater irrigation. From there the group toured wholesale and retail markets until they reached typical street-food restaurants serving the same vegetables that they had followed from the farm. At each of the stops, farmers, vendors or kitchen staff demonstrated common and locally fitting improved practices for health-risk reduction. Participants were encouraged to ask questions and discussed possible incentives for behaviour-change at each stop along the value chain.

The road trip was supported by the visualization of the invisible threat of microbiological hazards through the use of agar plates inoculated either with wastewater (showing growing bacterial colonies) or piped water (no bacterial colonies). The main learning objectives were for:

- participants to be aware of the presence of invisible risks moving from farm to table;
- participants to understand the concept of a multiple-barrier approach with joint responsibility for effective health-risk reduction;
- authorities to appreciate and support efforts of main stakeholders to contribute to solutions.

Source: Amoah et al. (2009)

international standards have very limited local application potential, although they are useful long-term goals. In addition, the application of the common HACCP concept is challenged by the multitude of existing sanitary hazards likely to affect the condition of the food along the farm to fork pathway as well as the many individual entities concerned, who often lack the collective organization, education, risk awareness and resources to undertake HACCP studies. While, for example, priority-setting via QMRA (see Chapter 2) would be desirable, the common lack of resources limits its application. What is required under these circumstances is an integrated but flexible approach, keeping in mind what is realistically possible, and the awareness and motivation level of all the concerned parties.

Agreeing on local FSO and striving for continuous improvement in the levels over time are key elements of an adapted concept. This mirrors the WHO (2006) recommended health-based targets for risk reduction in wastewater irrigation, which are, like the FSO, related to the time of consumption, i.e. the end of a food chain.

Critical control points remain important to avoid and/or reduce contamination. The studies in West Africa by Amoah et al. (2007b) found, for example, that it is very common practice to wash vegetables before consumption as raw salad. Although the reasons did not always reveal any understanding of pathogens and possible disease transmission, the fact that people adopted a washing behaviour can be considered a significant milestone on which a local food-safety campaign could build. While such post-harvest operations might not fully remove foodborne pathogens from leafy vegetables and herbs, they remain key steps complementing other options for risk reduction (FAO/WHO, 2008).

Given the basic need for food-safety education, a key pillar of any intervention will be awareness creation and training.

NOTE

1 The situation is different for chemicals, especially heavy metals. Also some crops, like cucumbers or carrots, are able to absorb smaller organic chemicals, like chlorobenzenes and polycyclic aromatic hydrocarbons (Collins et al., 2006).

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