CODEX ALIMENTARIUS
INTERNATIONAL FOOD STANDARDS

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World Health Organization

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GUIDELINES FOR THE SAFE USE AND REUSE OF WATER IN FOOD PRODUCTION AND PROCESSING

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1. INTRODUCTION

Water has an important role in all stages of the food chain from initial sourcing, storage, treatment, distribution, use in irrigation of food crops and forage for animals, primary production, and food processing through to consumption of the final food. It is used as an ingredient, in direct and indirect contact (e.g. washing, cooling the product, or cleaning of equipment surfaces in contact) with food, food packaging, and for hygiene sanitation in food processing. The important role of water in food production has led to the need to ensure its safety and quality since it can be a carrier for the transmission of diseases, contamination, or unwanted sensory attributes.

Water is a dwindling resource worldwide and not all food producers and processors have access to safe water sources, or this access may be limited. Noting that the availability and microbiological quality of water are different in each country, region, context, setting, and food establishment, water should always be fit for use for each specific purpose, and it should be managed in a way that the safety of food is ensured, while simultaneously avoiding unnecessary consumption and waste.

Water used along the food production and processing chain can have different microbiological quality requirements, and types of water other than potable water may be suitable for certain purposes, provided that they do not compromise the safety of the final product for the consumer.

Requirements for water safety should therefore be considered in context, considering the purpose of the water use, the potential hazards associated with the water use, and whether there is any subsequent measure to decrease the potential for contamination along the food chain.

A risk-based approach to water sourcing, treatment, handling, storage, and use can help in identifying the hazards associated with the water and its use and determine treatments, if applicable, that water needs to undergo to meet the safety parameters specific to each intended use. This approach can also provide a means to address many of the water access and safety challenges associated with reuse based on the principle of using the right type of water for the intended purpose/need.

Deciding whether water is fit for purpose should be based on a hazard analysis that considers risk factors such as those associated with the source water, the end use of the food product (e.g. whether the food is eaten raw – without steps that would mitigate potential hazards introduced by the water source), and management options such as treatment options and their efficacy and the application of multiple barrier processes for risk mitigation.

These guidelines respond to the need for a document outlining a risk-based approach to safe sourcing, use, and reuse of water fit for purpose, rather than focusing on the use of potable water or water of other quality types (e.g. clean water). Using the risk-based approach outlined in these guidelines will allow for a specific assessment of the fitness of the water for the intended purpose.

Associated annexes provide product-specific guidelines for the sourcing, collection, storage, treatment, handling, distribution, use, and reuse of water in both direct and indirect contact with food throughout the food chain. The annexes also provide examples such as decision tree tools (DTTs) that can help to determine if water is fit for purpose.

2. OBJECTIVES

The *Guidelines for the safe use and reuse of water in food production and processing* aim to:

- Provide guidance for food business operators (FBOs) and competent authorities on the application of a risk-based approach for the use and reuse of water that is fit for purpose.
- Provide practical guidance and tools (e.g. DTTs) and risk-based microbiological criteria as examples to help FBOs evaluate risks and potential interventions of water as part of their food hygiene system.

3. PURPOSE AND SCOPE

These guidelines provide a framework of general principles and examples for applying a risk-based approach to determine if the water to be sourced, used, and reused by FBOs involved in production and processing of relevant commodities is fit for purpose by addressing microbiological hazards, such as parasites, bacteria, and viruses.

4. USE

The document is intended for use by FBOs (primary producers, packing houses, manufacturers, processors) and competent authorities as appropriate.

These guidelines are complementary to and should be used in conjunction with all relevant Codex texts, including but not limited to: the *General Principles of Food Hygiene* (CXC 1-1969),[1] the *Code of Hygienic Practice for Fresh Fruits and Vegetables* (CXC 53-2003),[2] the *Code of Practice for Fish and Fishery Products* (CXC 52-2003),[3] the *Code of Hygienic Practice for Milk and Milk Products* (CXC 57-2004),[4] the *Principles and Guidelines for the Conduct of Microbiological Risk Management (MRM)* (CXG 63-2007),[5] the *Principles and Guidelines for the Establishment and Application of Microbiological Criteria Related to Foods* (CXG 21-1997),[6] the *Code of Practice on Food Allergen Management for Food Business Operators* (CXC 80-2020),[7] the *Code of Hygienic Practice for Meat* (CXC 58-2005),[8] and the *Principles and Guidelines for the Conduct of Microbiological Risk Assessment* (CXG 30-1999).[9]

5. GENERAL PRINCIPLES

a) Water, as well as ice and steam made from water, used at any stage of the food chain, should be fit for its intended purpose, as determined by a risk-based approach comprising the evaluation of microbiological, chemical, and physical hazards and should not compromise the safety of finished foods for consumers.

b) When re-using, water should be treated or reconditioned, effectively monitored and the treatment should be validated to eliminate or reduce hazards to an acceptable level according to its intended use.

c) In all situations, water sourcing, use, and reuse should be part of an FBO´s food hygiene system.

d) When using water as an ingredient in food, it should be potable.

6. DEFINITIONS

For the purposes of this document the following definitions apply:

Clean water: Water that does not meet the criteria for potable water but does not compromise the safety of the food in the context of its use.

Potable water: Water fit for human consumption.

Recirculated water: Water reused in a closed loop for the same processing operation without replenishment.

Reclaimed water: Water that was originally a constituent of a food material, which has been removed from the food material by a process step and is intended to be subsequently reused in a food processing operation.

Reconditioning: The treatment of water intended for reuse by means designed to eliminate or reduce microbiological contaminants to an acceptable level according to its intended use.

Recycled water: Water which has been obtained from a step in the food production or food processing operation to be reused in the same, prior or a subsequent step of the operation, after reconditioning, when necessary.

Reuse water: Water that has been recovered from a processing step within the food operation, including from the food components and/or water that, after reconditioning treatment(s) as necessary, is intended to be reused in the same, prior or a subsequent step of the food processing operation. Types of reuse water can include reclaimed water from food, recycled water from food operations, or recirculated water in a closed loop system.

Wastewater: Used water that has been contaminated because of human activities.

Water fit for purpose: Water that is determined to be safe for an intended purpose through the identification, evaluation, and understanding of potential microbiological hazards and other relevant factors (e.g. history of use, the intended use of the food, etc.), including the application of control measures such as treatment options and their efficacy to ensure effective elimination or mitigation of such hazards.

Water sourcing: The act of identifying and obtaining water for food production from a particular water source (e.g. groundwater, surface water, captured water).

7. WATER FIT-FOR-PURPOSE ASSESSMENT

Assessing if water is fit for purpose is required for all sectors and steps in the food chain. Risk principles (i.e. a risk-based approach) should be applied in evaluating if the water is fit for purpose during sourcing, collection, storage, treatment, handling, use, and reuse.

Conducting such an assessment requires complete knowledge of the water system, the diversity and magnitude of the hazards that may exist, and the capacity of existing processes and infrastructure to address and control risks.

Water fit-for-purpose assessments also require the identification of potential microbiological hazards with the capacity to cause damage to water safety and their sources and should also address safe water sourcing, use, or reuse, when developing and implementing the plan. Additional factors to be considered could include water storage and distribution, including the hygienic design, and the need for special expertise.

Water use and reuse systems should be subjected to routine, risk-based monitoring and verification of appropriate parameters. The frequency of monitoring and verification can be dictated by different factors such as the source of the water or its prior condition, the efficacy of any treatments, and the intended use and reuse of the water. Relevant routine monitoring data by environmental agencies and public health organizations could be also useful in determining the frequency of monitoring and verification activities.

In the context of safe water sourcing, collection, treatment, handling, storage, use, and reuse, water fit-for-purpose assessments can include the following risk-based approaches:

- Descriptive assessment (least comprehensive) – an onsite as well as a document-based evaluation from which a written descriptive assessment is generated. Examples include a sanitary inspection used in evaluating and managing risks from irrigation water and rapid assessment of water safety.
- Semi-quantitative water assessment – the development and use of risk matrices that establish categories of risks from high to low, including consideration of sanitary conditions and their likelihood and estimated frequencies of unacceptable sanitary conditions. These are normally used for planning, prioritization, and a rapid assessment of the safety and quality of water sources collection, storage, treatment, and handling.
- Quantitative microbial water assessment (QMWA) (most comprehensive) – a mathematical modelling approach that can be used for estimating risks related to water use with a health outcome target. QMWA helps identify how much of an impact a pathogenic microorganism will have on the health of the population, e.g. guiding wastewater use in agriculture.

8. WATER SAFETY MANAGEMENT

Water fit-for-purpose assessments can be used for management decisions in setting target objectives for water sources and treatments for achieving public health outcomes, performance targets (e.g. food safety objectives, performance objectives), acceptable levels of risk, and treatment process efficacies as appropriate.

Risks associated with the use of water should be managed with measures implemented within the framework of a structured food hygiene system with monitoring and verification activities in place to ensure that the system is operating as expected.

As part of the food hygiene system, where appropriate, all water systems should be mapped in a process flow diagram and evaluated in the hazard analysis.

Once potential hazards and their sources have been identified, the risks associated with each hazard or hazardous event should be compared so that priorities for risk management can be established and documented. A semi-quantitative matrix might be useful to identify hazards and prioritize control measures for risk management purposes.

Treatment or reconditioning of water intended for fit-for-purpose use and reuse should be based on hazard analysis of the sourced water and, where deemed necessary, treatments should ensure that hazards are eliminated, controlled, or reduced to an acceptable level.

9. DECISION SUPPORT SYSTEMS

Decision support systems (DSS) tools, such as decision trees (DTs) or matrices, are considered to be useful risk management tools to assist stakeholders in making decisions to determine if water is fit for purpose and the required quality for use or reuse at a given step in the supply chain.

DSS should allow for the diversity in food production, resulting in different types of risks and risk management steps necessary to ensure the water’s fitness for purpose in food production. Examples include the food types involved and their intended use; the food-water interactions; the specific waterborne food safety hazards; and their likelihood and magnitude of transmission to the consumer when present in different foods.

An example of a risk-based DSS tool with further guidance is provided in Figure 1.

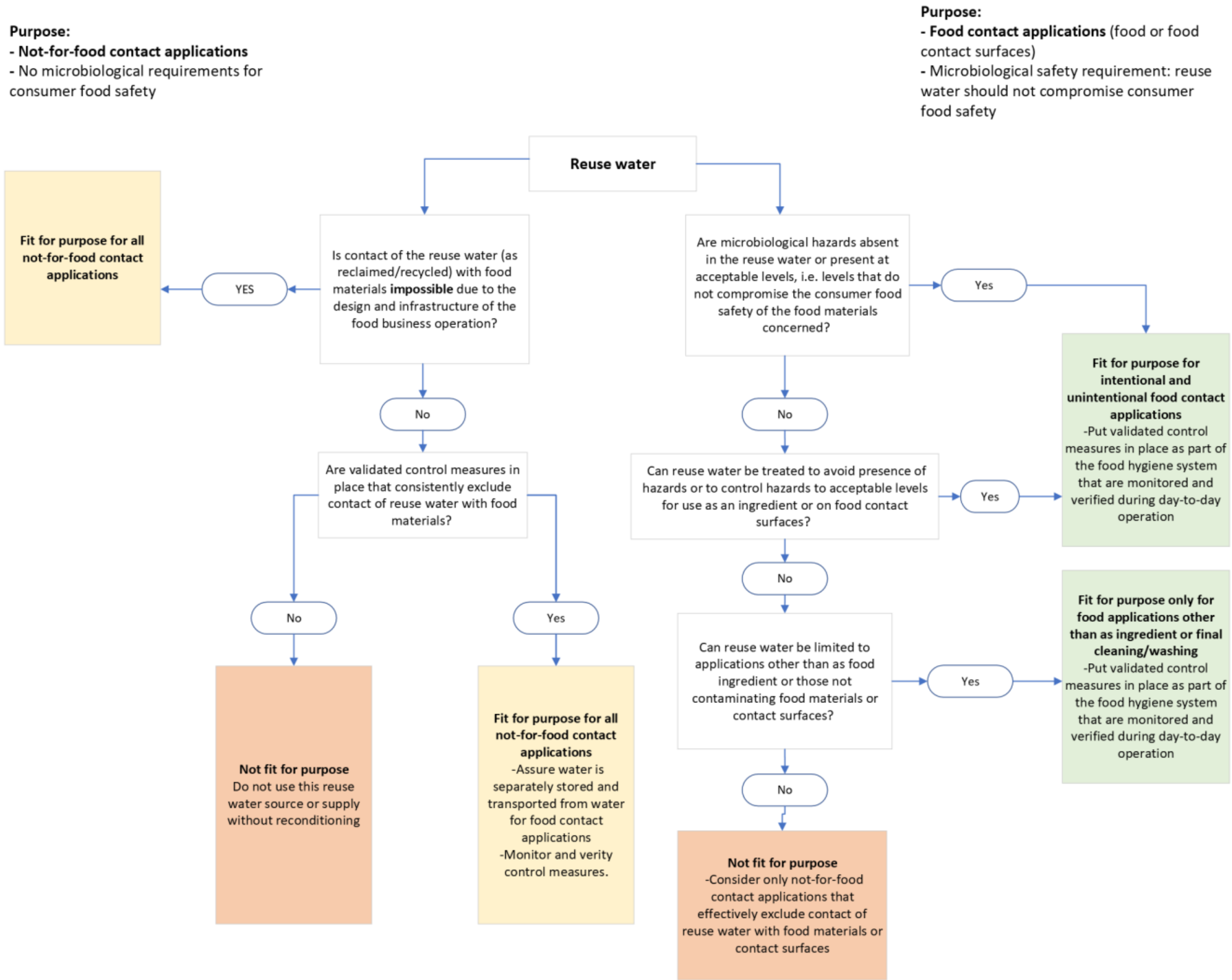

Figure 1. Example of a risk-based decision support system (DSS) framework tool for the purpose of deciding if reused water can be used in either a food contact application or a not-for-food-contact application for microbiological hazards

Annex I

FRESH PRODUCE

1. INTRODUCTION

Water can be a source of contamination of all microbiological pathogens associated with the consumption of fresh produce. These pathogens include bacteria such as, but are not limited to, *Salmonella* spp., *Shigella* spp., *Campylobacter* spp., *Listeria monocytogenes* and pathogenic strains of *Escherichia coli* spp., and also viruses such as hepatitis A and norovirus, and parasites such as *Cyclospora* spp*., Giardia* spp. and *Cryptosporidium* spp.

Water is used at all steps in the production chain of fresh produce, from irrigation and other pre-harvest practices, such as fertilization and pesticide application, during harvesting, such as washing in the field, and post-harvest practices, such as cooling, transporting, washing and rinsing, until final washing steps by the consumer. Control measures to prevent water from becoming a source of microbiological contamination of the fresh produce, should be considered at all stages, and an overall management strategy should be developed, taking into account risk factors and control measures applicable at each step.

2. PURPOSE AND SCOPE

The purpose and scope of this annex are to elaborate guidelines for the safe sourcing, use and reuse of water in direct and indirect contact with fresh produce (for primary production and processing) by applying the principle of 'fit for purpose' using a risk-based approach. The annex recommends good hygiene practices (GHP) and risk-based, sector-specific potential prevention and intervention strategies. It provides examples and/or practical case studies for determining appropriate fit-for-purpose microbiological criteria, (i.e. criteria for bacteria, viruses, parasites), as well as examples of the DSS tools such as DTs to determine the water quality needed for the specific intended purpose in the fresh produce supply chain.

3. USE

This annex is complementary to and should be used in conjunction with the main document, the *General Principles of Food Hygiene* (CXC 1-1969),[1] the *Code of Hygienic Practice for Fresh Fruits and Vegetables* (CXC 53-2003),[2] the *Principles and Guidelines for the Conduct of Microbiological Risk Management (MRM)* (CXG 63-2007),[5] the *Principles and Guidelines for the Establishment and Application of Microbiological Criteria Related to Foods* (CXG 21-1997),[6] and the *Principles and Guidelines for the Conduct of Microbiological Risk Assessment* (CXG 30-1999).[9]

4. DEFINITIONS

Biocide: A chemical substance or microorganism intended to destroy, deter, render harmless or exert a controlling effect on any harmful organism by chemical or biological means.

Fresh produce: Any fresh fruit, nuts, mushrooms, herbs, and vegetables that are likely to be presented to consumers in a raw form, either unprocessed or physically altered from its original form but remaining in the fresh state (e.g. washed, peeled, cut), and that are generally considered as perishable regardless of it being intact or cut from root/stem at harvest.

5. PRE-HARVEST USE OF WATER

An adequate supply of water of a suitable quality (fit for purpose) should be available for use in the various operations in the primary production of fresh produce.

Water has several uses in primary production, e.g. irrigation, application of pesticides and fertilizer, protection against frost/freezing and prevention of sunscald. The quality of water used in primary production is usually very variable. Several parameters may influence the risk of microbiological contamination of fresh produce via water: the source of water, water storage and delivery infrastructures, the type of irrigation system (e.g. drip, furrow, sprinkler/overhead) influencing whether the water has direct contact with the edible portion of the fresh produce, the timing of irrigation in relation to harvesting and exposure of plants to sunlight that can reduce contamination that occurs from water (e.g. microbial die-off). Water used for primary production, including for frost protection and protection against sunscald, which has contact with the edible portion of fresh produce, should not compromise produce safety.

5.1 Water sources

Growers should identify the sources of water used during primary production (e.g. municipality, groundwater including well water, surface water (e.g. open canal, reservoir, river, lake, farm pond), reused irrigation water, rainwater, reconditioned wastewater or discharge water from aquaculture). Apart from municipality (potable) water, examples of water sources that present the lowest risk of contamination (provided these sources and storage and distribution facilities are properly constructed, maintained, monitored and capped, as appropriate) are:

- water in deep wells or boreholes;
- water in shallow wells, provided they are not influenced by surface waters; and
- hygienically collected rainwater.

A number of preventive measures can be implemented to protect a water source if determined to be vulnerable:

- If using more than one water source, ensure all sources are clearly identified to prevent inappropriate use, e.g. provide separate systems for wastewater, potable water supplies, etc.
- Ensure water sources are protected (as much as possible) from contamination by wild and domestic animals, e.g. fencing or netting.
- If storing manure, slurry, composts and other soil amendments, ensure there are no leaks or spillage and they are positioned downhill from the water source, and far enough away to minimize contamination.
- Ensure the catchments and gutters of the water harvesting, distribution and delivery system are regularly cleaned and maintained.
- Ensure that all water storage tanks or water reservoirs are covered, i.e. protected, to prevent contamination.
- If using a private well, ensure it is located away from contamination sources, and constructed appropriately to prevent contamination, e.g. sealed on top.
- Regularly check irrigation systems for damage or leaks and flush lines to remove accumulated organic debris/biofilms. If there has been a period of wet weather, it is recommended to flush the system prior to use.

Water sources that pose a higher risk of contamination may need treatment, for example:

- Wastewater: before using wastewater for crop irrigation, an expert should be consulted to assess the relative risk and determine the suitability of the water source. Measures to ensure the safe use may include wastewater treatment, application techniques that minimize contamination, die-off periods before harvesting, produce washing, disinfection and cooking.
- Surface water (e.g. rivers, lakes, canals, lagoons, ponds, reservoirs): when contaminated, options such as application of chemical treatment, sand filtration (combined with other treatment such as application of UV-C), microfiltration or storage in catchments or reservoirs to achieve partial microbiological treatment should be considered. The efficacy of these treatments should be evaluated and monitored.

5.2 Assessing and testing of water

Growers or associated operators should assess the microbiological quality of water, as prescribed by the competent authority, and its suitability for the intended use, and identify corrective actions in case of unacceptable results, to prevent or minimize contamination (e.g. from livestock, wildlife, sewage treatment, human habitation, manure and composting operations or intermittent or temporary environmental contamination, such as heavy rain or flooding). A decision tree on the possible need for a fit-for-purpose assessment on the water is proposed in Figure 2.

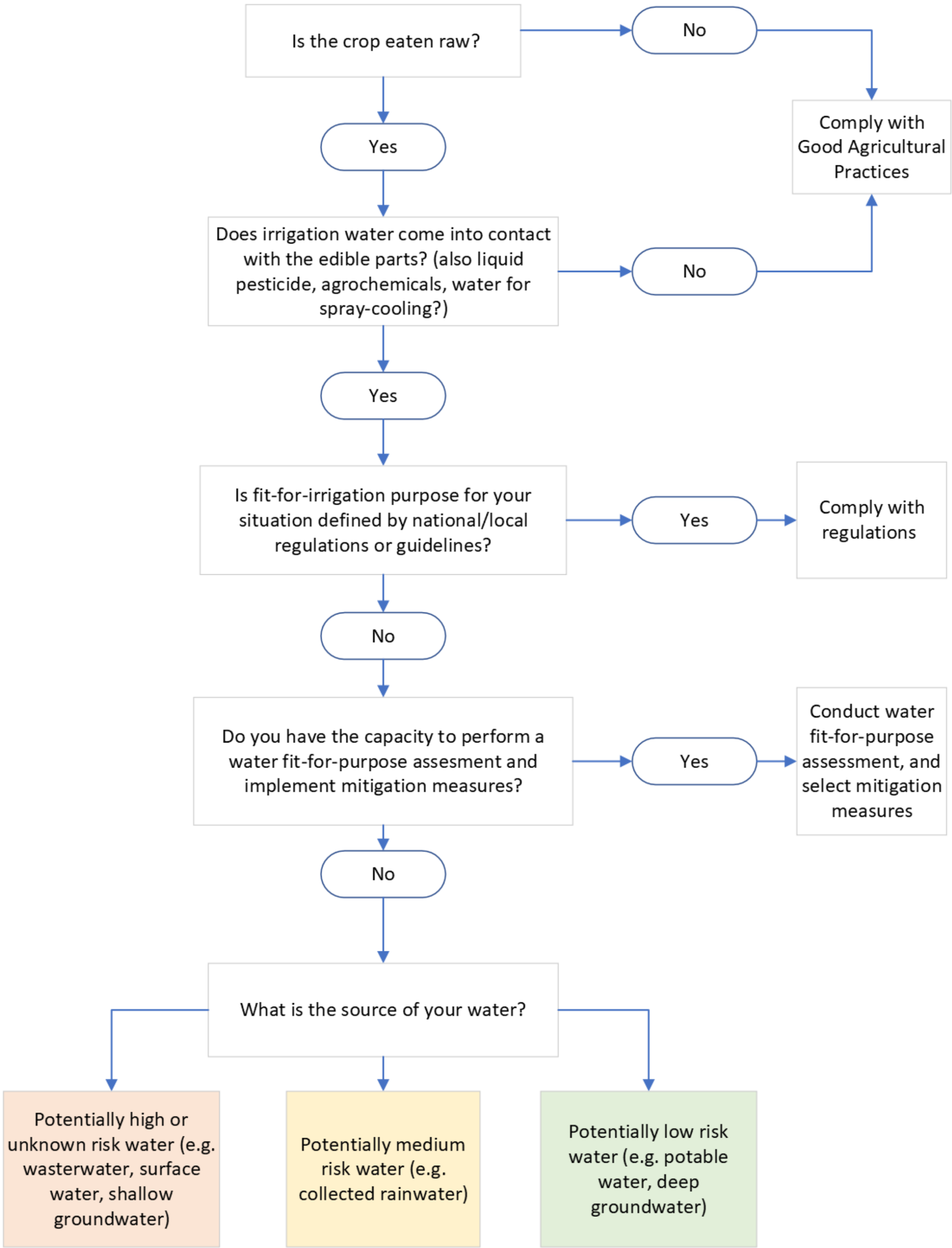

Figure 2: Decision tree on the possible need for a fit-for-purpose assessment on the water

When water is tested for microbiological hazards, the results should be used by growers and associated operators to inform on the use of water according to the risk associated with the production. The frequency of testing will depend on the water source (i.e. lower for adequately maintained deep wells, higher for surface waters), observed quality based on preceding testing, the risks of environmental contamination, including intermittent or temporary contamination, and factors such as the implementation of another water treatment process by growers.

If water testing is limited to indicator organisms, frequent water tests may be useful to establish the baseline water quality so that subsequent changes in the levels of contamination can be identified. Water testing should be more frequent when establishing the baseline, but the frequency can be lowered once there is a better understanding of the patterns (e.g. seasonality) for microorganisms in the water source. Then, if there are results outside of the range, testing frequency can be increased again at that point.

Growers and associated operators should reassess the potential for microbiological contamination and the need for additional testing if events, environmental conditions (e.g. temperature fluctuations due to change in season, heavy rainfall) or other conditions indicate that water quality may have changed.

When testing, growers may consult, if necessary, the competent authority or experts, or refer to regulations, in order to determine and document the following:

- where to sample (e.g. surface of the water or deeper, close to the edge of surface water or farther back from the bank) and how much to sample;
- which validated test methods should be conducted (e.g. for which pathogens and/or indicator organisms);
- which parameters should be recorded (e.g. temperature of water sample, water source location, weather description and/or time and temperature between sampling and analysis);
- how often tests should be conducted;
- how test results should be analysed and interpreted over time, for example, to calculate the rolling geometric mean; and
- how test results will be used to define corrective actions including use of an alternative source of water.

If the water source is found to have unacceptable levels of indicator organisms or is contaminated with waterborne pathogens, corrective actions should be taken to ensure that the water is suitable for its intended use. Possible corrective actions to prevent contamination of water and fresh produce at primary production may include:

- the installation of fencing to prevent large animal contact;
- improvement of good agricultural practices (GAPs) to prevent contamination from animal waste and fertilizer;
- the proper maintenance of wells;
- the prevention of the stirring of the sediment when drawing water;
- the proper maintenance of distribution and storage systems;
- changing the water application method to avoid direct contact of the water with the edible portion of the crop; and
- maximizing the interval between application of irrigation water and crop harvest, as time-to-harvest intervals will impact the die-off rate of microorganisms which is affected by different weather conditions, produce types, and type of bacteria.

Possible corrective action to reduce contamination at primary production may include:

- water filtering by a system that allows capturing particles on which microbiological contaminants may be attached;
- chemical water treatment; and
- the construction of settling or holding ponds or water treatment facilities.

The effectiveness of corrective actions should be verified by regular testing. Where possible, growers should have a contingency plan in place that identifies an alternative source of water.

5.3 Water for irrigation (including greenhouses)

The irrigation system or application method affects the risk of contamination. The timing, the quality of water used, and whether the water has direct contact with the edible portion of the plant should all be considered when selecting the irrigation system or application method to use. Overhead irrigation presents the highest risk of contamination where it wets the edible portion of the crop. The duration of wetting can be several hours, and the physical force of water-droplet impact and the splashing of the soil to the edible part of the product may drive contamination into protected sites on the leaf/produce. If overhead irrigation cannot be avoided, the use of low volume sprays can reduce the risk. Subsurface or drip irrigation that results in no wetting of the plant is the irrigation method with the least risk of contamination, although localized problems may still arise, e.g. when using drip irrigation, care should be taken to avoid creating pools of water on the soil surface or in furrows that may come into contact with the edible portion of the crop.

Water for irrigation should be fit for purpose. Special attention should be given to water quality in the following situations:

- irrigation by water-delivery techniques that expose the edible portion of fresh produce directly to water (e.g. sprayers), especially close to harvest time;
- irrigation of fresh produce that have physical characteristics such as leaves and rough surfaces that can trap water; and
- irrigation of fresh produce that will receive little or no post-harvest wash treatments prior to packing, such as field-packed produce.

A number of GAPs for irrigation might be considered:

- Establish no-harvest zones if the irrigation source water is known or likely to contain human pathogens, and where failure at connections results in overspray of plants or localized flooding;
- Record the crop, date and time of irrigation, water source and any pesticides or fertilizers applied using water.
- Maintain and protect the source of the water used/stored and verify its quality.
- Where possible, avoid the use of high-risk water sources such as poorly stored rainwater, untreated wastewaters and surface waters from rivers, lakes and ponds.
- Growers should focus on the adoption of GAPs to minimize and control the risk of contaminated water and not use testing as the sole method for ensuring control of microbial pathogens in water.
- The type of crop (i.e. ready-to-eat or requiring cooking), timing, irrigation system, soil type and whether the irrigation water has direct contact with the edible portion of the plant should be considered by growers. If contaminated water is in contact with the edible portion of plants, the risk of contamination increases, especially if close to harvesting.
- Where possible, avoid water spraying immediately prior to harvest. Water spraying, i.e. misting, immediately prior to harvest, presents an increased microbiological risk. If the soil is heavy and non-free draining, contaminated water can accumulate on the soil surface, increasing the risk of crop contamination.
- Minimize soil splashing from irrigation by choosing a system that delivers small water droplets. For low-growing crops, it may not be possible to minimize water contact in this way. The risk of contamination increases if large irrigation droplets are used or heavy rain occurs. It should also be noted that if the soil has been contaminated by irrigation water, soil splash can transfer contamination to crops.
- Inspect the complete irrigation system under the farmer's control at the beginning of each growing season and repair the system or apply corrective measures if necessary.
- Properly store organic fertilizers and manure in areas away from water sources, with no possibility of being washed away by runoff.

Those responsible for the water-distribution system, where appropriate, should regularly carry out an evaluation to determine if a contamination source exists and can be eliminated. Water testing records should be kept.

5.4 Water for fertilizers, pest control and other agricultural chemicals

Water used for the application of water-soluble fertilizers, pesticides and other agricultural chemicals that come in direct contact with products should be of the same quality as water used for direct contact irrigation and should not compromise produce safety, especially if they are applied directly on edible portions of the fresh produce close to harvest. Human pathogens can survive and multiply in many agrichemicals, including pesticides.

5.5 Hydroponic water

Microbiological risks of water used in growing fruits and vegetables hydroponically may differ from the microbiological risks of water used to irrigate fruits and vegetables in soil because the nutrient solution used may enhance the survival or growth of pathogens. It is especially critical in hydroponic operations to maintain the water quality to reduce the risk of contamination and survival/growth of pathogens.

The following should be taken into consideration:

- Water used in hydroponic culture should be changed frequently or, if recycled, treated to minimize microbiological contamination.
- Water-delivery systems should be maintained and cleaned, as appropriate, to prevent microbiological contamination of water.
- In the case of a combination of aquaculture and hydroponics (i.e. aquaponics), effluent from fish tanks should be treated to minimize microbiological contamination.

5.6 Water for other agricultural uses

Clean water should be used for other agricultural purposes, such as dust abatement and the maintenance of roads, yards and parking lots, in areas where fresh produce is grown. This includes water used to minimize dust on dirt roads within or near primary production sites. This provision may not be necessary when water used for this purpose cannot reach the fruits and vegetables (e.g. in the cases of tall fruit trees, live tree fences or indoor cultivation).

5.7 Water for indoor storage and distribution facilities

Where appropriate, an adequate supply of clean water with appropriate facilities for its storage and distribution should be available in indoor primary production facilities. Non-potable water should have a separate storage and distribution system.

Non-potable water systems should be identified (for example with labels or colour codes) and should not connect with or allow reflux into potable water systems. Water for indoor storage and distribution facilities should:

- avoid contaminating water supplies by exposure to agricultural inputs that may contain microbial hazards;
- clean and disinfect water storage facilities on a regular basis; and
- control the quality of the water supply.

6. HARVEST AND POST-HARVEST USE OF WATER

6.1 General

Water used during harvesting and post-harvest practices includes any water that contacts fresh produce during or after harvest including water used for rinsing, washing, transporting or fluming, cooling, waxing or icing. The microbiological quality of post-harvest water is critical because microbial die-off on the fresh produce before consumption is minimal, in particular in case of ready-to-eat produce.

Water-quality management varies throughout the operations. Packers should follow GHPs to prevent or minimize the potential for the introduction or spread of pathogens in processing water. The quality of water used should depend on the stage of the operation: for example, clean water could be used for initial washing stages, whereas water used for final rinses should be of potable quality.

Clean, or preferably potable water, should be used when water is applied under pressure or vacuum during washing, as these processes may damage the structure of and force pathogens into plant cells.

It is recommended that the quality of the water used in packing establishments be controlled, monitored and recorded by testing for indicator organisms and/or foodborne pathogens. When the results of such (verification) testing are not available right away, or when the frequency of verification testing is low, it is recommended to carry out other complementary operational monitoring such as rapid water-quality testing by testing of turbidity, chlorine residuals or visual observation.

If water is used in pre-washing and washing tanks, additional controls (e.g. changing water whenever necessary and controlling product throughput capacity) should be adopted.

If large quantities of fresh produce are washed in the same volume of water, accumulation of microorganisms occurs which favours cross-contamination between different product batches. Residual concentration of biocides in the process water can be used to maintain the microbiological quality of process water to avoid accumulation of microorganisms in the water tank and reduce cross-contamination in the washing tank.

Post-harvest operations/systems that use water should be designed in such a manner as to minimize places where the product may lodge, or cause dirt buildup.

The use of biocides to maintain the microbiological quality of process water should comply with the requirements established by the competent authority and should be validated for efficacy. Biocides should never replace GHPs but be used in addition to GHPs, and where necessary to minimize post-harvest cross-contamination with biocide levels, monitored, controlled and recorded to ensure the maintenance of effective concentrations. The application of biocides should be followed by rinsing of the fresh produce as necessary to ensure that chemical residues do not exceed levels established by the competent authority, using overhead spray, not by an immersion tank without cross-contamination attention.

Where appropriate, characteristics of post-harvest water that may impact the efficacy of the biocidal treatments (e.g. the pH, turbidity and water hardness) should be controlled, monitored and recorded.

Ice that may come in contact with fresh produce should be made from potable water and produced, handled, transported, and stored in such a manner as to protect it from contamination.

Immersion of warm, whole or fresh-cut produce in cool water may induce water into the internal parts of the fresh produce and some fresh produce with high water contents, e.g. apples, celery, melons and tomatoes, are more susceptible to internalization through openings in the peel such as stem-end vascular tissue, stomata or puncture wounds. If the temperature of the wash water is less than the temperature of the produce, the temperature differential can force water into the produce contaminating it on the inside. It is recommended that in these cases, the temperature of the initial wash water is 10 °C higher than the fresh produce, if possible.

6.2 Reuse of water

Water reuse is also possible in the fresh produce industry. As a principle, water reuse should move backwards through the system from clean to less clean steps in the process. Figure 3 shows how water from the rinsing step can be used for the washing tank and how the water in the washing tank can be used as a pre-washing step.

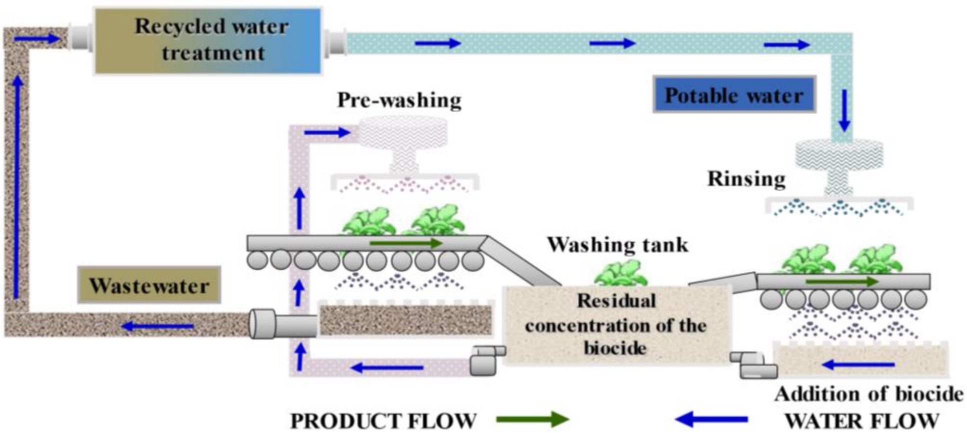

Figure 3. Example of a potential option for water reuse in the fresh produce industry

The water used in the final rinsing step should be potable water. After rinsing, this water should be treated with a biocide to have a residual concentration of the biocide able to minimize cross-contamination in the washing tank. By doing this, the water in the washing tank will have an “antimicrobial” activity to inactivate any potential pathogens that might be present in the washing tank coming from the produce.

The water from the washing tank can be also used as a pre-washing step. The pre-washing step should remove most of the organic matter and reduce the bacterial load that comes with the produce. This step will help maintain a residual concentration of biocides in the wash water tank, as some biocides are inactivated by organic matter. Reducing the soil and the dust that comes from the field in the pre-washing step will reduce the amount of organic matter and microorganisms introduced into the washing tank, increase the microbial quality of the water in the tank, and help maintain a residual concentration of biocides that are inactivated by organic matter.

The final rinsing step should also minimize the residues of the biocides (e.g. disinfection-by-products) in the fresh produce coming from the washing tank.

In order to have a more sustainable industry, which avoids the use of excessive amounts of water, the water used by the industry can be recycled using reconditioning treatments similar to those that are implemented in wastewater treatment plants to have water of a quality similar to that of potable water.

Recycled water should be treated and maintained in conditions that do not constitute a risk to the safety of fresh produce. The treatment process should be effectively monitored, controlled, and recorded. For example, a treatment process that includes primary screening, secondary filtration and a biocidal treatment could be used to maintain the suitability of recycled water.

Recycled water may be used with no further treatment, provided its use does not constitute a risk to the safety of fresh produce (e.g. use of water recovered from the final rinsing for the washing step).

If treating water for use in washing and rinsing, it is recommended to seek professional advice from experts on the safe (re-)use of water in fresh produce before purchasing, installing, and using any water treatment system, e.g. water chlorination system.

6.3 Documentation

Documented procedures should be developed for the washing and rinsing of fresh produce, including on:

- the use of vigorous washing to increase the chances of removing contamination if the fresh produce is not subject to bruising;
- the frequency of water replenishment for washing and rinsing considered suitable to minimize risks of fresh produce contamination;
- the monitoring of the water temperature during washing and rinsing, if necessary;
- the use of a de-watering step, where possible, to remove excess water from the fresh produce, as dry produce is less likely to become re-contaminated; in such case, water should be removed gently to prevent damage to produce.

Develop documented procedures for cleaning and sanitizing of surfaces coming into contact with the fresh produce and used in washing and rinsing of fresh produce which includes:

- All washing and rinsing equipment should be hygienically designed to help ensure adequate cleaning and sanitizing.
- All equipment should be cleaned after use. Mud, soil and fresh produce debris should be removed from equipment, then it should be washed with a detergent and rinsed before a final wash with a chemical disinfectant and, where necessary, a thorough rinse with potable water.
- Ancillary equipment such as knives and blades, and boots and protective clothing should be cleaned and disinfected at the end of each day.
- Maximum run time, between cleaning and sanitation cycles, should be determined for each process line.

7. WATER FIT-FOR-PURPOSE ASSESSMENT

The development of a risk-based strategy for water sourcing, use and reuse should take into account:

- identification of water-related microbiological hazards and source of those hazards, relevant for the area of production;
- sources of water available;
- the description of the water supply system (e.g. delivery and storage system);
- uses of water considered such as irrigation, washing (fresh produce, containers and surfaces), storage on ice, etc.;
- type of irrigation, in particular, if the water is in direct contact with the produce;
- type of crop (e.g. leafy greens versus fruit trees);
- physiological characteristics of the fresh produce (such as the peel and whether the produce would be subject to infiltration of water in the produce);
- water treatment and water disinfection techniques available such as heating, microfiltration and treatment with chlorine, chlorine dioxide, chloramine, ozone, UV-C;
- application after use of water (e.g. irrigation cessation, washing, peeling);
- consumers' habits such as eating raw, cooking, fermenting, etc.; and
- labelling with instructions for the intended use of the food.

If the fresh produce is consumed raw, the source of water should be identified, and the related risk should be assessed in view of determining the level of control measures.

- Potentially high or unknown risk if for example untreated wastewater, surface water or shallow groundwater.
- Potentially medium risk if for example collected rainwater.
- Potentially low risk if treated (waste) water, potable water or deep groundwater.

The matrix in Table 1 is an example that can be used as a simple approach to the potential level of risk posed by the use or reuse of various water sources during pre-harvest stages of fresh produce and their intended use.

Table 1.[10] Example to estimate the potential level of risk posed by the use or reuse of various water sources during pre-harvest stages of fresh produce according to their intended use

Intended use of fresh produce	Contact of the water with edible portion?	Water source				
		Wastewater	Surface and groundwater of unknown quality	Groundwater collected from protected wells	Hygienically collected rainwater	Potable water, deep groundwater, or other water, including treated reused water, which complies with the microbiological criteria applicable to potable water
Ready-to-eat	YES	High risk	High risk	Medium risk	Medium risk	Low risk
	NO	High risk	High risk	Low risk	Low risk	Low risk
Cooked	YES	Low risk*	Low risk*	Low risk	Low risk	Low risk
	NO	Low risk*	Low risk*	Low risk	Low risk	Low risk

* Instead of low-risk ranking in the JEMRA Report, No. 33, medium-risk ranking may be considered because the microbial reduction of cooking procedures can be highly variable, depending on the type of produce, the cooking time and temperature applied and the level of contamination of the water. Contact of water with the edible part may also enhance the risk.

When data (e.g. on microbial quality of the water sources, and on relevant health data from exposed populations) and resources allow the conduct of a quantitative or semi-quantitative risk assessment can be considered. This may allow risk mitigation measures to be more cost-effective and tailored to the specific needs.

8. RISK MITIGATION/RISK MANAGEMENT STRATEGIES

8.1 Indicator organism for monitoring hazards in water used in fresh produce production

Indicator organisms should be used as indicators of faecal contamination rather than presence or concentration level of any specific pathogen. The major indicator organisms are *E. coli* and enterococci.

Such faecal indicators can be used as process indicators or to validate the efficacy of water treatments if they respond to treatment processes in a similar manner to pathogens of concern.

It should be taken into account that, in general, faecal indicators reasonably predict the probable presence of faecal pathogens in water, but they cannot precisely predict the concentrations present, with the possible exception of heavily polluted waters. The correlation becomes erratic and biologically improbable as dilution occurs.

Bacteriophages are better indicators of enteric viruses than bacterial faecal indicators, although they cannot be absolutely relied upon as indicators for enteric viruses. A combination of two or more bacteriophages can be considered. Bacteriophages can be used as good process indicators to determine the efficacy of water treatments against enteric viruses.

Protozoa and helminths cysts/eggs survive more easily than bacteria and viruses and there is no suitable indicator of their presence/absence in irrigation water. Specific tests should be performed if the presence of these parasites is suspected.

8.2 Examples for determining water fit-for-purpose sampling frequency and microbiological criteria

The determination of a fit-for-purpose sampling frequency can contain the following steps:

- Identify the activities at the farm in which water is applied.
- Identify the sources of water available for the farm.
- Evaluate the use of water in relation to the potential contamination to edible parts of the fresh produce.
- Check the quality of the water before its use (before the start of the growth season).
- Monitor the quality of water regularly during the growing period.[i]

A risk-based approach can be used for determining testing frequency. For example, the use of potentially high or unknown risk water (see Figure 1 and Table 1) should result in a high frequency of testing, potentially medium-risk water should result in a medium frequency of testing, and potentially low-risk water should result in a low frequency of testing or no testing.

A decision tree approach (for example Figure 4)[ii] could also be used to determine the frequency of testing.

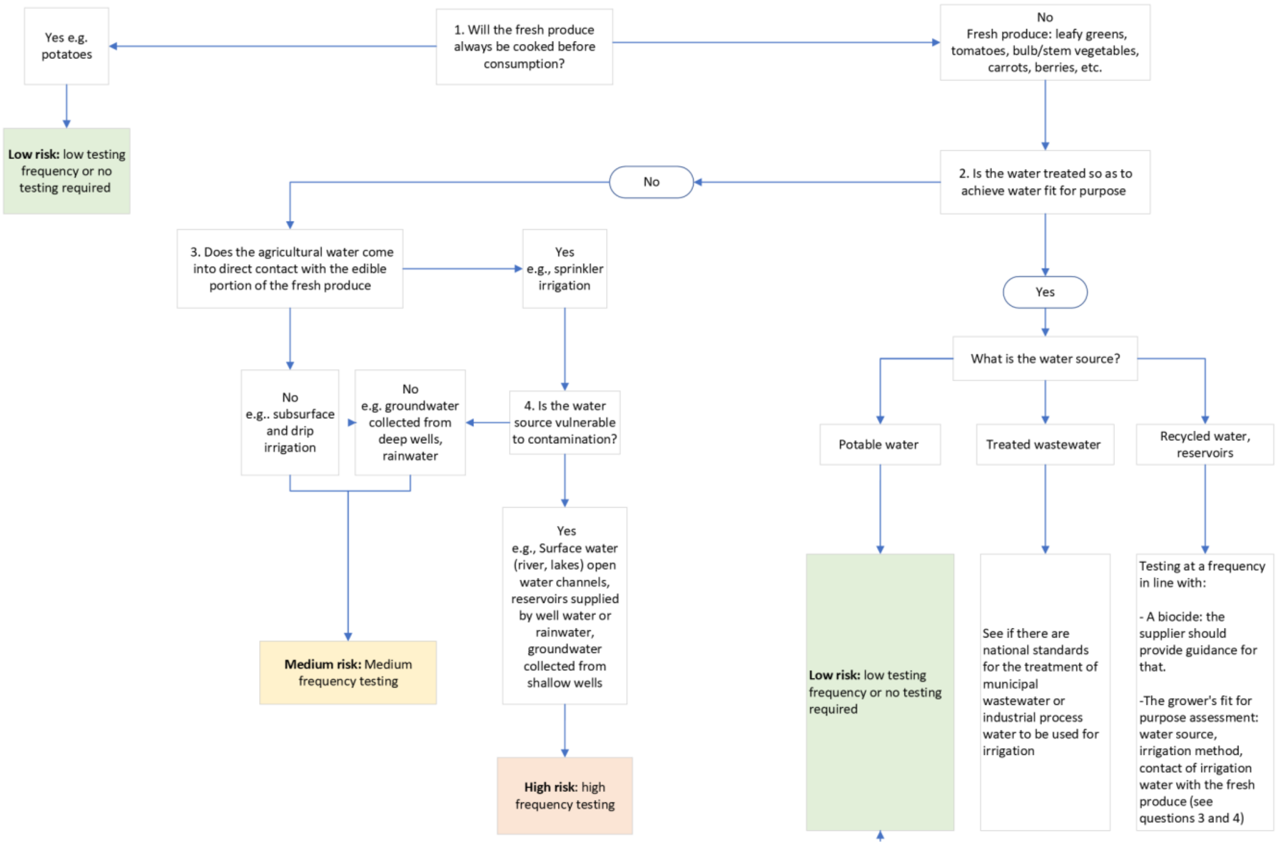

Figure 4. Example of a decision tree for water testing frequency

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[i] Examples of monitoring strategies have been provided in Annex 4 of the JEMRA Report (FAO and WHO. 2021. *Safety and quality of water used with fresh fruits and vegetables*. Microbiological Risk Assessment Series No. 37. Rome. https://doi.org/10.4060/cb7678en).

[ii] Adapted from European Commission Notice No. 2017/C 163/01 Guidance document on addressing microbiological risks in fresh fruit and vegetables at primary production through good hygiene. (https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52017XC0523(03)&from=LV). Accessed by JEMRA as resource for Figure 3 in the 2019 FAO/WHO *Safety and Quality of Water Used in Food Production and Processing* – Meeting report. Microbiological Risk Assessment Series No. 33. Rome.

8.3 Examples of decision support system (DSS) tools

There is no single DSS tool that applies/fits in all situations. The DTs and examples in Figure 2 and Figure 4, therefore should rather be considered as an approach to evaluate a situation instead of as a tool fixed for all purposes.

Based on Table 1 and Figure 3 of the Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment (JEMRA) Report No. 33 (FAO and WHO, 2019),[10] a DSS can be developed, using scores to assess the risk or the effectiveness of control measures related to the risk derived from the use of water. The scores below are examples for illustration only. There may be other considerations that could result in a different score.

Scores in the decision tool are:

- Related to the irrigation systems/direct or indirect contact with fresh produce:
  - No direct or indirect contact between irrigation water and produce: 3
  - Drip irrigation: 3
  - Furrow irrigation: 1
  - Overhead irrigation: 0
- Related to the application of mitigation options on water before irrigation:
  - On-farm water treatment ponds with 18+ h sedimentation period; water fetching without disturbing pond sediment: 1
  - Filtering water before irrigation: 1
  - None: 0
- Related to the application of one or more of the following mitigation options at or post-harvesting:
  - Irrigation cessation (3 days): 2
  - Washing with running potable water: 1
  - Washing with running potable water + added biocide: 2
  - Peeling: 2
  - None: 0

The sum of scores is used to determine whether the water is safe to use for its intended purpose. The higher the sum of the scores the lower the associated risk. If the score is too low, the above scores can be used to select additional mitigation options or have an indication to which extent the microbiological quality of the water should be improved.

- When low-risk water (potable water, deep groundwater, other water showing compliance with microbiological criteria of potable water) is used and without the use of fresh manure, excreta, or sludge as fertilizer, the risk at primary production can be considered as low.
- When medium-risk water (e.g. collected rainwater or other water showing low microbiological contamination [e.g. *E. coli* 10 CFU/100 ml to 100 CFU/100 ml]) is used, and without the use of fresh manure, excreta, or sludge as fertilizer, the risk at primary production can be considered as low, if a score of 4 is reached, by applying the irrigation system or mitigation options in the previous paragraph.
- When high or unknown risk water (wastewater, surface water, shallow groundwater, other water showing high microbiological contamination (e.g. *E. coli* 1000 CFU/100 ml or more)) and without the use of fresh manure, excreta, or sludge as fertilizer, the risk at primary production can be considered as low, if a score of 6 and more is reached by applying the irrigation system or mitigation options in the previous paragraph.

An example of a DSS tool[iii] is provided in the appendix, based on the decision tool described in this section.

[iii] Other region/country specific examples can be found as «Sources for Figure 3» in the 2019 FAO/WHO *Safety and Quality of Water Used in Food Production and Processing* – Meeting report. Microbiological Risk Assessment Series No. 33. Rome.

Appendix 1: Examples of decisions based on support systems tool

The scores below are examples for illustration only. They are based on the DSS described in the last section of the annex on fresh produce. There can be other considerations that would result in a different score.

- Medium risk water, irrigation water not in contact with the edible portion of the fresh produce (3), no other treatment => total of 3: better to use other source or add mitigation option(s)
- Unknown risk water, irrigation water not in contact with the edible portion of the fresh produce (3), filtering before irrigation (1) and irrigation cessation (2) => total of 6: acceptable
- Medium risk water, irrigation water in contact with the edible portion of the fresh produce (0), irrigation cessation (2) + washing with potable water and biocide (2) => total of 4: acceptable.
- Unknown risk water, irrigation water in contact with the edible portion of the fresh produce (0), but filtering before irrigation (1) and irrigation cessation (2) + washing with potable water and biocide (2) + peeling (1) => total of 6: acceptable
- Medium risk water, irrigation water in contact with the edible portion of the fresh produce (0) + washing with running potable water and added biocide (2) + peeling (2) => total of 4: acceptable.

Scoring:

- 1–3 unacceptable (use other source or add mitigation options).
- 4–6 acceptable without further mitigation options.

NOTES

[1] FAO and WHO. 1969. *General Principles of Food Hygiene.* Codex Alimentarius Code of Practice, No. CXC 1-1969. Codex Alimentarius Commission. Rome.

[2] FAO and WHO. 2003. *Code of Hygienic Practice for Fresh Fruits and Vegetables.* Codex Alimentarius Code of Practice, No. CXC 53-2003. Codex Alimentarius Commission. Rome.

[3] FAO and WHO. 2003. *Code of Practice for Fish and Fishery Products.* Codex Alimentarius Code of Practice, No. CXC 52-2003. Codex Alimentarius Commission. Rome.

[4] FAO and WHO. 2004. *Code of Hygienic Practice for Milk and Milk Products.* Codex Alimentarius Code of Practice, No. CXC 57-2004. Codex Alimentarius Commission. Rome.

[5] FAO and WHO. 2007. *Principles and Guidelines for the Conduct of Microbiological Risk Management (MRM).* Codex Alimentarius Guideline, No. CXG 63-2007. Codex Alimentarius Commission. Rome.

[6] FAO and WHO. 1997. *Principles and Guidelines for the Establishment and Application of Microbiological Criteria Related to Foods*. Codex Alimentarius Guideline, No. CXG 21-1997. Codex Alimentarius Commission. Rome.

[7] FAO and WHO. 2020. *Code of Practice on Food Allergen Management for Food Business Operators.* Codex Alimentarius Code of Practice, No. CXC 80-2020*.* Codex Alimentarius Commission. Rome.

[8] FAO and WHO. 2005. *Code of Hygienic Practice for Meat.* Codex Alimentarius Code of Practice, No. CXC 58-2005. Codex Alimentarius Commission. Rome.

[9] FAO and WHO. 1999. *Principles and Guidelines for the Conduct of Microbiological Risk Assessment.* Codex Alimentarius Guideline, No. CXG 30-1999. Codex Alimentarius Commission. Rome.

[10] FAO and WHO. 2019. *Safety and Quality of Water Used in Food Production and Processing – Meeting Report.* Microbiological Risk Assessment Series, No. 33. Rome. https://www.fao.org/3/ca6062en/CA6062EN.pdf