

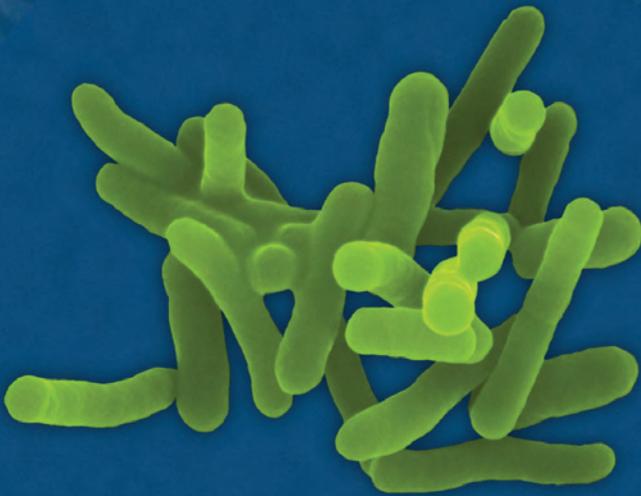


Food and Agriculture
Organization of the
United Nations



World Health
Organization

Safety and quality of water used with fresh fruits and vegetables



37

MICROBIOLOGICAL RISK
ASSESSMENT SERIES

Safety and quality of water used with fresh fruits and vegetables

Food and Agriculture Organization of the United Nations
World Health Organization

Rome, 2021

Required citation:

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>

The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations (FAO) or the World Health Organization (WHO) concerning the legal or development status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The mention of specific companies or products of manufacturers, whether or not these have been patented, does not imply that these have been endorsed or recommended by FAO or WHO in preference to others of a similar nature that are not mentioned.

The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or WHO.

ISSN 1726-5274 [Print]

ISSN 1728-0605 [Online]

FAO ISBN 978-92-5-135345-5

WHO ISBN 978-92-4-003022-0 (electronic version)

WHO ISBN 978-92-4-003023-7 (print version)

© FAO and WHO, 2021



Some rights reserved. This work is made available under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 IGO licence (CC BY-NC-SA 3.0 IGO; <https://creativecommons.org/licenses/by-nc-sa/3.0/igo/legalcode>).

Under the terms of this licence, this work may be copied, redistributed and adapted for non-commercial purposes, provided that the work is appropriately cited. In any use of this work, there should be no suggestion that FAO or WHO endorses any specific organization, products or services. The use of the FAO or WHO logo is not permitted. If the work is adapted, then it must be licensed under the same or equivalent Creative Commons licence. If a translation of this work is created, it must include the following disclaimer along with the required citation: "This translation was not created by the Food and Agriculture Organization of the United Nations (FAO) or the World Health Organization (WHO). Neither FAO nor WHO is responsible for the content or accuracy of this translation. The original English edition shall be the authoritative edition."

Disputes arising under the licence that cannot be settled amicably will be resolved by mediation and arbitration as described in Article 8 of the licence except as otherwise provided herein. The applicable mediation rules will be the mediation rules of the World Intellectual Property Organization <http://www.wipo.int/amc/en/mediation/rules> and any arbitration will be conducted in accordance with the Arbitration Rules of the United Nations Commission on International Trade Law (UNCITRAL).

Third-party materials. Users wishing to reuse material from this work that is attributed to a third party, such as tables, figures or images, are responsible for determining whether permission is needed for that reuse and for obtaining permission from the copyright holder. The risk of claims resulting from infringement of any third-party-owned component in the work rests solely with the user.

Sales, rights and licensing. FAO information products are available on the FAO website (www.fao.org/publications) and can be purchased through publications-sales@fao.org. Requests for commercial use should be submitted via: www.fao.org/contact-us/licence-request. Queries regarding rights and licensing should be submitted to: copyright@fao.org.

Cover picture © Dennis Kunkel Microscopy, Inc

Contents

| | |
|--|-----------|
| Acknowledgements | viii |
| Contributors | ix |
| Declaration of interests | xi |
| Abbreviations and acronyms | xii |
| Executive summary | xiv |
| <hr/> | |
| 1 Introduction | 1 |
| 1.1 Background | 1 |
| 1.2 The objectives of the meeting | 2 |
| <hr/> | |
| 2 Codex food safety risk management and WHO water quality management approaches | 4 |
| 2.1 Codex Alimentarius Commission food safety risk management | 4 |
| 2.2 WHO water quality management | 6 |
| 2.3 Applying WHO water quality management with Codex food safety risk management | 6 |
| <hr/> | |
| 3 Fit-for-purpose water and fruit and vegetable production | 8 |
| 3.1 Water quality and the intended use | 8 |
| 3.2 Primary production | 9 |
| 3.3 Post-harvest handling | 11 |
| 3.4 Conclusions | 13 |
| <hr/> | |
| 4 Overview of relevant risk assessment approaches | 14 |
| 4.1 Risk assessment approaches and fit-for-purpose water | 15 |
| 4.2 Qualitative risk assessments: sanitary inspections | 18 |
| 4.3 Semi-quantitative risk assessments | 19 |
| 4.4 Quantitative microbial risk assessment | 20 |
| 4.5 Conclusions | 21 |
| <hr/> | |
| 5 Examples of water used during fresh fruit and vegetable production | 22 |
| 5.1 Wastewater | 23 |
| 5.1.1 Risk reduction measures and wastewater use | 24 |
| 5.2 Greywater | 26 |
| 5.2.1 Risk reduction measures and greywater use | 26 |
| 5.3 Surface water | 27 |
| 5.3.1 Risk reduction measures and surface water use | 28 |

| | | |
|-----------|---|-----------|
| 5.4 | Groundwater | 28 |
| 5.4.1 | Risk reduction measures and groundwater use | 29 |
| 5.5 | Municipal water | 30 |
| 5.5.1 | Risk reduction measures and municipal water | 30 |
| 5.6 | Rainwater | 32 |
| 5.7 | Conclusions | 32 |
| 6 | Establishing tailored threshold values for microbial measures of water quality | 33 |
| 6.1 | Faecal indicator organisms and waterborne pathogens | 34 |
| 6.2 | Irrigation water | 38 |
| 6.3 | Post-harvest water | 39 |
| 6.4 | Approaches to establishing tailored water threshold values | 41 |
| 6.5 | Conclusions | 44 |
| 7 | Testing microbial water quality and microbial source tracking | 45 |
| 7.1 | Culture-based microbial methods | 45 |
| 7.2 | Non-culture based microbial methods | 47 |
| 7.3 | Microbial source tracking | 51 |
| 7.4 | Conclusions | 53 |
| 8 | Microbial monitoring of water quality | 54 |
| 8.1 | Validation | 54 |
| 8.2 | Operational monitoring | 55 |
| 8.3 | Verification | 56 |
| 9 | Fit-for-purpose water, knowledge gaps and limitations | 59 |
| 10 | Conclusions | 61 |
| 11 | Recommendations | 65 |
| | References | 66 |

ANNEXES

| | | |
|----------------|---|-----|
| Annex 1 | Comparison of terms used in management of the microbiological safety of food and water | 79 |
| Annex 2 | Comparison of risk assessment approaches for water quality management | 84 |
| Annex 3 | Advantages and disadvantages of the different testing methods for microorganisms | 86 |
| Annex 4 | Example from literature | 91 |
| | A4.1 Selected fresh leafy vegetables and herbs eaten raw | 91 |
| | A4.1.1 Ghana (lettuce) | 91 |
| | A4.1.1.1 <i>Background</i> | 91 |
| | A4.1.1.2 <i>Evidence and data collection</i> | 91 |
| | A4.1.1.3 <i>Summary</i> | 94 |
| | A4.1.2 Egypt (lettuce) | 94 |
| | A4.1.2.1 <i>Background</i> | 94 |
| | A4.1.2.2 <i>Evidence and data collection</i> | 95 |
| | A4.1.2.3 <i>Conclusions</i> | 95 |
| | A4.1.3 Jordan (lettuce and tomatoes) | 96 |
| | A4.1.3.1 <i>Background</i> | 96 |
| | A4.1.3.2 <i>Evidence and data collection</i> | 97 |
| | A4.1.3.3 <i>Summary</i> | 97 |
| | A4.1.4 Morocco (coriander) | 98 |
| | A4.1.4.1 <i>Background</i> | 98 |
| | A4.1.4.2 <i>Evidence and data collection</i> | 98 |
| | A4.1.4.3 <i>Conclusion</i> | 99 |
| | A4.1.5 Lebanon (lettuce, radish, parsley) | 99 |
| | A4.1.5.1 <i>Background</i> | 99 |
| | A4.1.5.2 <i>Evidence and data collection</i> | 99 |
| | A4.1.5.3 <i>Conclusion</i> | 101 |
| | A4.1.6 References | 101 |
| | A4.2 Berries | 104 |
| | A4.2.1 Background | 104 |
| | A4.2.2 Evidence and data collection | 104 |
| | A4.2.2.1 <i>Europe</i> | 104 |
| | A4.2.2.2 <i>Republic of Korea</i> | 105 |
| | A4.2.3 Example on berries in other countries | 107 |
| | A4.2.4 Summary | 107 |
| | A4.2.5 References | 107 |
| | A4.3 Carrots | 109 |
| | A4.3.1 Background | 109 |
| | A4.3.2 Evidence and data collection | 109 |

| | | |
|----------|---|-----|
| A4.3.2.1 | <i>Production</i> | 109 |
| A4.3.2.2 | <i>Epidemiological evidence</i> | 109 |
| A4.3.2.3 | <i>Microbial dynamics during carrot production</i> | 110 |
| A4.3.2.4 | <i>Fit-for-purpose requirements for water inputs</i> | 112 |
| A4.3.2.5 | <i>Fit-for-purpose determination for cooling/ pre-washing water</i> | 114 |
| A4.3.2.6 | <i>Scientific evidence in support of fit-for-purpose water criteria determination</i> | 116 |
| A4.3.3 | Summary | 117 |
| A4.3.4 | References | 117 |
| A4.4 | Melons | 120 |
| A4.4.1 | Background | 120 |
| A4.4.2 | Codex Committee on Food Hygiene | 120 |
| A4.4.2.1 | <i>Epidemiological evidence</i> | 120 |
| A4.4.2.2 | <i>Characteristics of melons, microbial interactions and managing risks</i> | 120 |
| A4.4.2.3 | <i>Water use and quantitative data on microbiological contamination levels</i> | 121 |
| A4.4.2.4 | <i>Conclusions</i> | 123 |
| A4.4.3 | United States of America | 124 |
| A4.4.3.1 | <i>Epidemiological evidence</i> | 124 |
| A4.4.3.2 | <i>Melon industry guidelines</i> | 124 |
| A4.4.3.3 | <i>Microbiological testing of water</i> | 125 |
| A4.4.3.4 | <i>Regulatory measures</i> | 126 |
| A4.4.4 | Summary | 128 |
| A4.4.5 | References | 129 |

TABLES

| | | |
|---------|--|-----|
| Table 1 | Norovirus concentrations in different water sources. Source of data (Karst, 2010). | 23 |
| Table 2 | Log reduction values for water treatment technologies and disinfectant dosages at water treatment plants supplying large communities. Data sourced from WHO (2017). | 31 |
| Table 3 | Common microbial faecal indicators for water quality: benefits, constraints and implementation considerations. (Sources of data Figueras and Borego, 2010; Ashbolt <i>et al.</i> , 2001; Saxena <i>et al.</i> , 2015). | 37 |
| Table 4 | Common microbial process indicators and index or model organisms used for assessing the effectiveness of microbial removal and inactivation by water treatment processes | 40 |
| Table 5 | Selected qPCR-based MST markers for differentiating human and animal sources of faecal contamination. | 52 |
| Table 6 | Key variables or processes involved in the determination of fit-for-purpose water quality criteria for carrot pre-washing water | 114 |
| Table 7 | Frequency of isolation of <i>Salmonella</i> and <i>E. coli</i> from samples of irrigation water collected at cantaloupe farms in the United States of America. Adapted from Castillo <i>et al.</i> (2004). | 121 |
| Table 8 | Prevalence of <i>Salmonella</i> and prevalence and count of <i>E. coli</i> in irrigation water and cantaloupes in the field in Texas, United States of America. Data from Duffy <i>et al.</i> (2005) | 122 |

FIGURES

| | | |
|----------|---|-----|
| Figure 1 | Main handling and processing steps in commercial carrot production, from preharvest to retail. Steps that involve water are highlighted in grey | 110 |
| Figure 2 | Qualitative assessment of main microbial dynamics along the carrot production chain | 111 |

预览已结束，完整报告链接和

<https://www.yunbaogao.cn/report/index/report?r>