

**SCIENCES**

**AGRONOMY AND FOOD SCIENCE**

**Food Safety**

**Microbiological Risk  
Assessment Associated  
with the Food Processing  
and Distribution Chain**

**Coordinated by  
Jeanne-Marie Membré**

**ISTE**

**WILEY**



Microbiological Risk Assessment Associated with  
the Food Processing and Distribution Chain



SCIENCES

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Jack Legrand and Gilles Trystram

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*Food Safety*, Subject Head – Jeanne-Marie Membré and  
Thierry Bénézech

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# Preface

**Jeanne-Marie MEMBRÉ**

*SECALIM, INRAE, Oniris, Nantes, France*

There are a number of food-associated hazards that can cause harm to human health. Chemicals used in agriculture, environmental pollutants and pathogenic bacteria are all examples of hazards that can ultimately end up on the consumer's plate and in some cases harm their health.

Food safety standards, the development of which began more than 20 years ago, are used to confront these hazards, with their basis in a formal process called "risk analysis". Risk analysis consists of three separate elements: risk assessment, risk management and risk communication.

Three volumes on the subject of Food Safety make it possible to articulate this link between food safety and risk analysis. They have been created by Jeanne-Marie Membré and Thierry Bénézech, with the assistance of Nabila Haddad, and published by ISTE Ltd and Wiley in the SCIENCES series:

– the volume coordinated by Nabila Haddad covers both chemical and microbiological hazards: Haddad, N. (2022), *Hazards in the Food Processing and Distribution Chain*;

– the volume coordinated by Thierry Bénézech and Christine Faille deals with risk management and focuses on microbiological risks: Bénézech, T. and Faille, C. (2022), *Control: Preventing the Biological Risks Associated with Food Contamination During Processing/Distribution and Consumer Usage*;

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– this volume, coordinated by Jeanne-Marie Membré, completes the series. It is entitled *Microbiological Risk Assessment Associated with the Food Processing and Distribution Chain*.

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**Jeanne-Marie MEMBRÉ**

*SECALIM, INRAE, Oniris, Nantes, France*

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# Introduction

**Jeanne-Marie MEMBRÉ**

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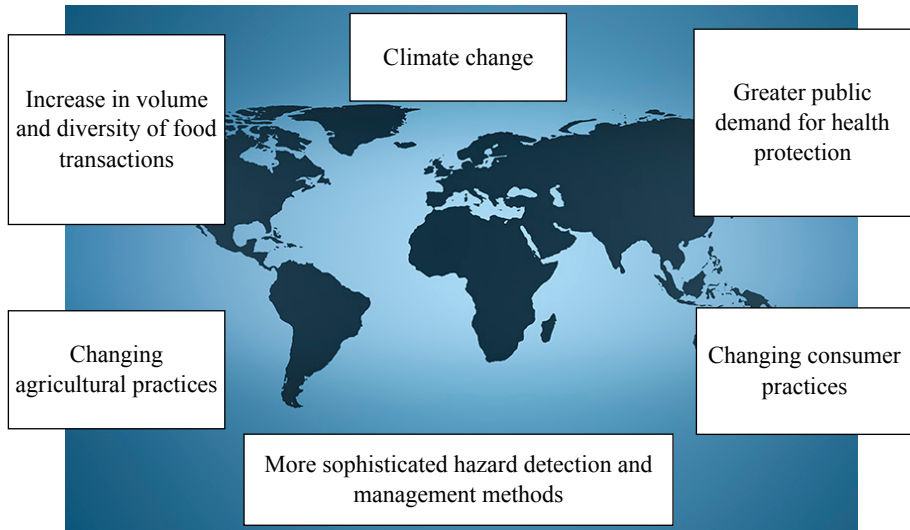
Food safety is the guarantee that food is harmless, in other words that its consumption will have no adverse consequences for health. As we are reminded by the World Health Organization (WHO), food safety encompasses all the measures taken to provide food that is as safe as possible, and hence the policies and measures applied must relate to the entire food chain, from production to consumption.

Ensuring a safe food supply poses major food safety challenges for public authorities (FAO and WHO 2006). Changing global patterns of food production, international trade, the emergence of new technologies, public expectations in terms of health protection and many other factors have created an increasingly demanding environment in which food safety must operate (Figure I.1).

There are a number of food-associated risks that can cause harm to human health. Chemicals used in agriculture, environmental pollutants and pathogenic bacteria are all examples of hazards that can ultimately end up on the consumer's plate and in some cases harm their health.

The first estimates of the global and regional burden of foodborne diseases, published by the WHO in December 2015 (WHO 2015), show that this burden is significant all over the world. Every year around the world, 1 in 10 people fall ill from eating contaminated food and 420,000 die from it, nearly a third of whom are children under the age of 5. The hazards

responsible for these foodborne illnesses include bacteria, viruses, parasites, toxins and chemicals. More specifically, diarrheal diseases are responsible for 550 million cases and 230,000 deaths per year. Children are particularly susceptible, with 220 million cases and 96,000 deaths per year. Diarrhea is often caused by eating raw or undercooked meat, eggs, fresh produce and/or dairy produce.



**Figure I.1.** Factors influencing the evolution of food safety. From the FAO and WHO (2006)

In Europe, more than 23 million people fall ill each year after consuming contaminated food, resulting in 5,000 deaths (WHO 2017). Still in Europe, the most common causes of foodborne diseases are noroviruses, followed by *Campylobacter* spp. Non-typhoid *Salmonella* spp. are responsible for the majority of deaths. We will review these three microbiological hazards below.

### *Norovirus*

One of the most common causes of gastroenteritis in humans worldwide is human norovirus, and specifically genogroup 2 noroviruses. Symptoms include diarrhea, vomiting (including projectile vomiting) and stomach pains. The virus can be transmitted to humans through the ingestion of contaminated food or water and directly from person to person, leading to infection in a relatively large proportion of those exposed.



Estimates by the WHO Foodborne Disease Burden Epidemiology Reference Group (FERG) show that, worldwide, norovirus is linked to about 20% of all foodborne illnesses caused by diarrheal disease hazards (125 million per year). It is the most common cause of diarrheal disease for all ages and in all risk groups, with the most serious outcomes being seen in young children and the elderly. Norovirus infection is the sixth leading cause of diarrheal death in children under 5 and the second leading cause of diarrheal death in children over 5, with similar trends in all regions of the world.

According to a study by ANSES (2018), in France, over the period 2006–2015, the main foods associated with outbreaks of collective food toxi-infections related to norovirus were mollusks (72%) and, in particular, oysters (usually consumed raw in France). Composite dishes were implicated in 10% of norovirus outbreaks. The other food categories (meat, fish, vegetables and egg products) were of equal significance and accounted for a total of 18% of outbreaks.

### *Campylobacter spp.*

*Campylobacter spp.* are a major cause of foodborne diarrheal disease. Infection with *Campylobacter* is usually acquired by consuming contaminated foods such as undercooked poultry and raw milk; contaminated broiler meat is considered the most significant source of this hazard to humans.

According to a study by ANSES (2018), in France, over the period 2006–2015, the main food categories identified at the time of *Campylobacter* outbreaks were meats (67%) and composite dishes (18%). Poultry was implicated in 71% of the outbreaks caused by meat. The composite dishes were basically sandwiches, mixed salads and ready-cooked meals. Eggs and egg products, milk and milk products and water accounted for a total of 9% of outbreaks.

Death from campylobacteriosis is rare and is usually limited to very young or elderly patients or those suffering from another serious illness such as AIDS. Complications such as bacteremia, hepatitis, pancreatitis and miscarriage have all been reported with varying frequency. Post-infection complications can include reactive arthritis, which can last for several months, and neurological disorders such as Guillain–Barré syndrome, a form of paralysis that can lead to severe respiratory and neurological dysfunction or death in a few cases.

According to the FERG, in 2010, *Campylobacter* spp. foodborne illnesses were responsible for more than 95 million cases of disease and just over 21,000 deaths worldwide. Since 2005, campylobacteriosis has been the most frequently reported foodborne illness in the European Union, with more than 236,000 confirmed cases in 2014. However, it should be noted that the growing trend in the incidence of campylobacteriosis in recent years is partly due to the improvement of surveillance and diagnostic systems in a number of European Union Member States.

Prevention consists of control measures at all stages of the food chain in order to reduce transmission, from the environment to farms, through enhanced biosecurity, appropriate wastewater and fecal disposal systems, hygienic slaughter and the application of good food-handling practices, in particular avoiding cross-contamination and ensuring proper heat treatment of poultry products.

### *Non-typhoid Salmonella* spp.

Non-typhoid *Salmonella* spp. are generally transmitted to humans through contaminated foods, usually of animal origin, such as eggs, pork and poultry, and dairy products; however, other foods, especially fresh produce, may also be involved in their transmission.

Typhoid *Salmonella* spp. generally cause gastroenteritis characterized by the acute onset of fever, abdominal pain, diarrhea, nausea and sometimes vomiting. Infection with *Salmonella* spp. can, however, cause disease, especially in children, the elderly and the immuno-compromised, and can lead to post-infection complications such as reactive arthritis. In the case of invasive *Salmonella* spp., a number of organs and systems can be affected, resulting in bacteremia, meningitis, osteomyelitis or septic arthritis and sometimes even death.

According to FERG estimates, non-typhoidal *Salmonella* spp. are the foodborne hazards responsible for the highest annual burden and the greatest number of deaths both globally and in the European region. Globally, according to FERG estimates, non-typhoid *Salmonella* spp. are responsible for approximately 78 million cases of disease and 59,000 deaths per year.

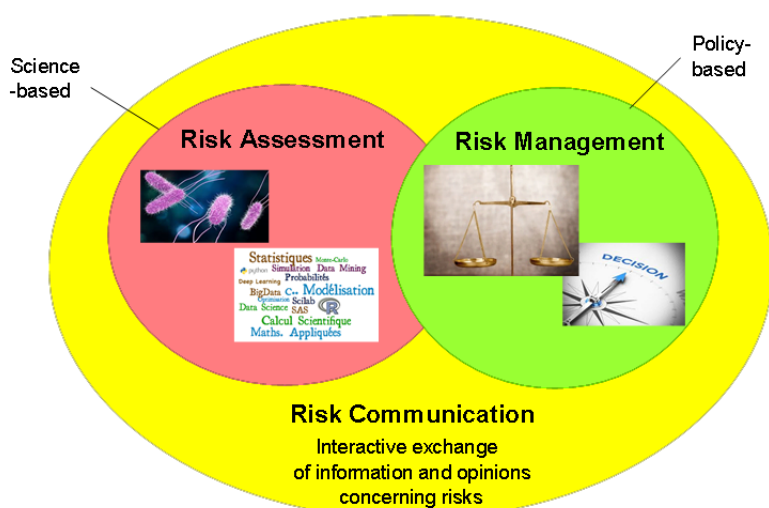
In Europe, non-typhoid *Salmonella* spp. hold the number one place in terms of deaths due to food risks. For example, in 2014, there were over 85,000 cases of salmonellosis and 65 deaths. The two most frequently reported *Salmonella* serovars in the European Union are *S. enteritidis* and

*S. typhi*. The European Food Safety Authority has estimated that the overall economic burden of human salmonellosis could reach €3 billion per year.

According to a study by ANSES (2018), in France, over the period 2006–2015, the foods identified at the origin of outbreaks were in 40–45% of cases related to eggs or egg-based preparations. Meats were implicated in around 30% of outbreaks. Milk and dairy products represented only 9% of outbreaks from a suspected or confirmed food, but 19% of outbreaks from a confirmed food. Composite dishes (ready-cooked meals made from multiple ingredients such as couscous, lasagna, pizza, tartiflette) and fishery products were, in total, linked to slightly over 5% of salmonella outbreaks.

### Risk analysis

Confronted by these dangers for more than 20 years, the development of food safety standards has been based on a formal process called “risk analysis”. Risk analysis includes risk assessment and risk management as well as risk communication (Figure I.2). The Food and Agriculture Organization of the United Nations (FAO) and WHO define risk assessment as a decision-making tool: its aim is not necessarily to extend scientific knowledge, but to provide risk managers with a rational and objective picture of what is known, or assumed to be known, about public health risks and their causes at any given time.



**Figure I.2.** The three components of risk analysis: risk assessment, risk management and risk communication. Adapted from the FAO and WHO (2006)

No matter what the institutional context, the discipline of risk analysis offers a tool that all public authorities can use to improve food safety (FAO and WHO 2020).

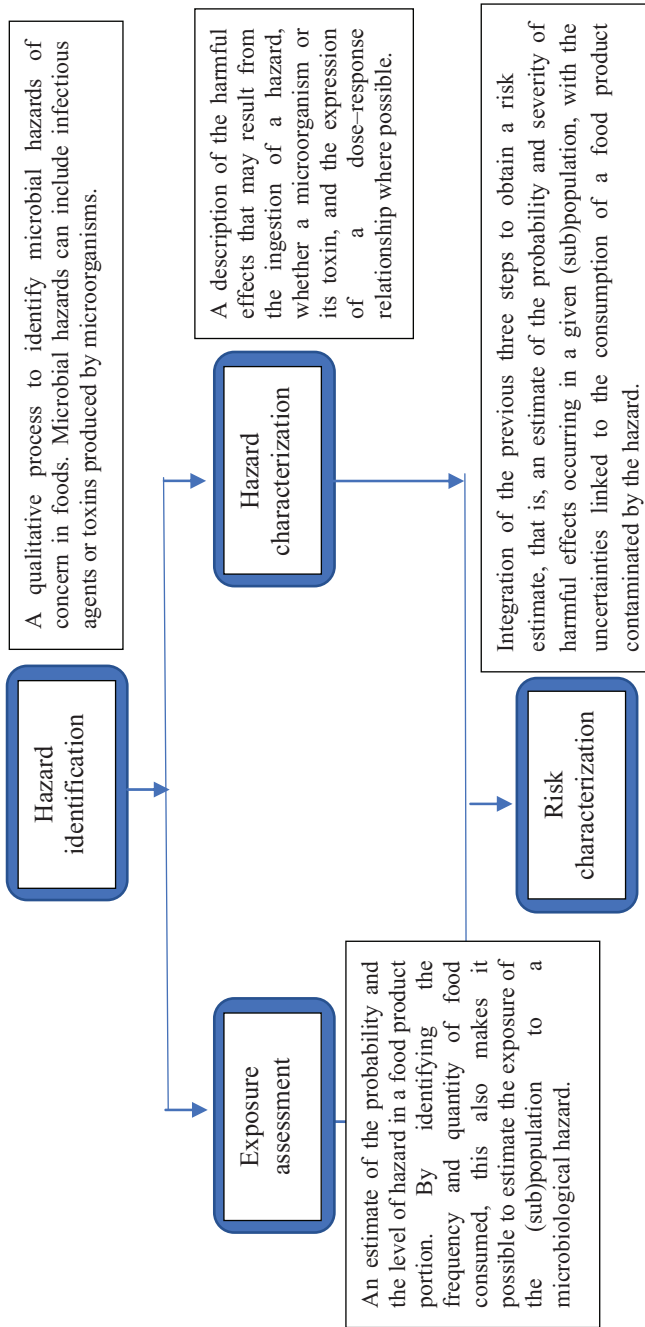
This book focuses on risk assessment and more specifically on microbiological risk assessment. Readers interested in chemical risk assessment can refer to a number of books and in particular to the recent book coordinated by Camel *et al.* (2018).

### *Microbiological risk assessment*

The purpose of microbiological risk assessment is to characterize the nature and probability of harm resulting from human exposure to the biological agents present in foodstuffs. Ever since 1999, the WHO and the FAO, through the Codex Alimentarius Commission (CAC), have set out principles and guidelines for conducting microbiological risk assessment of food (Codex Alimentarius Commission 1999). Since then, they have regularly augmented their work; for example, in 2020 they produced a very comprehensive methodological document (FAO and WHO 2020).

Microbiological risk assessment of food is a scientific process comprising four elements (Figure I.3): hazard identification, hazard characterization, exposure assessment and finally risk characterization. In the context of production, distribution and consumption of food products, the risks must take into account all stages of the chain: from the production of raw materials (“farm”) to consumption (“fork”), and even through to ingestion (“human”). Microbiological risk assessment thus covers the “farm-to-fork-to-human” continuum. Of course, depending on the food product, its composition, its manufacture and its packaging, the key steps to be taken into account in the risk assessment can be mostly upstream or mostly downstream of this continuum.

In 2000, the WHO and the FAO assembled a group of experts on the subject of microbiological risk assessment: JEMRA. JEMRA aims to develop and optimize the utility of microbiological risk assessment as a tool informing actions and decisions in order to improve food safety and make it available to developed and developing countries (FAO 2020). We strongly recommend the reader follow the work carried out by JEMRA and also consult on a regular basis the WHO and FAO websites dedicated to food safety and microbiological risk assessment.



**Figure I.3.** Microbiological risk assessment. Adapted from the *FAO and WHO (2020)*

The first chapter of this book deals with the first stage of microbiological risk assessment, namely hazard identification. It remains fairly general since the first book in this series is dedicated to hazard analysis (Haddad 2022). The other three stages of microbiological risk assessment, namely hazard characterization, exposure assessment and finally risk characterization, are, however, developed in the various chapters of this book. More specifically, in order to address the biological and mathematical aspects of these steps, hazard characterization and exposure assessment have each been divided into two parts: hazard characterization is subdivided into a pathogenicity mechanism and quantification of the dose–response; exposure assessment is subdivided into methods of detection and enumeration of pathogens and quantification of the level of exposure.

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# **PART 1**

## **Hazards and Food**