9. References cited in the text


Appendix 1

This Appendix supports Chapter 7, ‘Linking risk assessment and economic analysis’. Figure A1 is a generic disease outcome tree that can be used by the risk assessment team to display the diverse human health outcomes that occur after exposure to a foodborne pathogen. Table A1 lists foodborne pathogens and their possible complications that cover a diversity of outcomes, including paralysis, kidney failure, mental retardation, septicaemia or blood poisoning, and arthritis. Many foodborne pathogens are listed, suggesting that many foodborne illnesses have some probability of complications.

Table A2 lists the varied economic costs that can be included in a cost–benefit analysis. Exactly which costs are included depends on the type of cost–benefit analysis. It is important to be clear about the nature of the policy intervention, and to clearly understand which costs belong in the benefit vs. cost categories. For example, in installing an improved food safety programme and reducing the level of pathogen contamination in food, a company could see offsetting benefits in terms of increased product shelf-life, a decrease in product returns, reduced insurance premiums, fewer product liability cases, a reduced risk of product recalls due to foodborne illness, and even an increase in sales over time. These benefits to the company could offset the costs of its new food safety programme. Economic analysis is interested in identifying and comparing the present value of the net benefits and net costs for all parties affected by the public or private policy intervention.

![Figure A1. Generic disease outcome tree (adapted from Prüss and Havelaar, 2001).](image-url)
Table A1 Chronic complications associated with foodborne pathogens.

<table>
<thead>
<tr>
<th>Bacterial and parasitic infections transmitted by food</th>
<th>Complications/sequelae</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacterial infections</strong></td>
<td></td>
</tr>
<tr>
<td><em>Aeromonas hydrophila enteritis</em></td>
<td>Bronchopneumonia, cholecystis</td>
</tr>
<tr>
<td><em>Brucellosis</em></td>
<td>Aortitis, epididymo-orchitis, meningitis, pericarditis, spondylitis</td>
</tr>
<tr>
<td><em>Campylobacteriosis</em></td>
<td>Arthritis, carditis, cholecystitis, colitis, endocarditis, erythema nodosum, Guillain-Barré syndrome, haemolytic-uraemic syndrome, meningitis, pancreatitis, sepsicaemia</td>
</tr>
<tr>
<td><em>Escherichia coli (EHEC-types)</em> enteritis</td>
<td>Erythema nodosum, haemolytic-uraemic syndrome, seronegative arthropathy, thrombocytopenic purpura</td>
</tr>
<tr>
<td><em>Q-fever</em></td>
<td>Endocarditis, granulomatous hepatitis</td>
</tr>
<tr>
<td><em>Salmonellosis</em></td>
<td>Aortitis, cholecystitis, colitis, endocarditis, epididymo-orchitis, meningitis, myocarditis, osteomyelitis, pancreatitis, Reiter’s disease, rheumatoid syndromes, sepsicaemia, splenic abscesses, thyroiditis, septic arthritis (sickle-cell anaemic persons)</td>
</tr>
<tr>
<td><em>Shigellosis</em></td>
<td>Erythema nodosum, haemolytic-uraemic syndrome, peripheral neuropathy, pneumonia, Reiter’s disease, sepsicaemia, splenic abscesses, synovitis</td>
</tr>
<tr>
<td><em>Vibrio parahaemolyticus enteritis</em></td>
<td>Septicaemia</td>
</tr>
<tr>
<td><em>Yersiniosis</em></td>
<td>Arthritis, cholangitis, erythema nodosum, liver and splenic abscesses, lymphadenitis, pneumonia, pyomyositis, Reiter’s disease, sepsicaemia, spondylitis, Still’s disease</td>
</tr>
<tr>
<td><strong>Parasitic infections</strong></td>
<td></td>
</tr>
<tr>
<td><em>Cryptosporidiosis</em></td>
<td>Severe diarrhoea, prolonged and sometimes fatal</td>
</tr>
<tr>
<td><em>Giardiasis</em></td>
<td>Cholangitis, dystrophy, joint symptoms, lymphoidal hyperplasia</td>
</tr>
<tr>
<td><em>Taeniasis</em></td>
<td>Arthritis, cysticercosis (<em>T. solium</em>)</td>
</tr>
<tr>
<td><em>Toxoplasmosis</em></td>
<td>Encephalitis and other central nervous system diseases, pancarditis, polymyositis</td>
</tr>
<tr>
<td><em>Trichinosis</em></td>
<td>Cardiac dysfunction, neurological sequelae</td>
</tr>
</tbody>
</table>

**NOTES:** (a) Waterborne.  
**SOURCE:** Foegeding and Roberts, 1994.
Table A2 Examples of societal costs of foodborne illness involving a zoonotic disease.

<table>
<thead>
<tr>
<th>Costs to Individuals and Households¹</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Human Illness Costs</strong></td>
<td><strong>Medical costs</strong></td>
</tr>
</tbody>
</table>
### Industry Costs (contd)

<table>
<thead>
<tr>
<th>Outbreak costs</th>
<th>Regulatory and Public Health Sector Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herd slaughter/product recall</td>
<td>Monitor incidence/severity of human disease by foodborne pathogens</td>
</tr>
<tr>
<td>Plant closings and cleanup</td>
<td>Monitor pathogen incidence in the food chain</td>
</tr>
<tr>
<td>Regulatory fines</td>
<td>Develop integrated database from farm to table for foodborne pathogens</td>
</tr>
<tr>
<td>Product liability suits from consumers and other firms</td>
<td>Identify new foodborne pathogens for acute and chronic human illnesses</td>
</tr>
<tr>
<td>Reduced product demand because of outbreak</td>
<td>Establish high-risk products and production and consumption practices</td>
</tr>
<tr>
<td>Generic animal product - all firms affected</td>
<td>Identify which consumers are at high-risk for which pathogens</td>
</tr>
<tr>
<td>Reduction for specific firm at wholesale or retail level</td>
<td>Develop cheaper and faster pathogen tests</td>
</tr>
<tr>
<td>Increased advertising or consumer assurances following outbreak</td>
<td>Risk assessment modelling for all links in the food chain</td>
</tr>
<tr>
<td>Impact of outbreaks on tourism industry</td>
<td></td>
</tr>
</tbody>
</table>

### Regulatory and Public Health Sector Costs

- Monitor incidence/severity of human disease by foodborne pathogens
- Monitor pathogen incidence in the food chain
- Develop integrated database from farm to table for foodborne pathogens
- Identify new foodborne pathogens for acute and chronic human illnesses
- Establish high-risk products and production and consumption practices
- Identify which consumers are at high-risk for which pathogens
- Develop cheaper and faster pathogen tests
- Risk assessment modelling for all links in the food chain
- Costs of investigating outbreak
  - Testing to contain an outbreak (for example, serum testing and administration of Ig in persons exposed to Hepatitis A)
  - Costs of cleanup
  - Legal suits to enforce regulations that may have been violated

### Other considerations

- Distributional effects in different regions, industries, etc.
- Equity considerations, such as special concern for children

### Notes

1. Willingness-to-pay (WTP) estimates for reducing risks of foodborne disease is a comprehensive estimate of all these categories (assuming that the individual has included employer-funded sick leave and medical programmes in their estimates). The estimate covers reduced risks for all exposed persons: those who will become ill as well as those who will not.
2. Some industry costs may fall with better pathogen control, such as reduced product spoilage, possible increases in product shelf-life, and extended shelf-life permitting shipment to more distant markets or lowering shipment costs to nearby markets.
3. In adding up costs, care must be taken to ensure that product liability costs to firms are not already counted in the estimated pain and suffering cost to individuals. However, the legal and court expenses incurred by all parties are social costs.

**Source:** Adapted from Buzby and Roberts, 1997.
References


1 Risk assessments of *Salmonella* in eggs and broiler chickens: Interpretative Summary, 2002
2 Risk assessments of *Salmonella* in eggs and broiler chickens, 2002
3 Hazard characterization for pathogens in food and water: Guidelines, 2003
4 Risk assessment of *Listeria monocytogenes* in ready-to-eat foods: Interpretative Summary, 2004
6 *Enterobacter sakazakii* and microorganisms in powdered infant formula: Meeting Report, 2004
7 Exposure assessment of microbiological hazards in food: Guidelines, 2008
9 Risk assessment of choleragenic *Vibrio cholerae* 01 and 0139 in warm-water shrimp in international trade: Interpretative Summary and Technical Report, 2005
10 *Enterobacter sakazakii* and *Salmonella* in powdered infant formula: Meeting Report, 2006
11 Risk assessment of *Campylobacter* spp. in broiler chickens: Interpretative Summary, 2008
13 Viruses in food: Scientific Advice to Support Risk Management Activities: Meeting Report, 2008
14 Microbiological hazards in fresh leafy vegetables and herbs: Meeting Report, 2008
Publications of the World Health Organization can be obtained from:

WHO Press
World Health Organization, 20 Avenue Appia
CH-1211 Geneva 27, Switzerland
Tel: +41 22 7913264
Fax: +41 22 7914857
E-mail: bookorders@who.int
or
on the Internet from http://www.who.int/bookorders

Publications of the Food and Agriculture Organization of the United Nations can be ordered from:

Sales and Marketing Group, Communication Division
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla, 00153 Rome, Italy
Fax: +39 06 57053360
E-mail: publications-sales@fao.org
or
on the Internet from http://www.fao.org/icatalog/inter-e.htm
Risk characterization is one of the four steps of microbiological risk assessment. It is defined as an estimation of the probability of occurrence and severity of known or potential adverse health effects in a population based on the preceding steps of hazard identification, hazard characterization and exposure assessment. It comprises the results of the risk assessment in the form of risk estimates and risk descriptions and provides the best available science-based evidence to support food safety management.

This volume presents guidelines for risk characterization of microbiological hazards in foods. These guidelines provide descriptive guidance on how to conduct risk characterization in various contexts, and utilizing a variety of tools and techniques. They have been developed in recognition of the fact that a reliable estimation of risk is critical to the overall risk assessment.

This volume and others in this Microbiological Risk Assessment Series contain information that is useful to both risk assessors and risk managers, including international scientific committees, the Codex Alimentarius Commission, governments and food regulatory agencies, scientists, food producers and industries and other people or institutions with an interest in the area of microbiological hazards in foods, their impact on human health and food trade and their control.