Chapter 7: Food and agriculture

7.1. Typical cases of foodborne diseases
7.2. Problem-solving exercise: pesticide poisoning - an outbreak among antimalarial workers
7.3. Problem-solving exercise: toxic encephalopathy from a seafood toxin
7.4. Problem-solving exercise: HACCP in food production
7.1. Typical cases of foodborne diseases

Prepared by Gerald Moy

Cases 1 and 2 are adapted from Food Safety: It's All in Your Hands. Ministry of National Health and Welfare, Canada, 1993

 собранное время: 15 минут до 1 часа

✓ Objective:

At the end of the exercise, students will be able to:

List the primary causes of foodborne diseases and preventive measures.

❖ Procedures:

1. Divide class into small groups to discuss the three short cases (15 minutes). The exercise can be used for a quick review with a more experienced group and to introduce the topic in less experienced groups.

2. Review each case, inviting reports from the groups.

3. Summarize and conclude.

❖ Materials:

Problem-based exercises (Annex 16), flip chart, markers, tape.

Background information for instructors

Every year, people around the world are reported ill from foodborne illnesses, more commonly known as food poisoning. Many cases remain unreported so the extent of the problem is difficult to estimate. However, in many developed countries upwards of 10% of the population are thought to be affected each year. The most common cause of reported cases are foods which have been improperly handled in food service establishments, or in the home. Often the largest outbreaks are a result of food which has been mishandled in food-processing establishments.

All of the following cases actually took place and could easily occur again if food is not handled safely.

* Dr Gerald Moy, Scientist, World Health Organization
Case No. 1: The long-remembered wedding feast in Peru

It was to be the happiest day of Magda’s life. Relatives and friends from both sides of the family would be coming over for a lavish wedding feast. Her mother had worked late into the night preparing her best dishes for the guests. She finally went to bed at 04:00 in the morning after making sure that the food was attractively arranged on the tables. The next day was hot (over 30°C) but everyone enjoyed the good food. However, later that night, many people who attended the wedding started to experience severe stomach pains, nausea, vomiting and, in some cases, diarrhoea. While Magda felt fine, her new husband became so sick he had to go to the hospital.

Question 1. What might have caused the illness? What could have been done to prevent it?

To determine the answers to these questions, local health authorities interviewed everyone who attended the wedding, including people who did not suffer from the illness. It was determined that the people who had eaten the potato salad were the ones who also became ill. Samples of the potato salad were sent to the laboratory and it was found to contain high numbers of the bacterium *Staphylococcus aureus*, a common cause of acute foodborne disease.

This outbreak could have been avoided if the potato salad had been kept cool (less than 10°C). At cooler temperatures, the dangerous organism would not have multiplied rapidly to produce toxins as it did at the warmer temperature. Alternatively, the potato salad could have been made shortly before it was to be served. The important point, however, is that food which is otherwise properly prepared can become a source of illness, and perhaps even death, if it is left in the "danger zone" (temperatures between 10°C and 60°C) for too long (4 or 5 hours).

Case No. 2: Deadly dessert in Canada

One September evening, patients at a hospital in Scarborough, Ontario, were served tapioca pudding for dessert. Later the next day, patients began showing the symptoms of food poisoning (cramps, chills, vomiting, diarrhoea). In all, 103 patients became ill and two of these, both elderly and weak, died. No pudding was available for testing. However, it was known that the pudding, amounting to 225 servings, was refrigerated in one large container until dinner.

Question 2. What is a possible source of contamination? Was it food poisoning? What could have been done to prevent this?

The local health officials confirmed that 91 of the patients had been infected by *Salmonella enteritidis*, another common cause of foodborne disease. Given the incubation period of 12 - 36 hours for the disease, the tapioca pudding immediately fell under suspicion because the sick persons ate it and because it was made from raw eggs, which may have carried the organism. While the cook at the hospital had also fallen ill, it is likely that he was a victim rather than the cause as he had also eaten the pudding and was otherwise healthy at the time of the dinner.

Although no pudding was available for testing, the officials found out that the pudding was prepared and stored refrigerated in one large container until dinner. The heating of large quantities of thick foods, like pudding, frequently
leads to "false boiling" when only the bottom layer is at the boiling point. The temperature in other parts of the pan did not get high enough to destroy the Salmonella. Thick food should be stirred thoroughly in order to make sure that all parts reach at least 70°C. A food thermometer is a useful tool in commercial kitchens.

The other problem was that, when the pudding was placed in the refrigerator, the refrigerator had insufficient capacity to rapidly cool the large quantity of hot pudding. Consequently, the temperature of the pudding was not cold enough during storage to prevent the growth of the surviving organism (below 10°C). This is a common problem when foods prepared in large amounts are not cooled properly. Commercial kitchens should be equipped with refrigerators with sufficient capacity. In addition, large quantities of food may be placed in shallow pans to promote more rapid cooling.

Salmonella enteritidis is an emerging pathogen that may contaminate the egg prior to shell formation. As a result, there is no means to identify contaminated eggs. Consequently, all eggs must be handled as if they were contaminated. This means that they should be stored at low temperature and be thoroughly cooked to destroy any contamination. In addition, recipes with raw eggs should be avoided unless pasteurized eggs are used.

What causes food poisoning

These two incidents describe typical cases of foodborne illness. Food poisoning usually results from eating foods containing large numbers of harmful bacteria that infect the lining of the digestive tract or release toxins into it (i.e. infections), or from eating foods in which bacteria have previously produced toxins (i.e. intoxications).

Proper hygienic practices are important in the preparation, cooking and storage of foods. Since bacteria depend on moisture to move about, it is vital that their paths be blocked. Hand-washing will help prevent the spread of bacteria to goods or from one food to another. Making sure kitchen utensils, containers and work spaces are thoroughly cleansed, especially those that have been in contact with raw meat and poultry, will also help stop cross-contamination.

Ultimately, adequate cooking and avoidance of time-temperature abuse are the most important factors in preventing foodborne illness.

Case No. 3: A gift of fresh fish in Fiji

A man had very good luck fishing on the reef and offered to share some of the catch with his neighbours. The fish were nice and fresh, but about one hour after eating them, one person noticed a numbness of her lips and tongue. Soon other people also showed signs of illness, such as nausea, vomiting, headache and dizziness. Some people noticed that cold drinks felt hot, and hot water felt cold. Two people were hospitalized with irregular heartbeats. After several days, the signs of poisoning subsided, but for some people symptoms of weakness and dizziness persisted for several weeks.
Question 3. What was the cause of this illness? How could it have been prevented?

The people were made ill by ciguatoxin which is caused by the consumption of tropical and subtropical marine finfish which live near reefs. The fish become toxic when they feed on a naturally occurring algae which contains the toxin. As the toxin is not harmful to fish, the fish can accumulate high levels of it. The toxins are passed up the food chain so that larger predatory fish have high levels in their meat. Examples of fish which have been associated with ciguatoxin poisonings include barracuda, snapper, grouper, sea bass and king fish. The reversal of the sensations of hot and cold is a characteristic symptom but it is not always present.

The rapid growth ("blooming") of algae which produce the toxin is difficult to predict but is usually associated with disturbances in the reef caused by natural forces (e.g. typhoons) or human disturbances (e.g. construction). Afflicted persons should seek medical assistance immediately and local health authorities should take action to warn the public to avoid eating the type of fish implicated in the investigation.

Case No. 4. The good mother in Tanzania

Salome’s child was now nearly 5 months old and it was time to introduce food other than breast milk into the diet. She had heard that nutritious and inexpensive weaning food could be made from local foods and she wanted to make sure that her child would grow and thrive. Following the advice in the nutrition literature she had been given, she faithfully prepared the recipe for a follow-up food using boiled sorghum as the base. At first, her child loved the new solid food and clearly was eating more and more. However, it was difficult and time-consuming work so she started making larger batches so that she needed to prepare it only once a day. She carefully covered it with cloth gauze to protect it from flies. Subsequently, her child started to experience periodic episodes of diarrhoea and after a few months the child started to show signs of growth faltering.

Question 4. What might be the reason for growth faltering in this case? How could it be avoided?

The preparation of large amounts of weaning food which was subsequently allowed to stand at ambient temperature resulted in the growth of pathogens to infectious levels. Contamination of food has been estimated to be the cause of up to 70% of episodes of diarrhoea in children under the age of 5. WHO has estimated that worldwide there are 1500 million such episodes resulting in the deaths (usually from dehydration) of over 3 million children a year. In addition, episodes of diarrhoea result in growth faltering and stunting and make the child more susceptible to a range of other infectious diseases.
This problem could be avoided by making small batches of weaning food so that it is freshly prepared before each meal. Alternatively, a recipe based on fermentation could be used to extend the safe "shelf life" of the food. In recognition of the general problem, WHO has prepared a brochure entitled Basic principles of the preparation of safe food for infants and young children. These principles include:

1. Cook food thoroughly.
2. Avoid storing cooked food.
3. Avoid contact between raw foodstuffs and cooked food.
4. Wash fruits and vegetables.
5. Use safe water.
6. Wash hands repeatedly.
7. Avoid feeding infants with a bottle.
8. Protect foods from insects, rodents and other animals.
10. Keep all food preparation premises meticulously clean.

All of these principles should be observed in preparing food for infants and young children as they are well known to be highly susceptible to diarrhoeal diseases and the dangers of dehydration.
7.2. Problem-solving exercise: pesticide poisoning - an outbreak among antimalarial workers

Prepared by Linda Rosenstock, revised by Steven Markowitz


**Time:** 3 hours

**Objectives:**

At the end of the exercise, students will be able to:

1. Establish a case definition.
2. Understand the basic principles of study design, sampling, nonparticipant bias and routes of exposure.
3. Identify strategies to prevent recurrence of epidemics.

**Procedures:**

1. This is an unfolding exercise in seven parts, designed to mirror the real-life conditions of an environmental health practitioner in the field. Students are asked to analyse the information as it becomes available and to draw conclusions. If all parts of the exercise are distributed simultaneously, students should be instructed to work page by page and not to look ahead. Otherwise each part can be distributed separately. The decision to proceed to the next part can be made jointly by the students and instructor. Report-back sessions can take place after each part or at the conclusion of the entire exercise.

2. Introduce the exercise and review its objectives. Divide participants into small groups (4-6 persons). Instruct participants to identify a chairperson and a recorder.

3. Distribute the exercise and review the participants' tasks.

4. Reconvene the groups and invite a response from one group to the first question. Ask whether other groups have any different responses. Summarize and, if necessary, expand on the participants' responses and proceed to Question 2. Allow a different group to initiate the discussion and continue in this way until all questions have been answered. Possible answers to the questions are provided below. These answers are not all-

---


* Dr. Linda Rosenstock, Director, National Institute of Occupational Safety and Health, USA
Dr. Steven Markowitz, Division of Environmental and Occupational Medicine, Mt. Sinai School of Medicine, New York, NY, USA
inclusive. Instructors are encouraged to develop alternative responses and
intervention strategies that are appropriate to the local situation.

5. Summarize the results, emphasizing key messages.

Materials:
Problem-solving exercise (Annex 17), flip chart, coloured markers.

Case scenario, Part I
You are a medical officer recently appointed to take charge of a large malaria control programme. You
learn that a suspected increase in the number of pesticide poisonings started soon after the beginning
of the last spraying season.

Question 1. How would you proceed to investigate this situation? What
more would you like to know before getting started?
Participants should raise questions about what the "suspicion" of the epidemic
is based on. Students should ask about:
— person, time and place;
— types of pesticide poisonings;
— sources of information, including ones useful in epidemiological surveys-case
registries, hospital records, outpatient records, workplace records, individuals
(parents, employers, community residents, health care workers);
— new work exposures or work processes that may have occurred.

Case scenario, Part II
You learn that the pesticide malathion (an organophosphate) has replaced DDT this spraying season
because the mosquito had become resistant to DDT and because malathion is an effective pesticide,
that is thought to be relatively safe for human use on the basis of much experience, including field
trials in Nigeria and Uganda.

You learn that there are about 7700 antimalaria workers, making up 1100 teams of seven workers
each (5 spraymen, 1 mixer, 1 supervisor). In addition to the reported increase in illness (which
suggested organophosphate poisoning), five deaths have occurred—two in mixers and three in
spraymen. It is thought that one of the three brands of malathion was associated with the most severe
illness (used by three of the five who died). It is also reported that the illness was more common on
Friday and Saturday than on Sunday.
Question 2. What appears to be the main exposure problem in the episode described?

Malathion, an organophosphate pesticide that was believed to be relatively safe, has caused unexpected episodes of poisoning, including deaths. The problem is serious, unexplained and needs prompt attention.

Question 3. How can you plan organizationally to investigate this outbreak?

The study population is large. Are locally available resources sufficient to undertake the study? Use this as an opportunity to discuss resources, including outside assistance. In this case the study was undertaken in collaboration with WHO and the Centres for Disease Control and Prevention, USA.

Question 4. What case definition of "poisoning" would you suggest (use Table 1)?

Review the importance of case definition for proceeding with a formal study. The type of definition will vary according to the data available (e.g. questionnaire surveys will by definition rely on interview responses and not actual laboratory data). There is a trade-off between broad case definitions that will include all cases but also non-cases, and narrow case definitions that will include fewer non-cases but also fewer cases. A case definition should be based on knowledge about symptoms, signs and laboratory findings, but depends on the feasibility of data collection.

The case definition used in this study is given in Part III.

<table>
<thead>
<tr>
<th>Table 1. Symptoms of organophosphate poisoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild poisoning</td>
</tr>
<tr>
<td>headache</td>
</tr>
<tr>
<td>nausea</td>
</tr>
<tr>
<td>dizziness</td>
</tr>
<tr>
<td>anxiety, irritability</td>
</tr>
<tr>
<td>Moderate poisoning</td>
</tr>
<tr>
<td>muscle twitching, tremor</td>
</tr>
<tr>
<td>sweating, salivation</td>
</tr>
<tr>
<td>blurred vision</td>
</tr>
<tr>
<td>vomiting, diarrhoea, abdominal pain</td>
</tr>
<tr>
<td>chest tightness, wheezing</td>
</tr>
<tr>
<td>Severe poisoning</td>
</tr>
<tr>
<td>pulmonary edema</td>
</tr>
<tr>
<td>bradycardia (slow heart rate)</td>
</tr>
<tr>
<td>or tachycardia (fast heart rate)</td>
</tr>
<tr>
<td>confusion</td>
</tr>
<tr>
<td>seizures, coma</td>
</tr>
<tr>
<td>involuntary defecation, urination</td>
</tr>
</tbody>
</table>
Question 5. Why are there more symptoms on Friday and Saturday than on Sunday?

Why does there appear to be a problem with a pesticide that has apparently been safely used in other antimalaria programmes?

In this case study, workers were off work on Sunday. The increased number of cases at week's end reflected the cumulative exposure to the pesticide (and progressive decrease in cholinesterase levels).

Particular properties of the pesticide itself, or the way it is being used, need to be considered as reasons for the outbreak. Students should also be encouraged to maintain scepticism about past reports of chemical safety. The chemical may not be as safe as advertised.

Case scenario, Part III

The occurrence of cases of poisoning has been confirmed. Cases occur predominantly towards the end of the working week. You decide to study it further with a questionnaire survey.

You define a case as:
- occurring in a member of a spraying team;
- having at least four of the following five symptoms (blurred vision, dizziness, nausea, vomiting, abdominal pain).

You decide to interview a random sample (10%) of all the antimalaria workers to ask them about their past and present symptoms and their exposures at work.

Question 6. What type of epidemiologic study is this survey?

This is a cross-sectional study - at one point in time subjects will be investigated and exposures and effects will be assessed.

Question 7. What are the advantages and weaknesses of:
- this study design?
- this case definition?
- this sampling strategy?
### Issue

<table>
<thead>
<tr>
<th>a) Cross-sectional study design</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relatively inexpensive; easy</td>
<td>Selection bias - many affected workers may no longer be working and therefore are unavailable to participate in study. Recall bias - relies on memory of symptoms in the course of an epidemic.</td>
<td></td>
</tr>
</tbody>
</table>

| b) Case definition | Easy to elicit (symptoms only); cases are likely to be true cases because definition is relatively narrow. | Subjective only; may miss milder cases. Symptoms are not specific for pesticide poisonings. |

| c) Sampling strategy | Easy to perform; random; not influenced by investigator | May not be representative; may not be large enough to study subgroups. |

---

**Case scenario, Part IV**

You interview 79% of those targeted in your sample. Your main findings are shown in Table 2.

---

**Table 2. Number of acute poisonings during recent spray season**

<table>
<thead>
<tr>
<th></th>
<th>Number in sample</th>
<th>Number interviewed</th>
<th>% response</th>
<th>Number with at least 1 episode of poisoning</th>
<th>% poisoned</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a)</td>
<td>(b)</td>
<td>(b/ a)</td>
<td>(c)</td>
<td>(c/ b)</td>
</tr>
<tr>
<td>Spraymen</td>
<td>550</td>
<td>425</td>
<td>77</td>
<td>174</td>
<td>41</td>
</tr>
<tr>
<td>Mixers</td>
<td>110</td>
<td>86</td>
<td>78</td>
<td>33</td>
<td>38</td>
</tr>
<tr>
<td>Supervisors</td>
<td>110</td>
<td>95</td>
<td>86</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>770</td>
<td>606</td>
<td>79</td>
<td>226</td>
<td>37</td>
</tr>
</tbody>
</table>
Question 8. What do you think about the overall response rate of 79%? How could the non-responders affect your assessment of the problem?

The overall response rate (79%) is reasonably good. Non-responders could lead to underestimation or overestimation of the problem, depending on whether they were more or less frequently ill than responders.

Question 9. On the basis of these questionnaire results, how might you estimate the total number of workers with at least one episode of poisoning within the whole population of 7700 antimalaria workers during the recent spraying season?

Estimates derived from study results are as follows:

<table>
<thead>
<tr>
<th>Total at risk</th>
<th>Percent poisoned</th>
<th>Estimated number poisoned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spraymen</td>
<td>5500</td>
<td>41%</td>
</tr>
<tr>
<td>Mixers</td>
<td>1100</td>
<td>38%</td>
</tr>
<tr>
<td>Supervisors</td>
<td>1100</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7700</strong></td>
<td><strong>38%</strong></td>
</tr>
</tbody>
</table>

Optional: students may be encouraged to consider the role of participant/nonparticipant bias. For example, for spraymen only:

— if you assume that the survey is biased to find all sick (i.e. only those who were sick agreed to participate), then none of 125 not interviewed is sick, so the number of sprayman poisoned = 174/550 = 32%, extrapolated from the sampled group to the 5500 at risk (1740 poisoned);

— if you assume that the survey is biased to miss those who are sick (i.e. all 125 not interviewed are sick), then the total number of poisoned sprayman equals 299 (174 + 125) = 299/550 = 54%, extrapolated to 5500 at risk (2970 poisoned).

No matter what the magnitude and direction of the bias here, there is a major problem of poisoning.

Question 10. What would you do next?

Despite potential problems with the accuracy of the estimate, the problem is clearly significant, and further details about pesticide exposure are needed.
Case scenario, Part V

You now know that there has been a major outbreak (epidemic) of poisonings, having estimated a total of 2893 (38%) of workers with at least one episode of pesticide intoxication. Sprayers and mixers are at highest risk. Observations of spray teams showed problems such as:

— working in clothes wet from pesticides;
— direct pesticide contact with skin due to mixing with bare hands;
— leaking spray cans.

Skin patch samples confirm that there is high skin exposure, particularly for mixers and sprayers (about 10-20 times higher than for supervisors). Airborne estimates of malathion exposure to sprayers were obtained by standard methods and were determined to be low (3% of recommended US standards).

Question 11. What seems to be the most important route of exposure?

Airborne exposures are low for all. Skin exposures are high, and there is a crude dose-response effect to support the importance of this route of exposure.

Question 12. How could you study whether poor work practices and faulty equipment explain the epidemic? What are other possible explanations? How would you measure individual exposure more specifically?

Although poor work practices are present, they cannot be assumed to be the total explanation. The pesticide has been used in other settings where such practices are likely to have existed without this apparent extent of problems and the study has not shown the relationship between work practices and illness at the level of the individual workers. Other possibilities are that the pesticide may be more toxic than suspected, or that it is absorbed more than usual.

Studies to explore exposure-effect relationships at the level of the individual should be considered. Blood cholinesterase levels can be used to measure exposure.
Case scenario, Part VI

You conclude that factors other than poor work practices contribute to the epidemic. The workers themselves suggest that there are more problems among those using one or two malathion brands (out of three brands used). But a lot of workers use more than one brand in any given day. You collect blood and measure cholinesterase levels in a small sample of workers in the three job categories who used only one brand on the day of tests.

Your findings are shown in Table 3.

<table>
<thead>
<tr>
<th>Malathion Brand</th>
<th>End-of-day levels*</th>
<th>Mean % change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supervisors (N=22)</td>
<td>Mixers (N=21)</td>
</tr>
<tr>
<td>Brand 1</td>
<td>0.62</td>
<td>0.58</td>
</tr>
<tr>
<td>Brand 2</td>
<td>0.59</td>
<td>0.34</td>
</tr>
<tr>
<td>Brand 3</td>
<td>0.59</td>
<td>0.39</td>
</tr>
</tbody>
</table>

*Normal range: 0.53 - 0.93

Question 13. What do you think about these results? Is any brand safe? Which brand(s) might be causing the epidemic? Why might there be differences between brands?

All groups of workers have low cholinesterase levels, even at the beginning of the day (e.g. supervisors' cholinesterase levels do not change during one day but the mean is at the low level of the normal range, suggesting cumulative overexposure; only the mean is given, so even some supervisors will probably be definitely abnormal). Brands 2 and 3 are worse than Brand 1 for mixers and sprayers, who are likely to have larger exposures to any given brand than supervisors. Differences might be due to different concentrations of malathion, different concentration of other toxic components, or different properties such as greater skin absorption.
Case scenario, Part VII

Analysis of the chemicals in the three pesticide preparations showed Brands 2 and 3 had a much higher concentration of toxic breakdown products (formed when the main chemical, malathion, is degraded). This breakdown was thought to be due to different "chemical carriers" (believed to be non-toxic). You conclude that use of Brands 2 and 3 was the main cause of the epidemic, but you are also concerned about problems with poor work processes, faulty equipment and inadequate protective clothing.

**Question 14. Name at least three things you would do now to deal with the epidemic.**

Actions will include:

— product substitution (remove Brands 2 and 3, consider other products);
— change in work practices, including worker education, provision of better equipment and protective clothing;
— pesticide surveillance (disease registry programme);
— improved medical treatment for cases.

**Question 15. You learn that there may be a problem with children in the community becoming ill. How would you investigate this?**

Consider how this might be explored (e.g. questionnaire and laboratory surveys to assess the nature and extent of the problem).
7.3 Problem-solving exercise: toxic encephalopathy from a seafood toxin
Prepared by Evert Nieboer

* Time: Two 2-hour sessions, allowing time for independent study.

✓ Objectives:
At the end of the exercise, students will be able to:
1. Understand and apply the material on food quality criteria/assurance in Sections 7.3 and 7.4 of the textbook.
2. Describe investigative approaches that may be required in an episode of food poisoning to identify an unknown natural toxin and what actions might need to be taken to protect the public.
3. Identify the local public health practices that ensure food safety.

✍ Procedures:
1. Introduce the exercise and review its objectives. Divide participants into small groups (4-6 persons). Instruct participants to identify a chairperson and a recorder.
2. Distribute the exercise and review the participants' tasks.
3. Brainstorm a list of the issues raised in the case study with the entire group. Alternatively, this can be done in small groups. This helps to establish the existing knowledge of members of the group and to identify special resource persons within the group.
4. Following the small group work, reconvene the groups and invite a response from one group to the first question (or from the designated group if questions were assigned to a specific group). Ask whether other groups have any different responses. Summarize and, if necessary, expand on the participants' responses and proceed to Question 2. Allow a different group to initiate the discussion and continue in this way until all questions have been answered. Possible answers to the questions are provided below. These answers are not all-inclusive. Instructors are encouraged to develop alternative responses and intervention strategies that are appropriate to the local situation.
5. Summarize the results, emphasizing key messages.
Materials:
Problem-solving exercise (Annex 18), flip chart, coloured markers.

Case scenario
In late 1987, a mysterious and serious outbreak of food poisoning occurred in Canada. Symptoms of the poisoning included vomiting and diarrhoea, followed in some cases by confusion, memory loss, disorientation and even coma. Two elderly patients died and in some other severely affected cases the neurological symptoms still persist. Epidemiologists from Health and Welfare Canada soon attributed the illnesses to restaurant meals of cultured blue mussels (*Mytilus edulis* L.). Using the Association of Official Analytical Chemists’ mouse bioassay for “red-tide” paralytic shellfish poison (PSP), Health and Welfare Canada and Fisheries and Oceans scientists demonstrated that the mussels contained toxic material. Furthermore, they were able to trace the problem to mussels harvested from a specific area of eastern Prince Edward Island. All the Deputy Ministers of Health of the 10 Canadian Provinces were notified by telex of the recommendation to take Prince Edward Island mussels off the shelves in retail stores and to remove them from restaurants. Consumption was to be stopped. Statistical analysis of the mussel distribution records and reported cases showed that for each symptomatic case some 500 people ate the contaminated mussels without any toxic consequences.

Subsequently, a team of scientists using suitable chemical separation, analytical techniques and the mouse assay, established that a neuroexcitatory amino acid, domoic acid, was the probable toxic agent. It was shown that the diatom *Nitzschia pungens* (an alga) was the source of this compound. Mussels feed on plankton, of which *Nitzschia pungens* became a significant component during an algal bloom in the waters off the eastern coast of Prince Edward Island. When the toxic bloom waned early in 1989, shellfish were found to contain low levels (<20 µg/g) of domoic acid and distribution for human consumption was again allowed. No further illnesses were documented.

Question 1. Identify, without detailed discussion, important issues highlighted in the case scenario. (Do this in a group setting with a recorder at the blackboard or flip chart.)

Possible major issues are (in random order):
- domoic acid is a naturally occurring food toxin;
- is there a safe level?
- why were some individuals not affected?
- what is PSP?
- food safety surveillance;
- emergency response by public health authorities;
- need for an investigative team of medical specialists and scientists;
- need for bioassays and analytical methods;
- mechanism of action of domoic acid;
- rules of evidence.

Some of these issues are pursued in more detail in subsequent questions.
Question 2. What is paralytic shellfish poisoning (PSP)? Can domoic acid poisoning be distinguished from it?

The etiologic agent of PSP is saxitoxin, which is a relatively heat-stable alkaloid produced in plankton species (specifically, dinoflagellates of the genera Gonyaulax and Pyrodinium). It is found in mussels, cockles, clams, soft shell clams, butter clams, scallops and shellfish broth; bivalve mussels are the most common vehicles (Kotsonis et al., 1996). Saxitoxin is a neurotoxin that blocks neural transmission at the neuromuscular junction. Symptoms include tingling or burning numbness around lips and fingertips, ataxia, giddiness, staggering, drowsiness, throat dryness, incoherent speech, aphasia, rash, fever and respiratory paralysis (Kotsonis et al., 1996). Saxitoxin does not have emetic nor hypothermic action. Death occurs infrequently.

By contrast, domoic acid poisoning referred to as “neurovisceral toxic syndrome” is characterized by several of the following acute symptoms: nausea, vomiting, neurogenic gastric distress, gastric bleeding, diarrhoea, dizziness, confusion, weakness, lethargy, somnolence, headache, coma and seizures. A chronic consequence can be severe short-term memory deficit, devoid of dementia, which resolves very slightly and very slowly over time (Perl et al., 1990).

Question 3. Discuss possible mechanisms of action of domoic acid.

Domoic acid is an amino acid and an analog of glutamate, which is recognized as an excitatory amino acid. Domoic acid passes freely into certain regions of the brain that are not protected by the blood-brain barrier. There it interacts with specific neuronal receptors (specifically N-methyl-D-aspartate, NMDA, or kainic acid, KA, receptors). The apparent consequence of this action is hypervulnerability to overstimulation (excitotoxic degeneration). Domoic acid is believed to activate KA receptors. Seizure-mediated brain damage ensues (Olney, 1990; 1994).

Question 4. From the information given, do you expect there to be a safe intake level of domoic acid?

The fact that only one in 500 individuals eating the contaminated mussels became ill suggests that there is a safe level for most individuals. Interestingly, most people who become seriously ill had some underlying condition such as renal disease, liver failure, atherosclerosis or diabetes (Hynie et al., 1990). Further, studies in mice have indicated a four- to five-fold variability in dose response. It is important to emphasize that susceptibility (inherited or acquired) to toxicants is very important in occupational, environmental and public health settings.

The amount of domoic acid consumed by individuals was calculated to be as much as 5 mg/kg or 6 mg/kg body weight based on domoic acid levels in mussels of 960 to 1280 µg/g (ppm). Such levels produced vomiting in cynomolgus monkeys and are 10-fold higher than the amounts given as an anthelmintic (remedy for intestinal worms) in Japan.
Question 5. Suggest how one might determine quantitatively the concentration of domoic acid in mussel tissue.

Since domoic acid is an organic compound, some form of chromatography will be needed to separate/isolate it for quantitative determination. The following procedure was found to be adequate, with a detection limit of 1 µg/g (≡ mg/kg or ppm). The Association of Official Analytical Chemists' procedure for the isolation of saxitoxin was employed. Mussel tissue (50 g) was boiled gently for five minutes in 0.1 N HCl, followed by cooling and centrifuging. An appropriately diluted aliquot of the supernatant was analysed by high-performance liquid chromatography (HPLC). Detection was by UV absorption spectrometry (Iverson et al., 1989). Purified domoic acid isolated from mussels and characterized by spectroscopic techniques (Wright et al., 1990) served as the analytical standard. Any analytical chemistry textbook featuring instrumental analysis can provide additional details about HPLC and spectrometric detection.

Question 6. Are you convinced there was enough evidence to assign the blame to domoic acid as the causative agent?

The evidence may be itemized as follows (Wright et al., 1990; Hynie et al., 1990; Teitelbaum et al., 1990):

— Two localized sources of the contaminated mussels were established.
— The mussels from the two sources had the highest domoic acid content.
— Extracts were toxic in an official mouse test, with a response different from PSP (respectively, death in 30 minutes, preceded by typical scratching, compared to paralysis-type death in 15 minutes).
— Extracts from contaminated mussels had the same toxicologic outcome in rodents as did pure domoic acid added to non-toxic extracts.
— The neuropathology of the four patients who died in the outbreak was specific and strikingly similar to the findings in experimental animals poisoned by domoic acid.
— The action of domoic acid as an agonist of kainic acid in experimental systems provides an underlying molecular mechanism for the toxic effects.
— Unfortunately, since the investigators did not know exactly what they were looking for during the outbreak, urine or faeces samples were not collected for domoic acid analysis.
— Estimated intakes are qualitatively consistent with doses producing effects in animal models and appear to be higher in magnitude than doses reported with no effects in humans being treated for intestinal worms.
— The variability in human responses was reflected in animal experiments and the individuals affected appeared to be especially susceptible.

Although not absolute, the evidence of domoic acid as the putative agent is convincing to very convincing.
Question 7. Assess the role of the interdisciplinary investigative team.

It is clear from the details in the scenario and answers to the previous questions that, without the investigative team, the relatively quick action of the health authorities would have been delayed considerably and it would not have been possible to collect the evidence of causation.

Question 8. Suggest preventive actions to avoid future incidents.

Steps were taken to prevent the recurrence of domoic acid poisoning by shellfish consumption. Sacks of mussels are now labelled with respect to time and place of harvesting and the absence of domoic acid is confirmed by the mouse bioassay and HPLC before commercial distribution. These actions have been effective.

Question 9. Discuss the broad area of food safety in public health. In your discussions, highlight the status and practices of the following aspects in your geographical region: (i) regulatory authority; (ii) setting of food safety standards; (iii) routine food inspection/surveillance; (iv) emergency response capacity.

It is suggested that Sections 7.3 and 7.4 of the textbook be consulted as background. Students are encouraged to consult the local public health office and other appropriate local sources to obtain the information needed for an informed discussion/debate. Individual presentations about investigative projects are another approach.

Selected references


**Learner, peer and problem evaluation**

**Formative evaluation**

Make sure there is plenty of opportunity for feedback by the participants concerning how they felt about their own participation and contributions and that of the instructor/facilitator and fellow learners. This should be done after each group session, but especially at the close of the last one. Are the group sessions or classes stimulating? Is self-directed learning encouraged? Do the students feel that their group is approaching the problem and the stated objectives effectively. Were the objectives met? Is the problem as presented relevant and how can it be improved? Is the workload being shared?

**Summative evaluation**

Two suggestions seem relevant. First, test the response of individual students (orally or in writing) to a food poisoning episode. Test for knowledge, application of knowledge, judgement and decision-making. The scenario might contain more than one part, as in the modified essay questions (MEQs) approach (see Problem-solving Exercise 6.1 for more details). Second, have individual students prepare an investigative/critical assessment of a specific aspect of food safety in their own community, such as one of the issues suggested in Question 9. Performance in an oral presentation might be combined with the mark achieved on the investigative report.
7.4. Problem-solving exercise: Hazard assessment in food production

Prepared by Theo de Kok*

**Time:** Two 1-hour sessions, allowing time for independent study

**Objectives:**
At the end of the exercise students will be able to:
1. Identify and discuss critical control points in food processing.
2. Explain the origin of bacterial contamination of food items.
3. Indicate possible health effects of bacterial food contamination.
4. Discriminate between foodborne infections and food poisoning.
5. Describe possible chemical changes that nutrients may undergo leading to the formation of toxic products during storage, processing, manufacturing and preparation of foods.

**Procedures:**
1. Introduce the exercise and review its objectives. Divide your class into small groups (5-8 persons). Instruct participants to identify a chairperson and a recorder.
2. Let each group define its own approach to the problem posed. The role of the tutor is to visit all groups and ensure that each group:
   - formulates a clear problem definition;
   - conducts brainstorming to generate potential answers to the questions;
   - prepares a list of specific study objectives for independent study;
   - prepares a list of sources of additional information to be consulted (databases, libraries, specialists, etc.).

---

2 Based on: J. de Vries et. al, Food safety and toxicity workbook. Heerlen, Open University, 1994

* Dr Theo de Kok, Faculty of Natural Sciences, Open University, Heerlen, Netherlands
3. Reconvene the groups after 1-3 days. Invite one group to report back on the information gathered. Ask for comments from the other groups and reports on any responses which were different from those of group one. Alternatively, you may ask each group to give a short summary of its findings and have a plenary discussion about the key elements in the exercise.

**Materials:**

Problem-solving exercise (Annex 19), flip chart, coloured markers.
Exercise: Hazard assessment in food production

You are a health inspector who is visiting a food processing plant that produces infant food on a large scale. The product of the production line you are working on today is a drum-dried and spray-dried infant food, based on rice, maize, starch, coconut oil, sugar milk and a number of supplements. The flow diagram of the process given to you by the director is shown in Figure 1.

Figure 1
Flow diagram for drum- and spray-dried rice-based infant foods

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Water</th>
<th>Dispersion</th>
<th>Mixing</th>
<th>Belt mixer</th>
<th>Drum dryer</th>
<th>Pre-breaker</th>
<th>Sacks</th>
<th>Dry mixing</th>
<th>Grinding</th>
<th>Pneumatic transport</th>
<th>Trolley-tanks</th>
<th>Pneumatic transport</th>
<th>Spray-dryer</th>
<th>Packaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice flour, maize starch, soya flour, coconut oil, maize oil, vitamin supplement, vanillin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ingredients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sucrose, powdered milk, other dry ingredients, flavouring, vitamin supplement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend

ccp critical control point
●points of high concern
Based on your visit to the plant and interviews with staff and employees, you identified a number of critical control points. Table 1 lists the critical control points and the hazards involved.

**Table 1**  
Analysis chart of the process of spray-drying rice-based infant food and control points

<table>
<thead>
<tr>
<th>Critical control</th>
<th>Description</th>
<th>Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dispersal</td>
<td>Addition of hot water.</td>
<td>Bacterial proliferation occurs over time</td>
</tr>
<tr>
<td>2. Mixing</td>
<td>The solution is mixed in stir tank.</td>
<td>As above.</td>
</tr>
<tr>
<td>3. Belt mixer</td>
<td>To achieve the required mixing of all ingredients.</td>
<td>As above.</td>
</tr>
</tbody>
</table>
| 4. Drum dryer    | Evaporation of water by a Drum Dryer (DD)  
The dryer works at 150°C  
The product reaches ...°C | The products leaving DD meet the current of air caused by the extractor. Microorganisms may be transferred to the product. Bacterial proliferation occurs over time in plant and environment. |
| 5. Prebreaker    | The sheet form of the products is reduced to pieces. | |
| 7. Dry-mixing    | Addition of other ingredients to the semi-finished product. | Pathogens in milk and fruit powders (raw materials). |
| 8. Grinding      | The dry mixture is ground by milling. | Contamination from mill. |
| 9. Pneumatic transport | Pneumatic transport of product, then stored in trolley tanks until transferred to sprat dryer by pneumatic transport | During these operations the product can be contaminated by trolley-tanks as these are transferred from one building to another. Contact with air can introduce microorganisms |
| 10. Spray dryer  | Water is added to the dry mixture; this is then treated In a spray dryer with a fluid bed. | Atomizer rotor is subject to bacterial growth. |
| 11. Packaging    | Product placed in sachet of impermeable nitrogen flushed laminate before heat sealing. Sealed sachet placed in a box. | Packaging material can be contaminated. Contamination (pathogens) from the environment. Product residues in filler can contaminate fresh product as it is filled. |
It is your task to write a report on the safety of the foods produced by this plant. The following questions may give some guidance in doing so.

**Question 1. Describe when and how the microbial hazards may give rise to toxin formation, thus resulting in poisoning of the infant that consumes the food.**

As can be seen in Table 1, microbial hazards may occur at each stage of the process. Several steps allow bacterial proliferation over time (especially steps 1-3 since the product still has a high water content).

Rice flour, maize oil, maize starch and soya flour may contain 100-500 ng of mycotoxins per g of the product.

**Question 2. What could be the cause of mycotoxin formation in the flow of oil and starch products, and what types of mycotoxins may be formed under which conditions?**

The main problems can be expected as a result of the harvest and oil production conditions. Water activity and hygienic GMP (good manufacturing practice) during production, handling, transport and storage are especially important. In the flow of oil products, hydrophobic toxins like aflatoxin and ochratoxin can be expected. The critical water activity is 0.80 for mould growth and 0.83 for toxin formation.

**Question 3. What options are there to prevent mycotoxin formation?**

There are several options:

- the application of a GMP protocol preventing mould infection of the products and the equipment;
- the use of a quick-drying procedure down to aw = 0.80 (preventing mould growth);
- the use of a fast oil (maize) production processing technique with a CCP examining mould growth and mycotoxin formation.

**Question 4. Is it possible to inactivate the mycotoxins that have already been formed in the products, either chemically or physically?**

In practice, it appears to be difficult to detoxify a mycotoxin-containing product. Thus, once a product is contaminated, it has to be eliminated from the process.

**Question 5. Staphylococcus aureus enterotoxin may have been formed in the milk before it was dried (e.g. 1 ng per g dried milk powder). Is it possible that children show S. aureus poisoning after consuming 250 g of the contaminated product?**
These children will probably show no effects, as the milk powder is diluted before it is used in the preparation of food. The concentration of the S. aureus toxin may thus remain far below the toxic intake level of $1 \, \mu g$ per $100 \, g$ food (for adults).

**Question 6. Is it likely that children fall ill after consuming the product in case it is contaminated with $10^4$ viable Bacillus cereus spores per $g$ and the product was left at $20^\circ C$ for 16 hours?**

Yes, the B. cereus spores may germinate, multiply and produce their toxins up to a toxic level within 16 hours at $20^\circ C$.

Before use, the infant food is reconstituted by adding 90 g tap water to 10 g of the dried powder containing 10% w/w of milk powder.

**Question 7. Describe the toxicological hazards (other than microbiological) that may be associated with this infant formula. Take the whole sequence of production into account from raw material to the consumer (e.g. origin, level, hazards, possible avoidance/elimination).**

Study hint: take the following points into account

- **Regarding the raw materials:**
  - excess vitamin A/D;
  - antinutritive substances (soy);
  - lipid oxidation and its products;
  - contaminants (e.g. heavy metals, PCBs, dioxin, nitrate, packing materials);
  - additives.

- **Regarding the food processing:**
  - lipid oxidation (minerals, oxygen, heat treatment);
  - Maillard reactions (depending on conditions, spray-drying versus drum-drying);
  - maintenance or loss of nutritional value depending on the processing conditions;
  - contamination from the equipment;
  - oxidative and thermal degradation of proteins (drum-drying).

- **Regarding packaging/storage:**
  - contamination.
Suggested references

