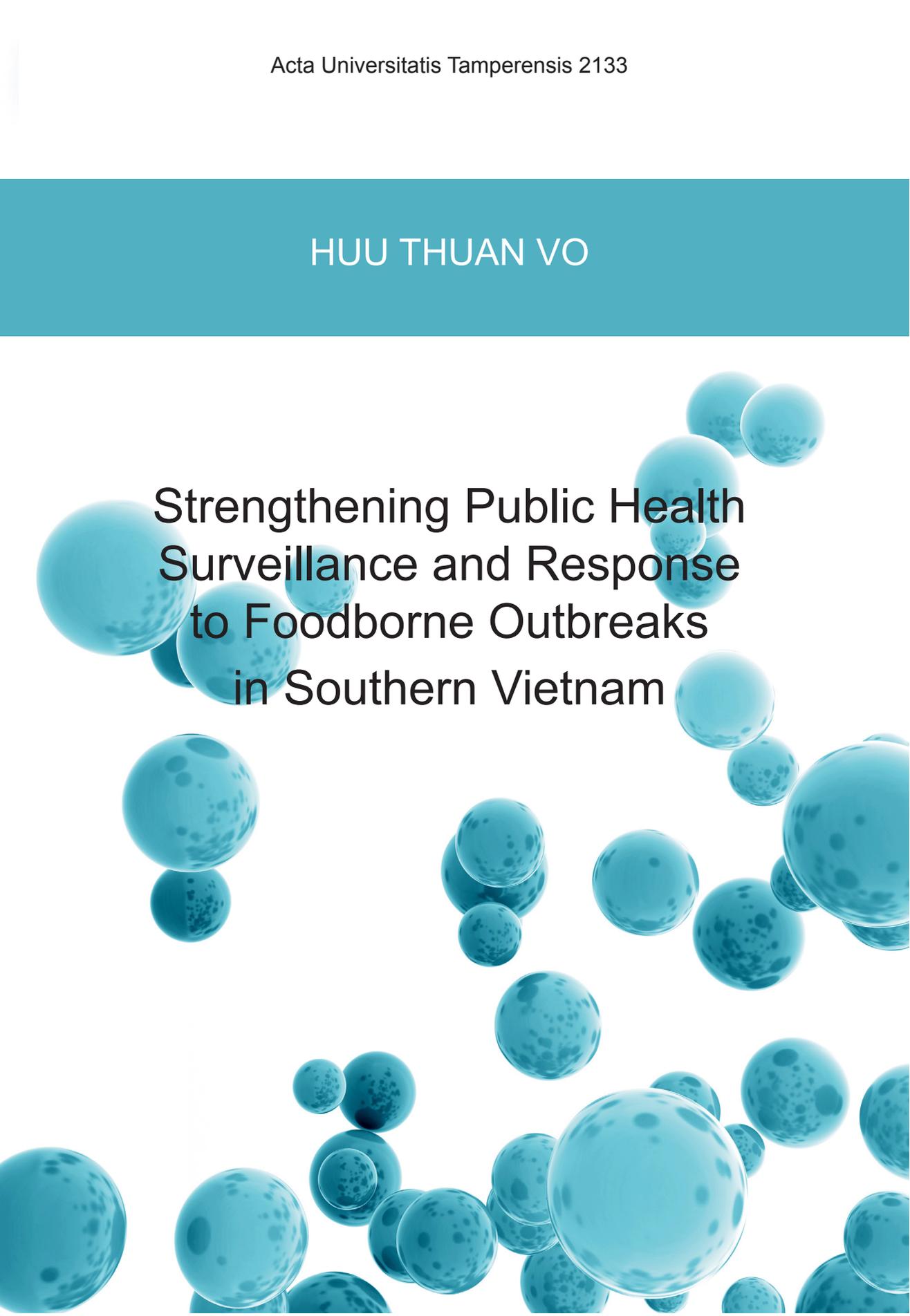


HUU THUAN VO

**Strengthening Public Health  
Surveillance and Response  
to Foodborne Outbreaks  
in Southern Vietnam**

The background of the cover features a collection of blue, semi-transparent spheres of various sizes. These spheres are scattered across the white background, with some appearing larger and more prominent than others. The spheres have a subtle texture and a slight gradient, giving them a three-dimensional appearance. The overall aesthetic is clean and modern, with a focus on the title text.



HUU THUAN VO

Strengthening Public Health  
Surveillance and Response  
to Foodborne Outbreaks  
in Southern Vietnam



ACADEMIC DISSERTATION

To be presented, with the permission of  
the Board of the School of Health Sciences of the University of Tampere,  
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UNIVERSITY OF TAMPERE

HUU THUAN VO

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to Foodborne Outbreaks  
in Southern Vietnam

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ACADEMIC DISSERTATION

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“Good surveillance does not necessarily ensure the making of the right decisions,  
but it reduces the chances of wrong ones.”

Alexander D. Langmuir, 1963

# Abstract

Foodborne diseases (FBD), with their varied clinical characteristics and causes, are a global public health concern. The World Health Organization (WHO) estimates that one billion people in developing countries and one-third of the population in developed countries are affected by FBD annually, resulting in significant economic losses. In Vietnam, approximately 200 foodborne outbreaks, 6,000 cases, and 50 deaths are reported annually. The majority of detected foodborne outbreaks have been linked to large canteens, while almost all fatal cases were associated with family meals. Public health statutory surveillance systems rely on outbreak investigation reports, and most outbreaks are only detected when severe cases are admitted to health facilities or when deaths occur. It is therefore clear that these figures are an underestimate, which implicates FBD as a significant public health and economic burden in Vietnam.

In developing countries, public health systems face many challenges in ensuring food safety, including shortages of human resources, laboratory capacities, and financial resources. These shortcomings result in poor surveillance and response systems, which are not able to accurately estimate the burden of FBD, trends, contributing factors, and source attribution. Principles of food safety and best practices of food production are critical for comprehensive FBD prevention and control. However, capacity to monitor the complete food production chain is limited and outside the jurisdiction of public health. Therefore, studies in this dissertation focus on improving surveillance and response systems for food safety.

The five studies (I to V) in this dissertation describe and evaluate the public health surveillance systems and responses to various foodborne outbreaks in Southern Vietnam from 2009 to 2013. Studies I to IV aim to identify the vehicles, sources, causative agents, and risk factors associated with the outbreak. These studies use various analytic methods to identify gaps and shortcomings in the surveillance and investigation of foodborne outbreaks. Study V then evaluates food-handlers' food safety knowledge, attitudes, and practices at large canteens. The main findings of these studies help to identify feasible approaches to build capacity and improve public health practices in resource-poor settings.

We identified likely outbreak vehicles and sources in four outbreak investigations, although we were unable to identify causative agents in Studies I and III. We identified risk factors contributing to these outbreaks, particularly the inadequate personal hygiene and food hygiene practices of food-handlers. Additionally, findings of outbreak investigations showed that only severe cases sought care at hospitals, clinicians alerted public health officials to suspected outbreaks, and these notifications were usually delayed. The notifiable disease system, operated by Southern Vietnam Preventive Medicine Centers, failed to detect clusters of cases or suspected foodborne outbreaks; it was also rare that surveillance data were analyzed and disseminated to Vietnam Food Safety Agencies (FSAs). Foodborne notification/complaint systems were not set up to receive FBD complaints from the public. Currently, only outbreak investigation reports are used to track food safety, but these reports usually contain only limited information and state few contributing factors and recommendations.

Almost all public health/preventive medicine personnel in Southern Vietnam were trained to conduct outbreak investigations, but standard epidemiologic methods were not appropriately applied. For example, no standard case definitions and questionnaires were developed for conducting outbreak investigations. Most case information that food safety authorities reported was transcribed from hospital records. Investigators did not request or obtain any specimens from patients; conclusions regarding the causes of outbreaks were mainly based on results of laboratory tests of food samples. Food-preparation site investigations yielded inadequate information. No flow charts of food operations were drawn and no interviews with food-handlers were conducted, and stool samples of food-handlers and environmental samples were not taken as required. Although most FSAs had limited capacity to perform foodborne outbreak investigations, they rarely requested technical support from the central level. Most microorganism and physico-chemical testing in water and foods were conducted in laboratories at the central level.

In Study V, we conducted a cross-sectional survey on food safety knowledge, attitudes, and practices (KAP) and on the training needs of food-handlers in large canteens. Of the 909 food-handlers participating in the study, knowledge, attitudes, and practices were considered adequate for 26%, 36%, and 26%, respectively. After controlling for potential confounders in logistic regression models, the number of food-handlers reporting adequate KAP in schools was about twice as high as the number of such food-handlers in factories. Food-handlers' suggestions for training needs included appropriate location of the training venue at the workplace,

involvement of managers, fewer trainees per course, more practical exercises, and longer course duration.

In these studies, we found that public health surveillance systems for food safety are mainly based on foodborne outbreak investigations, response capacities to foodborne outbreaks are limited, and food-handlers' KAP are poor. We therefore recommend the following:

- i) For public health surveillance and response in resource-poor settings, food safety authorities and policy-makers should consider including syndromic surveillance in food safety systems, based on existing notifiable disease reporting for infectious diseases. Notification/complaint systems should be available to receive calls from the public.
- ii) The Vietnam Field Epidemiology Training Program of the Ministry of Health, in collaboration with the Ministry of Agriculture and Rural Development, should develop a strategy and plan to train outbreak response teams at all administrative levels, in order to reach the target of making at least one trained field epidemiologist available per 200,000 people.
- iii) Efforts to educate food-handlers, together with supportive supervision conducted by managers, have great potential to improve food-handlers' KAP, especially among those working in factories.
- iv) We recommend that further studies investigate contributing factors in food preparation and foodborne outbreaks, the burden of foodborne diseases, and source attribution.

# Contents

1. Introduction .....	11
2. Review of the literature .....	13
2.1. Foodborne diseases.....	13
2.1.1. Definition of foodborne diseases.....	13
2.1.2. Causative agents associated with foodborne outbreaks .....	14
2.1.3. Epidemiology of foodborne diseases .....	19
2.1.4. Factors contributing to foodborne outbreaks .....	29
2.1.5. Economic burden of foodborne diseases.....	32
2.2. Surveillance systems of foodborne disease .....	33
2.2.1. Types of surveillance systems relevant to foodborne diseases .....	34
2.2.2. Foodborne disease surveillance in Vietnam.....	39
2.3. Human resources for food safety systems in Vietnam .....	40
2.4. Outbreak epidemiology.....	40
2.4.1. Choosing epidemiologic study designs .....	41
2.4.2. Methodological issues of case-control studies in outbreak investigations.....	43
2.4.3. Features of an outbreak investigation .....	45
2.5. Principles of investigating foodborne outbreaks .....	46
2.5.1. Detection and verification of an outbreak.....	47
2.5.2. Case definition and descriptive epidemiology.....	48
2.5.3. Development and evaluation of hypotheses .....	52
2.5.4. Implementation control and prevention measures .....	53
3. Objectives of the study.....	55
4. Methods .....	56
4.1. Methods of foodborne outbreak investigations (Studies I–IV) .....	56
4.1.1. Study settings and outbreak detection.....	56
4.1.2. Epidemiologic study designs.....	57
4.1.3. Case definitions:.....	58
4.1.4. Collection of data.....	58
4.1.5. Laboratory methods .....	59
4.1.6. Environmental investigation methods .....	59
4.1.7. Analysis of data .....	60
4.1.8. Ethical considerations .....	60
4.2. Survey methods for food-handlers' knowledge, attitudes and practices.....	60
4.2.1. Study setting.....	60
4.2.2. Study design.....	61
4.2.3. Collection of data.....	62
4.2.4. Analysis of data .....	62
4.2.5. Ethical considerations .....	63

5. Results.....	64
5.1. Outbreak investigations response to foodborne diseases in Southern Vietnam (I–IV).....	64
5.1.1. Outbreak #1: “Acute allergic reactions from milk”.....	65
5.1.2. Outbreak #2: “Cholera at district hospital”.....	66
5.1.3. Outbreak #3: “Gastroenteritis in a large canteen”.....	68
5.1.4. Outbreak #4: “Salmonellosis from stuffed bread”.....	70
5.2. Gaps and shortcomings in surveillance of foodborne outbreaks.....	72
5.2.1. Gaps and shortcomings identified in surveillance and outbreak detection.....	72
5.2.2. Gaps and shortcomings identified in response capacity.....	73
5.2.3. Gaps and shortcomings identified in laboratory capacity.....	74
5.3. Knowledge, attitudes and practices, and training needs of food-handlers at large canteens (V).....	75
5.3.1. Descriptive analysis.....	75
5.3.2. Comparison of food-handlers working in schools and factories.....	75
5.3.3. Observations at canteens.....	77
5.3.4. Training needs.....	78
6. Discussion.....	79
6.1. Assessing the evidence in foodborne outbreak investigations and food-handlers’ contributions to the outbreaks.....	79
6.2. Methodological strengths and limitations.....	81
6.3. Strengthening public health surveillance and response capacity for foodborne outbreaks.....	83
6.3.1. Developing surveillance systems.....	83
6.3.2. Strengthening human capacity for outbreak investigations.....	84
6.3.3. Food-handler training.....	86
6.4. Public health implications for FBD surveillance and capacity building.....	87
7. Conclusions.....	89
8. Recommendations.....	90
9. Acknowledgments.....	92
10. References.....	93
Original publications.....	108

# List of original publications

This dissertation is based on the following original papers which are referred to in the text by their Roman numerals (I to V)

- I Vo HT, Le HN, Patel SM, Phan TL, Tran Minh NN. Acute Allergic Reactions in Vietnamese Children after Drinking a New Milk Product. *Foodborne Pathog Dis.* 2012; 9(2): 156-159.
- II Vo HT, Le HN, Nuorti JP, Phan TL, Tran Minh NN. A Cluster of Cholera among Patients in a District Hospital, Vietnam, 2010. *J Infect Dev Ctries.* 2013; 7(12): 910-913.
- III Vo HT, Nguyen VD, Le TKL, Phan TL, Nuorti JP, Tran Minh NN. Applying Standard Epidemiologic Methods in Investigation of Foodborne Disease Outbreak in Resource Poor Settings – A Lesson from Vietnam. *J Food Prot.* 2014; 77(7): 1229-1231.
- IV Vo HT, Le HN, Cao TDT, Nuorti JP, Tran Minh NN. An Outbreak of Foodborne Salmonellosis Linked to a Bread Takeaway Shop in Ben Tre City, Vietnam. *Int J Infect Dis.* 2014; 26C: 128-131.
- V Vo HT, Le HN, Le TNA, Tran Minh NN, Nuorti JP. Knowledge, Attitude and Practices of Food-handlers at Large Canteens in Southern Vietnam, 2012. *Food Control.* 2015; 57: 190-194.

# Abbreviations

AGD	Acute gastroenteritis diseases
CDC	Centers for Disease Control and Prevention, USA
CI	Confidence Interval
FBD	Foodborne diseases
FELTP	Field Epidemiology and Laboratory Training Programme
FETP	Field Epidemiology Training Programme
FoodNet	Foodborne Diseases Active Surveillance Network
FSA	Food Safety Agency
GOS	Galacto-oligosaccharides
GHSA	Global Health Security Agenda
HACCP	Hazard Analysis Critical Control Point
HCMC	Ho Chi Minh City
ISO	International Organization for Standardization
IPH	Institute of Public Health
KAP	Knowledge, Attitude and Practice
LMICs	Low- and Middle-Income Countries
MOH	Ministry of Health
OR	Odds Ratio
PMC	Preventive Medicine Centre
POR	Prevalence odds ratio
PR	Prevalence ratio
RR	Relative Risk, Risk Ratio
VFA	Vietnam Food Administration
WHO	World Health Organization

# 1. Introduction

Foodborne diseases (FBD) are a global public health concern (Havelaar et al., 2013). These diseases have a variety of clinical characteristics (Scallan, Mabon, and Wong, 2013) and causes (Committee on the Control of Foodborne Illness, 2011; WHO, 2008). The World Health Organization (WHO) estimates that in developing countries, one billion people become ill and approximately 2.2 million people die annually due to foodborne and waterborne diseases of microbiological causes. In developed countries, it is estimated that FBD affect one-third of the population annually (WHO, 2010). FBD not only affect human health directly, but also have socioeconomic, political, and legal implications. Economic losses are substantial in both developed and developing countries (WHO, 2010). In the United States, for example, the costs associated with FBD have been estimated at US\$ 152 billion annually (Scharff, 2010).

In Vietnam, food safety is a major public health concern, resulting in substantial morbidity, mortality, and economic losses; an estimated 1,262 foodborne outbreaks, 41,962 cases, and 294 deaths occurred from 2007 to 2013 (Vietnam Food Administration, 2013; Vietnam Food Administration, 2014). The direct and indirect economic losses resulting from FBD were estimated to be more than US\$ 1 billion annually (WHO, 2015). Outbreaks with 30 or more cases accounted for 28% of all reported outbreaks and 81% of cases (National Institute of Nutrition - United Nations Children's Fund, 2011; Vietnam Food Administration, 2011). The majority of detected foodborne outbreaks have been linked to large canteens. Although these figures are clearly an underestimate - the tip of the iceberg - they indicate the significant public health and economic burden due to FBD.

Surveillance systems for FBD are under the authority of the Vietnam Food Administration (VFA). All health staff, whether they offer public or private services, have the responsibility to notify Food Safety Agencies (FSAs) at district or provincial levels when a suspected foodborne outbreak occurs in their setting. When cases of FBD are admitted to a health facility, the facility has to report regularly to a higher-level facility and ultimately to the VFA. In severe outbreaks or those leading to deaths, preventive medicine services, health facilities, or district

FSAAs are permitted to share data/reports beyond their jurisdiction. Statutory surveillance systems, outbreak investigation reports, maintained by public health authorities in Vietnam are mainly passive. Most outbreaks are detected when severe cases are admitted to health facilities or when deaths occur. A few events have been reported by district hospitals, health workers, or local residents; some events have been detected via daily newspaper reports. Response capacity and resources at local levels are very limited, and central/provincial public health officials are responsible for supporting outbreak responses in most instances.

Food safety therefore poses many challenges within the public health system. In 2006, the Ministry of Health (MOH) issued regulations and guidelines for reporting and investigation. The MOH has also collaborated with the WHO and the Center for Disease Control and Prevention (CDC) of the United States to conduct in-service food safety training courses for health workers. However, current trained human resources in Vietnam are still far from meeting the human resource qualifications recommended by the Global Health Security Agenda (GHSAs) (Centers for Disease Control and Prevention, 2014). The shortages in technical human capacity, laboratory equipment, and financial resources mean that surveillance and outbreak investigation data are often incomplete and inconsistent. Determinants of FBD, such as the environmental factors, hygiene practices and behaviors, have not been systematically studied in Vietnam. Late detection of outbreaks, insufficient information on trends of common FBD and high-risk populations, and limited human capacities all impact response systems. Principles of food safety and best practices of food production are critical for comprehensive FBD prevention and control (Council to Improve Foodborne Outbreak Response, 2009). As the capacity to monitor the complete food production chain is limited and outside the jurisdiction of public health, focusing on improving surveillance and response systems for food safety is critical to reducing morbidity and to saving lives.

## 2. Review of the literature

### 2.1. Foodborne diseases

#### 2.1.1. Definition of foodborne diseases

FBD can be defined as “those conditions that are commonly transmitted through ingested food” (WHO, 2007). FBD are infectious or non-infectious diseases that comprise more than 250 acute and chronic illnesses with mild to severe symptoms (Scallan et al., 2013). Causes can include microbiological, chemical, and toxic agents (Committee on the Control of Foodborne Illness, 2011; WHO, 2008). Although FBD are an important public health problem, the disease burden and economic losses are not well defined because of insufficient data for assessment, particularly in developing countries (Flint et al., 2005; Havelaar et al., 2013; Kuchenmuller et al., 2009; Stein et al., 2007; Torgerson et al., 2014).

“Foodborne” indicates the mode of transmission, so definitions of FBD might vary depending on the targets of surveillance programs/projects. Two common definitions used in surveillance programs are the World Health Organization’s (WHO) definition, “a disease of an infectious or toxic nature caused by or thought to be caused by the consumption of food or water,” (Schmidt and Gervelmeyer, 2003) and a symptom-based case definition for gastroenteritis, “a case of gastroenteritis is an individual with  $\geq 3$  loose stools, or any vomiting, in 24 h,” (Majowicz et al., 2008) although FBD may include other diseases than gastroenteritis (Flint et al., 2005). FBD outbreaks are defined as “two or more people who got gastrointestinal disorder after eating the same meal” (Lynch, Painter, Woodruff, and Braden, 2006; Olsen, MacKinnon, Goulding, Bean, and Slutsker, 2000; WHO, 2008). Some diseases that are generally called FBD are not foodborne in every case: e.g., salmonellosis, shigellosis, or campylobacteriosis (Charles and Lasky, 2007). For example, *Salmonella* can be directly transmitted through a fecal-oral route, *Shigella* through water and fecal-oral routes, and *Campylobacter* can spread through contaminated water or direct transmission from infected pets, such as kittens (Hawker, Begg, Blair, Reintjes, and Weinberg, 2001).

Some developed countries (e.g., the United States, England, and the Netherlands) have estimated the monetary and public health burden of FBD of their countries (Flint et al., 2005; Newell et al., 2010). However, most developing countries have not been able to estimate the disease burden because of insufficient and/or unavailable data (WHO, 2006).

## 2.1.2. Causative agents associated with foodborne outbreaks

There are many causative agents associated with FBD outbreaks, including microorganisms (bacteria, viruses, parasites, and fungi), toxins, and toxic chemicals. To facilitate control and prevention, causative agents can be classified based on predominant clinical features (upper or lower gastrointestinal, neurological, allergic-type, or infectious features) or pathogenic mechanism (intoxication, toxin-mediated infections, and infections) (Committee on the Control of Foodborne Illness, 2011; WHO, 2008).

### 2.1.2.1. Classification by predominant clinical features

Symptoms and signs of FBD vary from slight to severe, and can even result in death or chronic sequelae. Clinical manifestations depend on the causative agent, number of pathogenic microorganisms or concentration of poisonous substances ingested, and susceptibility and reaction of the host (Committee on the Control of Foodborne Illness, 2011; Scallan et al., 2013). Predominant clinical features can be categorized into groups of signs and symptoms of the upper gastrointestinal tract, the lower gastrointestinal tract, allergic type, burning mouth, sore throat, and/or respiratory, neurological, and generalized infection (Committee on the Control of Foodborne Illness, 2011; WHO, 2008).

The clinical features of nausea and vomiting occurring first are often associated with intoxication poisoning or norovirus gastroenteritis (WHO, 2008). Types of agents might include toxic chemicals (antimony, cadmium, copper, fluoride, lead, zinc, tin, and nitrite), natural toxins in mushrooms or marine shellfish, or pre-formed toxins of *Staphylococcus aureus*, *Bacillus cereus* (Committee on the Control of Foodborne Illness, 2011). The incubation time of these agents is quite short, from a few minutes to a few hours. In contrast, the incubation time of chemicals in high-

acidity food items is generally shorter than that of others (Table 1) (Committee on the Control of Foodborne Illness, 2011; WHO, 2008).

Predominant by stomach ache and diarrhea symptoms often arise from infections caused by bacteria, viruses and parasites, and toxin-mediated infections (enterotoxins) of bacteria, such as *Escherichia coli* strains. Incubation times of the group range from a few hours (e.g., *Clostridium perfringens*, *Bacillus cereus*, *Streptococcus faecalis*, *S. faecium*), a few days (e.g., *Salmonella* spp., *Shigella*, *Vibrio cholerae*, Rotavirus) to a few weeks/months (*Entamoeba histolytica*, *Giardia lamblia*, *Taenia saginata*, *T. solium*) (Table 1). Stool can contain blood and mucus when causative agents are invasive and/or infecting the lower gastrointestinal track, as in the cases of *Salmonella* and *Entamoeba histolytica* (Committee on the Control of Foodborne Illness, 2011; WHO, 2008).

Allergic-type features are usually caused by intoxication. In this case, agents are bacteria that produce histamine-like substances in those who consume certain types of fish (tuna, mackerel), cheese, or chemicals used for food addition and preservation (e.g., monosodium glutamate, nicotinic acid). Incubation time is quite short, from a few minutes to one hour (Table 1) (Committee on the Control of Foodborne Illness, 2011; WHO, 2008).

If predominant symptoms of FBD are burning mouth, sore throat, and/or respiratory symptoms, patients might have consumed foods contaminated by metallic salts such as calcium chloride or sodium hydroxide, or contaminated by bacteria such as *Streptococcus pyogenes* or *Corynebacterium diphtheria* (Committee on the Control of Foodborne Illness, 2011; WHO, 2008). Incubation time after the exposure to chemicals is only a few minutes, while that after exposure to the bacteria is about 1–5 days. Respiratory symptoms are associated with these bacterial infections (WHO, 2008).

Most neurological symptoms (visual disturbances, vertigo, tingling, and paralysis) are generated by toxic agents. They might be chemicals (organophosphate, carbamate in insecticides, or organic mercury), marine animals (shellfish, reef fish, tropical fish, puffer fish), or plants, such as muscaria-type mushrooms, manioc, or water hemlock. *Clostridium botulium* is included in this group. Incubation time varies from a few minutes to a few days/weeks, depending on specific agents (Committee on the Control of Foodborne Illness, 2011). Gastrointestinal symptoms appear in those who have consumed toxic shellfish (WHO, 2008).

**Table 1.** Predominant clinical features of major foodborne hazards

Associated organism or toxin	Time to onset of symptom	Signs and symptoms	Foods usually involved
<b><i>Upper gastrointestinal signs and symptoms (nausea, vomiting) predominate</i></b>			
Metallic salts	< 1 h	Nausea, vomiting, unusual taste, burning of mouth	High-acid foods and beverages
Nitrites	1–2 h	Nausea, vomiting, cyanosis, headache, dizziness, dyspnea, trembling, weakness, loss of consciousness	Cured meats, any accidentally contaminated food
<i>Staphylococcus aureus</i> and its enterotoxins	1–8 h	Nausea, vomiting, retching, abdominal pain, diarrhea, prostration	Ham, meat or poultry products; cream filled pastries; whipped butter; cheese; dry milk; food mixtures; high protein leftover foods
<i>Bacillus cereus</i>	½–5 h	Nausea, vomiting, occasionally diarrhea	Boiled or fried rice, cooked corn-meal dishes, porridge, pasta
Norovirus	12–48 h	Nausea, vomiting, diarrhea, abdominal pain, myalgia, headache, malaise	Human feces
Amanita fungi, mycotoxins	6–24 h	Nausea, vomiting, diarrhea, thirsty, dilation of pupils, collapse, coma	Toxic mushrooms
<b><i>Lower gastrointestinal signs and symptoms (abdominal cramps, diarrhea) dominate</i></b>			
<i>Clostridium perfringens</i> , <i>Bacillus cereus</i>	2–36 h	Abdominal cramps, diarrhea, sometimes nausea and vomiting	Cooked meat, poultry, gravy, sauces, meat containing soups, refried beans, cereal products
<i>Salmonella</i> spp., <i>Shigella</i> spp., <i>Aeromonas</i>	6–96 h	Fever, abdominal cramps, diarrhea, vomiting, headache	Poultry, eggs and meat and their products, raw milk and dairy products Food contaminated by infected person Fish, shellfish, snails
<i>Vibrio cholerae</i> , <i>V. vulnificus</i> , <i>V. fluvialis</i> , <i>V. parahaemolyticus</i>	6 h to 5 days	Abdominal cramps, diarrhea, vomiting, fever, malaise, nausea, headache, dehydration	Raw fish, raw shellfish, crustacean, foods washed or prepared with contaminated water
Enterohaemorrhagic <i>E. coli</i> , <i>Campylobacter</i>	1–10 days	Diarrhea (often bloody), abdominal pain, nausea, vomiting, malaise, fever	Undercooked hamburgers, raw milk, roast beef, sausages, unpasteurized apple juice/cider, sprouts, lettuce Raw milk, poultry, beef liver, raw clams
Rotavirus, astrovirus, enteric adenovirus	3–5 days	Fever, vomiting, watery diarrhea	Ready-to-eat foods
<i>Cryptosporidium parvum</i>	1–12 days	Profuse watery diarrhea, abdominal pain, anorexia, vomiting, fever	Apple juice/cider, water, raw milk any food touched by infected food handler
<i>Entamoeba histolytica</i>	1 to several weeks	Gastroenteritis, abdominal pain, constipation, fever, chills, skin, ulcers	Raw fruit, vegetable or seafood salads
<i>Taenia saginata</i> , <i>Taenia solium</i>	8–14 weeks	Vague discomfort, hunger pains, loss of weight, abdominal pain	Raw or insufficiently cooked beef

<b>Allergic signs and symptoms (facial flushing, itching) occur</b>			
Histamine	Less than 1 h	Headache, dizziness, nausea, vomiting, peppery taste, burning throat, facial swelling and flushing	Tuna, mackerel, Pacific dolphin, bluefish, cheese
Monosodium glutamate	Less than 1 h	Burning sensation in back of neck, forearms and chest, tingling, flushing, dizziness, headache, nausea	Foods seasoned with monosodium glutamate
Nicotinic acid	Less than 1 h	Flushing, sensation of warmth, itching, abdominal pain, puffing of face and knees	Meat or other food in which sodium nicotinate has been added

Sources: WHO, 2008 and Committee on the Control of Foodborne Illness, 2011

The predominant symptoms and signs of infections include fever, chills, malaise, fatigue, aches, and swollen lymph nodes. Agents may be bacteria such as *Vibrio vulnificus*, *Bacillus anthracis*, *Brucella melitensis*, and *Brucella abortus* or viruses such as Hepatitis A and E, *Trichinella spiralis*, and *Toxoplasma gondii* (Committee on the Control of Foodborne Illness, 2011; WHO, 2008). Incubation time is usually quite long and depends on the microorganism. The foods usually involve raw or contaminated foods such as oysters, shellfish, and unpasteurized milk and cheese (Committee on the Control of Foodborne Illness, 2011).

#### 2.1.2.2. Classification by pathogenic mechanism of foodborne outbreaks

“Intoxication” refers to toxins in prepared foods, including pre-formed toxins produced by microorganisms (Table 2). These can be natural toxins found in some plants/trees (mushrooms, manioc, bamboo, algae), animals (puffer fish, jellyfish, toads), or preformed toxins produced by microorganisms in prepared foods, such as toxins of *Staphylococcus aureus*, *Bacillus cereus*, or chemicals in foods such as pesticides, toxic metals (cadmium, lead, copper, tin, mercury), and nitrites. There is a short time interval (a few minutes to a few hours) between consuming foods containing toxins and onset signs and symptoms (Committee on the Control of Foodborne Illness, 2011; Navaneethan and Giannella, 2008; WHO, 2008).

Toxin-mediated infections occur when enterotoxins are produced by bacteria after contaminated foods are ingested (Committee on the Control of Foodborne Illness, 2011). As a result, bacteria can survive, colonize, and grow in the intestinal tract and continue to produce enterotoxins such as those of the *Vibrio cholerae* and *Escherichia coli* strains (Table 2). These enterotoxins cause disorders in water,

glucose, and electrolyte metabolisms in the intestinal tract, usually resulting in predominantly watery diarrhea (Gorbach, 1996; Navaneethan and Giannella, 2008).

Infections are inflammatory processes caused by microorganisms ingested in contaminated foods. The microorganisms (e.g., *Salmonella*, *Shigella*, and *Campylobacter*) invade and multiply in intestinal mucosa, such that blood cells can be found in the stool of patients (Table 2) (Gorbach, 1996; Navaneethan and Giannella, 2008).

Many enteric bacteria such as *Salmonella*, *Shigella*, or *Escherichia coli* may survive and proliferate in foods if favorable conditions exist (such as nutrients, appropriate moisture, acidity, and temperature of foods). Some viruses, such as Hepatitis A, noroviruses, and rotaviruses, need living cells and cannot multiply in foods. Some can survive in frozen foods and during high-temperature cooking. Illness is spread from infected person to foods and to others via surface contact or poor personal hygiene (Bhunia, 2008; Navaneethan and Giannella, 2008).

**Table 2.** Pathogenic mechanism of foodborne outbreaks

Mechanism	Important features	Common agents/pathogens
Intoxication	Short incubation time Symptoms: nausea, vomiting	Natural toxins in plants, trees, or animals Preformed toxins of bacteria: <i>Staphylococcus aureus</i> , <i>Bacillus cereus</i> , <i>Clostridium perfringens</i> Poisonous chemicals
Toxin-mediated infections	Enterotoxins Symptoms: Watery diarrhea, stomach ache	Noninvasive agents: <i>Vibrio cholerae</i> , <i>Escherichia coli</i> (ETEC, EAEC, EHEC), rotavirus, norovirus Invasive agents: <i>Escherichia coli</i> (EHEC), <i>Clostridium difficile</i>
Infections	Symptoms: Stool with blood and mucus, stomach ache, fever	Invasive agents: <i>Salmonella</i> , <i>Shigella</i> , <i>Campylobacter</i> , <i>Escherichia coli</i> (EIEC, EPEC), <i>Entamoeba histolytica</i>

Sources: WHO, 2008 and Committee on the Control of Foodborne Illness, 2011

## 2.1.3. Epidemiology of foodborne diseases

### 2.1.3.1. Foodborne diseases in developed countries

#### 2.1.3.1.1. Burden of foodborne diseases

There are two common approaches to estimate the burden of FBD currently: microbiological and epidemiologic approaches (Greig and Ravel, 2009; Hald and Pires, 2011; WHO, 2007). Many developed countries use foodborne illness surveillance systems to estimate the burden of FBD. For example, in the United States (US), the rate of acute gastroenteritis diseases (AGD) estimated by Foodborne Diseases Active Surveillance Network (FoodNet) is 0.65 episodes per person per year. The rates of AGD in European countries are lower: e.g., about 0.28–0.29 episodes per person per year in the Netherlands (de Wit et al., 2001; Havelaar et al., 2012), and 0.6 in Northern Ireland and the Republic of Ireland (Scallan et al., 2004). In Australia, the estimated rate is about 0.74 episodes per person per year (Kirk, Ford, Glass, and Hall, 2014).

Although absolute numbers of FBD can be quite high (e.g., the estimated annual number of FBD is about 48 million in the US) (The Center for Disease and Control, 2014), the overall burden of FBD in developed countries is not very great. According to Roy, Scallan, and Beach (2006) who reviewed 33 studies on AGD in developed countries from 1953 to 2003, the estimated incidence and prevalence of AGD ranged from 0.1 to 3.5 episodes per person per year.

#### 2.1.3.1.2. Causative agents

Of public health surveillance systems of developed countries, laboratory-based surveillance systems have contributed considerably to identifying important causative agents. The estimated proportion of known pathogens among reported cases ranges from 20 to 42% in the US, Canada, the Netherlands, England, and Wales (de Wit et al., 2001; Havelaar et al., 2012; The Center for Disease and Control, 2014; Thomas et al., 2013). The most common pathogens vary in their incidence among developed countries. For instance, noroviruses, nontyphoidal *Salmonella* spp., *Campylobacter* spp., and *Clostridium perfringens* are the most common known pathogens in the US and Canada (Batz, Hoffmann, and Morris, 2012;

Scallan et al., 2011; The Center for Disease and Control, 2014; Thomas et al., 2013); *Toxoplasma gondii*, and *Campylobacter spp.* are the most common in the Netherlands (de Wit et al., 2001; Havelaar et al., 2012); and the norovirus, enteropathogenic *Escherichia coli*, *Campylobacter spp.*, and *Salmonella spp.* are the most common in Australia (Hall et al., 2005).

**Table 3.** Microorganism-specific food source profile, by proportion for reported foodborne outbreaks from 1988 to 2007

Micro organism	N	Produce	Multi-ingredient foods	Seafood	Beef	Pork	Dairy products	Chicken	Other meats	Bakery items	Beverages	Turkey and other poultry	Eggs	Other foods	Total
<b>Bacterial</b>															
<i>Bacillus cereus</i>	74	8.1	56.8	4.1	6.7	2.7	4.1	13.5		1.4			1.4	1.4	100%
<i>Campylobacter spp.</i>	191	4.7	14.1	2.6	4.7	0.5	34.6	29.3	2.1	0.5		5.2	1.6		100%
<i>Clostridium botulinum</i>	108	14.8	0.9	25	7.4	4.6	3.7	0.9	13.9	0.9	2.8		0.9	24.1	100%
<i>Clostridium perfringens</i>	248	2.8	20.2	2	39.1	6.5	0.4	14.5	4.8			9.7			100%
<i>Escherichia coli</i>	389	19.5	11.8	0.5	44.2	0.5	9.8	1	6.9	1	4.4	0.3			100%
<i>Listeria monocytogenes</i>	53	1.9	5.7	11.3	5.7	11.3	41.5	1.9	13.2			7.6			100%
<i>Salmonella</i> Enteritidis	991	3.6	10.1	4.2	5.1	1.5	6.4	9.9	0.7	12.1	0.2	1.7	43.4	1.1	100%
<i>Salmonella</i> Typhimurium	270	3.6	10.7	4.8	8.5	6.7	11.9	10.4	6.7	7.4	1.1	2.2	18.2	1.5	100%
Other <i>Salmonella enterica</i>	657	21	13.9	2.6	9.6	5.6	6.2	13.6	3.5	3.4	1.7	4.6	13.6	0.9	100%
<i>Shigella spp.</i>	83	28.9	30.1	9.6	6	2.4	14.5	6			2.4				100%
<i>Staphylococcus aureus</i>	182	3.3	22	3.3	13.7	21.4	11	8.2	4.4	5		3.3	3.9	0.6	100%
<i>Vibrio spp.</i>	54	3.7	1.9	90.7				1.9			1.9				100%
Other bacteria	62	9.7	6.5	3.2	11.3	19.4	27.4	4.8	11.3	1.6		1.6	3.2		100%
<b>Parasitic</b>															
<i>Cyclospora spp.</i>	35	91.4	8.6												100%
<i>Trichinella spp.</i>	47				10.6	36.2			53.2						100%
Other parasites	23	26.1		13		8.7	17.4	8.7			26.1				100%
<b>Viral</b>															
Hepatitis A virus	55	40	14.6	20	1.8	1.8	2.2		7.3	1.8	9.1				100%
Norovirus	552	16.5	40.2	13	4.4	2	2.2	2.9	1.8	8.7	5.8	1.1	0.4	1.1	100%
Other viruses	19	21.1	26.3	31.6	5.3					15.8					100%

Source: Greig and Ravel, 2009

According to Greig and Ravel (2009), the most common pathogens are *Salmonella spp.*, noroviruses, and *Escherichia coli*, which accounted for 47%, 14% and 10%, respectively, among 4,093 worldwide foodborne outbreaks reported from 1988 to 2007 (Table 3). Another review of 816 foodborne outbreaks associated with food-handlers, from 1927 to 2006, showed that the most common agents in developed countries were noroviruses, nontyphoidal *Salmonella spp.*, the Hepatitis A virus, and *Staphylococcus aureus* (Greig, Todd, Bartleson, and Michaels, 2007). Noroviruses and non-typhoidal *Salmonella spp.* represented about 34% and 16% of the causes of the 816 outbreaks, respectively. Among 80,682 cases, 34% of cases were caused by noroviruses, 19% by *Shigella spp.*, and 11% by non-typhoidal *Salmonella spp.* (Table 4).

**Table 4.** Pathogens identified in outbreaks and cases involving food-handlers

Agents	No. of outbreaks (%)	No. of cases (%)
Viral	491 (60.2)	37,778 (46.8)
Norovirus	274 (33.6)	27,081 (33.6)
Hepatitis A virus	84 (10.3)	5,046 (6.3)
Viral/probable norovirus	64 (7.8)	2,085 (2.6)
Unknown viral	57 (7.0)	2,148 (2.7)
Rotavirus	12 (1.5)	1,418 (1.8)
Bacterial	280 (34.3)	38,536 (47.8)
<i>Salmonella</i> (nontyphoidal)	130 (15.9)	9,136 (11.3)
<i>Salmonella</i> Typhi	21 (2.6)	757 (0.9)
<i>Staphylococcus aureus</i>	53 (6.5)	6,423 (8.0)
<i>Shigella</i> spp.	33 (4.0)	15,276 (18.9)
<i>Streptococcus</i> groups A and G	17 (2.1)	3,670 (4.5)
<i>Vibrio cholerae</i>	11 (1.3)	2,399 (3.0)
<i>Yersinia enterocolitica</i>	7 (0.9)	532 (0.7)
<i>Campylobacter jejuni</i>	5 (0.6)	238 (0.3)
<i>Escherichia coli</i> O157:H7 and	3 (0.4)	105 (0.1)
Parasitic	23 (2.8)	3,852 (4.8)
<i>Cyclospora cayetanensis</i>	11 (1.3)	3,393 (4.2)
<i>Giardia lamblia/intestinalis</i>	9 (1.1)	302 (0.4)
<i>Cryptosporidium</i> spp.	3 (0.4)	157 (0.2)
Unknown	22 (2.7)	516 (0.6)
<b>Total</b>	<b>816 (100.0)</b>	<b>80,682 (100.0)</b>

Source: Greig et al., 2007

### 2.1.3.1.3. Source attribution

Source attribution poses several challenges. An FBD's food vehicle is often not identified in many foodborne outbreaks. Among food vehicles identified, a certain proportion was tested, of which pathogens could be detected in a smaller proportion of food vehicles tested; some vehicles consisted of multiple foods. There are more than 250 different foodborne illnesses, but laboratories are easily able to detect the most common causative agents (Scallan et al., 2013; The Center for Disease and Control, 2014). Hence, some common pathogens are usually tested for food attribution. For example, 14 common pathogens were estimated for source attribution in the US (Batz et al., 2012).

The WHO (2007) launched to estimate the food sources responsible for common etiologic agents. However, source attribution has been conducted mainly for developed countries. For example, among foodborne outbreaks with known etiologies and vehicles from 1999 to 2008 in the US, norovirus cases were most

often attributed to complex foods (nonmeat multi-ingredient foods, 46%) and produce (16%); nontyphoidal *Salmonella* cases to poultry (21%), complex foods (19%), produce (18%), and eggs (12%); and *Campylobacteriosis* cases were mainly attributed to dairy product (51%) and poultry (18%) (Batz et al., 2012). In European countries, *Salmonella* cases were mainly attributed to eggs (32%) and meat and poultry (11%), and *Campylobacter* cases attributed to chicken (10%) and meat (10%) (Pires, Vigre, Makela, and Hald, 2010).

In general, the study of Greig and Ravel (2009) found associations between noroviruses and multi-ingredient foods (40%), between *Salmonella* Enteritidis and eggs (43%), between *Escherichia coli* outbreaks and beef (44%), and between *Campylobacter* spp. and dairy products (35%) and poultry products (29%) (Table 3). Food sources for noroviruses and *Escherichia coli* were quite similar in North America and European countries. However, some source attribution varies from region to region. *Campylobacter* cases were attributed principally to poultry products in EU countries but to dairy products in the US (Greig and Ravel, 2009). Eggs were the most important food source for salmonellosis cases in European countries and Australia and New Zealand, while the US lacked important food sources for salmonellosis (Greig and Ravel, 2009; Moffatt, 2011). The roles of cross-contamination and of infected food-handlers should be considered in the case of etiologic agents associated with many food sources, such as noroviruses and *Salmonella* spp. (Greig and Ravel, 2009).

### 2.1.3.2. Foodborne diseases in low- and middle-income countries

Unlike the advanced surveillance systems in some developed countries, the surveillance systems in many low- and middle-income countries (LMICs) are suboptimal or non-existent and provide insufficient data (Stein et al., 2007). Hence, the FBD in LMICs is significantly underestimated. Because of difficulties estimating the burden of FBD in these countries, the burden of diarrheal diseases is a form of proxy estimation (although FBD might not be diarrheal diseases). According to Lamberti, Fischer, Walker, and Black (2012), there are an estimated 200 million diarrhea episodes among children 5–15 years of age and 430 million diarrhea episodes among persons 16 years of age and older in LMICs annually. Of these, 95% of episodes are mild and only 0.05% are severe. Among children under 5 years of age, there are about three episodes of diarrhea per child per year (Kosek, Bern, and Guerrant, 2003).

In recent years, some publications have investigated the burden of enteric diseases in regions of LMICs. In 2010, among persons 5 years of age or older with diarrhea in Africa, an estimated 15.0 million episodes were attributed to enterotoxigenic *Escherichia coli* and 30.4 million episodes attributed to *Shigella* spp.; the figures were nearly double in South Asia, with 28.7 million episodes attributed to enterotoxigenic *Escherichia coli* and 58.1 million episodes to *Shigella* spp. (Lamberti, Bourgeois, Fischer Walker, Black, and Sack, 2014). In Southeast Asia, the estimated incidence rate of diarrhea is 0.3 episodes per person per year for adults; the figure is 0.9 for older children in the Eastern Mediterranean region. The rates of diarrhea have remained stable over the last three decades (Walker and Black, 2010).

Enteric bacteria and parasites are understood to be the most important pathogens for diarrhea in LMICs. For persons 5 years of age or older with diarrhea, the most common pathogens among inpatients in LMICs from 1980 to 2008 were enterotoxigenic *Escherichia coli* and *Vibrio cholerae*, accounting for about a half of total inpatients, while those among outpatients were *Salmonella* spp., *Shigella* spp., and *Entamoeba histolytica* (Fischer Walker, Sack, and Black, 2010). According to Podewils et al. (2004), the most commonly identified pathogens among diarrhea cases in LMICs were enterotoxigenic *Escherichia coli* (11%), *Campylobacter* spp. (7%), and *Shigella* spp. (5%). Recently, the norovirus has been identified as a frequent cause of FBD in LMICs. Among acute gastroenteritis cases in LMICs from 2008 to 2014, prevalence of the norovirus ranged from 14–19% (Ahmed et al., 2014). Although the burden of *Campylobacter* spp. has not been assessed accurately in LMICs, it seems to be a widespread pathogen, particularly among children (Kaakoush, Castano-Rodriguez, Mitchell, and Man, 2015).

Although diagnostics and identification of causative agents have made some advances in recent years, understanding the burden and causative agents of FBD has been quite limited in LMICs. Because of limited capacities to identify specific food vehicles, sources, and causative agents during outbreak investigations, source attribution is difficult to estimate (Buzby, 2011; Dewaal, Robert, Witmer, and Tian, 2010). For example, among the 6,313 bacterial outbreaks reported by 20 countries in Latin America and the Caribbean, 30% of outbreaks did not identify food vehicles. Among outbreaks in which etiologic agents and food vehicles were identified, some common food sources were not linked to specific common pathogens (e.g., *Salmonella* spp., *Escherichia coli*, *Shigella* spp., *Clostridium perfringens*, *Staphylococcus aureus*, and *Bacillus cereus*) (Table 5). Non-bottled water, though not considered as a food, was identified as the most common food source in the

bacterial outbreaks. This may result from the use of unsafe water during food preparation (Pires, Vieira, Perez, Wong, and Hald, 2012).

**Table 5.** Estimates for food sources (%) and water per pathogen in Latin America and the Caribbean from 1993 to 2010

	Salmonella	E. coli	Shigella spp.	C. perfringens	S. aureus	B. cereus
Eggs	15	0	5	1	1	0
Dairy	2	9	2	2	44	19
Goat Milk	3	2	3	1	7	0
Meat	24	18	7	28	13	9
Poultry	6	2	3	4	3	6
Chicken	11	6	2	17	5	6
Ducks	0	1	0	1	0	0
Turkey	0	0	0	0	0	0
Beef	7	4	0	16	4	0
Pork	11	5	2	13	6	19
Lamb	0	0	0	0	0	0
Mutton	0	0	0	0	0	6
Game	0	0	0	0	0	0
Fruits Nuts	1	1	0	1	0	0
Vegetables	8	5	0	7	9	6
Grains Beans	6	5	5	4	3	44
Oils Sugar	0	2	2	1	0	0
Seafood	5	4	7	13	6	6
Water	4	50	71	1	0	0

Source: Pires et al., 2012

### 2.1.3.3. Foodborne diseases in Vietnam

Surveillance data on FBD in Vietnam are mainly based on outbreak investigation reports. From 2000 to 2010, a total of 2,147 foodborne outbreaks, 60,602 cases and 583 deaths were reported throughout Vietnam. The incidence of cases was 6.9 per 100,000 people per year (a range of 4.4 to 9.0 per 100,000 people per year). No foods were linked to the outbreaks during the study period (Lam, Nguyen, Nguyen, and Ta, 2013).

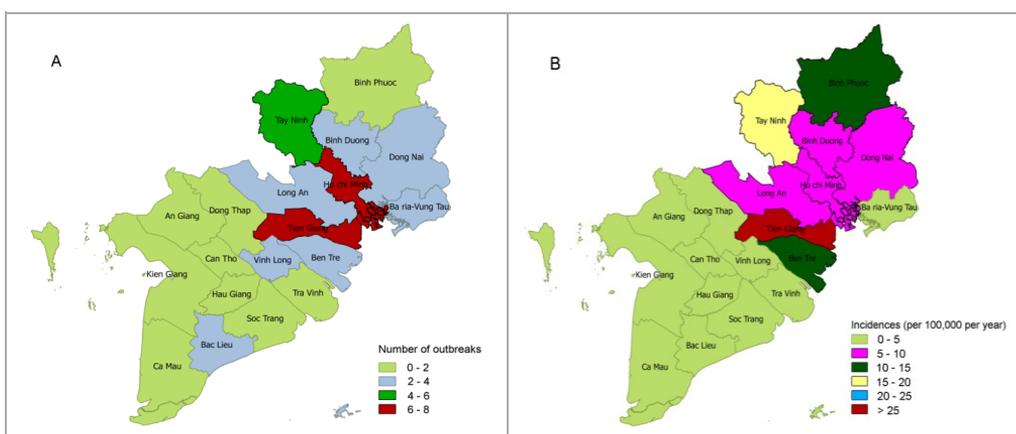
Among the outbreaks occurring from 2002 to 2010, the attributed causes for outbreaks were microorganisms (33.2%), natural toxins (25.2%), chemicals (10.4%), and unknown (31.2%) (Lam, Nguyen, Nguyen, and Ta, 2013). In 2013, the reported causes of foodborne outbreaks changed somewhat. Among 167 foodborne outbreaks, the proportions of microorganisms, natural toxins,

chemicals, and unknown were 49.7%, 16.8%, 4.8%, and 28.7%, respectively (Vietnam Food Administration, 2014). However, no comments reported on how the attributed causes differed from those during the period of 2000–2010.

Among the 175 outbreaks occurring in 2010, the leading implicated foods included multi-ingredient foods (47.4%), poisonous mushrooms (16.0%), aquatic foods (10.9%), meats and their products (10.3%), alcohol containing chemicals (3.4%), and vegetables and tubers (3.4%) (Lam, Nguyen, Nguyen, and Ta, 2013). Many of the reported outbreaks occurred at large canteens, particularly at factories in industrial zones. Outbreaks with 30 or more cases accounted for 28% of all outbreaks and 81% of all reported cases from 2007 to 2010 (Vietnam Food Administration, 2011).

### In Southern Vietnam

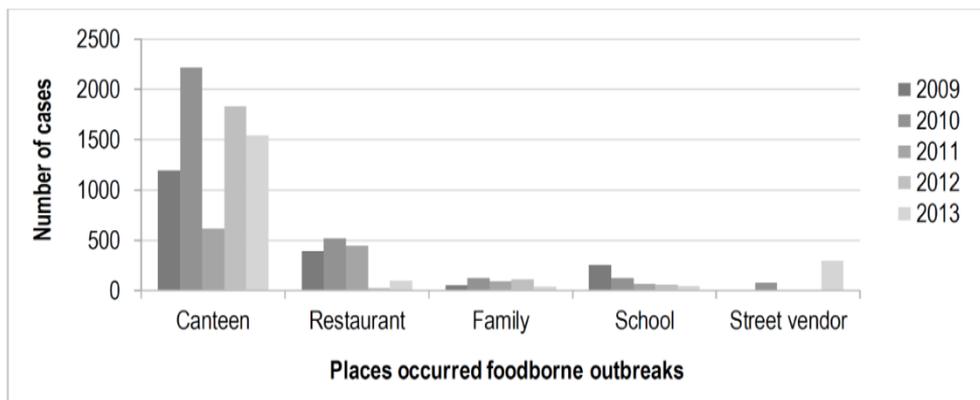
From 2009 to 2013, many foodborne outbreaks occurred in all provinces of Southern Vietnam. The number of outbreaks, cases and deaths were 261, 10,263, and 50, respectively. The number of exposed (defined as those who consumed the same meal as cases) was about 78,000 from 2011 to 2013 (Table 6). Two or more foodborne outbreaks occurred in Ho Chi Minh City (HCMC) and in provinces around HCMC annually (Figure 1A). The reported incidence of cases was high in Tien Giang (25.6 per 100,000 people per years) and the incidences were from 5.6–19.8 per 100,000 people per years in HCMC and other provinces around HCMC, where many industrial zones are located (Figure 1B).



**Figure 1.** Number of outbreaks (A) and incidence of cases of foodborne illness per 100,000 per year (B) Southern Vietnam during 2009–2013. Data source: Institute of Public Health, 2014

Among the 10,263 reported cases, most cases had consumed their meals at large canteens in industrial zones and in restaurants, while only a few cases were associated with schools, street vendors, and family meals (Figure 2). The percentages of cases who ate the contaminated meals in large canteens, restaurants, schools, street vendors, and family meals were 72%, 14%, 5%, 4%, and 4%, respectively.

Most of the implicated foods in the foodborne outbreaks were only suspected, except for meals in which only one food item was served. Among suspected foods (181), food items containing pork meat, tuna, jellyfish, poisonous alcohol, toad, and puffer fish were the most common foods associated with FBD (15%, 13%, 8%, 7%, 6%, and 6%, respectively). Among outbreaks with suspected causes, bacteria accounted for 42% and natural toxins for 17%, while unknown causes accounted for 23% of outbreaks (Table 6). The percentages of suspected causes in Southern Vietnam were quite similar to those found in all of Vietnam.



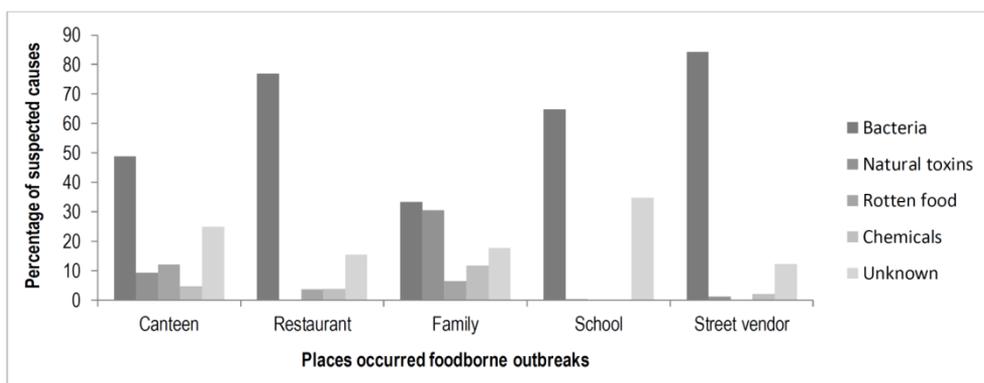
**Figure 2.** Location of foodborne outbreaks and number of cases by year Southern Vietnam from 2009 to 2013. Data source: Institute of Public Health, 2014

In each location where foodborne outbreaks occurred, bacteria accounted for the largest proportion (33% of family meals, 49% of large canteens, 65% of schools, 77% of restaurants, and 84% of street vendors). The percentage of unknown causes was quite high, and natural toxins accounted for 31% of outbreaks associated with family meals (Figure 3). About 96% of fatal cases (48 cases) were associated with family meals, while one case was associated with street vendors and one with a wedding party (Table 6). Poisonous puffer fish, jellyfish, toad, or alcohol containing methanol were the implicated foods in fatal cases.

**Table 6.** Characteristics of foodborne outbreaks in Southern Vietnam from 2009 to 2013

Characteristics of foodborne outbreaks	Year					Total
	2009	2010	2011	2012	2013	
Number of reported outbreaks	42	80	48	48	43	261
Number exposed	-	-	20,555	20,675	36,639	77,869
Number of cases	1,903	3,076	1,233	2,032	2,019	10,263
Number of deaths	11	12	12	12	3	50
Number of suspected foods	35	62	32	26	26	181
Number of outbreaks with suspected causes						
<i>Bacteria</i>	10	37	28	15	20	110
<i>Natural toxins</i>	3	11	11	9	10	44
<i>Rotten food</i>	17	10	1	0	2	30
<i>Chemicals</i>	3	7	3	5	0	18
<i>Unknown</i>	9	15	5	19	11	59
Etiology confirmed by laboratory tests	25	13	11	-	-	49

Data source: Institute of Public Health, 2014



**Figure 3.** Suspected causes by place of occurrence of foodborne outbreaks in Southern Vietnam from 2009 to 2013. Data source: Institute of Public Health, 2014

A hazard surveillance program conducted by the Institute of Public Health (IPH) in Southern Vietnam from 2011 to 2013 took samples of thirteen types of food products. A high proportion of the food samples did not meet Vietnam's standards for food safety (Vietnam Standard and Quality Institute). Aquatic products, vegetables and tubers, and prepared foods accounted for very high percentages of

contaminated samples (83%, 80%, and 73%, respectively) (Table 7). These samples were contaminated by biological and/or chemical hazards beyond the acceptable levels of Vietnam’s standards for food safety. For example, aquatic products were contaminated by microorganisms (*Salmonella*, *Staphylococcus aureus*, *Clostridium perfringens*, and noroviruses), metals (lead and arsenic), antibiotic and insecticide (Chloramphenicol and Trichlorfon), and other chemicals (borax, urea, ammoniac, and bleach); vegetables and tubers were contaminated by microorganisms (*E. coli*, *Salmonella*, coliforms and types of parasites), pesticide, and other chemicals (bleach, nitrate and nitrite).

**Table 7.** Number and percentage of samples of food products in a hazard surveillance in Southern Vietnam, 2011–2013

Food products	Number of samples	Number of contaminated samples (%)
Aquatic products	510	431 (85)
Vegetables and tubers	460	370 (80)
Processed foods	220	160 (73)
Grains	480	252 (53)
Function foods	118	59 (50)
Sauces and spices	480	224 (47)
Meats and their products	510	220 (43)
Fruits	480	174 (36)
Milks and their products	471	165 (35)
Food additives	177	42 (24)
Alcohol and beers	514	31 (6)
Beverages	514	31 (6)
Confectionary	514	31 (6)

Data source: Institute of Public Health, 2014

## 2.1.4. Factors contributing to foodborne outbreaks

### 2.1.4.1. Changes in dietary habits

Dietary habits have changed in recent decades, due to the variety of foods available from all over the world, changes to a more Western diet, and changes in culinary and dining habits (Council to Improve Foodborne Outbreak Response, 2009). In recent decades, Vietnam's patterns of food consumption show divergences in food quantity intake between urban and rural residents. The total food intake of rural people was larger than that of urban people. While rural people mainly consumed more rice, starch, and other cereals, urban people consumed more protein and fat (Dien Le, Thang, and Bentley, 2004; Khoi, 2005; Molini, 2006; Thang and Popkin, 2004).

Globalization and industrialization have contributed to dietary changes in many countries, including Vietnam (Council to Improve Foodborne Outbreak Response, 2009; Flint et al., 2005; WHO, 2006). Furthermore, trends of using undercooked or raw foods have contributed to FBD (Ho et al., 2011; Van De, 2004; Van, Moutafis, Istivan, Tran, and Coloe, 2007). Hundreds of thousands of low-income Vietnamese people move annually to work for factories (e.g., garments, textiles) in industrial zones (Jenkins, 2004). This results in demand for ready-to-eat food and processed foods. In addition, this trend may be linked to mass importation and distribution, which in turn influences growing, harvesting, packaging, handling, and transportation practices (Kuchenmuller et al., 2009). Because of rising domestic food prices, people with low incomes may consume cheaper meals in canteens and food caterings, especially in industrial zones (Thoburn, 2004). These services are typically associated with increased FBD (Dao and Yen, 2006).

### 2.1.4.2. Food from farm to fork

The contamination of food can occur anywhere along the supply chain, from farm to fork. Methods for crop cultivation or livestock-raising practices might contribute to foodborne outbreaks. These methods have changed all over Vietnam. Many kinds of pesticides and preservative chemicals are used for crops, and fruits and vegetables and food products containing plant hazards beyond an acceptable level have been introduced into markets (Jansen, Midmore, Binh, Valasayya, and Tru, 1996; Kannan, Tanabe, Quynh, Hue, and Tatsukawa, 1992; Van Hoi, Mol,

and Oosterveer, 2009). From 2000 to 2006, about 40% of vegetables samples in Vietnamese markets were contaminated with residues of pesticides and even with prohibited chemicals in pesticides (Food and Agriculture Organization, 2011). Similarly, domestic livestock and poultry are increasingly raised with hormones and antibiotics to gain weight. These chemical substances were found in animal food products in markets (Food and Agriculture Organization, 2011; Managaki, Murata, Takada, Tuyen, and Chiem, 2007; Thuy and Nguyen, 2013). Furthermore, the common use of the antibiotics might lead to human infections caused by antibiotic-resistance bacteria (Martinez, 2009; Mathew, Cissell, and Liamthong, 2007; Nelson, Chiller, Powers, and Angulo, 2007; van den Bogaard, and Stobberingh, 2000).

Pathogens can proliferate in contaminated food production and processing. Identifying the critical points in food production and processing is important in controlling and preventing foodborne outbreaks. Outbreaks related to food production and processing have occurred worldwide (Doane et al., 2007; Friesema et al., 2008; Lynch, Tauxe, and Hedberg, 2009; Winthrop et al., 2003). In Vietnam, many food products have been considered microbiological hazards to human health because of the presence of microorganisms in food products after food production and processing. For example, aflatoxin, citrinin, and ochratoxin were found in rice in markets and *Enterobacteriaceae* spp. in freshwater fish fillets after processing (Nguyen, Tozlovanu, Tran, and Pfohl-Leszkowicz, 2007; Tong Thi et al., 2013), including food products for exports (Noseda, Thi, Rosseel, Devlieghere, and Jacxsens, 2013; Thi et al., 2014). These risks arose from producers' lack of knowledge and practices in food production and processing (Dan, Visvanathan, and Thanh, 2003; Noseda et al., 2013).

Food products can be contaminated either accidentally or deliberately during distribution (Kuchenmuller et al., 2009). A mass distribution of contaminated food products can result in foodborne outbreaks over wide geographical areas or in many countries (Cavallaro et al., 2011; Centers for Disease Control and Prevention, 2007; Isaacs et al., 2005; Medus et al., 2009; Sheth et al., 2011). The Hazard Analysis and Critical Control Points (HACCP) system for food safety is used to control processing systems by identifying hazards and preventive measures (FAO/WHO, 2006). Although the HACCP system is not mandatory in Vietnam, it is often used by large national or multinational companies (Government of Vietnam, 2012; National Assembly of Vietnam, 2010).

Although monitoring pathogens and their distributions is important for preventing foodborne outbreaks, equally critical are good practices of food

handling and preparation to prevent contamination and survival of microbes in food-service establishments, so as to minimize the risk of foodborne outbreaks (Raspor, 2008). Even well cooked food products can become unsafe when food-handlers practice poor personal hygiene, cross-contaminate foods, and leave cooked foods at room temperature for a long time. These mistakes may allow pathogens to proliferate and cause foodborne outbreaks (Charles, 2007). Many outbreaks in Vietnam have been linked to mistakes in food handling and preparation (de Wit et al., 2007; Huong et al., 2010; McLaughlin, Castrodale, Gardner, Ahmed, and Gessner, 2006; Schmid et al., 2007; Varma et al., 2007).

### 2.1.4.3. Food-handlers

Appropriate food handling plays an important role in food safety and FBD outbreak prevention. However, the most common contributing factors for FBD outbreaks were poor personal hygiene, cross-contamination, and time/temperature abuse during food handling and preparation (Todd, Greig, Bartleson, and Michaels, 2007). In a survey of 800 food-service establishments in the US, improper hand-washing was implicated in 18% to 76% of FBD cases, improper cleaning and sanitizing of food-contact surfaces before use in 18% to 64%, and time-temperature abuse in 20% to 79% (U.S. Food and Drug Administration, 2009). It was estimated that infected food-handlers transmitted about 20% of bacterial-caused FBD outbreaks in the US. The main contributor in most of the outbreaks was food-handlers' poor personal hygiene practices (U.S. Food and Drug Administration, 2000).

Hands of food-handlers can be contaminated, For instance, after using the rest room, touching raw food materials, scratching body parts, sneezing, or nose-blowing. The probability of contamination increases if food-handlers suffer from an enteric infection or are asymptomatic carriers of enteric diseases (Todd, Michaels, Smith, Greig, and Bartleson, 2010) and bare-handed contact with ready-to-eat foods can transmit microbes such as *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella*, sufficient to cause disease (Greig et al., 2007). Frequent and proper hand-washing are recommended as an efficient measure to prevent contamination (Michaels, 2002; Todd et al., 2010). Although food-handlers reported that they properly washed their hands, studies have found nasopharyngeal and enteric bacteria on the hands of food-handlers (Andargie, Kassu, Moges, Tiruneh, and Huruy, 2008; de Wit and Kampelmacher, 1981; Ho, Boost, and O'Donoghue,

2014). Due to lack of compliance with hand-washing regulations, as well as the fact that transferring bacteria from hands to foods cannot be completely prevented, gloves should be worn when handling and preparing food, particularly with ready-to-eat food (Michaels, 2002).

Food can be contaminated from many sources, including infected food-handlers, raw foods, or other sources such as utensils and currency (Jiang and Doyle, 1999; Todd, Greig, Bartleson, and Michaels, 2009; Todd et al., 2010). During processing or preparation of raw products, food-handlers' hands, gloves, and equipment surfaces may cross-contaminate other foods or foods are processed by the equipment (Scott and Bloomfield, 1990; Todd et al., 2009). In addition, cleaning cloths or sponges, or even outdoor clothes, can spread microorganisms to equipment surfaces (Todd et al., 2010) and then foods leading to contamination (Kusumaningrum, Riboldi, Hazeleger, and Beumer, 2003; Scott and Bloomfield, 1990).

Another factor related to food-handler behaviors and FBD outbreaks is time/temperature abuse, particularly in mass catering if cooked foods are not kept at a safe temperature until they are served. Time and temperature abuse occur primarily with multi-ingredient foods. As contamination can occur at any stage of preparation, cooling, storing, or heating, time and temperature abuse before serving may be sufficient to allow bacteria to survive and proliferate (Charles, 2007; Todd et al., 2007). Sources of contamination can be from food-handlers, utensils or equipment. Mistakes made by food-handlers (e.g., slow cooling, inadequate cold-holding temperature, insufficient time and temperature during hot-holding, insufficient thawing) are often related to food-handlers' lack of knowledge or lack of manager supervision (H. Charles, 2007; Todd et al., 2007). Time pressure is a barrier that may prevent food-handlers from implementing correct practices. A shortage of food-handlers and lack of resources at food-service establishments may not allow for training of food-handlers, maintenance of equipment, and food-handlers' sick leave (H. Charles, 2007; Clayton, Griffith, Price, and Peters, 2002; Todd et al., 2009).

### **2.1.5. Economic burden of foodborne diseases**

FBD outbreaks cause considerable economic burden. When a foodborne outbreak occurs, costs include human illness costs (e.g., medical costs and productivity loss), public health sector costs (e.g., disease surveillance, research, outbreak investigation costs) and other costs (e.g., food recall, travel, control pathogen on the farms,

producer's costs, cost of revenue, cleaning, etc.) (Buzby, 2011). Data on economic burden from different databases are limited, particularly in LMICs (WHO, 2010). Most studies only estimated a small part of the costs and were mainly conducted in developed countries (Buzby, 2011; Dewaal et al., 2010). For instance, health care costs for children less than 5 years of age with diarrhea in the US were estimated at US\$ 411 million per year (Zimmerman et al., 2001). The figure for older children and adults would be much higher. In fact, total cost due to FBD has been estimated at US\$ 152 billion annually in the US (Scharff, 2010). In Australia, it is estimated at about A\$ 1.2 billion annually, primarily due to individuals taking sick leave or taking leave to care for a sick family member (Abelson, Potter Forbes, and Hall, 2006; Kirk et al., 2008). In Vietnam, the total human cost, production lost, and related markets losses caused by FBD is estimated to be more than \$1 billion a year (or 2% of GDP) (WHO, 2015).

Economic costs for FBD are probably underestimated. It is also difficult to estimate the specific burden attributed to a particular pathogen or all pathogens, because only a proportion of individuals with FBD symptoms seek care at health care facilities. Information on severity, duration, and outcomes of acute diseases and chronic complications are important for economic evaluation, but such information is limited for most pathogens (Buzby, 2011).

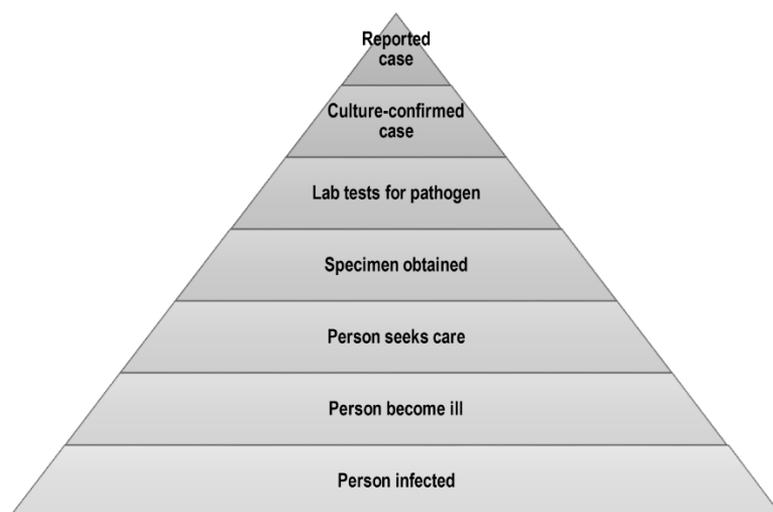
## 2.2. Surveillance systems of foodborne disease

***“Surveillance: Information for action.”*** CDC defines epidemiologic surveillance as “ongoing systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice closely integrated with the timely dissemination of these data to those who need to know” (Thacker and Berkelman, 1988).

Surveillance of FBD is the foundation of food safety programs. Foodborne surveillance systems are intended to identify potential outbreaks; to help identify vehicles, sources, and contributing factors of outbreaks; to provide critical data (incidence, trends, high-risk populations) for prioritizing, planning, implementing, and monitoring and evaluating effectiveness of foodborne control projects/programs; and to provide evidence for policy changes (Council to Improve Foodborne Outbreak Response, 2009; Gould et al., 2013; Scallan et al., 2013; WHO, 2010). Sources of information for FBD surveillance include data from health care services, human disease, population characteristics, and environmental data.

However, reported cases usually underestimate the true burden of disease (Figure 4) (Angulo et al., 1998; Scallan et al., 2013; Todd, Guzewich, and Bryan, 1997).

An effective FBD surveillance system should identify diseases caused by contaminated foods (Scallan et al., 2013). Although there are many types of surveillance methods, types of surveillance systems relevant to FBD include routine notifiable disease reporting, syndromic surveillance, notification/complaint system, and FBD outbreak investigation reports (Committee on the Control of Foodborne Illness, 2011; Council to Improve Foodborne Outbreak Response, 2009; Fisher, 2011; Guzewich, Bryan, and Todd, 1997; WHO, 2008).



**Figure 4.** Foodborne disease burden pyramid of reporting process. Source: Angulo et al., 1998

## 2.2.1. Types of surveillance systems relevant to foodborne diseases

### 2.2.1.1. Notifiable disease reporting

Notifiable disease reporting is a passive surveillance system. The process begins when ill people seek medical care from health care providers. The health care providers may take the patient's specimen and send it to laboratory for testing. After the disease or agent(s) are identified, the laboratory and/or the health care provider report the results to a local public health agency (Committee on the Control of Foodborne Illness, 2011; Scallan et al., 2013). Case information from

separate reports can be combined to identify trends or potential clusters of specific diseases (Council to Improve Foodborne Outbreak Response, 2009). Based on the requirements of each country/region, health care providers or laboratories must report a list of certain required diseases or conditions to local public health agency, after which local public health agencies report these diseases to a higher administrative level and/or the central level (Council to Improve Foodborne Outbreak Response, 2009; Fisher, 2011; Reintjes and Krickeberg, 2010).

Case definitions of selected diseases in notifiable disease reporting can vary from country to country. In developed countries with sufficient laboratory capacity and resources, case definitions of selected diseases require laboratory criteria, such as those of notifiable disease surveillance systems in European countries, the United States, in Canada, in Australia (Centers for Disease Control and Prevention, 2015; European Centre for Disease Prevention and Control, 2012; Public Health Agency of Canada, 2011; The Department of Health, 2015). On the other hand, in developing countries such as Vietnam, case definitions of selected diseases in notifiable surveillance systems may not require laboratory evidence.

Overall, notifiable disease reporting can provide information about diseases trends, high-risk populations, potential outbreaks, and intervention evaluations (Guzewich et al., 1997; Scallan et al., 2013). However, notifiable disease surveillance is limited in that it only measures patients who visit health care facilities, requires a reliable laboratory system, and cannot identify undiagnosed events (Council to Improve Foodborne Outbreak Response, 2009; Scallan et al., 2013).

#### 2.2.1.2. Syndromic surveillance

Syndromic surveillance systems can predict the early stages of large outbreaks, illness clusters, or unusual events before a health event is confirmed and reported to public health agencies (Council to Improve Foodborne Outbreak Response, 2009; Henning, 2004; Mandl et al., 2004). It is critical to determine definitions of syndromes based on clinical symptoms, diagnoses with/without laboratory information, thresholds for alert, and data sources and reporting (Mandl et al., 2004; Mostashari and Hartman, 2003; Scallan et al., 2013). The International Classification of Diseases (ICD) is useful in developing and categorizing syndromes (Henning, 2004).

Demographic information, early symptoms of the syndromes, and spatial and temporal information must be collected to “determine the size, spread and tempo

of an outbreak” (Henning, 2004; Mandl et al., 2004; Mostashari and Hartman, 2003). Data, entered automatically or manually, can be categorized by symptoms and grouped into syndromes; the data are immediately analyzed and sent to those responsible for outbreak investigation (Heffernan et al., 2004b; Henning, 2004; Mandl et al., 2004). Although syndromic surveillance is critical for early detection of outbreaks, it cannot replace notifiable surveillance systems and reporting from clinicians/health care providers. In addition, non-specific information from syndromic surveillance could be less useful for small events and create false-positive signals. To be effective, the system requires clear plans, procedures for data collection, analysis and dissemination, and electronic data systems (Council to Improve Foodborne Outbreak Response, 2009; Henning, 2004; Reintjes and Krickeberg, 2010).

The syndromic surveillance system has shown some success in monitoring FBD syndromes. For example, a syndromic surveillance system detected outbreaks with syndromes of diarrhea and vomiting in New York City, and the Athens 2004 Olympic Games used syndromic surveillance systems to successfully detect FBD outbreaks early, including syndromes such as bloody diarrhea, gastroenteritis, and botulism-like syndrome (Heffernan et al., 2004a; Heffernan et al., 2004b; Tsouros and Efstathiou, 2007). It is recommended that the syndromic surveillance system should be incorporated into existing surveillance systems to improve specificity of indicators and exposure information and to reduce costs for system development (Council to Improve Foodborne Outbreak Response, 2009).

### 2.2.1.3. Foodborne disease notification/complaint systems

A complaint-based surveillance system can also receive and respond to complaints from the public. This kind of system can identify foodborne cases, clusters, or unusual events in the community (Committee on the Control of Foodborne Illness, 2011; Council to Improve Foodborne Outbreak Response, 2009). Complaints including illness status and exposures are usually passively received from the public via telephone and/or email, then recorded in a log book, a standard form, or an electronic database. The system can be used to actively investigate workplaces where sick leave was reported. Complaints must be regularly reviewed to identify common patterns in order to detect outbreaks or clusters (Council to Improve Foodborne Outbreak Response, 2009; Scallan et al., 2013).

Because the system can detect outbreaks from all causes, it is more sensitive to outbreaks caused by diseases with short incubation or unique symptoms than systems dependent on laboratory confirmation (Table 8 shows comparisons of three FBD surveillance systems in terms of the speed of outbreak detection, sensitivity in detecting specific health events, etiology detection, and outbreak signals). However, a complaint-based system is less capable of excluding unrelated cases or detecting mild events (Council to Improve Foodborne Outbreak Response, 2009; Wethington and Bartlett, 2004). In many parts of the US (such as Utah and New York City), the general public reports their problems after consuming food items to health authorities (The City of New York, 2015; Utah Department of Health, 2012). A survey of local health departments in the United States found that the system detected 69% of outbreaks (Li, Shah, and Hedberg, 2011).

#### 2.2.1.4. Foodborne outbreak reporting

In this traditional surveillance system, public health agencies report results of foodborne outbreak investigations to higher administrative levels. The system can be voluntary or compulsory, depending on the regulations of each country. These reports can provide information on the link among foods, vehicles, sources, transmission mode, risk factors, and pathogens (Council to Improve Foodborne Outbreak Response, 2009; Scallan et al., 2013). Contributing factors can be identified from environmental assessments in outbreak investigations. Collected information includes associations between epidemiologic, clinical, microbiologic characteristics, and on-site environmental conditions, referring to the association of foods with disease, of specific pathogens with specific foods, and contributing factors to outbreaks (Council to Improve Foodborne Outbreak Response, 2009; Scallan et al., 2013). For example, salad products have been associated with a number of outbreaks, particularly norovirus outbreaks (Schmid et al., 2007; Showell, Sundkvist, Reacher, and Gray, 2007; Wadl et al., 2010), *Salmonella enteritidis* is associated with eggs, and improper food handling practices (Cowden et al., 1989; Lin et al., 1988; Stevens et al., 1989).

**Table 8.** Comparison of foodborne disease surveillance systems

Functional characteristic of system	Surveillance method			
	Pathogen-specific	Notification/Complaint		Syndromic
		Group notification	Individual complaint	
Inherent speed of outbreak detection	Relatively slow	Fast	Fast	Potentially fast*
Sensitivity to widespread, low-level contamination events ( <i>best practices used</i> )	High	Intermediate	Intermediate	Low†
Types of outbreaks (etiology) that system can potentially detect	Limited to clinically suspected or laboratory-confirmed diseases under surveillance	Any‡	Any, although effectiveness limited to agents with short incubation periods‡	Limited to syndromes ( <i>or indicators</i> ) under surveillance
Initial outbreak signal ( <i>at public health level</i> )	Cluster of cases in space or time with common agent	Report of group illnesses recognized by health-care provider, laboratory, or the public	Multiple independent reports with common exposures in space or time or unique clinical presentation recognized by the agency receiving the reports	Trend in health indicator different from expected, space/time clusters of diagnosed cases
No. cases needed to create initial signal	Low to moderate	Low	Low to moderate	High§
Signal-to-noise ratio	High** (after interview of cases and collection of appropriate food history) Even higher when combined with subtyping	High** (after interview of cases and collection of appropriate food history)	Low to moderate (after interview of cases and collection of appropriate food history)	Low¶

\* An advantage in speed is limited mainly to nonspecific health indicators (preclinical and clinical prediagnostic data). Data must be analyzed, and a follow-up investigation is required, including comparison with standard surveillance, before public health action can be taken.

† Sensitivity is higher for rare, specific syndromes, such as botulism-like syndrome.

‡ Although outbreaks can be detected without an identified etiology, linking multiple outbreaks to a common source may require agent information.

§ The number of cases needed to create a meaningful signal is related to the specificity of the indicator. Indicators that offer an advantage in speed also tend to have low specificity.

¶ Exposure histories are not typically obtained.

\*\* A high signal-to-noise ratio means that even a small number of cases stand out against a quiet background. A low ratio means a cluster of cases or events is difficult to perceive because it is lost in the many other similar cases or events happening simultaneously— similar to a weak radio signal lost in static noise. The signal-to-noise ratio is lowest for nonspecific health indicators, such as Immodium® use or visits to the emergency department with diarrheal disease complaints. The ratio increases with increasing specificity of agent or syndrome information. For highly specific, rare syndromes, such as “botulism-like” syndrome, the signal-to-noise ratio would approach that of pathogen- specific surveillance.

Source: Council to Improve Foodborne Outbreak Response, 2009

## 2.2.2. Foodborne disease surveillance in Vietnam

Surveillance systems for FBD are under the authority of the VFA. According to current regulations, all health officials, whether they offer public or private services, have the responsibility to notify FSAs at the district or provincial levels when they suspect that a foodborne outbreak has occurred. When cases of FBD are admitted to a health facility, the facility has to report the cases to a higher-level facility, and ultimately to the VFA. In severe outbreaks or when a death occurs, preventive medicine services, health facilities or district FSAs are permitted to share data/reports beyond their jurisdiction (Ministry of Health, 2006).

In Vietnam, public health statutory surveillance systems are mainly passive. Foodborne and waterborne diseases are reported from lower levels of Preventive Medicine Centers (PMCs), to PMCs at higher levels, and ultimately to the General Department of Preventive Medicine in the MOH. The VFA and FSAs mainly receive reports of food poisoning outbreaks or gastroenteritis outbreaks where food transmission is suspected. Most outbreaks are detected when severe cases are admitted to health facilities or when deaths occurred. Some events are detected from daily newspapers. Hence, available surveillance data of FBD in Vietnam emerge primarily from foodborne outbreak reporting (Vietnam Food Administration, 2013).

Central institutes and FSAs typically conduct hazard surveillance systems. The system covers thirteen types of food products, including meats and meat products, vegetables and tubers, fruits, aquatic products, types of milks and their products, grains, sauces and spices, confectionary, beverages, alcohol and beers, function foods, food additives, and prepared foods. Central institutes and FSAs take samples of food products based on annual guidelines of the VFA, with a focus on high-risk foods in each province. Laboratory tests for each type of food products are based on the capacities of each institute or provincial laboratories, or on quick-test kits. Because of limited budgets, the VFA only allocates a small number of food samples to institutes and FSAs, and samples are taken from any convenient market, rather than from strategic locations.

In Vietnam, only outbreak investigations reports and hazard surveillance systems are used to monitor FBD, while other types of important surveillance systems (e.g., FBD notifiable surveillance, syndromic surveillance, behavior risk factors, complaints, and antimicrobial resistance systems) have not been established. Many health professionals are not aware of the importance of notifications, except in the case of severe events. Food inspections have been conducted sporadically and depend on annual budget that the VFA allocates to each FSA.

## 2.3. Human resources for food safety systems in Vietnam

From 2007 to 2010, many in-service training courses for health workers on food safety were conducted nationwide. The VFA trained for 7,880 health workers in 109 training courses on food safety at provincial level and for 1,259,172 health workers in 37,258 training courses related to food safety at district levels in all of Vietnam. According to the VFA, these training courses met only 20% of the needs of health workers learning about food safety. In addition, almost all participants were new health workers who were not trained on food safety before they were recruited (Vietnam Food Administration, 2011).

Since 2009, the Vietnam MOH, in collaboration with the WHO and CDC of the United States, has implemented the Field Epidemiology Training Program (FETP). Under the FETP, there have been five classes of two-year FETP fellowship trainings for 30 epidemiologists, and 21 three-week courses in field epidemiology for 434 public health staff at the national, provincial, and district levels. In addition, a total of 83 public health staff and veterinarians working for the MOH and Ministry of Agriculture and Rural Development, respectively, participated in a three-month modular training of the One Health epidemiological team, with each team consisting of 4–6 public health staff and veterinarians. However, the program is far from reaching the targets of workforce development that the Global Health Security Agenda recommends (Centers for Disease Control and Prevention, 2014). In terms of laboratory capacity, among 63 laboratories in provincial PMCs, only 16 laboratories are able to test for food samples, and none of the laboratories have been accredited by the International Organization for Standardization (ISO), e.g., ISO 17025 (Vietnam Food Administration, 2011).

## 2.4. Outbreak epidemiology

Outbreak epidemiology involves the investigation of an outbreak, epidemic, or disease cluster for a variety of purposes, such as controlling or preventing further disease in a population, identifying opportunities for research and training, and public, political, or legal concerns (Centers for Disease Control and Prevention, 2012; Dwyer, Groves, and Blythe, 2012). An outbreak is defined as the occurrence of observed cases of a disease in excess of expected cases in a specific population/place over a particular period of time (Centers for Disease Control and Prevention, 2012).

The interaction among agent, host, and environment leads to outbreaks. The occurrence of new agents, reemerging agents or a change in the virulence of agents causes disease clusters or outbreaks. Individuals with certain habits (e.g., not washing hands as recommended, consuming unsafe water or food), or underlying medical conditions (e.g., asthma, human immunodeficiency virus, chronic obstructive pulmonary disease) may be more susceptible to diseases. Urbanization and rapid population growth can contribute to spreading disease. Changes in environment, such as climate change, conditions after severe weather events, and increased population and population density, might allow causative agents to emerge. Changes in agricultural practices, food processing, and human behaviors may also lead to disease outbreaks (Dwyer et al., 2012).

### 2.4.1. Choosing epidemiologic study designs

Outbreaks are natural experiments that can be studied by observational epidemiologic methods. Frequently, an outbreak investigation is initiated by a case-series study. Findings of the case series can be used to control an outbreak, to develop working case definitions, and/or to generate hypothesis for subsequent analytical studies. The principles of choosing analytical study designs in outbreak investigations depend on the size and availability of at-risk populations, how quickly the results are needed, and available resources (Dwyer et al., 2012).

Historical/retrospective cohort and case-control designs are used to determine exposure-disease association in outbreak investigations. Cohort studies are prioritized when affected populations are small and/or well-defined, meaning they can be enumerated completely; entire populations can be included in a cohort study when the population is small enough (Committee on the Control of Foodborne Illness, 2011; Dwyer et al., 2012; Lasky, 2007; WHO, 2008). For example, a foodborne outbreak among 63 workers of a company in the US, a *Cyclopora cayetanesis* outbreak among 101 attendees at a wedding in the US, and a microsporidiosis outbreak among 525 people attending an event in Sweden (Decraene, Lebbad, Botero-Kleiven, Gustavsson, and Löfdahl, 2012; Devasia et al., 2006; Fleming, Caron, Gunn, and Barry, 1998). If an entire affected population is too large to be included, types of random sampling can be applied (Dwyer et al., 2012), or a case-cohort study can sometimes be used (Rothman, Greenland, and Lash, 2008; Szklo and Nieto, 2012a). For instance, 13 day care centers were randomly selected from 30 in a large Norwalk-like virus outbreak or a foodborne

outbreak in a health care facility in Austria, where subjects of reference groups were randomly selected from case-cohort studies (Götz et al., 2002; Schmid et al., 2011).

Case-control methods are used if the entire population at risk of an outbreak cannot be identified or if the potential exposure is unknown (Committee on the Control of Foodborne Illness, 2011; Dwyer et al., 2012; Lasky, 2007; WHO, 2008). For example, case-control studies are useful for investigating community-wide, large-scale/multistate outbreaks (Hutin et al., 1999; Nuorti et al., 2004; Slutsker et al., 1998). Matched case-control designs should be considered when important potential confounders are known (e.g., age or gender), when only one specific group is affected by an outbreak, or increasing expedience/efficiency are critical such as selecting friend or neighboring controls (Dwyer et al., 2012; Gordis, 2014; Gregg, 2008b). For example, to control the effect of age, frequency-matching was applied; to increase efficiency in investigating a community-wide outbreak, the case's year of birth, gender, and postal code of residency were matched in *Yersinia pseudotuberculosis* outbreaks in Finland (Jalava et al., 2006; Nuorti et al., 2004).

To ensure that cases in the at-risk population are as representative as possible, cases should be sought using multiple case-finding techniques, e.g., i) reviewing data of existing surveillance systems including outbreak complaint logs and laboratories; ii) reviewing records of hospitals, clinics, emergency wards, private doctors' rooms, and receipts; iii) asking for further cases from known cases; and iv) informing the at-risk population via mass media as appropriate (Dwyer et al., 2012; Dwyer, Strickler, Goodman, and Armenian, 1994). In addition, population controls must come from the source population at risk of the same disease. Population controls can select from many sources (e.g., attendees of an event, child care centers, roommates, nursing homes, hospitals, friends, neighbors, and households) (Dwyer et al., 2012; Dwyer et al., 1994). After collecting risk information (name, age, gender, occupation, contact details, date of onset, symptoms, signs, laboratory results, treatment, setting of occurrence, and risk factors), thorough descriptive epidemiologic analysis is conducted. Using appropriate statistical methods (based on study design and variables), analytic studies were used to identify and quantify associations between the disease and risk factors of interest (Dwyer et al., 2012; Dwyer et al., 1994).

The case-control designs have some advantages in outbreak investigations, although risk ratios cannot be directly calculated in traditional case-control designs (Dwyer et al., 2012). These designs are suitable for outbreaks with many possible exposures, such as FBD. The design is also used when the at-risk population is not

defined/enumerated, and when results of investigations are urgent and/or resources are limited to conduct a cohort study (Dwyer et al., 2012; Dwyer et al., 1994).

#### **2.4.2. Methodological issues of case-control studies in outbreak investigations**

Random errors, biases, and confounders should be considered before inferring associations between the disease and risk factors. A random error arises if a sample size of a study population is not large enough.

At every step of outbreak investigations, bias might occur that affects researchers' abilities to determine associations between disease and exposure. Selection bias can occur when cases and controls are selected from the at-risk population. A clear case definition (well defined criteria of time, place, and person; clinical criteria; and consistency with the problem) plays a vital role in outbreak investigations (Centers for Disease Control and Prevention, 2012; Dwyer et al., 2012). Criteria of case definition affect not only control selection but also all steps in investigations; they also serve to minimize differential misclassification. Detection bias must be considered when outbreak diseases of interest are mild or new diagnostics are used. Cases in this situation are usually those who visit hospitals. The mild disease may lead to errors in selecting controls that are asymptomatic/subclinical cases, when control samples do not undergo laboratory testing (differential misclassification) (Gordis, 2014; Grimes and Schulz, 2002; Szklo and Nieto, 2012c; Webb and Bain, 2010). For example, during a norovirus outbreak (Grotto et al., 2004), the case definition were sensitive and included cases who had only one symptom of abdominal pain. Active case finding is necessary during an outbreak, but it can also result in more suspected cases, while asymptomatic/subclinical cases could be included as controls.

For acute diseases with fatal cases, Neyman bias can arise when researchers select non-incident cases without stratification analysis. In hospital-based studies, bias can arise if hospital controls are selected without concern for the source of the referral (referral bias) or levels of exposure (Berkson's bias) (Gordis, 2014; Grimes and Schulz, 2002; Szklo and Nieto, 2012c; Webb and Bain, 2010). For example, in the case of an avian influenza A H5N1 outbreak in Vietnam, Neyman biases were minimized because cases included both fatal and survival cases (Dinh et al., 2006).

During an outbreak of dengue hemorrhagic fever (DHF) in Vietnam, patients with central nervous system symptoms were selected as cases. Neyman bias could occur because the study only included survivors, and the mortality rate of DHF among the patients was quite high, even when controls were matched on age and gender. In addition, referral bias could occur because controls were often the next DHF patients who did not present the symptoms, without regard for the source of referral. However, Berkson's bias could be minimized because the case and matched-control were in the same grade of DHF (Cam et al., 2001). In a *Clostridium difficile* outbreak at a hospital, Berkson's bias was also minimized when controls were matched by the date of admission, type of medical service, and length of stay in the hospital (Muto et al., 2005). Nonresponse bias should also be considered, particularly in self-administered questionnaires (Gordis, 2014; Gregg, 2008a; Grimes and Schulz, 2002; Szklo and Nieto, 2012c; Webb and Bain, 2010).

Information bias may occur if measuring exposure levels for cases and controls has not been planned and implemented strictly. A case's history of exposure must be specified, including amount, intensity, and duration of exposure, if possible (Dwyer et al., 1994; Grimes and Schulz, 2002; Szklo and Nieto, 2012c). Bias can arise if cases' and controls' exposures are not measured for the same time period. For instance, in an *Escherichia coli* O157:H7 outbreak investigation, researchers selected cases and controls that had not consumed ground beef at the same time as each other (Olsen et al., 2005). Recall bias can occur, particularly when diseases have long incubation periods or when data collection occurs long after the outbreak. Additionally, cases tend to remember exposures more precisely than controls. For example, in a case of *Listeria monocytogenes* outbreaks, it was difficult for cases and controls to remember all food and drink consumed within the previous 30 days (Olsen et al., 2005; Salamina et al., 1996). During investigations of an aflatoxicosis outbreak in Kenya, recall bias likely existed because the investigation occurred far after the onset time, and reports varied regarding the amount and quality of maize consumed (Azziz-Baumgartner et al., 2005).

Interviewer bias should be considered, as the knowledge of interviewers on the conditions or exposures of interest can affect the quality of data, especially for interviewers who try to search for the putative cause or exposure. Interviewers should be trained uniformly and the hypothesis of the study concealed to the greatest extent possible. Data collection tools should be standardized, tested, or validated. Misclassification may occur due to mistakes in exposure classification (Dwyer et al., 1994; Grimes and Schulz, 2002; Szklo and Nieto, 2012c).

Further confounding factors can distort the association between the disease and the exposure. Known confounders such as age and gender should be considered. In foodborne outbreak investigations, confounders should be considered when two or more food items are associated with disease. For example, during a cholera outbreak on an aircraft, a number of food items were associated with cholera in univariate analysis, but only seafood salad was significant in multivariate analysis (Eberhart-Phillips et al., 1996). Knowledge of diseases, microbe characteristics, and typical exposures could help investigators identify potential confounders. In case-control studies, confounders can be controlled in the design stage (restriction and matching) or adjusted in the analysis stage (stratified analysis and multivariate analysis) (Gregg, 2008b; Grimes and Schulz, 2002; Szklo and Nieto, 2012b). For example, matched case-control and stratified/multivariate analysis were used to control for confounders (Daniels et al., 2000; Desenclos et al., 1996; Hutin et al., 1999; Mahon et al., 1997; Wendel et al., 2009).

### **2.4.3. Features of an outbreak investigation**

Several features of outbreak investigations are unique compared with those of planned epidemiologic studies. Almost all outbreaks require urgent public health responses. Very limited time is available for designing, implementing, and communicating the findings of such studies. The process of an outbreak can change over time, and approaches and designs must also change. In some cases, multiple studies with different designs are needed to identify sources. Hence, the preparation of skilled professionals is critical to minimize biases (Centers for Disease Control and Prevention, 2012; Goodman, Hadler, and Vugia, 2008).

The central goal of outbreak investigations is to control and prevent outbreaks as soon as possible. Therefore, control and prevention measures are often implemented during the investigation to limit the emergence of new cases, even when the control measures might be based on limited information or incomplete data, before the results from epidemiologic studies are available (Centers for Disease Control and Prevention, 2012; Goodman, Fontaine, Hadler, and Vugia, 2008). To provide sufficient evidence for interventions in the limited time available, an outbreak investigation can use different methods and designs: e.g., epidemiologic (case series, cohort, and case-control studies), laboratory, and environmental investigations (Centers for Disease Control and Prevention, 2012; Dwyer et al., 2012).

Sources and modes of transmission are critical in outbreak control even if causative agents are unknown (Centers for Disease Control and Prevention, 2012; Goodman et al., 2008). For example, control measures for droplet and contact transmission against severe acute respiratory syndrome (SARS) had been conducted before its etiologic agent was isolated (Chan-Yeung and Yu, 2003; Lee et al., 2003). The inability to identify causative agents could result from unavailable samples, inappropriate timing of sample collection, or limited laboratory capacities (Etzel, 2008). In small outbreaks, it is difficult to determine risk factors by means of statistical tests due to the tests' limited power, so plausible risk factors must be considered (Dwyer et al., 2012).

## 2.5. Principles of investigating foodborne outbreaks

**Table 9.** Steps in the investigation of an outbreak (multiple steps should be undertaken simultaneously)

Confirm the diagnosis	Contact cases and obtain the following information
Develop a case definition	using a written protocol: demographics (age, gender, occupation), date of onset of illness, clinical symptoms and signs, potential risk factors for infection
Document and organize findings at each step in the investigation	Formulate a hypothesis about the source and reservoir for infection and likely mode of transmission
Ascertain all cases via active surveillance: obtain information regarding person, place, and time	Institute preliminary control measures
Plot the epidemic curve and geographic area involved	Confirm the hypothesis by performing a case-control study or retrospective cohort study
Demonstrate that an epidemic exists by showing the epidemic rate is higher than the baseline rate	Document the source, reservoir, and mode of transmission microbiologically
Communicate with public health department	Demonstrate the biologic plausibility of the suspected source and reservoir and mode of transmission; confirm using molecular epidemiology
Perform a literature review	Update control measures
Notify all persons who need to be informed	Revise policies to preclude further outbreaks
Request that personnel save all isolates from patients and suspected sources or vehicles	Document efficacy of control measures by continued surveillance
Assemble a team of investigators	Write a report and publish report of investigation and control measure
Appoint a spokesperson to ensure that consistent information is disseminated; be prepared to answer questions and address the concerns of the community	
Record all actions taken by the team	

Source: Weber et al., 2001

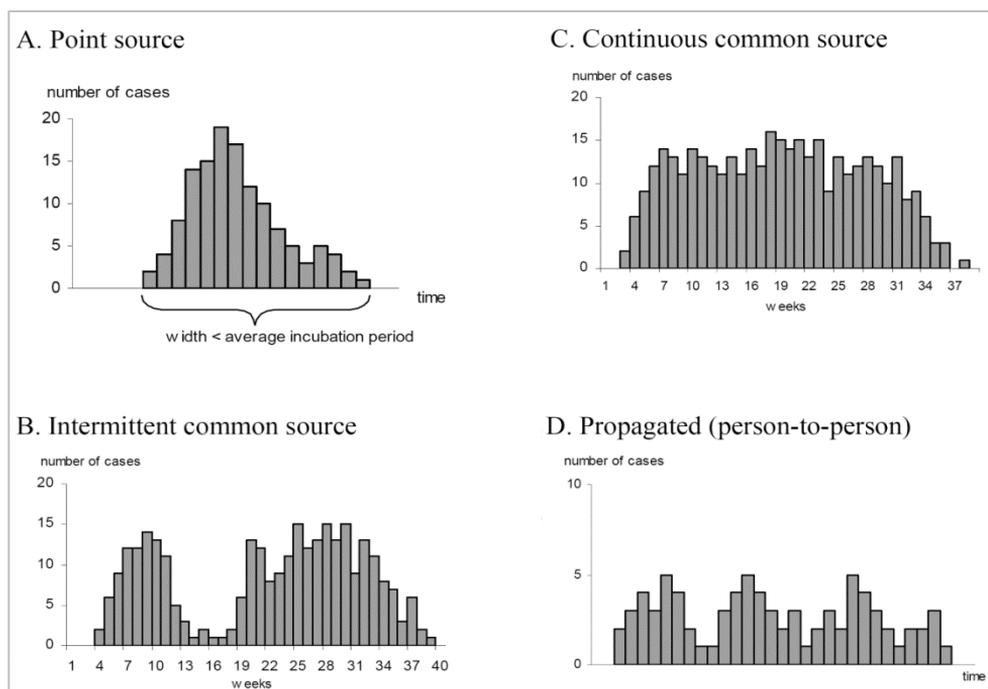
Overall, principles for investigating foodborne outbreaks are similar to those for investigating other types of outbreaks. Foodborne outbreak investigations include not only epidemiologic but also environmental investigation of food-preparation sites, food items and products, food-handlers and managers, water supply, and laboratories. Hence, an outbreak response team should include epidemiologists, clinicians, environmental specialists, laboratorial experts, and other supporters. However, based on the extent of an outbreak and resources available for the investigations, the number of staff on the outbreak response team may vary, as might the staff's specializations (Centers for Disease Control and Prevention, 2012; Committee on the Control of Foodborne Illness, 2011; Council to Improve Foodborne Outbreak Response, 2009; Kile, 2007; WHO, 2008). The steps in such investigations tend not to vary from outbreak to outbreak, consisting of basic tasks described in a conceptual order; however, investigators may not always conduct each step in the sequence listed (Table 9) (Brownson and Petitti, 1998; Centers for Disease Control and Prevention, 2012; Committee on the Control of Foodborne Illness, 2011; Council to Improve Foodborne Outbreak Response, 2009; Gregg, 2008a; Kile, 2007; Reintjes and Zanuzdana, 2010; Weber, Menajovsky, and Wenzel, 2001; WHO, 2008).

### 2.5.1. Detection and verification of an outbreak

FBD outbreaks are often detected by affected persons, workers at health care facilities, or health care providers who suspect an outbreak and contact health authorities. Another common mean of detection is to observe an unusual increase in reported cases or subtypes of submitted isolates (e.g., *Salmonella*, EHEC, *Listeria*) through surveillance systems. After receiving information about an increased number of cases or clusters of cases, investigators have to verify whether these cases are a part of an outbreak (the occurrences of more cases of a disease or a condition than expected in a specific area/group people in a specific period time, where there is a linkage among the cases). In many circumstances, these are sporadic or unrelated cases of the same or different conditions. Several suspected outbreaks have been reported due to changes in the surveillance system, such as reporting procedures, case definition, case detection, officers in charge, or increased interest in related groups (Brownson and Petitti, 1998; Centers for Disease Control and Prevention, 2012; Committee on the Control of Foodborne Illness, 2011; Gregg, 2008a; Kile, 2007).

## 2.5.2. Case definition and descriptive epidemiology

Case definitions and descriptive epidemiology are important components of outbreak investigation. These allow us to decide whether to include a person of interest as a case (case-patient) and generate appropriate hypotheses. After we check consistency in clinical features, epidemiologic findings, and/or laboratory results among cases from preliminary investigation, a case definition can be developed with clinical features and restrictions by time, place, and person (Centers for Disease Control and Prevention, 2012; Committee on the Control of Foodborne Illness, 2011; Gregg, 2008a; Kile, 2007). Demographic, clinical, and epidemiologic information of participants must be collected, along with samples from foods and the environment. It is necessary to conduct on-site investigations (food preparation review) including meeting managers, drawing a flow chart of operations, reviewing monitoring records, and interviewing food-handlers to trace sources, routes of contamination, and the ways in which agents survived and/or proliferated (Committee on the Control of Foodborne Illness, 2011; Council to Improve Foodborne Outbreak Response, 2009; Kile, 2007; WHO, 2008).

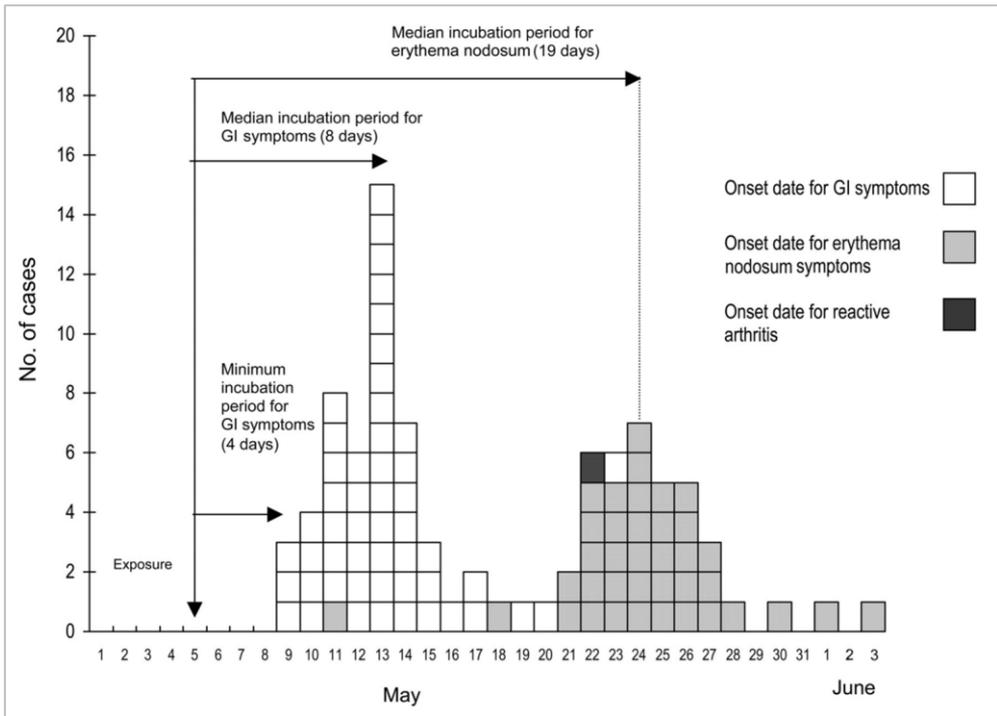


**Figure 5.** Types of Epidemiologic Curve. Source: WHO, 2008

The collected data include demographic, clinical, and laboratory information. Contributing factors are described in text, tables, and figures. An epidemic curve is graphed to show the relationship between the occurrences of cases by time, incubation of the disease, epidemic patterns, and progression of the outbreak. Overall, there are five types of epidemiologic curves: point source (showing exposure to one source of pathogen at one point in time, as in figure 5A), intermittent common source (showing exposure at several points in time, as in figure 5B), continuous common source (showing exposure over a continuous period, as in figure 5C), propagated epidemic (showing spread of pathogen from person to person, as in figure 5D), and mixed epidemic (showing both common source and propagated spread).

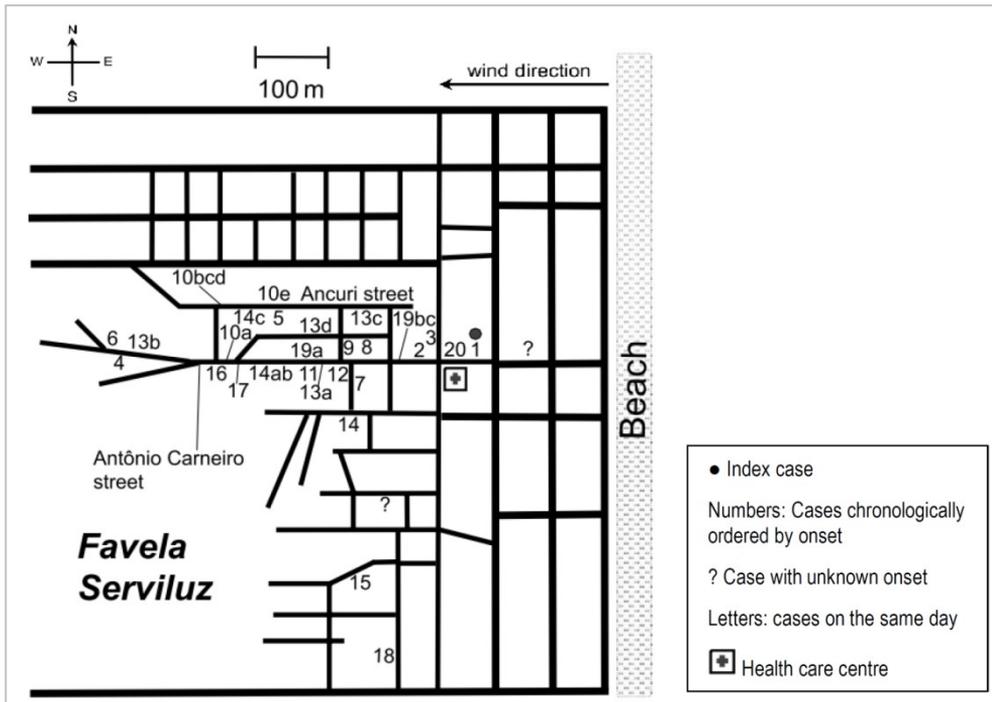
Usually, for point-source outbreaks, we can use known incubation periods of diseases to estimate the probable time of exposure (WHO, 2008). For example, during a Hepatitis A outbreak in Colbert county, Alabama, from October to November in 1972, the number of cases increased starting on October 20 and peaked on October 28–31 (Centers for Disease Control and Prevention, 1992). This is a point source because all cases ranged within the incubation period for Hepatitis A, and we could estimate that the cases' period of exposure probably occurred between September 28 and October 6, 1972 (Figure 6). In addition, the epi-curve shows that the number of cases declined after immune serum globulin treatments were implemented. Though we did not have data through October 27, we could safely predict that new cases would occur during that time. On the contrary, the outbreak would likely have been finished by November 5.





**Figure 7.** Distribution of incubation periods for *Yersinia pseudotuberculosis* infection to onset of gastrointestinal (GI) symptoms and erythema nodosum after point source exposure to contaminated carrots. Source: Jalava et al., 2006

A geographic map shows the distribution of cases, the extent of the outbreak, and clues about causative agents. In particular, a spot map may provide useful information, such as the living/working places of cases, other information about exposures. However, it does not show the size of the at-risk population (Centers for Disease Control and Prevention, 2012; Gregg, 2008a). In the example of a dengue outbreak in Brazil, dengue cases spread in the houses of Favela Serviluz from June to July 1999; contributing factors (e.g., containers suitable for breeding sites and uncovered water containers) were found in the house (Figure 8) (Heukelbach, De Oliveira, Fabíola Araújo Sales, Kerr-Pontes, and Feldmeier, 2001). Clinical signs and symptoms can provide clues to identifying the direction and determination of the causative agents (Centers for Disease Control and Prevention, 2012; Gregg, 2008a).



**Figure 8.** Distribution of dengue cases in the houses of Favela Serviluz, Fortaleza, Brazil from June to July 1999. Source: Heukelbach et al., 2001

### 2.5.3. Development and evaluation of hypotheses

Hypotheses are generally developed based on findings from descriptive epidemiology, defined as the process of critical thinking based on characteristics of an outbreak by its time, place, person, and specific outbreak information. Evaluable hypotheses should focus on sources of agents, transmission mode, food vehicles, and exposures. If available evidence is clearly sufficient to support the hypotheses, it is unnecessary to test the hypotheses. For example, a case-series report suggested that the food consumption of 21 Hepatitis A cases were epidemiologically linked to a supermarket where a food-handler with inappropriate personal hygiene practices had been infected with Hepatitis A; no other possible sources were identified (Schmid et al., 2009). In less clear cases, an analytical study (historical cohort or case-control study) can be used to test the hypotheses (Brownson and Petitti, 1998; Centers for Disease Control and Prevention, 2012; Committee on the Control of Foodborne Illness, 2011; Gregg, 2008a; Kile, 2007).

A historical cohort study is suitable for a well defined population, such as outbreaks in schools or factories, while a case-control study is conducted if a cohort study is impractical (Grimes and Schulz, 2002; Kile, 2007; Schulz and Grimes, 2002). Case-control studies are susceptible to bias study and cannot calculate direct relative risk; however, they generally require fewer resources (time, money, and effort) in comparison with cohort studies (Grimes and Schulz, 2002; Schulz and Grimes, 2002).

#### 2.5.4. Implementation control and prevention measures

Control and prevention measures are always high priority and can be implemented at any time during the investigation. Investigation efforts or control measures should be selected based on how much investigators know about a specific outbreak. If investigators have already identified vehicles and sources of the agent, officials must prioritize implementing control measures, such as recalling implicated foods and closing plants or restaurants. Otherwise, investigation efforts should be implemented first (Table 10) (Centers for Disease Control and Prevention, 2012; Goodman, Buehler, and Koplan, 1990; Gregg, 2008a). In the example of a large outbreak of gastroenteritis associated with cheese in England, although the causative agents were unknown, using pasteurized milk to make cheese and voluntarily withdrawing suspected cheese controlled the outbreak (Maguire et al., 1991). In another example, during a Shiga-toxin-producing *E. coli* O104:H4 outbreak in Germany in May 2011, some investigations were conducted at the beginning of the outbreak when causative agents, vehicles, and sources had not yet been identified. After *E. coli* O104:H4 had been isolated in patients, investigations continued to identify vehicles and sources of infection: raw tomatoes, cucumbers, and leafy salads were significantly associated with the syndromes in a case-control study conducted in Hamburg. Investigation efforts continued to confirm vehicles and sources of the *E. coli* O104:H4 and to identify other possible sources of infection in other places, until sprouts and fenugreek seeds were identified as the source of contamination (Askar et al., 2011; Buchholz et al., 2011; Centers for Disease Control and Prevention, 2013; Frank, Faber et al., 2011; Frank, Werber et al., 2011; Scheutz et al., 2011).

**Table 10.** Relative priority of investigative and control efforts during an outbreak

		Source/mode of transmission	
		Known	Unknown
Causative agent	Known	Investigation + Control +++	Investigation +++ Control +
	Unknown	Investigation +++ Control +++	Investigation +++ Control +

+++ Highest priority

+ Lower priority

Sources: Goodman et al., 1990

Control measures for foodborne outbreaks usually consist of closing food service establishments, recalling implicated foods from the markets, and educating the public/consumers (Committee on the Control of Foodborne Illness, 2011; Council to Improve Foodborne Outbreak Response, 2009; WHO, 2008). Ongoing communication with the public and with health professionals is one of the most important aspects of outbreak investigations.

### 3. Objectives of the study

The overall aim of this study is to describe and evaluate public health surveillance systems and responses to foodborne outbreaks in Southern Vietnam from 2009 to 2013, and to identify feasible approaches for building capacity and improving public health practices, specifically:

(1) To identify vehicles, sources, causative agents, and risk factors associated with foodborne outbreaks, to implement evidence-based control measures, and to make recommendations to prevent future outbreaks (Studies I–IV).

(2) To identify gaps and shortcomings in surveillance of foodborne outbreaks, in connection with routine outbreak investigations conducted by public health officials in Southern Vietnam (Studies I–IV).

(3) To identify knowledge, attitudes, and practices related to food safety among food-handlers at large canteens in Southern Vietnam (Study V).

## 4. Methods

### 4.1. Methods of foodborne outbreak investigations (Studies I–IV)

#### 4.1.1. Study settings and outbreak detection

Southern Vietnam includes 19 provinces and about 33 million inhabitants, accounting for 37% of the total population of Vietnam in 2013 (General Statistics Office of Vietnam, 2013). Each province has an FSA that is responsible for investigating foodborne outbreaks in its province. In complicated or severe outbreaks, the provincial FSA may consult the central institution (the IPH) for technical support. Foodborne outbreaks detected in Southern Vietnam from 2009 to 2013 and reported to the central level (IPH) were used as the data to address specific study objective (2). A foodborne outbreak was defined as two or more people who developed gastrointestinal illness after eating the same meal (Ministry of Health, 2006; Olsen et al., 2000; WHO, 2008).

We investigated four food-borne outbreaks that took place from 2009 to 2013 in Southern Vietnam. In all of these outbreaks, health facilities in the southern provinces of Vietnam requested technical support from the IPH at HCMC.

**Outbreak #1:** In September 2009, a large multinational food company had recently introduced and marketed a new commercial fresh milk product, supplemented with galacto-oligosaccharides (GOS). The following month, hospital-based pediatricians in HCMC reported a sudden increase in the number of children who presented with allergic skin reactions and some with breathing difficulties; the increase was well beyond the two to four children with similar reactions expected each month at the hospitals.

**Outbreak #2:** On July 20, 2010, a district hospital reported three cases of cholera to the Ca Mau provincial PMC. Cholera had not been reported in the province in 10 years. As local residents generally use water from canals around their homes and dispose human waste into these canals, public health officials were concerned about the potential risk of high morbidity and mortality in the population.

Outbreak #3: On July 10, 2012, a district health center reported to the FSA of Binh Duong Province an outbreak of gastroenteritis among workers who had eaten lunch at a large canteen for a manufacturing company in an industrial zone (land planned for industrial development). Meals were provided by a food catering service. Of 430 workers attending the lunch, 56 were hospitalized with stomachache, diarrhea, nausea, and vomiting. This event halted all operations of a major manufacturing company. According to the initial report, the food catering service also provided meals for 65 workers of another company in a different industrial zone and, in addition, cooked at canteens of three other companies, providing meals to about 880 workers in different industrial zones.

Outbreak #4: On May 23, 2013, a provincial hospital of Ben Tre City reported to the Ben Tre FSA two cases of acute gastroenteritis, which occurred shortly after the cases consumed stuffed bread from a food stand. The number of cases admitted to the hospital increased sharply to more than 150 by May 24, 2013.

#### 4.1.2. Epidemiologic study designs

To identify vehicles, sources, causative agents, and risk factors associated with the above foodborne outbreaks, detected by surveillance in Southern Vietnam, we conducted descriptive epidemiological and case-control studies. In addition, we implemented control measures and made recommendations to prevent similar outbreaks.

*Descriptive study:* After an outbreak was reported, we first conducted descriptive case-series investigations. If the link between epidemiological, environmental, and biological evidence (such as testing samples of implicated food items and patients' specimens) was sufficient to draw conclusions regarding sources and vehicles of a foodborne outbreak, we did not conduct further studies (Outbreak #2). In outbreaks where descriptive data were not sufficient, we continued the investigation by conducting case-control studies, as appropriate, to identify the cause of the outbreak.

*Case-control studies:* When community-wide foodborne outbreaks occurred or the at-risk population was too large to enumerate for a cohort design, we conducted case-control studies to investigate the outbreak (Outbreaks #1, 3, and 4).

### 4.1.3. Case definitions:

Outbreak #1: A case was defined as a child who visited a hospital in HCMC with acute onset of a skin rash and/or other allergic reactions, as diagnosed by a physician, starting on October 9, 2009. Control subjects were two to three age-matched ( $\pm 1$  year) healthy children who lived in the immediate neighborhood of the case-patient.

Outbreak #2: In this case-series report, a case was defined as a resident of the district of any age with acute watery diarrhea and positive culture for *Vibrio cholerae* between July 12 and 22, 2010.

Outbreak #3: A case was defined as a worker who attended the canteen meal on July 9, was admitted to a hospital in Binh Duong Province with diarrhea, stomachache, and/or vomiting and nausea, and was diagnosed with acute gastroenteritis by an attending doctor from July 9 to July 10, 2012. Controls were randomly selected from a list of workers who were verified to have attended the meal and did not have any of the above symptoms.

Outbreak #4: Cases were residents of Ben Tre City who had visited a local health center/hospital, presented with fever, diarrhea, and abdominal pain, and were diagnosed with gastroenteritis by a clinician between May 22 and May 25, 2013. Controls were healthy subjects (no symptoms of gastroenteritis in the past 7 days) who lived in the same community as the case, matched on gender and age ( $\pm 1$  year).

### 4.1.4. Collection of data

Case finding was performed by local health authorities who reached out to the affected community and advised those with suspected symptoms to immediately visit a hospital. All hospitals in affected areas were requested to report cases immediately to their FSA or relevant institutions. These FSAs and institutions provided a list of the patients visiting health centers/hospitals.

A case was defined based on findings of initial interviews with a few hospitalized cases that had the featured characteristics of a specific outbreak (person, place, or time). For case-control studies, population or neighborhood controls were selected, and matched controls were considered based on specific outbreak circumstances. No more than four controls were used for each case (Woodward, 1999).

For case-control studies, patients meeting the case definition of a specific outbreak, or their surrogates, were interviewed face-to-face at the hospital or their house as soon as possible after illness onset. A standard/structured questionnaire was used to collect details about the food items that the cases consumed before the onset of illness. Data on food items that controls consumed was collected for the same time period as that of the (matched) case. Appropriate memory aids such as calendars and menus of implicated meals were also used. We also collected demographic-related past history, if appropriate, and clinical and epidemiological information of the participants. Details of clinical symptoms, signs, diagnosis, and treatment were transcribed from hospital records.

#### 4.1.5. Laboratory methods

Stool specimens were collected from patients who had typical clinical features and had not taken any antibiotics before the investigation. Appropriate means of transportation (e.g., Carry Blair Transport Medium for Gram-negative and anaerobic organisms) and culture methods (e.g., eosin-methylene blue agar for gram-negative bacteria) were used.

Food samples, suspected food sources, and environmental samples were collected and then kept in sterile containers at 4°C. These samples were shipped to reference laboratories (e.g., those of the IPH) for testing. Testing methods were based on those of the Association of Analytical Communities (Horwitz and Latimer, 2006), or the Vietnam standards, approved by ISO/IEC 17025.

#### 4.1.6. Environmental investigation methods

Food preparation inspections were conducted when appropriate. The review included meeting managers, drawing a flow chart of operations, reviewing monitoring records, and interviewing food-handlers to identify possible sources, routes of contamination, and contributing factors by which pathogens may have survived and/or proliferated. Stool specimens of food-handlers were collected when indicated. Implicated and suspected food items were sampled if available. Surface samples were collected and suspected food products traced back to their source when necessary (Committee on the Control of Foodborne Illness, 2011; Council to Improve Foodborne Outbreak Response, 2009).

#### 4.1.7. Analysis of data

Data were analyzed using R software (Epi and survival packages) and STATA software. Frequencies and proportions were used to describe categorical variables, and measures of central tendency were used to describe continuous variables. Epi-curves and spot maps were drawn when appropriate.

Odds ratios (OR) or matched OR for case-control studies and 95% confidence intervals (95% CI) were calculated by univariate analysis for the consumption of specific food items with the illness of a specific outbreak. We used (conditional) logistic regression models for variables with a significantly elevated OR in univariate analysis to identify risk factors independently associated with illness.

We used links between epidemiological data, environmental investigation results, and testing of samples of implicated food items and patients' specimens in order to develop hypotheses regarding the causes of the outbreaks.

#### 4.1.8. Ethical considerations

In all four outbreaks, written informed consent was obtained from participants or from their surrogates for participation in the study. As all investigations were public health responses to acute outbreaks, no institutional review was required.

### 4.2. Survey methods for food-handlers' knowledge, attitudes and practices

#### 4.2.1. Study setting

From 2007 to 2013, a total of 1,262 foodborne outbreaks, foodborne outbreaks, 41,962 cases, and 294 deaths 36404 cases were reported to the VFA (Vietnam Food Administration, 2013; Vietnam Food Administration, 2014). Many of these outbreaks occurred in large canteens of factories in industrial zones and schools. The proportion of outbreaks with 30 or more cases accounted for 28% of the total number of outbreaks and 81% of the total number of reported cases from 2007 to 2010 (Vietnam Food Administration, 2011).

Contamination of food can occur anywhere along the chain from production, processing, and preparation to consumption. National authorities have issued guidelines to reduce contamination during the production and processing phase, but potential contamination during the preparation phase has not been specifically addressed, particularly in terms of the food-handlers' knowledge, attitudes, and practices (KAP) about food safety. An observational study conducted in HCMC in 2007 showed that 95% of food-handlers in public kitchens had inadequate knowledge and 88% of the food-handlers demonstrated improper food safety practices (Nguyen, Nguyen, and Le, 2010). In addition, outbreaks were reported to occur more frequently in factories than in schools (National Institute of Nutrition - United Nations Children's Fund, 2011; Vietnam Food Administration, 2011).

We conducted a study of food-handlers' KAP in large canteens in three provinces of Southern Vietnam to evaluate the current KAP of food-handlers in large canteens, to compare the KAP of food-handlers working in schools with those in factories, and to identify training needs customized for food-handlers in schools and factories.

#### 4.2.2. Study design

In 2012, cross-sectional survey was conducted on KAP of food-handlers working in large canteens serving >500 meals a day, in 3 of the 20 provinces where many industrial zones are located (Ho Chi Minh City, Binh Duong, and Dong Nai provinces) in Southern Vietnam. Study variables include food-handler's KAP regarding food safety in the following categories: food handling and preparation, food storage, and food safety control. The questionnaires were developed based on findings of the exploratory pilot study and adapted from findings of other studies.

A sample size of 888 food-handlers was calculated using the following parameters:  $p_1 = 0.6$ ,  $p_2 = 0.5$ ,  $\alpha = 0.05$ ,  $power = 0.8$ ,  $non-response\ rate = 10\%$  (Vietnam Food Administration, 2011). From a sampling frame of 169 large canteens, 66 were selected randomly; all food-handlers in selected canteens (estimated 444 food-handlers from schools and 444 from factories) were interviewed face-to-face and were directly observed at food-service establishments.

### 4.2.3. Collection of data

The questionnaires were developed on the basis of the MOH's current food safety regulations and guidelines, with adaptations from previous studies (Angelillo, Viggiani, Greco, and Rito, 2001; Askarian, Kabir, Aminbaig, Memish, and Jafari, 2004; Baş, Şafak Ersun, and Kıvanç, 2006; Cuprasitrut, Srisorrachatr, and Malai, 2011; Green et al., 2006; Lin and Sneed, 2005; Marais, Conradie, and Labadarios, 2008; Nee and Sani, 2011). The data collection tools were pre-tested and revised. All members of the study team were trained and practiced to obtain consistent interviewing standards. Face-to-face interviews were used to identify the current KAP of food-handlers, and direct observations took place in the establishments to cross-check the current practices of food-handlers. Data were processed daily to ensure completeness and internal consistency.

To obtain information on the training needs of food-handlers, ten focus group interviews were conducted, each with 8–12 food-handlers. For each study setting, maximum variation sampling was used to select food-handlers who had different responsibilities in food handling. Qualitative data were coded and analyzed manually. Open coding, focused coding, and axial coding were applied to analyze the data.

### 4.2.4. Analysis of data

Data were analyzed using R software (Epi, BMA, and car packages). Frequencies and proportions were used to describe categorical variables, and measures of central tendency were used to describe continuous variables. Prevalence ratios (PRs) and 95% CI were used to assess the relationship among KAP. Logistic regression models were used to calculate prevalence odds ratios (PORs) and 95% CI used to assess differences in KAP between food-handlers in schools and factories. Model-building and selection for KAP variables were based on the Bayesian Model Average and on variables that were known to be associated with KAP in previous studies (including gender, age, educational level, and length of work experience). The Hosmer-Lemeshow test was used to assess the goodness-of-fit of the best models.

Qualitative data were coded and analyzed manually. Open coding, focused coding, and axial coding were applied to analyze the data.

#### 4.2.5. Ethical considerations

The KAP study protocol was reviewed and approved by the World Health Organization Office in Hanoi, Vietnam. Informed consent was obtained from all study subjects, and the identities of individuals and establishments were kept confidential.

## 5. Results

### 5.1. Outbreak investigations response to foodborne diseases in Southern Vietnam (I–IV)

**Table 11.** Summary of methods and results of outbreak investigations

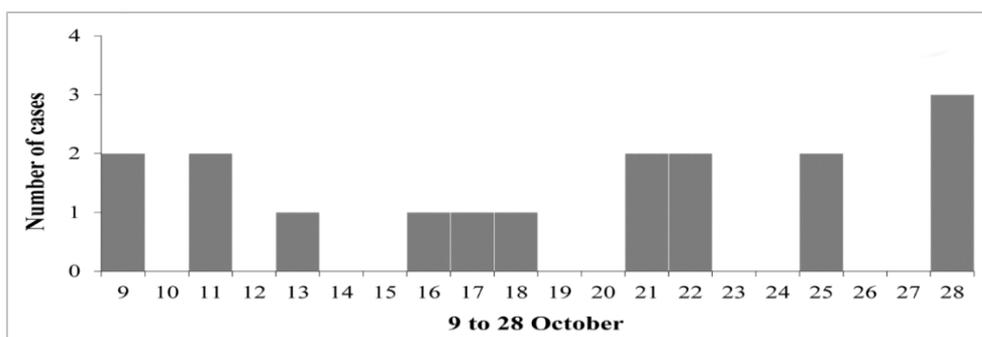
Investigation	Setting	No. cases	Study design	Source, associated food	Demonstration of link	Control measures
<b>Outbreak #1</b>	Community	17	Case-control	Fresh milk	- OR*=27.1 (2.8, 258.9)	Withdrawal/recall of the milk
<b>Outbreak #2</b>	Community	7	Case-series	<i>Not confirmed</i>	- Epidemiologic link to the index case - Cases positive culture for <i>V. cholerae</i> , El Tor, Ogawa - Poor infection control at the hospital - Poor personal and food hygiene of caregivers	Case and contact management Hospital infection control Health education to improve KAP of community on personal hygiene and food hygiene
<b>Outbreak #3</b>	Large canteen	54	Case-control	Squash and pork soup	- OR=9.5 (3.2, 27.7) - Not separate cooked from raw foods - Time-temperature abuse - No training on food safety among food-handlers	Cease preparation of the soup Closure of establishment Training on food safety for food-handlers
<b>Outbreak #4</b>	Community	41	Case-control	Stuffed bread	- OR=21.3 (6.3, 71.8) - Cases and foods positive for <i>Salmonella</i> spp. - Time-temperature abuse - No training on food safety, poor hygiene practices among food-handlers	Cease preparation of the stuffed bread Closure of premises Training on food safety for food-handlers

\* OR: Odds ratio

### 5.1.1. Outbreak #1: “Acute allergic reactions from milk”

The outbreak was detected on October 9, 2009, in HCMC. Seventeen cases resided in nine of the 24 districts of HCMC, were aged 2–15 years, with a median of 10 years and had attended one of the two pediatric hospitals, no cases were fatal. Figure 9 shows the 17 cases by date of onset of illness.

Twelve of the 15 cases had onset of symptoms within 3–20 minutes of drinking milk containing GOS, and the median onset time was 5 minutes. The most frequent symptom was an itchy maculo-papular skin rash (94%), mainly affecting the eyelids, face, and limbs. Eleven cases visited a hospital 5–90 minutes after onset. Three children had acute breathing difficulties and visited a hospital about 5, 20, and 90 minutes after onset; they were treated with adrenaline, steroids, and salbutamol, without ventilation assistance, and recovered within 30 minutes of treatment. The remaining 14 cases recovered within 15–30 minutes after treatment with antihistamines and were discharged within 1 h of arrival. No cases had a past history of milk allergy. The common exposure was that 16 of the 17 cases had consumed milk containing GOS.



**Figure 9.** Number of children (17) with allergic reactions by date of onset, October 2009, Ho Chi Minh City, Vietnam

Based on a preliminary investigation, the milk product was suspected to be an implicated food, and a case-control was conducted to test the hypothesis. In the case-control study, of the 30 food/drink items consumed by study participants, the milk supplemented with GOS and the 100% milk product not supplemented with GOS (produced by the same company B) were both significant in univariate analysis (Table 12). After adjusting for the association of the GOS-supplemented milk product in a logistic regression model, the mOR for fresh milk was no longer

statistically significant (adjusted mOR 1.8; 95% CI 0.2, 17.3). Only the milk supplemented with GOS remained significant, with mOR 27.1, 95% CI 2.8, 258.9 (Table 12). The milk containing GOS was obtained from shops and supermarkets in the neighborhood of the cases and tested by the Center for Food Safety Testing of IPH. Laboratory testing of the milk containing GOS did not detect any unusual properties, allergens, chemicals, or other toxic substances.

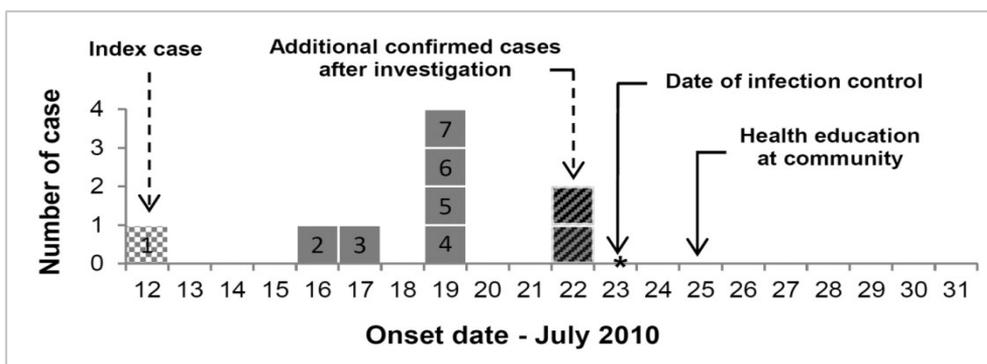
When the results of the case-control study were available on October 28, 2009, the company immediately withdrew the GOS-containing milk from the market across Vietnam. Hospitals in HCMC continued surveillance for additional cases until the end of March 2010, but no new cases were reported.

**Table 12.** Univariate and adjusted matched odds ratios for association between milk products and allergic reactions

Milk products	Cases (n=17)	Controls (n=50)	Crude mOR (95% CI)	Adjusted mOR (95% CI)
Fresh milk supplemented GOS, Company B	16	14	34.0 (3.9, 294.8)	27.1 (2.8, 258.9)
100% pure fresh milk, Company B	11	21	5.5 (1.0, 29.5)	1.8 (0.2, 17.3)
100% pure fresh milk, Company C	13	23	3.4 (0.6, 18.1)	
Pasteurized milk, Company D	4	7	2.3 (0.4, 14.5)	
Fresh milk, Company A	4	10	1.7 (0.3, 8.6)	
Milk product, Company G	4	7	0.9 (0.2, 4.3)	
Milk product, Company E	1	2	4.3e+13 (0)	
Milk product, Company F	0	1	- (-)	
Other milk products	3	16	0.6 (0.1, 4.3)	

### 5.1.2. Outbreak #2: “Cholera at district hospital”

Outbreak #2, a cluster of cholera among patients at a district hospital in Ca Mau, was detected on July 12, 2010. Seven cholera cases were identified through hospital-based investigations. Six cases were from the same village; five were males whose ages ranged from 7 days to 72 years; the median age was 2 years. All cases had a positive culture for *Vibrio cholerae* O1 (biotype El Tor, serotype Ogawa). Figure 10 shows the culture-confirmed cases by the date of illness onset.



\*No more cases identified by surveillance until 21 days from the last case

**Figure 10.** Culture confirmed cholera patients by date of onset, July 2010, Ca Mau, Vietnam

Four cases were admitted to the hospital 3 to 18 hours after illness onset. All cases admitted to the hospital had severe watery diarrhea, and four cases had vomiting. No cases were fatal. Six cases were epidemiologically linked to the index case. Their severe watery diarrhea began 4 to 7 days after the index case. Of the six secondary cases, three cases were acquired at the hospital; one was a seven-day-old newborn sharing the hospital room with the index case, two were inpatients in the same ward who had shared home-prepared food with the index case, and three were relatives of and shared the same caregivers as the index case (Table 13). Two additional cases, confirmed after the investigation, were relatives of case three and case five who had visited the cases at the hospital.

**Table 13.** Demographic and epidemiologic data for seven cholera patients in Ca Mau, Viet Nam, 2010

Case No.	Age/gender	Onset date 2010	Admission date - 2010	Contact to the index case	Shared caregiver with	Condition of previous admission
1*	3 years/male	12/7	13/7	n/a	n/a	-
2**	7 days/female	16/7	-	Yes	-	Delivery
3	3 years/female	17/7	17/7	No	Case 1	-
4	72 years/male	19/7	-	Yes	-	Gastritis
5	1 years /male	19/7	20/7	No	Case 1	-
6	6 years /male	19/7	-	Yes	Case 2	Asthma
7	1 years /male	19/7	19/7	No	Case 1	-

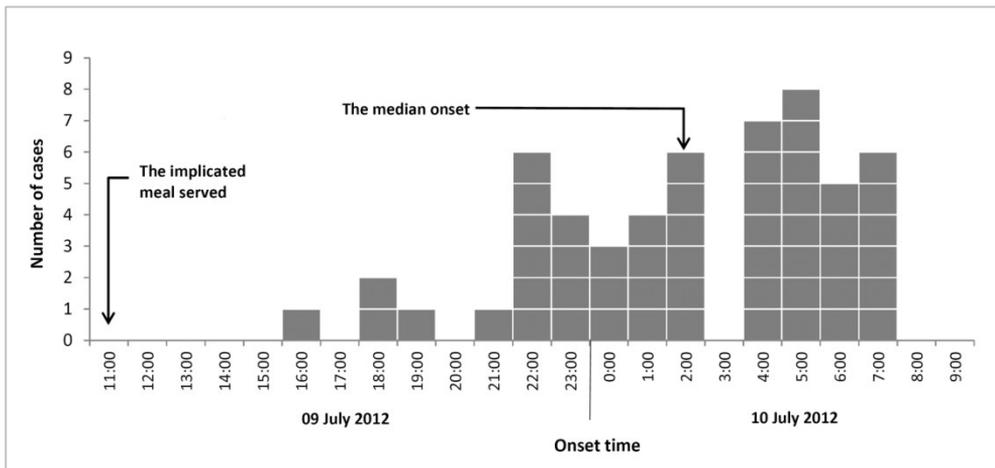
\*case 1 and 5 are brothers, case 3 and 7 are sibling, and they are cousins.

\*\*case 2, 4 and 6 are relatives; case 2 and 6 lived in same house and were cared by a same grandmother

The investigation revealed that the index case had not been identified or treated as a cholera case at the hospital until the laboratory test results were received four days later. Hence, hospital infection control was implemented only after the results were received. Basic infection control practices, however, still did not comply with the guidelines of the MOH, and hygiene was below standard at the time of the investigation (Ministry of Health, 2010).

No suspected foods items were identified in the epidemiological investigation at the village. The environmental investigation found that drinking water was taken from drilled wells and chlorinated inappropriately, though health workers had guided the water chlorination. Patients and their family members had not boiled the drinking water before consuming it. Water for other daily activities was taken from canals directly linked to the residents' water latrines; the latrines were situated above the residents' fish ponds. Other waste was also thrown into the canals. No *V. cholerae* was detected from water samples taken at the hospital or patients' households. Caregivers had poor knowledge and practices of personal and food hygiene, and therefore failed to implement prevention measures for diarrheal diseases.

### 5.1.3. Outbreak #3: "Gastroenteritis in a large canteen"



**Figure 11.** Point source epidemic curve of 54 cases with acute gastroenteritis by time of onset, July 2012, Binh Duong, Vietnam

An outbreak of gastroenteritis occurred among manufacturing workers who ate at a large canteen in Binh Duong. The workers ate a meal at 11:30 a.m. on July 9, 2012. Among the 430 workers who attended the meal, there were 54 cases of gastroenteritis of whose median age was 24.5 years; 64% of the cases were male. Figure 11 shows the epidemic curve of 54 cases by time of acute gastroenteritis onset.

The gastroenteritis patients were previously healthy (no symptoms in the 7 days before hospitalization). The onset time of symptoms ranged from 5–21 h after the meal (median, 14.5 h). Upon hospitalization, 100% of patients had a stomach ache, 96% diarrhea, 39% nausea, and 35% vomiting. The vital signs of all patients fell in the normal range. All patients recovered and were discharged about 24 h after being treated with rehydration solutions (Ringer’s lactate or oral rehydration salts solution), antibiotics (ciprofloxacin, 500 mg), probiotics (Probio), and antispasm or antiemetic drugs (Domperidone).

A case-control study design was used because the at-risk population was too large for a cohort design, and information could be obtained from clearly identifiable exposure groups. Of the four food items eaten by study subjects, the omelet and the squash and pork soup were significantly associated with gastroenteritis in univariate analysis, but only the squash and pork soup remained statistically significant in multivariate analysis (aOR 9.5; 95% CI 3.2, 27.7) (Table 14).

**Table 14.** Univariate and adjusted odds ratios for the association between food items and acute gastroenteritis

Food items	Cases (n=54)	Controls (n=72)	Crude OR (95% CI)	Adjusted OR (95% CI)
Squash and pork soup	49	32	12.3 (4.4, 34.3)	9.5 (3.2, 27.7)
Omelet	36	25	3.8 (1.8, 7.9)	1.9 (0.8, 4.5)
Braised pork with pickled cabbages	3	20	0.2 (0.0, 0.6)	
Water spinach with garlic sauce	22	37	0.7 (0.3, 1.3)	

Stool samples from patients were not available because the samples were not collected at the hospitals. Patients had also been treated with antibiotics before the investigation was conducted.

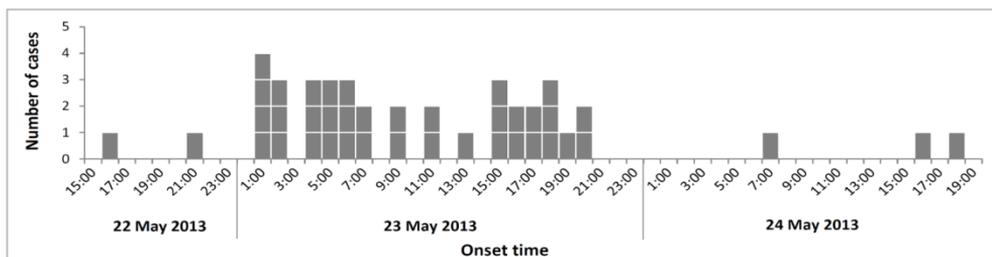
Food samples at the catering establishment were negative; however, they were taken in inadequate quantities, shortly after cooking, and stored in the food catering service.

Hygiene practices at food preparation site and equipment were poor. Insects were found in food preparation and storage areas. Utensils for cooked and raw foods were not separated, and the same counter was used to prepare raw and cooked foods. After the food items were prepared in the catering establishment, they were kept at room temperature for about 4 h before serving.

Fourteen food-handlers were involved in preparing the implicated meal. Four (19%) of them had no health certificate and no training on food safety before they started working, while the remaining 10 food-handlers passed their medical checkup on July 3, 2012. None of food-handlers had any symptoms of gastroenteritis at the time of investigation.

#### 5.1.4. Outbreak #4: “Salmonellosis from stuffed bread”

An outbreak of foodborne salmonellosis was linked to a bread takeaway shop in Ben Tre City. A community-wide outbreak of gastroenteritis was detected on May 23, 2013, and a case-control study was subsequently conducted. Of the 41 cases enrolled in the case-control study, 25 (61%) were males, and the median age was 33 years (range 3–57 years). Figure 12 shows the epidemic curve of 41 cases by time of onset of acute gastroenteritis. The cases resided in 12 wards of Ben Tre City and were distributed around the food stand. Twenty-nine (71%) cases who had consumed bread from the food stand had onset of symptoms within 5–23 h (median 9 h).



**Figure 12.** Cases (n = 41) with acute gastroenteritis by time of onset, May 2013, Ben Tre, Vietnam

All cases were healthy in the 7 days before hospitalization. Thirty-four (83%) cases had abdominal pain as the first symptom. Symptoms upon hospitalization were fever (100%), diarrhea (100%), abdominal pain (100%), vomiting (76%), nausea (68%), headache (61%), myalgia (20%), and bloody diarrhea (17%). The vital signs of all patients fell within the normal range, except for fever. The white blood cell count was elevated in most cases, and the median percentage of neutrophils was 83%. All patients recovered after treatment and were discharged uneventfully after 1–5 days of hospitalization.

In case-control study, cases had consumed 13 food items including two drinks. Of the 13 food items consumed by the study subjects, only stuffed bread was significantly associated with gastroenteritis in the univariate analysis: mOR 21.3; 95% CI 6.3, 71.8 (Table 15).

Of the collected bread ingredients, 200 g each of pork bologna, pork pate, salted and dried pork, and raw egg mayonnaise all grew *Salmonella* species and *E. coli*. Of the 16 patient specimens collected, seven were positive for *Salmonella* species, and none for *E. coli*. Because the eggs used to prepare the mayonnaise were bought from many vendors in wet markets of the city, their origins could not be traced.

**Table 15.** Univariate matched odds ratios for the association between food items and gastroenteritis, May 2013, Ben Tre, Vietnam

Food items eaten	Cases n=41	Controls (n=41)	mOR	95% CI
Stuffed bread from food stand X	29 (70.7%)	4 (9.8%)	21.3	6.3-71.8
Iced-tea	8 (19.5%)	7 (17.1%)	1.2	0.4-3.6
Brined pork	17 (41.5%)	16 (39.0)	1.1	0.5-2.7
Brined goby	7 (17.1%)	7 (17.1%)	1.0	0.3-3.1
Sweet bread	1 (2.4%)	1 (2.4%)	1.0	0.1-16.3
Noodle without meats	1 (2.4%)	1 (2.4%)	1.0	0.1-16.3
Soya milk	3 (7.3%)	3 (7.3%)	1.0	0.2-5.2
Fresh vegetables	7 (17.1%)	10 (24.4%)	0.6	0.2-1.9
Vegetable soup with pork	14 (34.1%)	19 (43.6%)	0.6	0.3-1.5
Fried pork	3 (7.3%)	5 (12.2%)	0.6	0.1-2.6
Brined duck egg and pork	4 (9.8%)	8 (19.5%)	0.5	0.1-1.6
Noodle with meats	1 (2.4%)	9 (22.0%)	0.1	0.01-0.8
Coconut soup	1 (2.4%)	0 (0%)	-	-

We observed poor hygiene practices at all three food preparation sites. Cooked foods were not separated from raw foods. No food samples were stored after cooking at the preparation sites. Cooked foods were kept at room temperature before being served, and leftovers were stored at the end of each working section.

Eight food-handlers were involved in preparing the bread and its ingredients. Six did not have any valid health certificates, and the health certificates of two had expired. No food-handler had a valid certificate for training in food safety, and their knowledge and practices of food safety, personal hygiene principles, and safe temperatures for cooked food were poor. No food-handler had had symptoms of food-borne illness a week before the outbreak. Their rectal swabs were culture-negative for enteric bacterial pathogens.

No new cases related to the stuffed bread were reported after the food stand was closed on May 24, 2013.

## **5.2. Gaps and shortcomings in surveillance of foodborne outbreaks**

### **5.2.1. Gaps and shortcomings identified in surveillance and outbreak detection**

In all of the four outbreaks, physicians from health care providers (hospitals and health centers) alerted FSAs or PMCs to the possibility of an outbreak. However, the notifications of the outbreaks were reported late to relevant health authorities (4 to 17 days after), except in Outbreak #3, which occurred in a large canteen. For severe disease, such as cholera in Outbreak #2, laboratory staff only returned the results of stool specimens to the hospital that had sent them but did not immediately inform relevant health facilities about cholera-positive cases. Currently, no foodborne surveillance systems are in effect to detect foodborne outbreaks early. There are no focal points for disease control and prevention in the Department of Health at the district or provincial levels. Foodborne notification/complaint systems are not set up to receive reports from the public. Private health sectors are not obliged to report/notify foodborne cases or suspected outbreaks to food safety health facilities.

After outbreak investigations, an FSA must prepare a report to submit to the VFA and central institutes. However, for most reports, the contents only included

administrative information and very basic public health information (e.g., number of cases, hospitalizations, and deaths). Environmental investigations yielded limited data identifying contributing factors that were likely associated with the outbreaks. Few comments, suggestions, or lessons learned were stated in the reports. Aggregation and analysis of the surveillance data were only conducted annually or for national food safety conferences, and the aggregated data only compared the number of foodborne outbreaks, cases, and deaths of the current year with these figures from previous years.

Current FBD surveillance data only capture the “tip of the iceberg.” The surveillance data is provided by a single source of outbreak investigation reporting. Foodborne outbreak data account for only severely ill patients who went to hospitals. The current foodborne surveillance system does not identify clusters of cases and non-severe cases. Notifiable disease surveillance systems for infectious diseases exist and are managed by PMCs, but FSAs do not make use of FBD data in the surveillance system.

## 5.2.2. Gaps and shortcomings identified in response capacity

Although almost all FSA staff members were trained in conducting outbreak investigations, the quality of the outbreak investigation reports was poor. The main weakness was incorrectly applying principles of outbreak investigations. First, in all four outbreaks, case-finding approaches were hardly applied, and a working case definition for a specific outbreak was rarely developed. The staff assumed that outbreak cases consisted only of patients who went to hospitals/health centers and reported any gastroenteritis symptoms. Second, they hardly developed a standard questionnaire for each specific outbreak, to collect data for descriptive epidemiology (Outbreaks #1, 2, and 4). While investigating the outbreaks, we searched available information related to specific outbreaks that local health workers had already investigated. We found that the FSA staff simply recorded name, age, gender, address, hospitalized date, available testing results, and diagnosis from hospital records, but observed few symptoms and signs of patients (Outbreaks #1, 2, and 4). Third, members of an outbreak response team took food samples for testing from sites where outbreaks occurred (if such samples were available) and used results of these tests draw conclusions about the cause of the outbreaks; they did not, however, take or request patient specimens (Outbreaks #3 and 4). Finally, while inspecting food-preparation sites, the FSA staff simply

checked whether food-handlers were trained in basic food safety principles, obtain medical clearance certificates of the food-handlers, and checked receipts of food to confirm foods origins. No flow charts of food operations were drawn and no interviews with food-handlers were conducted (Outbreaks #2, 3, and 4).

In terms of organization and coordination, FSAs had clearly assigned roles at the provincial level. FSAs are responsible for foodborne outbreak investigations; hospitals allowed the staff of FSAs to access patients and the patients' hospital records, while provincial PMCs only sent a laboratory staff member to collect food samples. The outbreak investigation teams consisted of mainly FSA staff for inspection and provincial PMC laboratory staff members to collect food samples for testing; clinicians or skilled epidemiologists were rarely present. In addition, roles and responsibilities of team members were not agreed on beforehand. Although the capacities of most FSAs for foodborne outbreak investigations were limited, they rarely requested technical support at the central level, except in cases of severe outbreaks or when under pressure from local governments. They usually sent administrative reports of outbreaks after the outbreaks had ended, or requested for technical support after the relevant time for investigations had already passed.

### 5.2.3. Gaps and shortcomings identified in laboratory capacity

Laboratory systems at the local level only conducted basic testing of the microorganisms, tested physicochemical in water such as coliform and *E. coli* counts, and determined taste, smell, color, and turbidity of the water. Laboratories in provincial PMCs are able to identify the phenotype of a number of common microbes, and a few PMCs can identify a number of serotypes, subtypes, or genotypes of common microorganisms such as *Vibrio cholerae* and *Staphylococcus aureus*. Standard operating procedures for testing have not been developed and quality assurance programs have not been implemented in laboratories in provincial PMCs, so the ISO has not accredited the PMCs' laboratory testing. As a result, FSAs have sent their samples to the accredited laboratories at the central level.

Central institutes (e.g., Pasteur Institute in HCMC, IPH) performed most of the testing for serotypes, subtypes, or genotypes of microorganisms, and performed all physicochemical testing in water and foods. All food samples were sent to IPH for testing.

### 5.3. Knowledge, attitudes and practices, and training needs of food-handlers at large canteens (V)

#### 5.3.1. Descriptive analysis

A total of 909 out of 919 food-handlers participated in the study (response proportion, 99%); 692 (76%) of them were females. The median age was 38 years (interquartile range [IQR] 27, 45) and median length of work experience in food handling was 36 months (IQR 8, 84) (Table 16). Eighty-four percent of food-handlers had graduated from secondary school or above; only about 1% was illiterate. Ninety-eight percent of food-handlers had been trained in food safety principles within one year of the study, and 99% had passed a medical check-up before beginning work. Of all participants, 26%, 36%, and 26% were considered to have adequate KAP regarding food safety, respectively (Table 16).

Based on univariate analysis of the relationship between knowledge and attitudes, 101 (43%) of participants with adequate knowledge had appropriate attitudes, compared with 224 (33%) with inadequate knowledge (PR 1.3; 95% CI 1.1, 1.7). Similarly, in the analysis of the relationship between knowledge and practice, 116 (48%) of participants with adequate knowledge had appropriate practices, compared with 124 (18%) who had inadequate knowledge (PR 2.7; 95% CI 2.2, 3.3). There was no significant association between appropriate attitudes and adequate practice.

#### 5.3.2. Comparison of food-handlers working in schools and factories

Among the 909 food-handlers participating in the study, 461 (51%) worked in schools and 448 (49%) worked in factories. Among those working in schools, 450 (98%) were female, whereas 242 (54%) of those in factories were female (Table 16). Of food-handlers working in schools, 91% were secondary school graduates (attended 6 or more years of school), compared with 77% of those working in factories. The median ages were 41 years (IQR 34, 47) and 28 years (IQR 22, 42) for food-handlers in schools and factories, respectively. The median lengths of work experience for those working in schools and those working in factories were 60 months (IQR 24, 108) and 12 months (IQR 3, 36), respectively. When comparing food-handlers working in schools and those working in factories, we

found significant differences for gender, educational level, age, and duration of working experience (Table 16).

**Table 16.** Demographic characteristics and knowledge, attitudes and practices of food-handlers by type of establishment, Southern Vietnam, 2012

Variables	School (n=461)	Factory (n=448)	Total	p-value/ Crude POR (95% CI) <sup>†</sup>
Gender (n, %)				<0.001
<i>Female</i>	450 (97.6)	242 (54.0)	692 (76.1)	
<i>Male</i>	11 (2.4)	206 (46.0)	217 (23.9)	
Educational level (n, %)				<0.001
<i>Primary School (1-5 school years)</i>	43 (9.4)	104 (21.4)	147 (16.2)	
<i>Secondary School (6-9 school years)</i>	181 (39.3)	213 (47.5)	394 (43.3)	
<i>High School or higher (≥10 school years)</i>	237 (51.4)	131 (29.3)	368 (40.5)	
Age (median, IQR)	41 (34, 47)	28 (22, 42)	38 (27, 45)	< 0.001
Working experience by months (median, IQR)	60 (24, 108)	12 (3, 36)	36 (8, 84)	< 0.001
Food-handlers received food safety training (n, %)	450 (97.6)	443 (96.1)	893 (98.2)	NS*
Food-handlers passed a medical examination before being recruited (n, %)	461 (100)	443 (96.1)	904 (99.4)	NS
Adequate knowledge	157 (34%)	80 (18%)	237 (26%)	2.4 (1.7, 3.2)
Appropriate attitudes	200 (43%)	125 (28%)	325 (36%)	2.0 (1.5, 2.6)
Appropriate practices	152 (33%)	88 (20%)	240 (26%)	2.0 (1.5, 2.7)

<sup>†</sup>POR: Prevalence odds ratio; 95% CI: 95% confidence interval

\*NS: non-significant

The proportions of food-handlers with adequate KAP scores were significantly higher in schools than in factories. After adjustment for gender, age, educational level, and length of work experience, the odds of food-handlers in schools reporting adequate KAP were about twice as high as those in factories. Educational level was the only other significant variable in the knowledge model (POR 1.9; 95% CI 1.4, 2.5) (Table 17).

**Table 17.** Comparison of knowledge, attitudes and practices regarding food safety among food-handlers in schools and factories, Southern Vietnam 2012

Variables	Crude POR (95% CI)	Adjusted POR <sup>f</sup> (95% CI) <sup>*</sup>
Adequate knowledge	2.4 (1.7, 3.2)	2.1 (1.5, 2.9)
<i>Educational level</i>		1.9 (1.4, 2.5)
Appropriate attitudes	2.0 (1.5, 2.6)	2.0 (1.5, 2.6)
Appropriate practices	2.0 (1.5, 2.7)	2.0 (1.5, 2.7)

<sup>f</sup>POR: Prevalence odds ratio; 95% CI: 95% confidence interval

<sup>\*</sup>Adjusted for age, gender, education level, and length of working experience. Separate logistic regression models were fitted for knowledge, attitudes and practices.

### 5.3.3. Observations at canteens

Among the 66 canteens we investigated, about 29% did not separate the food preparation area from other areas (Table 18). Fifty-two per cent of the canteens did not have soap and/or napkins/drier in the rest room, and 83% of the canteens had not posted a hand-washing reminder in the appropriate places. About 9% of canteens did not separate the areas for raw food from the ones for cooked food during the preparation process. About 14% of canteens did not separate raw food from cooked food in refrigerators, and about 11% of canteens did not cover or protect the food while the kitchen was being cleaned (Table 18). There were no significant associations between practices in schools and factories.

**Table 18.** Observed food service practices in Schools and Factories , Southern Vietnam, 2012

Practices of food service establishments	School Yes (n, %)	Factory Yes (n, %)	Total Yes (n, %)
<b><i>Canteens</i></b>			
The areas to deliver, prepare and serve food are separated	30 (75.0)	17 (65.4)	47 (71.2)
Handwashing IEC <sup>y</sup> materials are displayed in the toilet	6 (15.0)	5 (19.2)	11 (16.7)
Soap and napkins/drier available in the toilet	23 (57.5)	9 (34.6)	32 (48.5)
<b><i>Preparation and storage of food</i></b>			
No separate areas for raw and cooked food during the preparation	4 (10.0)	2 (7.7)	6 (9.1)
Food covered/protected during the cleaning of the kitchen	35 (87.5)	24 (92.3)	59 (89.4)
Raw and cooked food not separated in the refrigerator	5 (12.5)	4 (15.4)	9 (13.6)

<sup>y</sup>Education Information and Communication

#### 5.3.4. Training needs

Most food-handlers who participated in the focus group discussion were satisfied with the content of the previous training courses. However, the participants complained that “training courses provided only theories without exercises, so they could not apply what they learned in practice.” They also noted that “the numbers of participants of each training course were often too high. Too many trainees (100 or more) were attending the course to efficiently follow the lectures and to concentrate on what is taught.” Furthermore, “the duration of one training course was too short, with only three to six hours to cover all contents.”

For training needs, most participants would like to receive additional training on how to select safe raw materials, how to handle, prepare and store food appropriately, and how to ensure personal hygiene and cleanliness. They also suggested that “training should be organized at their workplace and that the number of participants should be limited to 20 to 30 per training course.” Participants recommended that “training courses should be more practical with fewer lectures but more time for question and answer sessions as well as group discussions.” Participants suggested that the lectures provided during the training courses be more interactive, with more visuals and less text.

## 6. Discussion

The overall aim of the dissertation is to describe and evaluate public health surveillance systems and responses to foodborne outbreaks, and to identify feasible approaches for building capacity and improving public health practices. In this chapter, the evidence in foodborne outbreak investigation, food-handlers' contributions to the outbreaks, the strengths and limitations of the studies are discussed first. Second, the possibility of strengthening public health surveillance and response capacity foodborne outbreak will be considered. Lastly, public health implications for FBD surveillance and capacity building from the results are presented.

### 6.1. Assessing the evidence in foodborne outbreak investigations and food-handlers' contributions to the outbreaks

Four outbreak investigations were conducted to identify likely vehicles, sources, causative agents, and risk factors contributing to these foodborne outbreaks. In Study I, the age-matched case-control provided a strong association (adjusted mOR 27.1; 95% CI 2.8, 258.9) between drinking the fresh milk product supplemented with GOS and the allergic reactions. The specific allergen was not identified because milk samples were unavailable during the investigations and laboratory capacity was limited. However, the strong epidemiologic association, the temporal relationship between drinking the milk and onset of symptoms, and the absence of new cases after withdrawal of the milk from the market implicated the milk as the source.

In Study II, we conducted a case-series study to investigate cases in the district hospital where cholera cases (*Vibrio cholerae* O1, biotype El Tor, serotype Ogawa) were detected. We found that inappropriate hospital infection control, limited

capacity in outbreak investigation, and poor personal and food hygiene of close contacts were the main reasons for the spread of cholera at and from the hospital. Although *V. cholerae* was not detected in water samples, no new cases were reported after effective control measures were implemented at the hospital and in the community.

In Study III, the case-control provided a strong epidemiologic association between eating squash and pork soup and acute gastroenteritis (aOR 9.5; 95% CI 3.2, 27.7). Although no microbiologic confirmation was obtained, food-handlers' behavior (including not separating cooked from raw food, time-temperature abuse, and poor knowledge and practices), in conjunction with epidemiologic evidence, implicated the squash and pork soup as the cause of the outbreak.

In Study IV, the case-control study found a strong association (mOR 21.3; 95% CI 6.3, 71.8) between the stuffed bread and the gastroenteritis. *Salmonella* species was isolated from both the bread ingredients (raw egg mayonnaise, pork bologna, pork pate, and salted and dried pork) and the patients. In environmental investigations, several risk points (poor personal hygiene and food hygiene of food-handlers, time-temperature abuse, and poor hygiene practices at the three food preparation sites) were identified in the food handling, and preparations of the bread and raw egg mayonnaise. Although the origin of the eggs could not be traced for testing, considering all the above evidence we conclude the raw egg mayonnaise may have been contaminated by *Salmonella* species from the raw eggs, and *Salmonella* species were considered the likely etiology of the outbreak.

In Study V, we conducted a cross-sectional study to assess the KAP of food-handlers in large canteens of schools and factories. The proportions of all participants whose knowledge, attitudes, and practices were considered adequate were 26%, 36%, and 26%, respectively, although they all had received annual food safety training. Food-handlers in schools reported adequate KAP about twice as often as food-handlers in factories. Based on food-handlers' suggestions for improving previous training courses, it is clear that course planning, organization, and teaching methods must be revised to incorporate training at the workplace, the involvement of managers in enforcing practices, fewer trainees per course, more practical exercises, and a longer course duration.

## 6.2. Methodological strengths and limitations

Applying standard epidemiologic methods is critical for successful foodborne outbreak investigations. We used a case-series report and case-control designs in foodborne outbreak investigations and cross-sectional surveys for food-handlers' KAP assessments. In Study II, it was unnecessary to conduct a subsequent analytical study for hypotheses testing, as available epidemiologic, microbiologic, and environmental evidence of the case-series report were sufficient to support the hypotheses, and control measures were urgently needed for the severe and rapidly spreading disease of cholera. In Studies I and IV, case-control designs were used because the studies looked at community-wide outbreaks with several potential exposures, and full lists of source populations were unavailable (Committee on the Control of Foodborne Illness, 2011; Dwyer et al., 2012; Lasky, 2007; WHO, 2008). We applied matched case-control designs in Studies I and IV to increase the studies' efficiency and to control for known confounders, such as age and gender (in Study I, as only children were affected by the allergic reactions) (Dwyer et al., 2012; Gordis, 2014; Gregg, 2008b). In Study III, we used case-control design because the entire at-risk population was too large to enumerate using the available resources (Dwyer et al., 2012). In Study V, the cross-sectional design enabled us to assess and compare proportions of KAP in specific populations: food-handlers in large canteens and schools. We also used qualitative study methods to explore issues in food safety training courses for food-handlers.

We used several techniques to minimize selection bias and information bias, and to control for confounders in the study design and implementation phases. In the context of developing countries such as Vietnam, where laboratory data and outbreak complaint logs were not available, we reviewed records in hospitals, consultant rooms, and emergency wards (Studies I, II, and IV), asked the known cases whether they knew of additional cases in the four outbreak investigations, and used the at-risk populations (Study II and III) or the mass media (Studies I and IV) as case-finding strategies. Interviewers were trained and standardized questionnaires were used in face-to-face interviews during the data collection phase. Food items consumed by controls were ascertained for the same time periods as those for the cases in Studies I and IV (Grimes and Schulz, 2002) and memory aid was used in Studies I and II to improve the recall of participants (Grimes and Schulz, 2002; Schulz and Grimes, 2002). Case definitions of four studies were developed based on an initial case series and were consistent with the clinical features of the diseases. For the control group, controls in Study III came

from the source population at risk for gastroenteritis, and neighborhood controls enabled matching for confounders, such as age in Study I and age and gender in Study IV. In Study V, we pre-tested the data collection tools and revised them based on pre-test findings. Confounder control was also implemented in analysis stages of Studies I and III. Trained interviewers explained the aims of the study to participants and obtained a high response proportion (99%). Collected data were processed daily to ensure completeness and internal consistency.

Although several techniques were used to minimize bias and control for confounders in study design and implementation, our studies revealed a number of limitations. The major limitation in Studies I, II, and IV was the delay in initiating the investigations, which led to subsequent delays in identifying the vehicles and inability to collect appropriate samples for laboratory testing. We were unable to identify specific causative agents in the investigations due to limited laboratory capacity and/or unavailability of samples at the time of investigation. In Study I, the allergen in the milk product was not identified. It is possible that a constituent such as a new allergen, a side product of the metabolic process, an alien protein absorbed with GOS, or a contaminant from the manufacturing process may have caused the illness. In Study II, although we identified the serotype of *Vibrio cholerae* in patients' specimen, its genotype and phenotype were not determined, and results of samples from the environment were negative for *V. cholerae*. In Study III, the pathogen that caused gastroenteritis was not determined. Food samples collected from the storage areas of the catering service were different from the food served for workers, which likely contributed to the negative culture finding. Similarly, in Study IV, serotyping of *Salmonella* was not performed in laboratories. In addition, our outbreak investigations were limited to symptomatic cases who went to hospitals in the study settings, suggesting that only those with more severe symptoms were likely to have been included (Kelsey, Petitti, and King, 1998). In Study V, we could not collect information related to contributing factors in food preparation, such as insufficient time and temperature during cooking or reheating, keeping cooked foods at a safe temperature, and improper cooling, all of which might contribute to outbreaks in large canteens.

## 6.3. Strengthening public health surveillance and response capacity for foodborne outbreaks

### 6.3.1. Developing surveillance systems

Analysis of outbreak investigation reports revealed several gaps and shortcomings in public health surveillance for food safety in Vietnam. Observant clinicians in the government health care system usually alert PMCs, FSAs, or the provincial Department of Health; however, health staff members in the public health or private sectors are rarely the first to identify and report outbreaks. Complaints from affected individuals are not recorded in the current surveillance systems. Therefore, points of contact in the Department of Health at district or provincial levels should be assigned responsibility for coordinating disease control and prevention. Furthermore, a lack of effective public health surveillance system for early detection of potential outbreaks is a critical shortcoming, particularly the lack of syndromic surveillance and notification/complaint systems for otherwise undetectable outbreaks (Scallan et al., 2013).

Clinicians play critical roles in alerting officials to potential outbreaks (Henning, 2004). In our investigations, however, clinicians were delayed in reporting three potential outbreaks. The clinicians notified the suspected outbreaks to relevant health authorities 4 to 17 days after the first cases were identified. The late reporting of the outbreaks was the main reason for the subsequent delays in investigations, identification of vehicles, sample collections, and testing of suspected food items. Therefore, clinicians should be reminded to report any unusual health events in their patient population to points of contact for disease control and prevention in the Department of Health at the district or provincial levels. It is clear that early detection of FBD outbreaks is a pressing priority for Vietnam's current FBD surveillance system.

A syndromic surveillance system based on the existing notifiable disease system could promote the early detection of foodborne outbreaks in resource-poor settings with limited laboratory capacities, such as Vietnam (Scallan et al., 2013). Notifiable disease reporting for infectious diseases exists in Vietnam and is managed by PMCs, but analysis of surveillance data related to FBD has not been conducted. As a result, no foodborne outbreaks were detected through notifiable disease systems. Definitions of FBD-related clinical syndromes should be

developed, and notifiable disease database records that meet the definitions should be extracted (Mostashari and Hartman, 2003). Data sources are readily available and should include complaints of patients reporting to emergency departments, outpatient visits to clinics/consultant rooms, and the general public's reports to health authorities as recorded in log books, and absenteeism at workplaces in factories and schools (Heffernan et al., 2004a; Heffernan et al., 2004b).

Conducting syndromic surveillance system is feasible, despite the challenges of recruiting skilled people or training staff in surveillance data collection, analysis, and report (Mostashari and Hartman, 2003). In general, the system may be developed based on existing systems, so costs are not particularly high (Kirkwood et al., 2007; Mostashari and Hartman, 2003). Lessons learned and approaches for syndrome groupings are available from previous studies (Buehler, 2004; Heffernan et al., 2004b). Methods for analysis of spatial and temporal data, such as the SaTScan software, are available (Kulldorff, 2014).

Syndromic surveillance systems capture a proportion of FBD (Roy et al., 2006) and usually identify large outbreaks (Scallan et al., 2013), but they cannot incorporate notifications from the community or complaints from affected individuals who do not visit health care facilities. Notification/complaint systems must therefore be established. Notification/complaint systems are sensitive and useful for early detection of unknown, new, or emerging agents in settings where good timely disease surveillance systems do not exist. Developing such systems is feasible because forms for data collection can be adopted from other documented forms of the Committee on the Control of Foodborne Illness (2011), the Council to Improve Foodborne Outbreak Response, (2009) and/or World Health Organization (2008). Quality data can be obtained through triage and notifications from affected people. Hence, the use of notification/complaint systems may increase the likelihood of early detection of foodborne outbreaks (Council to Improve Foodborne Outbreak Response, 2009) and provide a data source for the syndromic surveillance (Heffernan et al., 2004a; Heffernan et al., 2004b).

### **6.3.2. Strengthening human capacity for outbreak investigations**

Adequately applying standard epidemiologic methods is critical to investigating foodborne outbreaks successfully. During the investigations, however, we found that provincial and district health authorities had hardly conducted case findings and had rarely developed working case definitions and data collection tools. The

outbreaks' contributing factors were inadequately identified due to poor environmental investigations and inspections of food-handlers. Because of poor quality/non availability of epidemiologic, microbiological and environmental findings, laboratory tests of food samples were used to draw conclusions about the causes of outbreaks. Despite attending training courses, most investigators at the provincial and district levels did not master principles of outbreak investigations (Vietnam Food Administration, 2011; Vietnam Food Administration, 2014). Capacity building for foodborne outbreak investigation is a high priority in the context of Vietnam.

The training courses appeared to have little impact on investigation practices, probably due to teaching methods and/or failure to target the right participants. Applying lecture teaching methods, with little interaction between teachers and students, did not help students apply theory to practice. In addition, more than 50% of public health officials of FSAs did not have a background in health sciences. A teaching approach that emphasized interaction and critical thinking development would help public health officials develop outbreak investigation skills (Goodman and Buehler, 2008). Hence, the FETP is an appropriate means of training epidemiologists and public health practitioners in Vietnam. The FETP emphasizes 'learning by doing,' in which facilitators and field supervisors play an important role in effectively transferring to trainees knowledge of epidemiologic methods and lessons learned from the field (Jones, MacDonald, Volkov, and Herrera-Guibert, 2014; Thacker, Dannenberg, and Hamilton, 2001). The programs have been implemented successfully in many countries such as Thailand, the Philippines, Malaysia, Saudi Arabia, and Zimbabwe, particularly among public health officials responsible for monitoring foodborne outbreaks (Thacker et al., 2001; White, McDonnell, Werker, Cardenas, and Thacker, 2001). In addition, the FETP empowers trainees to perform foodborne outbreaks investigations by making field supervisors available for consultation. By applying several methods of foodborne outbreak investigations, trainees can make inferences about the likely causes of a foodborne outbreak. Furthermore, it is critical to apply standard epidemiologic methods to outbreak responses in resource-poor countries like Vietnam, where laboratories are not available or testing results may not be obtained in a timely manner.

Another way to make inferences about the likely causes of a foodborne outbreak is to link information from laboratory investigations with those from epidemiologic and environmental investigations. However, laboratory capacities are limited in Southern Vietnam, particularly at a district level. In our investigations,

the absence of laboratory results from patient, food, and environmental samples was a major barrier to identifying causative agents of the foodborne outbreaks. Therefore, strengthening laboratory capacities should be an important priority for future FBD control and prevention. Field Epidemiology Laboratory Training Programs (FELTPs) have been conducted successfully in many countries in Asia and Africa (AFENET, 2014; Centers for Disease Control and Prevention, 2011). Hence, a Vietnamese FELTP could be offered as a parallel track along with the FETP to strengthen the capacities of laboratory staff.

### 6.3.3. Food-handler training

Food-handlers play an important role in food safety. Many foodborne outbreaks are related to food-handlers (e.g., improper hand-washing, inadequate cleaning utensils, cross-contamination, and time-temperature abuse) (Todd et al., 2007). Food-handlers' adequate knowledge and practices of personal hygiene and food hygiene may prevent the most severe consequences of foodborne outbreaks, such as deaths, hospital visits, and substantial economic losses. However, our study showed food-handlers' KAP to be rather poor, particularly among food-handlers in factories. Therefore, food-handlers must be trained in safe food-handling practices, and such practices must be enforced to prevent similar outbreaks in the future and to avoid economic losses due to business closures and compensation for the consequences of foodborne outbreaks (Hogue et al., 1997; Kassa, 2001; Raspor, 2008).

In our study, almost all participants had received annual food safety training, but their level of knowledge remained rather low. It showed that training had had little impact in increasing food-handlers' knowledge. It is plausible that several factors (e.g., incompatible curriculum, inappropriate teaching methods, and unplanned training course arrangements) may have contributed to suboptimal learning during the training courses. Therefore, these factors should be considered when designing effective training courses. Although knowledge alone is not enough to change practices, food-handlers with adequate knowledge can change their practices more easily if they are closely supervised and supported by their on-site managers (Green et al., 2007; Rennie, 1994; Roberts et al., 2008). In addition, guidance and supervision provided by managers during work improve workers' attitudes (Tones and Tilford, 2001) and practices (Egan et al., 2007; Nee and Sani, 2011).

Adequate food-handling practices are important for food safety. To improve knowledge and change practices of the food-handlers in Southern Vietnam, it may be suitable to apply the health belief model to training (Nutbeam, Harris, and Wise, 2010). Managers must encourage and guide food-handlers to “understand the importance of food safety, their roles in safe food-handling practices and willingness to implement what they have learned” (Kile, 2007). Therefore, educational efforts, together with supportive supervision conducted by managers, have great potential to improve food-handlers’ KAP, especially those in factories in Vietnam.

#### **6.4. Public health implications for FBD surveillance and capacity building**

In addition to early detection of FBD outbreaks, the use of syndromic surveillance and notification/complaint systems could be prospects for Vietnam. Because the country relies only on outbreak investigation reporting, current surveillance only captures the “tip of the iceberg” and underestimates the burden of FBD. When implementing new systems, data from the systems can only estimate the incidence, trends, and populations at risk of FBD. For example, applying capture-recapture analysis from the different surveillance systems of same population could be used to estimate the burden of FBD (Amstrup, McDonald, and Manly, 2010). Such information about the burden of FBD would be useful for planning, prioritizing, monitoring, and evaluating control and prevention measures for foodborne outbreaks (Henning, 2004; Scallan et al., 2013; WHO, 2010). Because the syndromic surveillance system is based on the notifiable disease system, data on an individual case in the syndromic surveillance system can be combined with its pathogen, when laboratory results are available. In future, this method could be the basis for laboratory-based surveillance development when laboratory capacities are strengthened in Vietnam.

Outbreak investigation is one element in a cycle of FBD surveillance and prevention (Tauxe, Doyle, Kuchenmüller, Schlundt, and Stein, 2010). Conducting epidemiologic investigations to outbreaks can identify knowledge gaps, new hazards to food safety, and contributing factors to the outbreaks, such as inappropriate food handling, food processing, and agricultural practices (Charles, 2007; Kile, 2007). The findings of the investigations may provide opportunities for

research and new information regarding prevention measures (Nuorti and Kuusi, 2002). Along with strengthening laboratory capacity, trained epidemiologists can identify links between pathogens and foods, and between foods and risk factors associated with foodborne outbreaks. Food attribution, inferred from the link between a specific pathogen and specific food, provides evidence for policy changes on foodborne prevention and effective resource allocation (Greig and Ravel, 2009). Findings from outbreak investigations can help to implement specific prevention measures and can monitor the incidence of the health event (Tauxe et al., 2010). Strengthening human capacity for outbreak investigation significantly impacts FBD surveillance and prevention.

Foodborne surveillance and epidemiologic investigations involve the collaboration of multi-sectoral personnel (e.g., epidemiologists, clinicians, laboratory specialists, veterinarians, biostatisticians). While conducting foodborne investigations in Southern Vietnam, we observed limited human capacity and poor coordination among sectors. Hence, developing a strategy and plan for the personnel is crucial to preventing FBD, particularly so that field epidemiologists and veterinarians can meet the recommendations of the Global Health Security Agenda (Centers for Disease Control and Prevention, 2014). Joint field-based training programs such as FETP/FELTP are highly recommended in order to strengthen capacities of the personnel and to expedite coordination among the personnel and their organizations.

Public health threats must be responded to in a timely manner. Therefore, training for public health officials at district and provincial levels is critical to detect potential outbreaks early and to investigate outbreaks in a timely manner. Field supervisors are one of the main keys to success of the FETP; however, few field supervisors are available in developing countries such as Vietnam (Krause, Stefanoff, and Moren, 2009). It is highly recommended that field supervisor trainings be implemented in effective and efficient postgraduate epidemiology programs, such as the International Postgraduate Program in Epidemiology (IPPE) (School of Health Sciences, 2014).

## 7. Conclusions

In this thesis, we conducted four foodborne outbreak investigations and one assessment of food-handlers' KAP. The results showed that:

Our foodborne investigations of outbreak #1 contained the first report of an allergic reaction to fresh milk supplemented galacto-oligosaccharides. However, we were unable to identify the specific allergen in the milk product. The vehicles and sources associated with the foodborne outbreaks #2, 3, and 4 were identified using standard epidemiological investigations, and the outbreaks resulted from inadequate personal hygiene and food hygiene practices. However, the etiologic agent of outbreak #3 was not found because no appropriate samples were available at the time of the investigation. After evidence-based control measures were applied (e.g., withdrawal of the fresh milk from the market for outbreak #1, corrective measures to establishments violating regulations, and training on food safety for outbreaks #2, 3, and 4), no new cases related to the implicated foods were reported.

While investigating the foodborne outbreaks, we identified that public health surveillance systems for food safety were mainly based on foodborne outbreak reporting, with no systematic notifiable disease reporting or disease outbreak detection systems in place. Another key finding was that public health officials generally had poor capacity to respond to foodborne outbreaks at the provincial or district levels, though they had received training on foodborne outbreak investigations.

The KAP of food-handlers were rather poor, although almost all participants had received annual food safety training, particularly employees working in factories in industrial zones in Southern Vietnam.

## 8. Recommendations

A lack of systematic disease outbreak detection systems results in delays in detecting foodborne outbreak, and subsequent delays in responding to outbreaks. In resource-poor settings with limited laboratory capacities, syndromic surveillance system could be developed based on existing notifiable disease reporting for infectious diseases. To shorten delays in outbreak detection and to detect unknown, new, or emerging agents, notification/complaint systems should be available to receive calls from the public.

The application of standard epidemiologic methods is critical for responding to outbreaks in resource-poor settings. However, we found that suboptimal command of principles of outbreak investigations and outdated teaching methods are the main gaps and shortcomings preventing improved response capacity to FBD. Field Epidemiology Training Programs are therefore relevant to epidemiologists and public health practitioners in Vietnam. The Vietnam Field Epidemiology Training Program of the Ministry of Health, in collaboration with the Ministry of Agriculture and Rural Development, should develop a strategy and plan to train outbreak response team members at all administrative levels, with the goal of dealing with common public health concerns and making at least one trained field epidemiologist available per 200,000 people and one trained veterinarian available per 500,000 people (Centers for Disease Control and Prevention, 2014).

Many foodborne outbreaks are to some degree related to inadequate KAP of food-handlers. From the findings of Study V, we observe that educational efforts, together with supportive supervision conducted by managers, have great potential to improve food-handlers' KAP and to enforce the application of their training in practice.

Finally, studies in this thesis comprise the first Vietnamese epidemiologic foodborne outbreak investigations, led by local investigators and published in peer-reviewed international journals. Our studies provide lessons from the field and highlight good practices in systematic investigation and analytic study design.

Based on the findings of the foodborne outbreak investigations, we recommend that studies be conducted on factors contributing to foodborne outbreaks and

food preparation. Findings from such studies may identify areas in need of improvement in FBD surveillance systems and may generate lessons learned to support the effective development of training courses for public health professionals and food-handlers.

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## Original publications

# Acute Allergic Reactions in Vietnamese Children After Drinking a New Milk Product

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## Abstract

In early October 2009, pediatricians in hospitals in Ho Chi Minh City (HCMC) reported an unusual increase in the number of children presenting with an acute onset of itchy rash and some with breathing difficulties shortly after drinking milk products. The pediatricians considered the illness to be an allergic reaction to milk. The objective of our investigation was to identify the cause of this acute illness. Following early case reports, all hospitals in HCMC were requested to report cases of this illness. Parents were advised to take children with symptoms to a hospital immediately. A case-series was conducted to generate hypotheses on the possible causes of the illness and was followed by a case-control study to test the hypothesis. Parents of all cases and controls were interviewed face-to-face. The association between food items and the allergy was tested using conditional logistics regression. From 9 to 28 October 2009, 19 cases fulfilled the case definition, and 16 of the 17 cases included in the study had consumed milk supplemented with galacto-oligosaccharides (GOS) shortly before the onset of illness. Fifty age-matched, neighborhood controls were enrolled into the case control study. Of the 30 food items consumed by study participants in the preceding 24 h, only the odds ratio (OR) of milk supplemented with GOS was statistically significant: OR = 34.0 (95% CI = 3.9, 294.8). Laboratory tests of this milk product did not reveal any unusual properties, chemicals, or other toxic substances. This is the first report of an acute allergic reaction to fresh milk supplemented with GOS. However, the specific allergen in this product was not identified. Further cases were not reported once this product was withdrawn from sale. Vietnam's food safety authorities should expand laboratory capacity to detect allergens in food products.

## Introduction

IN SEPTEMBER 2009, a new, fresh milk product supplemented with galacto-oligosaccharides (GOS) was marketed across Vietnam by a multinational company. The following month, hospital-based pediatricians in Ho Chi Minh City (HCMC) reported a sudden increase in the number of children who presented with allergic skin reactions and some with breathing difficulties; the increase was well beyond the two to four children expected each month at the hospitals with similar reactions. Because the illness appeared shortly after drinking milk, the pediatricians considered the illness was probably caused by a milk product. Between 9 and 28 October 2009, 15 cases were reported by two children's hospitals to the HCMC Department of Health. Approximately 3 million cartons of this milk product were sold across Vietnam each day.

Our study was conducted to identify the extent of illness following consumption of this product among children at-

tending hospitals in HCMC, and to identify the cause and risk factors for the illness.

## Methods

In order to generate a hypothesis on the cause of the illness, a case-series was conducted on patients attending hospitals in HCMC with acute skin reactions and/or unexplained breathing difficulties. This hypothesis was then tested through a case-control study. As no adults had been identified with unexplained allergic reactions from any of the hospitals, the study focused only on children.

### *Case ascertainment*

From 21 October to 15 November 2009, health authorities in HCMC informed the community repeatedly of the outbreak of allergic reactions and advised parents to take children with symptoms to a hospital immediately. This message was announced through radio, television, and newspapers, and no

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reference was made to any suspected causes of the illness or to the milk products that were suspected as a possible cause by the pediatricians. All hospitals in HCMC were informed of the outbreak and of the media announcements. They were requested to report cases immediately to the Institute of Hygiene and Public Health (IHPH) by fax or phone, and to submit a daily report of "zero cases" if no cases were seen; reporting was continued until 31 March 2010.

#### Case definition

A case was defined as a child who attended a hospital in HCMC with acute onset of a skin rash and/or other allergic reactions as diagnosed by the clinician from 9 October 2009 onward.

#### Data collection

Parents of children fulfilling the case definition were interviewed face-to-face at their home by using a structured questionnaire. Both parents were interviewed on the same day whenever possible, up to 2 weeks after the onset of illness. Parents were shown calendars to help them recall the dates the milk had been consumed, as well as photos of different milk containers to identify the milk products consumed in their household. Questions included demographic details, past history of allergy in the patient or family member, food items consumed in the 24 h before onset of illness, the time of onset of symptoms, the nature and duration of symptoms, and time of attendance at hospital. By the time of the home visit, none of the families had samples of the milk product available for laboratory testing.

Details of the symptoms, signs, and clinical diagnosis as recorded by the attending doctor, and the treatment and response to the treatment were transcribed from hospital records. Based on the descriptive data from the cases, consumption of milk supplemented with GOS was implicated consistently in almost all cases. A case-control study was designed to confirm this result and to identify if any other specific food items may have been associated with the illness.

Control subjects were either two or three age-matched ( $\pm 1$  year) healthy children who lived in the immediate neighborhood of the case-patient; they were identified by the head of the local Health Posts where the case resided. Informed consent was then obtained from parents prior to participation in the study.

#### Analysis of milk samples

The milk containing GOS was obtained from shops and supermarkets in the neighborhood of the cases and tested by the Regional Center for Food Safety Testing of IHPH for the following chemicals and properties: physicochemical norms (carbohydrate, lipid, protein, vitamins A and B1, pH, density); metals (antimony, arsenic, cadmium, lead, bronze, zinc, mercury); aflatoxins B1, B2, G1, G2, M1; antibiotics (tetracycline, oxy-tetracycline, chlor-tetracycline, ampicillin, chlor-amphenicol); and bacteria (total aerobic bacteria, coliform bacteria, *Escherichia coli*, *Staphylococcus aureus*, *Salmonella species*, *Listeria monocytogenes*). The laboratory methods were based on Vietnam Food Safety Standards (TCVN 7028:2009) and Association of Official Analytical Chemists International standards for sterilized fresh milk (Horwitz *et al.*, 2005, Vietnam Food Safety Standards, 2009). The Netherlands Organisation for Applied Scientific Research tested the milk for the following allergens: peanuts, egg, fish, soy, shellfish, sulphite, gluten, and histamine.

#### Statistical analysis

Data were analyzed by Stata 11 software. Matched odds ratio (OR) and 95% confidence intervals (CI) were calculated for the consumption of 30 food items by univariate analysis. We used conditional logistic regression for items with a significantly elevated OR in order to assess the confounding effect of the GOS-supplemented milk.

## Results

#### Descriptive epidemiology

From 9 to 28 October 2009, we identified 19 cases through our investigation at the hospitals; this was four more cases than had been reported to the HCMC Department of Health. One case could not be located, and the parents of another case refused to participate in the study. The cases resided in nine of the 24 districts of HCMC, were aged 2–15 years, with a median of 10 years, and had attended one of the two pediatric hospitals. Figure 1 shows the 17 cases by date of onset of illness.

Four cases had a past history of allergy to various food items, but not to milk. Twelve of 15 cases had onset of symptoms within 3–20 min of drinking milk containing GOS, while onset in the remaining three cases was at 1, 6, and 49 h after consuming the milk, resulting in a median of 5 min. The

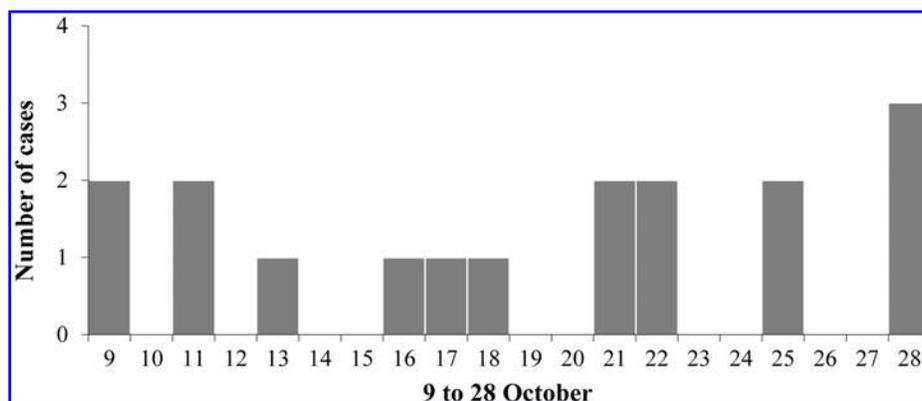


FIG. 1. Number of children ( $n = 17$ ) with allergic reactions by date of onset, October 2009, Ho Chi Minh City, Vietnam.

TABLE 1. AGE AND SEX DISTRIBUTION OF CASES AND CONTROLS

	Cases (17)	Controls (50)	P
Age (Years)			
Range	2–15	1–15	p=0.98
Median	10	9	
Sex			
Male	12 (71%)	26 (52%)	p=0.18
Female	05 (29%)	24 (48%)	

most frequent symptom was an itchy maculo-papular skin rash (94%), mainly affecting the eyelids, face, and limbs. Eleven cases attended hospital 5–90 min after onset, and the others >90 min after onset, with a maximal delay of 47 h.

Three children had acute breathing difficulties and attended hospital at approximately 5, 20, and 90 min after onset; they were treated with adrenaline, steroids, and salbutamol at the hospital. They did not require assisted ventilation, recovered within 30 min of treatment, and were monitored in hospital for 8 h to 2 days. The remaining 14 cases recovered within 15–30 min after treatment with antihistamines (chlorpheniramine, loratadine, promethazine), and were discharged within 1 h of arrival. Fifteen cases were given corticosteroids (metasulfobenzate prednisone, methylprednisolone, hydrocortisone, and prednisone), and seven cases were given a beta-2 adrenergic agonist (salbutamol).

As 16 of the 17 cases had consumed milk containing GOS, the case control study was conducted to assess whether GOS and/or other food items had caused the illness.

#### Case-control study

The age and sex distribution of the cases and 50 neighborhood controls were similar (Table 1). Of the 30 food/drink items consumed by study participants, the milk supplemented with GOS was highly significant on univariate analysis: OR=34.0 (95% CI 3.9, 294.8) (Table 2). Sixteen of the 17 cases had consumed the milk before the illness. The only case who did not drink this milk product had similar symptoms and signs as the other 16 cases, did not have breathing difficulties, and responded immediately to treatment; he did not have a past history or family history of allergies. The OR for the 100% milk product from the same company B that was not supplemented with GOS was also statistically significant (Table 2). After adjusting the OR of the pure milk product for

the confounding effects of the GOS-supplemented milk, the OR was no longer statistically significant (adjusted OR 1.8; 95% CI 0.2, 17.3). Table 2 shows the OR for the milk products only, because the results for all other food items were statistically not significant (not shown).

The laboratory tests on the milk containing GOS did not reveal any unusual properties, allergens, chemicals, or other toxic substances.

When the results of this study were confirmed on 28 October 2009, the GOS-containing milk was withdrawn immediately from the market across Vietnam. Surveillance for more cases was continued at the hospitals in HCMC until the end of March 2010, but no new cases were reported.

#### Discussion

Drinking the fresh milk product supplemented with GOS was strongly associated with the allergic reaction; only one of the 17 symptomatic children did not drink the milk before the illness. Milk samples were not available from any of the case households, and the specific allergen was not identified from the product obtained from shops and supermarkets in the neighbourhood of the cases. However, the strength of association between exposure and outcome, the temporal relationship between the time of drinking the milk and onset of symptoms, and the absence of any further cases once the product was withdrawn from the market implicates the GOS-supplemented milk as the cause of the outbreak. This was the first time the company had ever used GOS at its factory in Vietnam, and GOS was not added to any of its other products.

We were unable to identify the specific allergen in the milk product or to confirm whether the GOS constituent was implicated. It is possible that another constituent such as a new allergen, a side product of the metabolic process, an alien protein absorbed with GOS, or a contaminant from the manufacturing process may have caused the illness.

The major limitation of the study was that it was limited to symptomatic children attending hospitals in HCMC, suggesting that only those with more severe symptoms were likely to have been included. Consequently, the true extent of the outbreak across HCMC and across Vietnam was not determined. We cannot explain why cases were not reported from other towns and cities across Vietnam; it is possible that only batches of the milk distributed in HCMC had been contaminated, or perhaps surveillance in other emergency health services was not as sensitive as in HCMC. However, we could not verify either possibility. To minimize measurement bias, we

TABLE 2. ODD RATIOS OF ASSOCIATION BETWEEN MILK PRODUCTS AND ILLNESS ON UNIVARIATE ANALYSIS

Milk products	Cases (n=17)	Controls (n=50)	Matched OR	Matched 95% CI
Fresh milk supplemented GOS, Company B	16	14	34.0	3.9, 294.8
100% pure fresh milk, Company B	11	21	5.5	1.0, 29.5
100% pure fresh milk, Company C	13	23	3.4	0.6, 18.1
Pasteurized milk, Company D	4	7	2.3	0.4, 14.5
Fresh milk, milk, Company A	4	10	1.7	0.3, 8.6
Milk product, Company, G	4	7	0.9	0.2, 4.3
Milk product, Company E	1	2	4.3e+13	0
Milk product, Company F	0	1	—	—
Other milk products	3	16	0.6	0.1, 4.3

OR, odds ratio; CI, confidence interval; GOS, galacto-oligosaccharides.

used a calendar to help parents recall consumption of the milk and used photos of different milk containers to help parents identify the milk product consumed.

GOS is a non-digestible carbohydrate that reaches the colon and promotes the growth of a limited number of indigenous bacteria. We were unable to locate literature reports of allergic reactions to GOS in humans. GOS appears effective in reducing allergy in mice (Schouten *et al.*, 2009). However, its beneficial effects of reducing the incidence of allergy (Kukkonen *et al.*, 2007) as well as preventing allergy in humans (Heine and Tang, 2008; Kuitunen *et al.*, 2009; Prescott and Björkstén, 2007) are debated in the literature (del Giudice and Brunese, 2008). Furthermore, its safety in humans has not been assessed systematically and is based mainly on testing GOS-supplemented products released in the market (Vandenplas, 2007).

### Conclusion

To our knowledge, this is the first report of an allergic reaction to fresh milk supplemented with GOS. However, we were unable to identify the specific allergen in the milk product. This study highlights the importance of reminding clinicians to report any unusual health events in their patient population in order to enable prompt public health responses and the collection of suspected food samples for testing. Vietnam's food safety authorities should expand their laboratory capacity for detecting allergens in food products.

### Acknowledgments

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### Disclosure Statement

No competing financial interests exist.

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## **A cluster of cholera among patients in a Vietnamese district hospital in 2010**

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### **Abstract**

On July 20, 2010, three cases of cholera were reported from a district hospital in Ca Mau province, Vietnam. We investigated the likely source and mode of transmission of the outbreak. All hospitals in the province were requested to notify cases of acute watery diarrhoea. Epidemiological, clinical, and laboratory data were collected. Between July 12 and 22, seven cases with positive culture for *Vibrio cholera* were identified. Six cases were epidemiologically linked to the index case. Basic infection control practices were not in place at the hospital. Clinicians and public health staff should consider the possibility of nosocomial cholera transmission even in non-endemic areas.

**Key words:** Cholera; outbreak; diarrhoea; infection control

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### **Introduction**

Cholera re-emerged in the northern provinces of Vietnam in 2007. It spread throughout the country including the southern provinces, a lowland region with entangled canals. On July 20, 2010, a district hospital reported three cases of cholera to Ca Mau Provincial Preventive Medicine Centre (PMC). Cholera had not been reported in the province for the past 10 years. As local residents generally use water from canals around their homes and dispose human waste into these canals, public health officials were concerned about the potential risk of high morbidity and mortality in the population. We conducted an investigation on July 22, 2010, to identify the likely source and mode of transmission of the outbreak.

### **Methodology**

According to provincial health statistics in 2010, the population of the district was 88,461, with 19,150 households; the proportion using safe drinking water was estimated to be 20% to 30%.

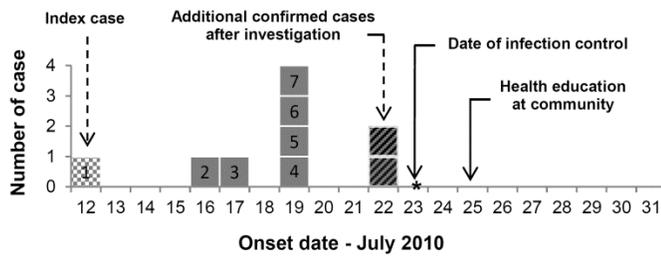
A case was defined as a resident of the district of any age with acute watery diarrhoea and positive culture for *Vibrio cholera* between July 12 and 22, 2010. Following the initial report, all hospitals in the province were requested to notify the PMC of any

cases of acute watery diarrhoea. Faecal specimens were sent to provincial and regional laboratories for culture. Cultures were obtained using Thiosulphate, citrate, bile salts, and sucrose agar. Patients or parents of children meeting the case definition were interviewed at the hospital within one week of illness onset. A standard questionnaire was used in the interviews. The patients or the children's parents were shown calendars to help them recall the dates that specific food items were consumed. Information obtained from hospital records and interviews of patients and their parents included demographics; clinical symptoms; food items consumed in the three days before the onset of diarrhoea; water sources used for drinking and other activities; knowledge and practices on diarrhoea disease prevention; and personal and food hygiene practices. Details of clinical symptoms, signs, diagnoses, and treatments were transcribed from hospital records. Water samples were taken from the hospital and from patients' households.

### **Results**

Between July 12 and 22, seven cholera cases were identified through hospital investigations. Six cases were from the same village; five were males whose ages ranged from seven days to 72 years; the median

**Figure 1:** Culture-confirmed cholera patients by date of onset, July 2010, Ca Mau, Vietnam



\*No more cases identified by surveillance until 21 days from the last case

age was two years. All cases had a positive culture for *Vibrio cholera* O1, biotype El Tor, serotype Ogawa. Figure 1 shows the culture-confirmed cases by date of illness onset. Four cases were admitted to the hospital between three and 18 hours of the onset of illness. All cases admitted to the hospital had severe watery diarrhoea, and four cases had vomiting. No cases were fatal. Medications for the seven cases included rehydration (Ringer’s lactate in seven cases; oral rehydration salts solution in five cases), antibiotics (erythromycin in five cases; cefuroxime in one case; gentamycin in one case), probiotics (four cases), and smectites for intestinal adsorbent (four cases).

The index case had not been identified or treated as a cholera case at the hospital until the laboratory test results were received four days later. Hospital infection control was implemented four days after admission of the index case, but basic infection control practices still did not comply with guidelines of the Ministry of Health (MOH) at the time of investigation [1]. Particularly, the entrance and exit to the isolation area were not restricted; hand-washing bowls, carpet, and gowns were not present in front of the isolation room’s door; a chlorine solution to wipe the isolation room’s floor was below the required minimum chlorine concentration; door handles were not cleaned; hospital bed sheets were not changed regularly; dirty

clothes of patients were left in the corner of the room; and the bathroom in this room was far below the minimum hygiene standards [1].

Six cases were epidemiologically linked to the index case. Their severe watery diarrhoea began four to seven days after that of the index case. Of the six secondary cases, three cases were acquired at the hospital; one was a seven-day-old newborn sharing the hospital room with the index case, two were inpatients in the same ward and shared home-prepared food with the index case, and three were relatives of and shared the same caregivers with the index case. Two additional cases confirmed after the investigation were relatives of case three and case five. They had visited the cases at the hospital. Ciprofloxacin (500 mg x 2) was administered to close contacts of the cases only after the index case had been confirmed. Table 1 shows demographic, clinical, and epidemiologic characteristics of the cholera patients.

No suspected foods items (e.g., seafood, ice cubes, raw vegetables) were identified in the epidemiologic investigation. Drinking water was taken from drilled wells within a 300-metre distance of patients’ residences. Water was transported by hand and/or boats in open plastic 10- to 20- litre containers and stored in 50- to 100-litre jars at the households. The water was chlorinated inappropriately, though the water chlorination was guided by health workers. Patients and their family members had not boiled the drinking water before the illnesses occurred. Water for other daily activities was taken from canals, which are directly linked to the residents’ water latrines; the latrines were situated above the residents’ fish ponds. Also, other waste was thrown into the canals. Caregivers had poor knowledge and practices of personal and food hygiene, no knowledge about hand washing when needed or about preparing, consuming, and storing safe drinking water and foods. The caregivers also had inadequate knowledge about prevention measures for diarrhoeal diseases; they

**Table 1:** Demographic and epidemiologic data for seven cholera patients in Ca Mau, Viet Nam, 2010

Case No.	Age/gender	Onset date (2010)	Admission date (2010)	Contact to the index case	Shared caregiver with	Condition of previous admission
1*	3 years/male	12/7	13/7	n/a	n/a	-
2**	7 days/female	16/7	09/7	Yes	-	Delivery
3	3 years/female	17/7	17/7	No	Case 1	-
4	72 years/male	19/7	06/7	Yes	-	Gastritis
5	1 years /male	19/7	20/7	No	Case 1	-
6	6 years /male	19/7	10/7	Yes	Case 2	Asthma
7	1 years /male	19/7	19/7	No	Case 1	-

\*Case 1 and 5 were brothers; case 3 and 7 were siblings; all four were cousins

\*\*Case 2, 4 and 6 are relatives; case 2 and 6 lived in same house and were cared for by the same grandmother

believed that chemoprophylaxis and vaccination were the best ways to prevent diarrhoea and did not know that diarrhoea diseases can be prevented by hand washing, consuming thoroughly cooked food items, and safe disposal of human excreta. No cholera was identified from water samples taken at the hospital or patients' households.

## Discussion

Our study identified three main reasons for the spread of cholera at the hospital. First, inappropriate hospital infection control was likely the key failure. Since cholera had not been reported in the province during the past 10 years, health professionals may no longer consider cholera as a possible cause of diarrhoea. Second, educational messages for the population at risk were ineffective in reducing the risk of infection in close contacts. Third, steps for standard outbreak investigations or World Health Organization (WHO) cholera control and prevention guidelines were not followed appropriately at the hospital [2]. Moreover, antibiotics, smectites, or probiotics are not recommended in the guidelines of MOH [1] or WHO for the treatment of cholera, as the clinical benefit is very small [3].

Standard hospital infection control measures should be implemented immediately at hospitals once cholera is reported in the community [4], even when a single patient is admitted with watery diarrhoea and symptoms compatible with cholera [5]. Close contact with cholera patients may result in infection [6]. Poor hygiene practices are known risk factors [7], so infected caregivers may transmit cholera to children in their households. Although antibiotics may reduce the infection risk among inpatients [8], two inpatients at the hospital did not receive any antibiotics before contracting cholera. Furthermore, health education during outbreaks could be effective in the control of cholera [9]. Health education messages should focus on water treatment and avoiding contamination during distribution and storage of water at home [7].

Although our study focused only in one hospital, the findings are applicable to the control and prevention of cholera elsewhere in Vietnam. Bias was minimized as the investigators were trained and calendars were used to minimize recall bias. However, delayed response was a limitation of the study. In fact, faecal samples of close contacts could not be tested because they had already received chemoprophylaxis. Negative results of cholera in environmental samples could be due to sub-optimal methods for detection of

cholera in water environments and chlorinated households' water.

Based on the findings of this study, public health actions were immediately implemented. Extensive control measures were implemented at the hospital, and operational communications in the community on cholera control and prevention were deployed. No new cases were reported after the control measures at the hospital and in the community were implemented.

This cluster of cholera resulted from inappropriate hospital infection control and inadequate personal hygiene and food hygiene practices. No new cases were reported after standard infection control measures were implemented at the hospital, emphasizing the critical role of hospitals in controlling cholera transmission. Clinicians and public health staff should be aware of the possibility of cholera in non-epidemic areas as well, so that case reporting, investigation, and responses can be done as soon as possible. Local health workers should be trained in the principles of field epidemiology, and laboratories should be equipped to collect and test environmental samples.

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**Conflict of interests:** No conflict of interests is declared.

## Research Note

# Applying Standard Epidemiological Methods for Investigating Foodborne Disease Outbreak in Resource-Poor Settings: Lessons from Vietnam

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## ABSTRACT

An outbreak of gastroenteritis occurred among workers of company X after eating lunch prepared by a catering service. Of 430 workers attending the meal, 56 were hospitalized with abdominal pain, diarrhea, vomiting, and nausea, according to the initial report. We conducted an investigation to identify the extent, vehicle, and source of the outbreak. In our case-control study, a case was a worker who attended the meal and who was hospitalized with acute gastroenteritis; controls were randomly selected from non-ill workers. Cases and controls were interviewed using a standard questionnaire. We used logistic regression to calculate adjusted odds ratios for the consumption of food items. Catering service facilities and food handlers working for the service were inspected. Food samples from the catering service were tested at reference laboratories. Of hospitalized cases, 54 fulfilled the case definition, but no stool specimens were collected for laboratory testing. Of four food items served during lunch, only “squash and pork soup” was significantly associated with gastroenteritis, with an adjusted odds ratio of 9.5 (95% CI 3.2, 27.7). The caterer did not separate cooked from raw foods but used the same counter for both. Cooked foods were kept at room temperature for about 4 h before serving. Four of 14 food handlers were not trained on basic food safety principles and did not have health certificates. Although no microbiological confirmation was obtained, our epidemiological investigation suggested that squash and pork soup caused the outbreak. Hospitals should be instructed to obtain stool specimens from patients with gastroenteritis. Food catering services should be educated in basic food safety measures.

On 10 July 2012, Tan Uyen Health Centre reported to the Food Safety Agency (FSA) of Binh Duong Province an outbreak of gastroenteritis among workers who had eaten lunch at a large canteen of company X. Meals had been provided by a food catering service. Of 430 workers attending the lunch, 56 were hospitalized with stomachache, diarrhea, nausea, and vomiting. This event halted all operations of a major manufacturing company. According to the initial report, the food catering service also provided meals for 65 workers of another company in a different industrial zone and, in addition, cooked at canteens of three other companies, providing meals for about 880 workers in different industrial zones. There had been no new cases reported from the abovementioned four companies at the time of this investigation. We conducted an investigation the same day to assess the extent of the outbreak, identify the vehicle and source, and initiate appropriate control measures.

## MATERIALS AND METHODS

Initial investigation of hospitalized patients suggested that the lunch served at the canteen on 9 July was likely responsible for the outbreak. A case-control design was used because information could be obtained from clearly identifiable exposure groups, whereas the entire population at risk was too large for a cohort design. The FSA informed workers who ate the implicated meal that they should visit the nearest hospital if they had any symptoms of stomachache, diarrhea, or vomiting. All hospitals were requested, if any patient with these symptoms presented, to notify the FSA immediately by telephone and written report.

A case was defined as a worker who attended the meal on 9 July, was admitted to any hospital in Binh Duong Province with diarrhea, stomachache, and/or vomiting and nausea, and was diagnosed with acute gastroenteritis by an attending doctor from 9 to 10 July 2012. Controls were randomly selected from the list of workers who attended the meal and did not have any symptoms. We aimed at enrolling 30% more controls than cases to compensate for lower participation.

The persons who met the case definition were interviewed face-to-face, using a questionnaire adapted from a standard questionnaire of the Ministry of Health. The menu was used to help patients to recall which food items they had eaten. The questionnaire included a list of the food items on the menu, onset time of symptoms,

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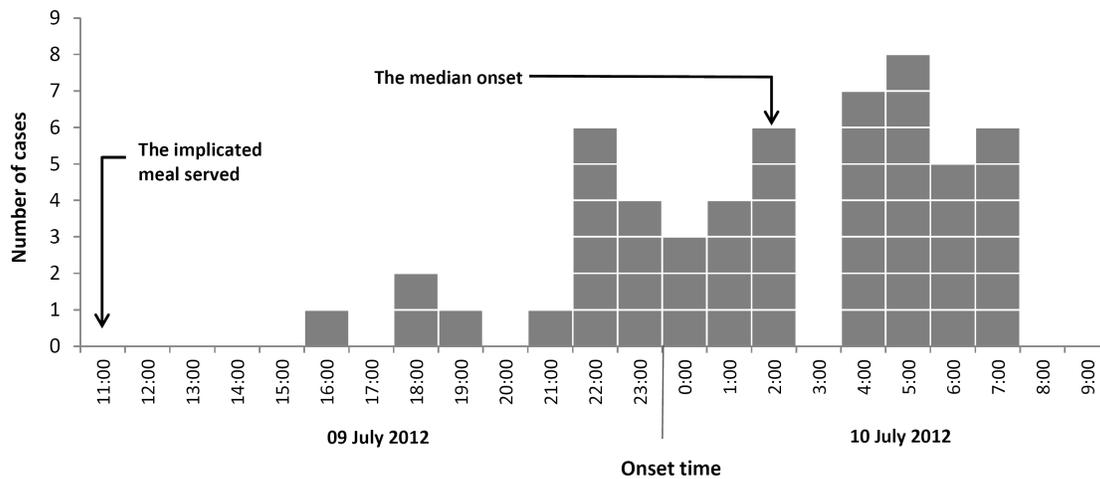


FIGURE 1. Number of cases ( $n=54$ ) with acute gastroenteritis by time of onset, July 2012, Binh Duong, Vietnam.

symptoms, and signs. Data on clinical signs and symptoms, diagnosis, and treatment were obtained from hospital records.

Food samples were collected from storage areas, put into sterile Inox boxes, and kept at 4°C. These samples were shipped to laboratories of the Institute of Hygiene and Public Health at Ho Chi Minh City for testing based on AOAC International–approved methods or Vietnam standards approved by ISO/IEC 17025.

To inspect sanitation conditions of the catering establishment, we observed the house foundation, ceiling, dustbins, soak basin, and measures taken to prevent animals and insects from entering. We also inspected the kitchen design, cleanliness of the restroom, hygiene of utensils, and storage conditions of raw and cooked foods. Origin of food products and methods of food preparation and storage were recorded. We reviewed food handlers' and servers' records for health checkups and training on food safety.

Data were analyzed by R-software (<http://CRAN.R-project.org>). Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for the consumption of four food items in univariate analysis. We used logistic regression for items with a significantly elevated OR ( $OR > 1$ ) to identify independent associations.

## RESULTS

**Descriptive epidemiology.** From 9 to 10 July 2012, we identified 56 cases of gastroenteritis at hospitals of Binh Duong, two of which did not meet the case definition. There were no fatal cases. Median age was 24.5 years (interquartile range 22, 28), and 33 (64%) of 54 cases were men. Figure 1 shows the 54 cases by time of onset of acute gastroenteritis.

These workers were previously healthy and did not have any symptoms of gastrointestinal disorder within the 7 days before hospitalization. All cases had lunch at the canteen of company X at 1130 h on 9 July 2012. The four lunch menu selections were omelet, braised pork with pickled cabbages, squash and pork soup, or water spinach

with garlic sauce, along with bottled water. Onset time of symptoms ranged from 5 to 21 h after the meal (median, 14.5 h). Most cases (93%) had onset of symptoms about 9.5 h after the implicated meal.

Major symptoms upon hospitalization were stomachache (100%), diarrhea (96%), nausea (39%), and vomiting (35%). Vital signs of all patients were within normal ranges. Medications for the 54 cases included rehydration solutions (Ringer's lactate or oral rehydration salts solution), antibiotics (ciprofloxacin, 500 mg), probiotics (Probio), and antispasm or antiemetic drugs (Domperidone). All patients recovered after the treatment. By 1730 h on 10 July 2012, 37 cases had been discharged, and the last case was discharged at 2200 h on the same date.

**Case-control study.** The age and gender distribution of cases and controls were similar. Of the four food items consumed by study subjects, the squash and pork soup had the highest significant OR in univariate analysis: 12.3 (95% CI 4.4, 34.3). The OR for the omelet was also statistically significant, with  $OR = 3.8$  (95% CI 1.8, 7.9). Braised pork with pickled cabbages was not associated with gastroenteritis (Table 1).

After adjusting the OR of omelet for the confounding effects of squash and pork soup in a logistic regression model, the OR of omelet was no longer statistically significant (adjusted OR 1.9; 95% CI 0.8, 4.5), whereas the OR of squash and pork soup remained statistically significant (adjusted OR 9.5; 95% CI 3.2, 27.7) (Table 1).

**Other results.** Patient specimens were not available because they were not collected at the hospitals. Patients had also been treated with antibiotics before we conducted the investigation. Food samples collected from storage areas consisted of squash and pork soup (250 ml), braised pork

TABLE 1. Univariate and adjusted odds ratios for the association between food items and acute gastroenteritis

Food items	Cases ( $n = 54$ )	Controls ( $n = 72$ )	Crude OR (95% CI)	Adjusted OR (95% CI)
Squash and pork soup	49	32	12.3 (4.4, 34.3)	9.5 (3.2, 27.7)
Omelet	36	25	3.8 (1.8, 7.9)	1.9 (0.8, 4.5)
Braised pork with pickled cabbages	3	20	0.2 (0.0, 0.6)	
Water spinach with garlic sauce	22	37	0.7 (0.3, 1.3)	

with pickled cabbages (100 g), omelet (100 g), water spinach with garlic sauce (50 g), and steamed rice (100 g). According to government regulations on storing cooked foods at canteens, the minimum quantities required are 250 ml for liquid foods and 150 g for solid foods.

Based on our observations of the food preparation site and equipment, poor hygiene practices were in use in general. Dustbins were not covered and were surrounded by garbage. The soak basin water was stagnant. Insects were found in preparation and food storage areas. Utensils were not separated for cooked and raw foods. The same counter was used to prepare raw as well as cooked foods. Inadequate quantities of food samples were taken for storage shortly after cooking and stored in the food catering service.

After the food items were prepared in the catering establishment, they were shipped to company X to be served in the canteen to the workers. In addition, they were kept at room temperature for about 4 h before serving.

Fourteen food handlers were involved in preparing the implicated meal. Four (19%) of them had no health certificate and no training on food safety before they started working, whereas the remaining 10 food handlers passed their medical checkup on 3 July 2012. No food handler had any symptom of gastroenteritis at the time of investigation. Some food handlers smoked in the food preparation area and did not wear standard clothes.

The food catering service was closed until the poor hygienic conditions and preparation process were addressed. Food handlers and their managers were trained in food safety and principles of personal hygiene. In addition, managers were trained on how to keep cooked food at the appropriate temperature as well as how to supervise food handlers during their food preparation.

## DISCUSSION

Squash and pork soup was the only food item implicated in this outbreak by epidemiological investigation. Because the main symptoms were diarrhea and vomiting 5 to 21 h after the implicated meal, the outbreak was likely caused by preformed toxins or by enterotoxin production (5), suggesting *Clostridium perfringens*, *Bacillus cereus*, or *Staphylococcus aureus* as possible causative agents (1, 6, 7).

There was no laboratory confirmation of this outbreak because the hospitals did not take any stool specimens of patients for testing, even though they were hospitalized. In addition, patients had already been treated with antibiotics by the time of investigation. This outbreak illustrates the urgent need to develop and implement recommendations for hospitals to mandatorily obtain patient specimens for testing before giving antibiotics; this practice would strengthen surveillance and response to foodborne disease outbreaks in Vietnam. Hospitals should take at least 10 specimens from patients suffering from acute gastroenteritis before giving antibiotics (if any), so as to increase the likelihood of finding the causative agents (1, 7).

Food samples collected from the storage areas of the catering service were different from the food served to workers, which probably contributed to the negative culture finding. The

samples were stored at 5°C shortly after cooking, so bacteria could not develop and proliferate. For this reason, food samples should be stored at the point of serving. Although the recommendation that patient specimens should be obtained is obvious and should be considered, the shortage of laboratory capacity and human resources is a major challenge in developing countries, as illustrated by this outbreak (2). Culture-independent diagnostic tests, although potentially useful, cannot currently be recommended in our setting because of limited financial and human capacity. Although the causative agent of this outbreak was not found, we identified the source and vehicle through standard epidemiological investigations. The validity and reliability of our findings was increased by rapid data collection after the occurrence of the outbreak, using only confirmed cases and randomly selected controls. Therefore, capacity building to train health personnel in sound epidemiological investigation methods is critical to prevent and control foodborne disease outbreaks in resource-poor settings of developing countries, where laboratories are not available or testing results may not be obtained in a timely manner.

The observed personal hygiene practices among food handlers were poor, and hand washing facilities did not have paper towels or driers. In addition, in the preparation of the squash and pork soup, fresh leaves of onion and cilantro were added after cooking, and the soup was kept at room temperature for about 4 h before serving. These practices and conditions may have resulted in contamination and proliferation of bacteria in the food (3, 4).

This outbreak also emphasizes that foodborne diseases remain a significant public health and economic burden and may cause major economic losses in industrial zones in Vietnam. Manufacturing companies need to ensure that their food handlers are trained in personal hygiene practices and that food catering services either serve their cooked foods within 2 h after preparation (if foods are kept at room temperature) or else keep cooked foods at a safe temperature until serving.

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# An outbreak of food-borne salmonellosis linked to a bread takeaway shop in Ben Tre City, Vietnam



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## SUMMARY

**Objectives:** To identify the vehicle, source, and causative agent of a community-wide food-borne outbreak of gastroenteritis.

**Methods:** We conducted a case–control study. Cases were city residents diagnosed with gastroenteritis and hospitalized in Ben Tre City from 22 to 25 May 2013; 41 cases were selected randomly from a list of hospitalized patients. Controls were age- and gender-matched healthy neighbours of cases. Participants were interviewed using a standard questionnaire. Samples from patients and food were tested at reference laboratories. We used conditional logistic regression to calculate matched odds ratios (mORs) for the association of gastroenteritis with food items consumed.

**Results:** Of the 41 cases enrolled in the study, 61% were males and the median age was 33 years; cases resided in 12 wards of the City. Of 13 food items consumed by the cases, only stuffed bread was significantly associated with gastroenteritis (mOR 21.3, 95% confidence interval 6.3–71.8). Among the 29 cases who ate stuffed bread, the median time to illness onset was 9 h. Patient stool samples and bread samples were positive for *Salmonella* species.

**Conclusions:** Stuffed bread was the likely vehicle of the outbreak. The laboratory testing capacity for serotypes of *Salmonella* should be strengthened in Vietnam. Food-handler training in basic food safety measures should be improved.

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## 1. Introduction

Food safety is an important public health concern in Vietnam. In 2013, the media repeatedly reported that dozens to hundreds of people had been hospitalized with acute gastroenteritis due to the consumption of stuffed bread across the country.<sup>1</sup>

On May 23, 2013, two cases of acute gastroenteritis occurring shortly after the consumption of stuffed bread from a food stand were reported by a provincial hospital of Ben Tre City to the Ben Tre Food Safety Agency (FSA). The number of cases admitted to the hospital increased sharply to more than 150 by May 24, 2013. After preliminary investigations, the FSA suspected that stuffed bread

sold at the food stand was associated with the outbreak. As the food stand sold more than 1000 bread items daily, the FSA requested that the business close pending further investigations.

On May 27, 2013 the FSA requested further technical support from the regional Institute of Hygiene and Public Health to investigate the outbreak. We conducted an investigation to identify the vehicle, source, causative agents, and risk factors associated with the outbreak, and to make recommendations to prevent similar outbreaks.

## 2. Methods

According to baseline surveillance of notifiable diseases, 7–12 cases of gastroenteritis per month had been attended to at health centres and/or hospitals in the city during the 3 months prior to the

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outbreak. Initial interviews with 12 patients hospitalized with fever, diarrhoea, abdominal pain, vomiting and/or nausea at Ben Tre City suggested that the bread sold at the food stand may have been linked with the illness. To confirm the association and to identify the vehicle and risk factors linked to the outbreak, we conducted a matched case–control study.

**Case finding:** Local health authorities informed the communities in Ben Tre City and advised those with symptoms of gastroenteritis to visit a health centre or hospital. All health centres/hospitals were requested to report any patients with these symptoms immediately to the FSA by telephone and written report. A list of 173 patients (no fatal cases) attending six health centres/hospitals from 22 to 25 May 2013 was obtained from the FSA.

**Case definition:** A case was a resident of Ben Tre City who had attended a local health centre/hospital with fever, diarrhoea, and abdominal pain, and was diagnosed with gastroenteritis by a clinician between 22 and 25 May 2013.

**Neighbourhood controls** were used: one healthy control subject (no symptoms of gastroenteritis in the past 7 days), matched for gender and age ( $\pm 1$  year), who lived in the same community as the case. Neighbourhood controls were identified by staff at the local health centre of the case.

Among 163 cases who met the case definition, 41 were selected randomly from the list of gastroenteritis patients admitted to one of the six hospitals using random numbers created by R software. Cases and controls were interviewed face-to-face using a standard questionnaire collecting details of 13 food items consumed by the cases in the 24 h before illness onset. Clinical, diagnosis, and treatment information was obtained from the hospital records. Data on food items consumed by controls were collected for the same time period as for the matched case. Informed consent was obtained from all study participants. As this was a public health response to an outbreak, no institutional review was required.

Data were analyzed using R software (Epi and survival packages). We used conditional logistic regression to calculate matched odds ratios (mORs) and 95% confidence intervals (CIs) for the consumption of the 13 food items.

Food samples, including ingredients of the bread, were taken by the FSA from the food stand on May 23, 2013, put into sterile boxes, and kept at 4 °C. Sixteen stool samples were collected from hospitalized patients. All samples were shipped to the provincial and regional reference laboratories for testing of the following: *Salmonella* species, *Escherichia coli*, *Bacillus cereus*, *Clostridium perfringens*, and *Staphylococcus aureus*. The laboratory methods were based on the Vietnam Food Safety Standards (approved by ISO/IEC 17025) and the Association of Official Analytical Chemists international standards for food items.<sup>2,3</sup> Cultures were obtained using Hektoen enteric medium, xylose lysine deoxycholate agar, and eosin methylene blue agar.

We inspected the sanitary conditions at the three sites where the bread ingredients were processed, including the kitchen layout, restroom conditions, and hygiene and storage conditions for raw and cooked foods. The origin of food products and the methods of food preparation and storage were recorded. We collected rectal swabs from the food-handlers and reviewed their health check-up and training on food safety records. They were also interviewed regarding knowledge and were observed for personal hygiene practices.

### 3. Results

#### 3.1. Descriptive epidemiology of the outbreak

Of the 41 cases enrolled in the study, 25 (61%) were males and the median age was 33 years (range 3–57 years). **Figure 1** shows the 41 cases by time of onset of acute gastroenteritis. The cases resided in 12 wards of Ben Tre City, distributed around the food stand. Twenty-nine (71%) cases who had consumed bread from the food stand had onset of symptoms within 5–23 h (median 9 h).

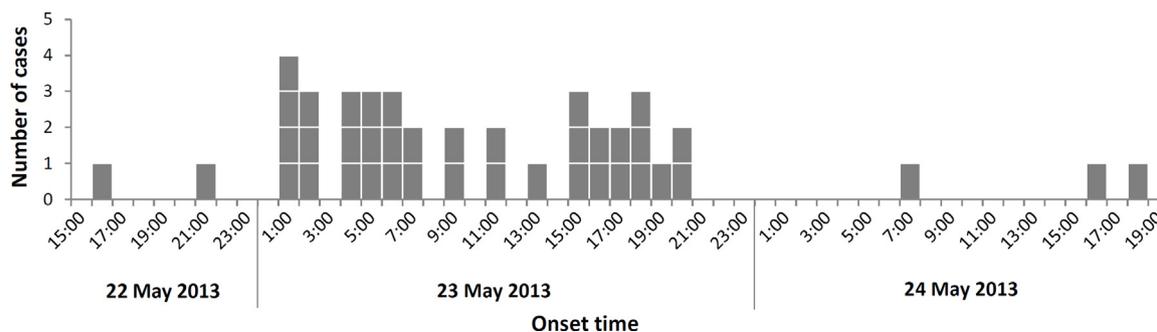
All cases were previously healthy and had not had any symptoms of gastrointestinal disorder within 7 days prior to hospitalization. Thirty-four (83%) cases had abdominal pain as the first symptom. Symptoms upon hospitalization were fever (100%), diarrhoea (100%), abdominal pain (100%), vomiting (76%), nausea (68%), headache (61%), myalgia (20%), and bloody diarrhoea (17%). Vital signs of all patients were within the normal ranges except for fever. The white blood cell count was elevated in most cases, and the median percentage of neutrophils was 83% (interquartile range 79–88%). All patients recovered after treatment. By 8:00 a.m. on May 30, 2013, all cases had been discharged uneventfully after 1–5 days of hospitalization (median 3 days).

#### 3.2. Case–control study

Cases had consumed 13 food items including two drinks. Of the 13 food items consumed by the study subjects, only the stuffed bread was significantly associated with gastroenteritis in the univariate analysis: 70.7% of the cases compared with 9.8% of controls reported eating stuffed bread (mOR 21.3, 95% CI 6.3–71.8). The 12 other food items were not associated with gastroenteritis (**Table 1**).

#### 3.3. Environmental and laboratory investigation

Bread ingredients included pork bologna, pork pate, salted and dried pork, and raw egg mayonnaise. Pork products were prepared at food preparation sites 1 and 2 (**Figure 2**). At food preparation site 3, raw chicken egg yolk was used to make mayonnaise.



**Figure 1.** Cases ( $n = 41$ ) with acute gastroenteritis by time of onset, May 2013, Ben Tre, Vietnam.

**Table 1**

Univariate matched odds ratios for the association between food items and gastroenteritis, May 2013, Ben Tre, Vietnam

Food items eaten	Cases (n=41)	Controls (n=41)	mOR	95% CI
Stuffed bread from food stand X	29 (70.7%)	4 (9.8%)	21.3	6.3–71.8
Iced-tea	8 (19.5%)	7 (17.1%)	1.2	0.4–3.6
Brined pork	17 (41.5%)	16 (39.0)	1.1	0.5–2.7
Brined goby	7 (17.1%)	7 (17.1%)	1.0	0.3–3.1
Sweet bread	1 (2.4%)	1 (2.4%)	1.0	0.1–16.3
Noodle without meats	1 (2.4%)	1 (2.4%)	1.0	0.1–16.3
Soya milk	3 (7.3%)	3 (7.3%)	1.0	0.2–5.2
Fresh vegetables	7 (17.1%)	10 (24.4%)	0.6	0.2–1.9
Vegetable soup with pork	14 (34.1%)	19 (43.6%)	0.6	0.3–1.5
Fried pork	3 (7.3%)	5 (12.2%)	0.6	0.1–2.6
Brined duck egg and pork	4 (9.8%)	8 (19.5%)	0.5	0.1–1.6
Noodle with meats	1 (2.4%)	9 (22.0%)	0.1	0.01–0.8
Coconut soup	1 (2.4%)	0 (0%)	-	-

mOR, matched odds ratio; CI, confidence interval.

Of the collected bread ingredients, 200 g each of pork bologna, pork pate, salted and dried pork, and raw egg mayonnaise all grew *Salmonella* species and *E. coli*. Of the 16 patient specimens collected, seven were positive for *Salmonella* species, but none for *E. coli*. Because the eggs used to prepare the mayonnaise were bought from many vendors in wet markets of the city, their origins could not be traced.

We observed poor hygiene practices at the three food preparation sites: insects were found and the kitchenware was not separated for cooked foods and raw foods. No food samples were stored after cooking at the preparation sites.

After bread ingredients were prepared, cooked foods were brought to preparation site 3 to make the bread and to sell to consumers. Cooked foods were kept at room temperature during serving and leftovers were stored at the end of each working section.

Eight food-handlers were involved in preparing the ingredients and the bread. Their rectal swabs were culture-negative for enteric bacterial pathogens. Six did not have any valid health certificates, and the health certificates of two had expired. No food-handler had a valid certificate for training in food safety, and their knowledge and practices of food safety, personal hygiene principles, and safe temperatures for cooked food were

poor. No food-handler had had symptoms of food-borne illness a week before the outbreak.

On May 24, the food stand was closed until the poor hygiene conditions and preparation processes were addressed. After closing, no new cases related to the stuffed bread were reported. Food-handlers were trained in food safety, personal hygiene principles, and safe temperatures for cooked food.

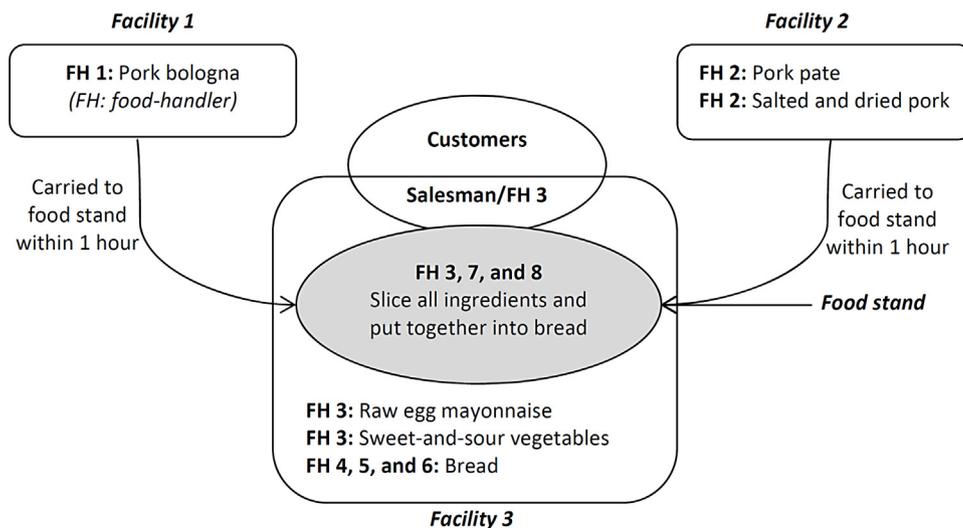
#### 4. Discussion

The results of our epidemiological investigation support the hypothesis that bread from the food stand was responsible for this outbreak. In addition, cases consuming the bread had clinical symptoms and laboratory findings compatible with salmonellosis. Seven out of 16 stool specimens as well as all four specimens of bread ingredients grew *Salmonella* species. Taken together, these findings suggest that *Salmonella* species was the likely aetiology of the outbreak.<sup>4–6</sup>

Food handlers did not have any symptoms of gastroenteritis and their rectal swabs were negative for *Salmonella*. Hence, the source of *Salmonella* could have been the food ingredients. Although the raw egg mayonnaise was positive for *Salmonella*, eggs were no longer available during the investigation of the food preparation sites and we could not trace the origin of the eggs. We could therefore not investigate whether the eggs were contaminated by *Salmonella*, but it is plausible that the source of *Salmonella* species was eggs.<sup>4,7</sup> Although there is no direct evidence, the preparation procedures for the raw egg mayonnaise (Figure 2) and poor personal hygiene practices of the food-handlers during bread preparation, suggest that the mayonnaise may have been contaminated by *Salmonella* species from raw eggs and subsequently cross-contaminated the other ingredients of the bread.<sup>4,7</sup>

*Salmonella* can survive the food preparation process<sup>8</sup> and even in mayonnaise kept at 4 °C.<sup>9</sup> In addition, *Salmonella* can grow faster at room temperature.<sup>4</sup> The fact that mayonnaise is a high fat product, which could reduce the infecting dose of *Salmonella*,<sup>4</sup> could explain the sharp increase in cases in a short time. *E. coli* bacteria found in the ingredients were likely a contaminant due to the poor personal hygiene of the food-handlers during bread preparation.

All case-control studies are susceptible to selection and information biases. To minimize these biases, we employed



**Figure 2.** Flow chart of preparation of stuffed bread at food stand X by food-handlers (FH).

unambiguous case and control definitions, trained the interviewers, and pre-tested the questionnaire. Also, food items consumed by controls were ascertained for the same time period as for the matched case. A major limitation of the study, however, was a delay in initiating the investigation, resulting in delayed identification of the vehicle and testing of suspected food items, including raw eggs. Another limitation was that serotyping of bacteria was not performed by laboratories because of the limited capabilities of provincial laboratories as well as a lack of knowledge and skills of local health workers in specimen collection during the investigation. Training in sound epidemiological investigation methods and laboratory capacities for health personnel are therefore critical in resource-poor settings.

Many outbreaks of food-borne illness from stuffed bread have occurred throughout Vietnam in recent years.<sup>1</sup> However, these outbreaks were investigated only by testing food items in the laboratory without epidemiological data to support the testing results. Our investigation highlights the application of standard approaches for outbreak investigation combining several lines of investigation (including epidemiological, clinical, laboratory, and environmental) to provide more comprehensive evidence.

This outbreak also illustrates the substantial economic losses to business resulting from food handlers' poor knowledge of hygiene and food safety practices. Therefore, health education for food-handlers and the enforcement of safe food-handling practices are critical for the prevention of similar outbreaks and to avoid the loss of income resulting from business closure and the need to compensate those affected for the consequences of food poisoning.<sup>10</sup>

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*Conflict of interest:* No conflict of interest to declare.

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# Knowledge, attitudes, practices and training needs of food-handlers in large canteens in Southern Vietnam



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## ABSTRACT

Frequent foodborne outbreaks occurring in large canteens of factories and schools are a public health concern in Vietnam. Potential for contamination of food during the preparation phase has not yet been addressed by public health authorities, particularly the food-handlers' knowledge, attitudes and practices (KAP) regarding food safety. To identify training needs, we conducted an analytical cross-sectional study assessing KAP of food-handlers in large canteens of schools and factories in 2012. From a sampling frame of 169 large canteens (50 in schools and 119 in factories; a total of 3399 employees) in Southern Vietnam, 40 schools and 26 factories were selected on the basis of type of establishment; all food-handlers (N = 909) in the selected canteens were interviewed by using standard questionnaire. After descriptive analysis, potential confounders were controlled by using logistic regression models to calculate prevalence odds ratios (PORs) and 95% confidence intervals (CI) for differences in KAP between employees in schools and factories. A qualitative study of ten focus groups with participants selected by using maximum variation sampling was also conducted to identify training needs. Of the 909 food-handlers participating the study, 76% were females, 84% had secondary school or higher education; median age and work experience were 38 years and 36 months, respectively. Proportions of all participants whose KAP were considered adequate were 26%, 36%, and 26%, respectively. There were associations between knowledge and attitudes, and knowledge and practices. After controlling for gender, age, educational level, and length of work experience in logistic regression models, the odds of food-handlers in schools reporting adequate KAP were about twice as high as those for food-handlers in factories. Among 66 investigated canteens, 9% did not separate raw food from cooked food area and 52% did not have standard rest rooms. Food-handlers' suggestions for training needs included appropriate location of the training venue at the work place, involvement of managers, fewer trainees per course, more practical exercises, and longer course duration. KAP of food-handlers were generally poor, especially among food-handlers working in factories. Public health authorities in Vietnam should prioritize food-handlers in factories for training courses.

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## 1. Introduction

Food safety is one of the major public health concerns in Vietnam. From 2007 to 2012, a total of 1095 foodborne outbreaks, 36,404 cases, 28,277 hospitalizations, and 266 deaths were reported to the Vietnam Food Administration (Vietnam Food

Administration, 2011). Many of these outbreaks occurred in large canteens of schools and factories in industrial zones. The proportion of outbreaks with 30 or more cases accounted for 28% of the total number of outbreaks and 81% of the total number of reported cases during 2007–2010.

Contamination of food can occur anywhere along the chain from production, processing, and preparation to consumption. National authorities have issued guidelines to reduce contamination during the production and processing phase, but potential for contamination during the preparation phase has not been specifically

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addressed, particularly in terms of the food-handlers' knowledge, attitudes and practices (KAP) about food safety. An observational study conducted in Ho Chi Minh City in 2007 showed that 95% of food-handlers in public kitchens had inadequate knowledge and 88% of the food-handlers had improper food safety practices (Nguyen, Nguyen, & Le, 2010). In addition, outbreaks were reported to occur more frequently in factories in industrial zones than in schools (National Institute of Nutrition – United Nations Children's Fund, 2011; Vietnam Food Administration, 2011). The objectives of the study were to evaluate the current KAP of food-handlers in large canteens, to compare the KAP of food-handlers working in schools with those in factories, and to identify training needs customized for food-handlers in schools and factories in Southern Vietnam.

## 2. Material and methods

In 2012, an analytical cross-sectional study was conducted to assess KAP of food-handlers working in large canteens (defined as those serving > 500 meals a day) in three provinces where the industrial zones of Southern Vietnam are located (Ho Chi Minh City, Binh Duong and Dong Nai provinces). From a pooled sampling frame of 169 large canteens, we stratified the large canteens into two groups: those in schools ( $n = 50$ ) and those in factories ( $n = 119$ ). A sample size of 444 food-handlers in each group was calculated by using the following parameters:  $p_1 = 0.6$ ,  $p_2 = 0.5$ ,  $\alpha = 0.05$ ,  $power = 0.8$ ,  $non-response\ rate = 10\%$  (Vietnam Food Administration, 2011). The required number of schools and factories was estimated by taking sample size of each group divided by its average number of food-handlers, resulting in 40 schools (444/11) and 26 factories (444/17). We then randomly selected 40 of 50 schools and 26 of 119 factories; all food-handlers in selected canteens were interviewed and their practices observed at the food-service establishments (McGinn, 2004).

The questionnaires were developed on the basis of current regulations and guidelines of the Ministry of Health (MOH) on food safety with adaptations from previous studies (Angelillo, Viggiani, Greco, & Rito, 2001; Askarian, Kabir, Aminbaig, Memish, & Jafari, 2004; Baş, Şafak Ersun, & Kivanç, 2006; Cuprasitrut, Srisorrachart, & Malai, 2011; Green et al., 2006; Lin & Sneed, 2003; Marais, Conradie, & Labadarios, 2008; Nee & Sani, 2011). The questionnaire had four parts. Part 1 collected demographic information. Part 2 included 19 questions on knowledge of foodborne diseases, personal hygiene, cross-contamination, cleanliness, safe raw materials and temperature control. Of the questions, 16 close-ended questions were scored from 0 to 1, and 3 multi-choice questions were scored from 0 to 3. Food-handlers who scored 50% or more of the maximum score (25) were considered to have adequate knowledge; a score of < 50% was considered inadequate knowledge. Part 3 included 10 likert scale questions on attitudes towards cleanliness, personal hygiene, raw and cooked food handling, safe raw materials and temperature control. These questions were graded from 1 (completely disagree) to 5 (completely agree). Food-handlers who received 60% or more of the maximum score (50) were considered to have appropriate attitudes towards food safety. In Part 4 trained members of the study team observed 14 practices regarding cleanliness, behaviors, personal hygiene and food hygiene. There were 11 close-ended question (scored from 0 to 1) and three multi-choice questions (scored from 0 to 3). Food-handlers who received 50% or more of the maximum score (20) were considered to have demonstrated adequate food safety practices.

The data collection tools were pre-tested and revised accordingly. All members of the study team were trained to obtain consistent interviewing standards. Data were processed daily to ensure completeness and internal consistency.

Data were analyzed by using R software (Epi, BMA and car packages). Frequencies and proportions were used to describe categorical variables and measures of central tendency were used to describe continuous variables. Prevalence ratios (PRs) and 95% confidence intervals (95% CI) were used to assess the relationships among KAP. Logistic regression models were used to calculate prevalence odds ratios (PORs) and 95% CI to assess differences in KAP between food-handlers in schools and factories. Model building and selection for KAP variables was based on Bayesian Model Average and variables which were known to be associated with KAP in previous studies (including gender, age, educational level and length of work experience). Goodness-of-fit of the models was assessed by Hosmer–Lemeshow test.

To obtain information about the training needs of food-handlers, ten focus group interviews were conducted with groups of 8–12 food-handlers. Maximum variation sampling was used to select food-handlers in each study setting who had different responsibilities in food handling. Qualitative data were coded and analyzed manually. Open coding, focused coding and axial coding were applied to analyze the data.

The study protocol was reviewed and approved by the World Health Organization Office in Hanoi, Vietnam. Informed consent was obtained from all study subjects and identities of individuals and establishments were kept confidential.

## 3. Results

### 3.1. Descriptive analysis

A total of 909 of 919 food-handlers participated in the study (response proportion, 99%); 692 (76%) of them were females. The median age was 38 years (interquartile range (IQR) 27, 45) and median length of work experience in food-handling was 36 months (IQR 8, 84) (Table 1). Eighty-four percent of food-handlers had graduated from secondary school or above, only about 1% were illiterate. Ninety-eight percent of food-handlers were trained in food safety principles within one year and 99% had passed a medical check-up before beginning work. Overall, of all participants, 26%, 36%, and 26% were considered to have adequate KAP regarding food safety, respectively (Table 2).

In univariate analysis of the relationship between knowledge and attitudes, 101 (43%) of participants with adequate knowledge had appropriate attitudes compared with 224 (33%) with inadequate knowledge (PR = 1.3; 95% CI: 1.1, 1.7). Similarly, in the analysis of the relationship of knowledge and practice, 116 (48%) of participants with adequate knowledge had appropriate practices compared with 124 (18%) who had inadequate knowledge (PR = 2.7; 95% CI: 2.2, 3.3). There was no significant association between appropriate attitudes and adequate practice.

### 3.2. Comparison of food handlers working in schools and factories

Among the 909 food-handlers participating in the study, 461 (51%) worked in schools and 448 (49%) worked in factories. Among those working in schools, 450 (98%) were female, whereas 242 (54%) of those in factories were female (Table 1). Of food-handlers working in schools, 91% were secondary school graduates (attended 6 or more years of school) compared with 77% of those working in factories. The median ages were 41 years (IQR 34, 47) and 28 years (IQR 22, 42) for food-handlers in schools and factories, respectively. The median work experience for those working in schools and those working in factories was 60 months (IQR 24, 108) and 12 months (IQR 3, 36), respectively. There were significant differences for gender, educational level, age and duration of

**Table 1**  
Demographic characteristics and knowledge, attitudes and practices of food-handlers by type of establishment, Southern Vietnam, 2012.

Variables	School (n = 461)	Factory (n = 448)	Total	p-value/Crude POR (95% CI) <sup>a</sup>
Gender (n, %)				<0.001
Female	450 (97.6)	242 (54.0)	692 (76.1)	
Male	11 (2.4)	206 (46.0)	217 (23.9)	
Educational level (n, %)				<0.001
Primary School (1–5 school years)	43 (9.4)	104 (21.4)	147 (16.2)	
Secondary School (6–9 school years)	181 (39.3)	213 (47.5)	394 (43.3)	
High School or higher (≥10 school years)	237 (51.4)	131 (29.3)	368 (40.5)	
Age (median, IQR)	41 (34, 47)	28 (22, 42)	38 (27, 45)	<0.001
Working experience by months (median, IQR)	60 (24, 108)	12 (3, 36)	36 (8, 84)	<0.001
Food-handlers received food safety training (n, %)	450 (97.6)	443 (96.1)	893 (98.2)	NS <sup>b</sup>
Food-handlers passed a medical examination before being recruited (n, %)	461 (100)	443 (96.1)	904 (99.4)	NS
Adequate knowledge	157 (34%)	80 (18%)	237 (26%)	2.4 (1.7, 3.2)
Appropriate attitudes	200 (43%)	125 (28%)	325 (36%)	2.0 (1.5, 2.6)
Appropriate practices	152 (33%)	88 (20%)	240 (26%)	2.0 (1.5, 2.7)

<sup>a</sup> POR: Prevalence odds ratio; 95% CI: 95% confidence interval for comparing schools to factories.

<sup>b</sup> NS: non-significant.

working experience between food-handlers working in schools compared with those working in factories (Table 1).

The proportions of food-handlers with adequate KAP scores were significantly higher in schools than factories. We developed three separate logistic regression models in which the outcome variables of interest were: knowledge, attitudes and practices, respectively. After adjustment for gender, age, educational level and length of work experience, the odds of food-handlers in schools reporting adequate knowledge was 2.1 (95% CI 1.5, 2.9) times as high as that for food-handlers in factories. Educational level was the only other significant variable in the knowledge model (POR = 1.9; 95% CI: 1.4, 2.5). The odds of food-handlers with appropriate attitudes in schools was 2.0 (95% CI 1.5, 2.6) times as high as that for food-handlers in factories. Similarly, the odds of food-handlers in schools reporting adequate practices was 2.0 (95% CI 1.5, 2.7) times as high as that for food-handlers in factories (Table 2).

### 3.3. Observations at canteens

Among the 66 canteens we investigated, about 29% did not separate food preparation area from other areas (Table 3). Fifty-two percent of the canteens did not have soap and/or napkins/drier in the rest room and 83% of the canteens had not posted a hand washing reminder in appropriate places. About 9% of canteens did not separate areas for raw food from ones for cooked food during the preparation process. About 14% of canteens did not separate raw food from cooked food in refrigerators and about 11% of canteens did not cover or protect the food while the kitchen was being cleaned (Table 3). There were no significant differences between practices in schools and factories.

**Table 2**  
Comparison of knowledge, attitudes and practices regarding food safety among food-handlers in schools and factories, Southern Vietnam 2012.

Variables	Crude POR (95% CI)	Adjusted POR <sup>a</sup> (95% CI) <sup>b</sup>
Adequate knowledge	2.4 (1.7, 3.2)	2.1 (1.5, 2.9)
Educational level		1.9 (1.4, 2.5)
Appropriate attitudes	2.0 (1.5, 2.6)	2.0 (1.5, 2.6)
Appropriate practices	2.0 (1.5, 2.7)	2.0 (1.5, 2.7)

<sup>a</sup> POR: Prevalence odds ratio; 95% CI: 95% confidence interval.

<sup>b</sup> Adjusted for age, gender, education level, and length of working experience. Separate logistic regression models were fitted for knowledge, attitudes and practices.

### 3.4. Training needs

Most food-handlers who participated in the focus group discussion were satisfied with the content of the previous training courses. However, the participants complained that “training courses provided only theories without exercises, so they could not apply what they learned in practice”. Besides, “the number of participants in each training course was often too high. A large number of trainees (100 or more) were attending the course to efficiently follow the lectures and to concentrate on what has been taught”. In addition, “the duration of one training course was too short with only three to 6 h to cover all contents”.

For training needs, most participants would like to receive additional training on how to select safe raw materials, handle, prepare and store food appropriately and how to ensure personal hygiene and cleanliness. They also suggested that “training should be organized at their work place and that the number of participants should be limited to 20 to 30 per training course”. Participants recommended that “training courses should be more practical with less lectures but more time for question and answer sessions as well as group discussions”. The lectures provided during the training courses should also be more interactive with more visuals and less text.

## 4. Discussion

Overall, the knowledge, attitudes and practices among food-handlers in large canteens were rarely adequate. Although the KAP of food-handlers had improved somewhat in comparison to a study conducted six years before (Nguyen et al., 2010), they were still relatively poor. The KAP scores of food-handlers in our study were low compared with similar studies conducted in Malaysia (Abdul-Mutalib et al., 2012; Nee & Sani, 2011; Tan, Bakar, Abdul Karim, Lee, & Mahyudin, 2013), and in Brazil, Jordan and Canada (McIntyre, Vallaster, Wilcott, Henderson, & Kosatsky, 2013; Sharif, Obaidat, & Al-Dalalah, 2013; Soares, Almeida, Cerqueira, Carvalho, & Nunes, 2012).

In our study, there were relationships between knowledge and attitudes, and knowledge and practices, as observed in other studies (Abdul-Mutalib et al., 2012; Cuprasitru et al., 2011; Soares et al., 2012; Tan et al., 2013). Furthermore, our findings were consistent with other studies (Jianu & Chiş, 2012; Kitagwa, Bekker, & Onyango, 2012; Martins, Hogg, & Otero, 2012; Soares et al., 2012), regarding the positive effects of educational level on knowledge

**Table 3**  
Observed food service practices in schools and factories, Southern Vietnam, 2012.

Practices of food service establishments	School	Factory	Total
	Yes (n, %)	Yes (n, %)	Yes (n, %)
<b>Canteens</b>			
The areas to deliver, prepare and serve food are separated	30 (75.0)	17 (65.4)	47 (71.2)
Handwashing IEC <sup>a</sup> materials are displayed in the toilet	6 (15.0)	5 (19.2)	11 (16.7)
Soap and napkins/drier available in the toilet	23 (57.5)	9 (34.6)	32 (48.5)
<b>Preparation and storage of food</b>			
No separate areas for raw and cooked food during the preparation process	4 (10.0)	2 (7.7)	6 (9.1)
Food covered/protected during the cleaning of the kitchen	35 (87.5)	24 (92.3)	59 (89.4)
Raw and cooked food not separated in the refrigerator	5 (12.5)	4 (15.4)	9 (13.6)

<sup>a</sup> Education information and communication.

and practices (Table 2). Although knowledge alone is not enough to change practices, food-handlers with adequate knowledge can change their practices easier if they are closely supervised and supported by their on-site managers (Green et al., 2007; Rennie, 1994; Roberts et al., 2008). In addition, guidance and supervision by their managers during work improves attitudes (Tones & Tilford, 2001) and practices (Egan et al., 2007; Nee & Sani, 2011).

Because of suboptimal knowledge among the food-handlers, the health belief model should be applied during training courses to improve knowledge and change incorrect beliefs about food safety. After food-handlers acquire positive changes in the knowledge and beliefs, provisions of health benefits and perceived food safety norms can change their behavior (Nutbeam, Harris, & Wise, 2010). Nudging and framing by managers are a critical point for food-handlers to “understand the importance of food safety, their roles in safe food-handling practices and willingness to implement what they have learned” (Kile, 2007). Therefore, educational efforts together with supportive supervision conducted by managers have great potential to improve food-handlers' KAP, especially of those in industrial zone factories in Vietnam.

Differences in KAP among food-handlers in schools and factories were significant. Our logistic regression model for knowledge showed a similar effect of educational levels of food-handlers on their knowledge as previous studies (Jianu & Chiş, 2012; Martins et al., 2012; Soares et al., 2012). This suggests that higher educational level among those in schools may be associated with better knowledge compared with those in factories although the proportions of employees in schools and factories who had received food safety training were the same. Similarly, several studies have shown effects of food-handlers' knowledge on their practices similar to our results (Abdul-Mutalib et al., 2012; Kitagwa et al., 2012; Tan et al., 2013). This suggests that better knowledge of the food-handlers in schools may lead to better practices compared with those in factories. These findings may explain why those in schools had better KAP than those in factories.

Almost all participants had received annual food safety training, but their knowledge was rather poor. Obviously, the training had little impact in increasing food-handlers' knowledge. It is plausible that several factors may have contributed to suboptimal learning during the training courses. First, it seems to be difficult for food-handlers to gain sufficient knowledge (food safety principles, current laws and regulations and hazard analysis and critical control points) in just 6 h (Ministry of Health, 2005). Hence, contents of the course should be shortened and focused on the key knowledge or the duration of the course should be prolonged. Secondly, it is difficult to achieve the set learning objectives with 100 or more participants in one training course. The number of trainees is recommended to be small enough so that exercises can be easily conducted and other interactive learning methods applied (Northwest Center for Public Health Practice, 2012). Third, for adult

learning, using lectures as the only pedagogic method seems inappropriate. Each module should include a lecture, discussion, demonstration and exercise with appropriate aids (Food and Agriculture Organization, 1998). Last but not least, training in classroom with no opportunity for practical exercises, could be another factor hampering effective learning of food-handlers. Training at workplaces with appropriate teaching methods will help the food-handlers to grasp knowledge more easily as it is more practical (Egan et al., 2007; Rennie, 1994) as well as improve practices of the food service establishment (Table 3).

Food service establishments in this study were selected from three provinces of Southern Vietnam where food-handlers' KAP were expected to be better than in other provinces in the region because of previous food safety training activities. However, their KAP were quite low. The proportion of non-response was small, the data collection tools were standardized through a pilot study and interviewers were trained, which could minimize biases. However, we did not collect information on the contributing factors in food preparation such as insufficient time and temperature during cooking or reheating, keeping cooked foods at room temperature for more than 2 h, improper cooling that might contribute to outbreaks in large canteens (Vo et al., 2014). Hence further studies taking into account these factors should be conducted.

## 5. Conclusions

The KAP of food-handlers in Southern Vietnam were poor, particularly among food-handlers working in factories. Educational efforts, together with supportive supervision conducted by managers have great potential to improve food-handlers' KAP, especially among those working in industrial zone factories where the economic implications of food-borne outbreaks are substantial (Vo et al., 2014).

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