UTILIZING THE RISK REDUCTION EFFECTIVENESS AND CAPABILITIES ASSESSMENT PROGRAM TO EMPHASIZE EMERGENCY RESPONSE CAPABILITIES FROM A FOOD TERRORISM ATTACK

by

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(Under the Direction of Curtis Harris)

ABSTRACT

A predictive system was developed and tested in a series of exercises with the objective of evaluating the preparedness and effectiveness of multi-agency response to food terrorism attacks. A computerized simulation model, Risk Reduction Effectiveness and Capabilities Assessment Program (RRECAP) was developed to identify the key factors that influence the outcomes of an attack and quantify the relative reduction of such outcomes caused by each factor. The model was funded by a grant from the U.S. Department of Agriculture. The exercises showed that RRECAP was an inexpensive and effective way for agencies to identify and prioritize their advance preparation to effectively mitigate such attacks. RRECAP also demonstrated the relative utility and limitations of the ability of medical resources to handle large numbers of patients if the attack is not recognized and mitigated rapidly; and exercise results showed that proper advance preparation would reduce these deficiencies to adequately handle all affected patients.

A study was conducted to estimate a total cost of illness due to a hypothetical foodborne attack where terrorists intentionally contaminate chicken nuggets with a lethal chemical. The study used the morbidity, hospitalization, and mortality data from RRECAP to estimate the cost of illness, applying the online Foodborne Illness Cost Calculator created by the U.S. Department of Agriculture's Economic Research Service. The model showed a strikingly high cost ranging from $87 billion—if the head of the state agriculture issues a stop movement /stop sale and there is a public announcement intervention—to $349 billion if no interventions are invoked from this one attack. Mortality costs drive the total cost estimates. Direct medical cost estimates of the attack ranged from $538 million to $2 billion, from outpatient and physician office visits and indirect costs resulting from lost workdays, and premature mortality costs ranged from $86 billion to $346 billion. The findings from this study strongly support early intervention to reduce the economic burden from a foodborne terror attack. This provides justification to strengthen support for increased terrorism surveillance and public health preparedness by both government agencies and the private sector.

INDEX WORDS: Emergency response, Food terrorism, Simulation, Public health preparedness, Intervention, Food defense, Cost of illness

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A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PUBLIC HEALTH

ATHENS, GEORGIA

2015

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December 2015

DEDICATION

To the loving memory of my father and mother.

Bruce and Joanne Hodoh

You have successfully made me the person I am becoming.

You will always be remembered.

ACKNOWLEDGEMENTS

First and foremost, I thank God for all the blessings in my life. Thank you for providing me with the perseverance, courage, and wisdom to embark and complete this journey.

The creation and completion of this dissertation would not have occurred without the support of my doctoral committee. My major professor, Dr. Curtis A. Harris, provided me with the guidance and support I needed to envision, conduct, and complete this study. Thank you for taking me under your wing, sculpting me into the scholar I have become, and helping me realize my own potential. I would also like to thank Dr. Cham Dallas, Dr. Jayani Jayawardhana, and Dr. Paul Williams for serving on my committee, and their guidance and support during the dissertation. I would like to express special thanks to Dr. Phaedra Corso for her assistance in reviewing and providing expertise on the cost of illness manuscript. I would also like to gratefully acknowledge Dr. Andrew Jaine, the developer of the Risk Reduction Effectiveness and Capabilities Assessment Program (RRECAP) simulation model. His willingness to contribute and to provide me with the model made this dissertation possible. Specially, I would like to thank Dr. Joel Lee, who encouraged and supported me during my DrPH program and dissertation process.

Without the loving support of family, nothing would be possible. Thanks to my aunt, Dr. Gloria L. Hilton, her supportive and encouraging nature helped me make the decision to pursue my doctoral studies at The University of Georgia, and mentored me through the very end. Thanks to my siblings and the rest of my extended family and friends for providing encouragement throughout my journey. Lastly, from the bottom of my heart, thanks to my beloved husband, Frank, who believed in me and pushed me to do my best.

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CHAPTER 1

INTRODUCTION

Background of the Study

There is a heightened public awareness to national security in the U.S. and worldwide after the September 11, 2001 attacks and the events that followed (i.e. anthrax through the mail). President George W. Bush created the Office of Homeland Security eleven days following the terrorist attacks on 11 September 2001. This office was given the responsibility to coordinate and direct a comprehensive national strategy to keep America safe from terrorism and to be able to effectively respond to any future terrorist attack. Even though mass casualty from a bioterrorism event is considered a low probability, it is critical to emphasize that the threat remains and can be of extremely high consequence (Karwa, Currie, & Kvetan, 2005). The consensus view of the intelligence community, of which Department of Homeland Security is a member, is that the terror threat to the homeland is, "persistent and evolving"[1].

While a great deal is known about the public health response to likely biological agents, much less is known or even discussed about response to deliberate contamination on the food supply. The U.S. has only had one confirmed incident of "successful" bioterrorism event involving food, the 1984 deliberate contamination of restaurant salad bars in Oregon (Torok et al., 1997). The U.S. food processing, distribution and supply

[1] Remarks by Secretary Napolitano at the Council on Foreign Relations Release Date: July 29, 2009. http://www.dhs.gov/ynews/speeches/sp_1248891649195.shtm

systems are vital to our economy and present an area of vulnerability to deliberate attacks. Although most food safety and response efforts have focused mainly on unintentional contamination, a deliberate "successful" attack would have a major impact on public health, emergency response and the private sector. Food security has emerged as a priority for bioterrorism preparedness (Afton, Nakata, Ching-Lee, & Effler, 2005). Intentional contamination of the food supply has been reported overseas, in Canada and in the United States (Johnson, Herrmann, Wallace, Troutt, & Myint, 2009). To meet this threat, professionals in the field of emergency preparedness and response must be educated and trained to recognize and respond to bioterror events in a timely manner in an effort to minimize human health consequences. However, funding for these activities are typically only available via the federal grants and since 2002 appropriations for preparedness and response has been on a steady decline and become increasingly competitive. The funding for Public Health Emergency Preparedness administered through CDC for health departments decreased from $9 billion in 2003 to $584.69 million in FY 2013 (Pines, Pilkington, & Seabury, 2014). This makes securing funding in this space especially difficult due to the low probability of manifestation, especially when regulatory agencies want their constituents to prepare for and exercise based on threats at the top of their hazard vulnerability analysis, and military and/or first responders (i.e., police, fire) at the state and local level receiving bulk shares of available dollars due to being first responders to acts of terrorism (Sincavage, 2003). For example, the Centers for Medicare & Medicaid Services (CMS) has proposed an emergency preparedness rule to ensure that Medicare and Medicaid participating providers and suppliers ensure that plans are in place for coordinated response to both natural and manmade disasters with federal, state, tribal, regional, and local emergency preparedness systems (Centers for Medicare and Medicaid Services, 2013). In order to successfully receive this limited funding, 21st Century preparedness capabilities must be able to prioritize the various competing requirements for improvement, and providing justification for investments of funding.

Statement of the Problem

Few techniques currently exist to enable assessment and prioritization of competing requirements for bioterrorism response and emergency preparedness. The Risk Reduction Effectiveness and Capabilities Assessment Program (RRECAP)[2] by Jaine (2011) is one example of a technological innovation that can accurately measure the effectiveness of various response exercises based on the current levels of performance, in preventing, protecting against, responding to and recovering from consequences of attacks. Decision support tools, such as simulation modeling, have been used for comparing various food contamination scenarios and quantifying the benefits of improvement and managing threats (Hartnett, Paoli, & Schaffner, 2009). Sholl (2004) described a computer-based modeling tool that could dynamically identify the quantity and location of contaminated food product, estimate consumer exposure to select agents, and gauge the potential impacts on morbidity, mortality and economic consequences to businesses and the public if interventions were to occur. Liu & Wein (2008) also developed a model that simulated an attack on the food supply and estimated the mean number of casualties when food consumption is halted. Wein, Liu & Bloom (2005) developed a model of cows-to-consumer supply chain from a deliberate release of

[2] Patent Pending

botulism toxin. Tabletop exercises (TTX) have been used to simulate deliberate contamination on the food supply (Abraham et al., 2012; Funk, 2000; Hegle et al., 2011; Morris et al., 2012). Hennessey, Kennedy et al. (2010) determined from their Tabletop exercise simulating contaminated chicken nuggets at a G8 meeting that “there is a recognized need for increasing the knowledge of food safety and law enforcement response protocols both within and among nations”. Training workshops and computer simulation in which participants responded to a mock intentional food contamination events have also been used in bioterrorism exercises (Linton et al., 2011).

The U.S. federal government has invested more than $21 billion in the last decade to help state and local health departments prepare for large scale emergencies such as bioterrorism and pandemic influenza (M. Stoto, 2013). From an economic perspective, losses resulting from direct farm costs, the reduction in purchasing in all food outlets, the cost of “worried well” and government cost associated with response are some of the major issues associated with this event. Economic damages of food bioterrorism could potentially range from lost revenues, reduced consumer confidence, cost of destruction of animals and international trade costs. Kaufmann, Meltzer & Schmid (1997) estimated that the economic impact (i.e., hospitalizations, outpatient visits, premature human death and cost of an intervention) of a biological attack with no post exposure prophylaxis program could range from $477.7 million per 100,000 people exposed to $26.2 billion per 100,000 people, depending on the agent. This estimate does not include the possibility of extended human illness and treatment costs associated with extended care, or the possibility of decontamination and disposal of potentially hazardous waste materials (Kaufmann, Meltzer, & Schmid, 1997). From an economic perspective, agricultural terrorism would involve the assessment of economic damages; evaluating economic effectiveness of available prevention and response options and policies; and consideration of the speculative nature of terrorism (Elbakidze, 2004).

Purpose of the Study and Research Objectives

The goal of this research is to provide a system to increase the operational effectiveness of federal, state, tribal, local and private sectors in preventing and responding to deliberate attacks on the food supply.

It is hypothesized that few techniques currently exist to enable assessment and prioritization of competing requirements for improvement and justification for sufficient funding. The most often used technique is embodied in the Homeland Security Exercise Evaluation Program (U.S. Department of Homeland Security, 2013a), but this program lacks the essential ability to measure how fast and how well critical activities can be performed. A computerized simulation model, RRECAP uses a systematic, science-based process to perform sensitivity analyses to prioritize the cost/benefit of improvements to the critical capabilities that are most influential in minimizing outcomes of attacks. Target capabilities developed by the Department of Homeland Security (U. S. Department of Homeland Security, 2011c) are used to determine the critical capabilities and then validates the effect of investments by testing the capabilities using Tabletop and Full Scale Exercises.

This dissertation employed a case study approach to explore research questions using data collected from the Full Scale exercise entitled Georgia FoodEx 2009 (U. S. Department of Homeland Security, 2009). The specific objectives of the study includes:

1. Quantify public health consequences (i.e. morbidity and mortality) resulting from a food terrorism incident and a lack of bioterrorism response by emergency managers in the public and private sectors using the RRECAP model.

2. Determine the economic impact of a food attack, specifically, indirect costs including cost of medical care for worried well, government costs, and downtime costs.

3. Identify recommendations for helping organizations determine which Key Performance Indicators are most influential in minimizing outcomes of attacks.

The primary outcome measures from the RRECAP model are to reduce associated morbidity, mortality and economic impact resulting from a bioterror event. RRECAP simulates food and agriculture interdictions with associated progressions of the event through the consuming population with and without interventions at varying time intervals. To validate this hypothesis, the RRECAP model system was validated via data collected from the previously conducted TTX.

Significance of the Study

The proposed research will contribute to multiple core capabilities described under the National Preparedness Goal to secure the nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from threats and hazards that pose the greatest risk (U. S. Department of Homeland Security, 2011b) and the "Presidential Policy Directive 8" for National Preparedness (U. S. Department of Homeland Security, 2011c). Ultimately, this research will contribute to the body of evidence supporting and guiding public health investments to improve operational effectiveness of public and private sectors in preventing and responding to attacks.

Conceptual Framework

The conceptual framework for the study is based upon FEMA's National Response Framework (NRF) which guides how the nation conducts all-hazards incident response (U.S. Department of Homeland Security, 2013b). The development of the NRF was mandated by the Homeland Security Act of 2002 (U. S. Department of Homeland Security, 2002) and Homeland Security Presidential Directive-5 (U. S. Department of Homeland Security, 2003) and integrates the National Contingency Plan (NCP) and other national-level contingency plans. The NRF is used to prevent, prepare for, respond to, and recover from terrorist attacks, major disasters, and other emergencies. The key concepts of the NRF includes: "Building on the National Incident Management System (NIMS) with its scalable, flexible and adaptable coordinating structures; Aligns key responsibilities and roles across jurisdictions; Links all levels of government (local, tribal, State and Federal), the private sector and nongovernmental groups in a unified approach to emergency management; Can be partially or fully implemented; and Coordinates Federal assistance without the need for a formal cause.

Logic Model

The Public Health Preparedness Logic Model (M. A. Stoto et al., 2005) with an emphasis on how preparedness can be measured and assessed, will be utilized for creating a functional diagram of how this study works to achieve the research aims. In response to a food terrorism attack, the specific measures (i.e. morbidity, mortality and economic impact) are illustrated in Figure 1. In the model, capacity-building activities contribute to public health's functional capabilities, which are used during a public health emergency. The model presents the capabilities in four categories: assessment, policy development, assurance, and coordination and communication (M. A. Stoto et al., 2005). Both the capacity-building activities and the functional capabilities support the objectives of early food terrorism detection, early and effective response, and early recovery and return to normal function. These objectives, in turn, support the broad goal of mitigating mortality, morbidity, minimizing psychological and social disruption, and the economic impact of a food terrorist attack (Potter, Houck, Miner, & Shoaf, 2013; M. Stoto, 2013).

Organization of the Study

Chapter 1, Introduction, establishes the problem, and provides the background of the study. Chapter 2, Literature Review, will include an exhaustive search of available literature expanding upon studies identified in Chapter 1 while also including additional studies that are relevant to the research. This expansion on the historical use of chemical, biological, radiological, and nuclear agents of bioterrorism and deliberate attacks on the food supply will serve to begin making connections between the two bodies of research as well as incorporate the RRECAP simulation model focusing on benchmarking preparedness via TTX and FSE. Further, this chapter will discuss the economic impacts of food terrorism on the U.S. economy resulting from reduction of income within sectors directly impacted by the attacks. Please note: the economic impact model analysis of RRECAP is incomplete. In order to avoid delays with this dissertation, we deviated from the research prospectus and assessed the economic burden of illness due to a foodborne attack with a lethal agent.

Chapter 3, Manuscript #1, "A benchmark system to optimize our defense against an attack on the U.S. food supply utilizing the Risk Reduction Effectiveness and Capabilities Assessment Program", has been accepted for publication in the *American Journal of Disaster Medicine.* The manuscript will present RRECAP, a simulation model that examines the consequences of food bioterrorism with a lethal chemical agent on a chicken processing plant and the resulting public health response on preparedness of emergency management agencies and the private sector. The chapter describes the methodology for the study in detail, which includes the research design, data collection methods, quality of the data and data analysis procedures, results of the study, and the conclusions, implications and summary.

Chapter 4, Manuscript #2, "Estimating the cost of illness due to a food terrorism attack using the risk reduction effectiveness and capabilities assessment program (RRECAP) data" will be submitted to a public health journal (e.g., *Journal of Food Protection*; *American Journal of Disaster Medicine*; *Disaster Medicine and Public Health Preparedness;* or *Journal of Homeland Security and Emergency Management*) for publication. The manuscript provides the economic burden of illness resulting from a terrorist attack on the food supply. Using morbidity, hospitalization and mortality data from the RRECAP model, the cost of illness is estimated applying the Cost of Illness Calculator created by the U.S. Department of Agriculture's Economic Research Service. The manuscript describes the methodology for the study in detail, which includes the research design, data collection methods, quality of the data and data analysis procedures, results of the study, and the conclusions, implications and summary.

Chapter 5, Summary and Conclusions, summarizes the overall dissertation; reflect on the findings of the dissertation, detail the significance and contributions to the field of public health and recommendations for future research.

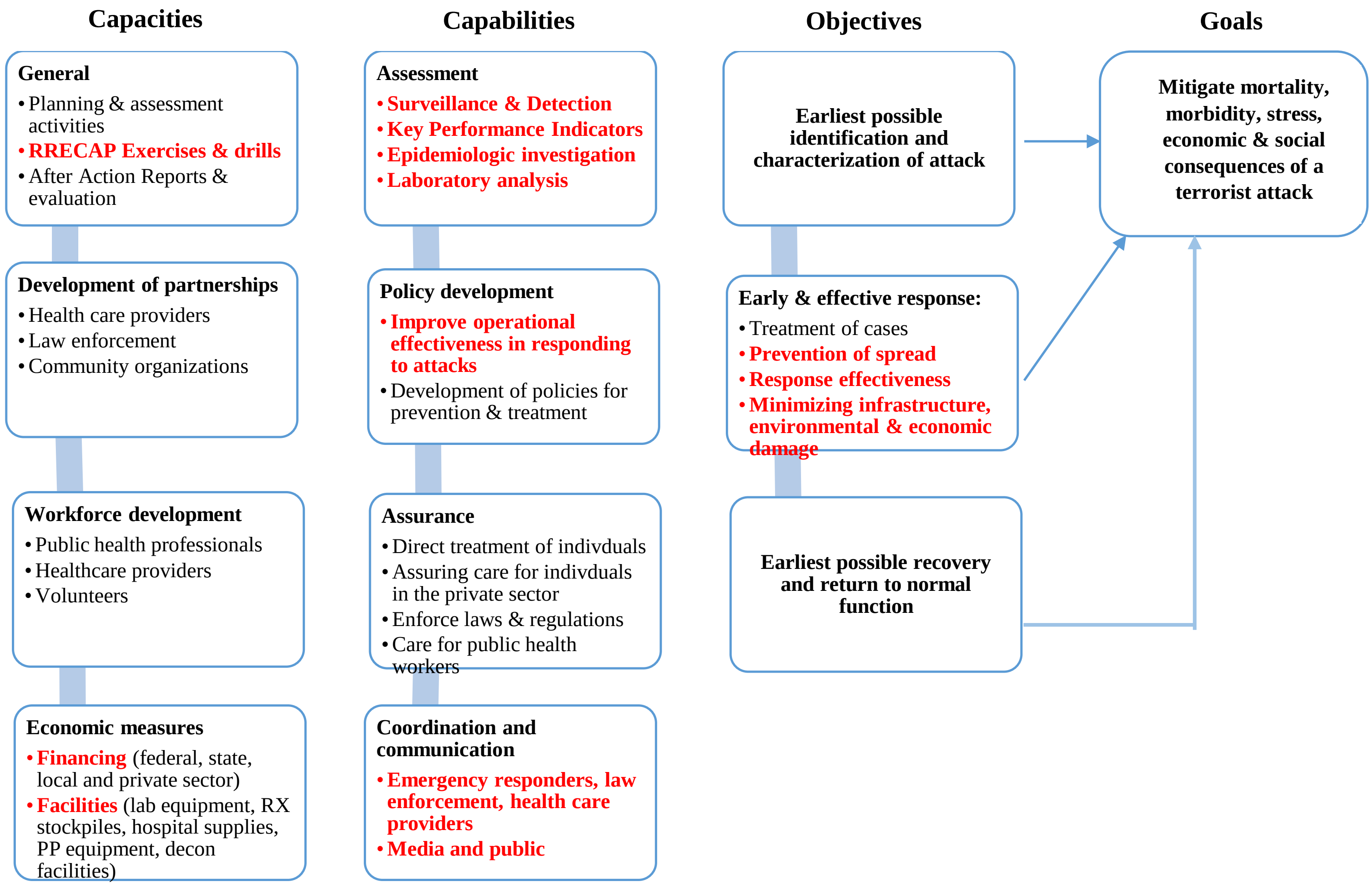

Figure 1. Logic Model for the research study.
(M. Stoto, 2013; M. A. Stoto et al., 2005).

CHAPTER 2

LITERATURE REVIEW

This chapter presents a review of research studies relevant to food terrorism, food defense and its potential economic burden due to illnesses associated with ingesting contaminated food. It begins by exploring the plausibility of food as a vehicle for terrorism and identifying the history of food terrorism by culling information related to intentional and unintentional food contamination events. Research and practices related to public health preparedness for food terrorism and defense are also identified and discussed.

Subsequently, the issue of economic burden of food terrorism-related illnesses with respect to healthcare costs, productivity losses and loss of life is examined. As stated earlier, the dissertation focuses on a hypothetical case study in which a terrorist group intentionally contaminates chicken nuggets with lethal doses of methyl parathion at a poultry processing facility in Jesup, Georgia.

Research related to food terrorism and the cost of foodborne illness was readily available via library and Internet database searches. However, attempts to locate research related to the economic burden of food terrorism were very limited and largely unsuccessful. This gap in the literature required broadening the search parameters to include research related to the economic impact of terrorism and the cost of foodborne illnesses.

A Food Terrorism Attack on the U.S. is Tenable

The World Health Organization (WHO) has defined food terrorism as “an act of threat of deliberate contamination of food for human consumption with chemical, biological or radionuclear agents for the purpose of causing injury or death to civilian populations and/or disrupting social or economic political stability” (World Health Organization, 2008).

Mohtadi and Murshid (2009) identified 314 biological, chemical and radiological incidents and recorded 64 that involved either a direct attack or a plan to attack the food or water supply chains. Approximately 50 of these incidents used chemicals, 8 incorporated the use of biological agents, and 1 attack may have involved the delivery of plutonium into New York City's water reservoirs. The agent(s) used in the remaining attacks are unknown.

Scholarly opinions as to whether there should be concerns regarding potential acts of food terrorism vary from feasible to improbable. Some individuals believe that a food terrorism attack is probable and there has been a recent increase in the severity of deliberate food attacks (Mohtadi & Voeller, 2008). In a 2008 report of the Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism to Congress, the authors indicate that the United State’s “margin of safety” facing a Weapon of Mass Destruction (WMD) attack is declining, not expanding (Graham & Talent, 2008).

The deliberate or intentional contamination of food by a terrorist could occur at locations within the production, use, storage, and disposal or transportation cycle of food.

Most experts concede that the food chain, from production to distribution and processing, is highly exposed (Karwa et al., 2005; Smith DeWaal, 2004). Terrorists could possibly introduce a biological weapon into the food supply potentially resulting in serious morbidity and mortality, especially if several people ate the contaminated food simultaneously (Evans, Crutcher, Shadel, Clements, & Bronze, 2002). Terrorists could also potentially attack food supply sources (plant and animal products intended for human consumption), food processing, and distribution facilities by gaining access via forced entry or utilize an insider to compromise the food. Meat packing plants and food processing facilities are inclined towards insufficient security and biosecurity measures (Jin, McCarl, & Elbakidze, 2009; King, 2009). The food supply is vulnerable to botulinum toxin (Sekheta, Sahtout, Sekheta, Pantovic, & Al Omari, 2006) and it could be easily added to food (Evans, Crutcher, Shadel, Clements, & Bronze, 2002). A few specific examples of terrorist acts of poisoning food include: contamination of salad bars in The Dalles, Oregon, with *Salmonella typhimurium* in 1984 where more than 750 people became ill (Torok et al., 1997) and the deliberate food tampering by a lab technician in Texas in 1996, when 12 coworkers fell ill after eating muffins and donuts contaminated with *Shigella dysenteriae* Type 2 (Kolavic et al., 1997). These occurrences validate the ease with which readily available food are deliberately contaminated resulting in serious consequences.

Former senior members of the U.S. Congress and Senate, The White House and many policymakers believe that terrorism is a credible threat, and have gone on record to make the case strongly. Tommy Thompson, former U.S. Secretary of the Department of Health and Human Services, is somewhat famous in the emergency management community when he stated that "I, for the life of me, cannot understand why the terrorists have not ... attacked our food supply because it is so easy to do" (M. T. Roberts, 2007). Dr. John Bailar, a scholar in residence at the National Academies, supported the notion that the U.S. should have a combined "food safety structure" and when issues of bioterrorism are added to the demands of the regulatory agency, it becomes evident that change is imperative (DeWaal, 2007). The National Academies represent some of the nations preeminent scholars regarding high-quality, objective advice on science, engineering, and health matters.

In the event of an attack on the U.S. food supply system, consumer confidence in the government's fragmented food safety programs would collapse as fast as confidence in airport security did following September 11, 2001 (Smith DeWaal, 2004). The U.S. Food and Drug Administration (FDA) has concluded that there is a high likelihood that an act of food terrorism could occur and a significant number of people could potentially be affected, resulting in serious foodborne illness (U.S. Food and Drug Administration, 2004).

There are major concerns about the United States' vulnerability to attacks on the water and food supply due to the centralized food and distribution methods over large areas, including food processing and the increase of food imports (Karwa et al., 2005; Smith DeWaal, 2004). The U.S. food supply system (see Figure 2), is dependent upon farm goods for animal and crop products, which progress through processing and distribution before coming into contact with the human consumer (Hope, 2004). There are numerous vulnerability points for a terrorist to introduce a contaminant in the food processing and distribution system infrastructure (e.g., slaughterhouses, warehouses) or a regional or national economic sector (Hope, 2004). The threat of deliberate or intentional delivery of biologic agents to inflict illnesses and death among humans, agriculture and livestock or threaten communities or intimidate governments in the present scenario of elevated terrorist actions is feasible (Das & Kataria, 2010).

Separate from human health consequences, the probable impact of food terrorism in the U.S. could result in immense civil, financial, and political insecurity (Roberts, 2007). If a food terrorism event were to occur in the U.S., it could potentially diminish local or national economies, reduce consumer assurance in food production and processing, and overwhelm public health services (Manning, Baines, & Chadd, 2005). Depending on the chemical, biological, radiological or nuclear (CBRN) agent a terrorist might use to deliberately contaminate the food supply, the presentation of illnesses and the symptoms people might experience would usually begin relatively slowly, disperse through a population, and then increase in intermittent cases, or produce a frenzied epidemic abruptly generating many illnesses (Sobel, Khan, & Swerdlow, 2002). Deliberate or intentional food terrorism is a rare occurrence in the U.S. but retail and food distribution systems should not dismiss the fact that someone could possibly intentionally contaminate foods or beverages produced or served by these establishments (Rasco & Bledsoe, 2008).

Some experts are concerned that terrorists could use social media to incite a bioterrorism or agroterrorism attack (Sjöberg et al., 2013). Social networking media such as Facebook, Twitter, Instagram, podcasts and blogs have become a major part of our daily lives. Terrorist organizations use social media as an indoctrination and recruiting tool and could potentially use it as a clarion call for a mass terror attack. The U.S.

Department of Homeland Security (DHS) and the Federal Bureau of Investigation (FBI) reported that the Mujahidin Poisons Handbook, which was posted on several Islamic websites and in existence for several years, describes techniques to attack the food supply (U. S. Department of Homeland Security, 2008).

Intentional or deliberate contamination episodes may also result from disgruntled employees (Centers for Disease Control and Prevention, 2003). Another example of such terrorist threats are the competitive practices of farmers and dairy companies in China that deceitfully increased the supposed protein content of milk and milk powder by adding melamine to increase the total nitrogen content (W. E. Nganje & Skilton, 2011).

A Food Terrorism Attack on the U.S. is Untenable

Many experts argue that a food terrorism attack is unlikely to occur in the U.S. (Burkle, 2002; Cheatham, 2013). In comparison to the large number of deaths from the September 11 attack, death from mass food poisoning is "relatively low" (Mohtadi & Murshid, 2009). Using fault tree analysis to examine the possibility of an attack on the food supply system, Hope (2004) determined that a bioagent would not be the optimal delivery mechanism for producing massive deaths. There are no "confirmed cases" of biological agents being deliberately introduced in either the early stages of the food supply system, or and endured numerous processing stages to cause morbidity and mortality to human consumers (Hope, 2004).

Probable Agents of Food Terrorism

Biological

The Centers for Disease Control and Prevention (2014a), has classified biological agents (i.e., viruses, bacteria, fungi or their toxins) that could potentially be used in a food attack into two major categories; A and B, with preference given to agents that pose the greatest risk to national security and are easily disseminated (Das & Kataria, 2010). Category A agents have the highest priority in terms of national security due to higher death rates; ease of dissemination or transmission from person to person; potential for major public health impact; may potentially cause public panic and social disruption; and requires special action for public health preparedness. The Category A agents, include: *Bacillus anthracis*, which causes anthrax, and *Clostridium botulinum*, which causes the most lethal substance known, botulism. For example, a lethal dose for a 70-kg person by the oral route is estimated at 70 mcg, by the inhalational route 0.80 to 0.90 mcg, and by the intravenous route 0.09 to 0.15 mcg (Sobel, 2005). Category B agents (e.g., salmonella species, shigella dysenteriae) are the second highest priority of the CDC because these food related agents are easily disseminated and the mortality and morbidity of pathogens related to these threats are moderate to low (Yoon, 2007). Rasco and Bledsoe (2008) indicate that bioterrorists using the food supply as an origin of outbreak are “higher than” CDC’s category A threats (i.e., anthrax, plague) due to its ease of distribution. Another reason terrorists may prefer to use a particular biological agent to deliberately contaminate the food supply is due to ease of containment (i.e. fitting in small glass containers), manufactured in meager quantities (Nelson, 2011), and some are odorless and tasteless. For example, from 1964 to 1966, several people became ill after it was reported that several outbreaks of typhoid fever and dysentery occurred in hospitals in Japan that were attributed to food contaminated by a research bacteriologist (Anon, 1966). It is suspected that the motive might have been related to his perceived ill-treatment by co-workers, also suggesting that he may have been creating cases to further his academic research in bacteriology (Mohtadi & Murshid, 2006).

Chemical

Chemical agents of food terrorism include, but are not limited to, elemental metalloids (e.g., arsenic), elemental metals (e.g., mercury, thallium), pesticides (e.g., endrin, malathion, sevin), and rodenticides (e.g., rat poisoning), cleaning chemicals and toxic chemicals. Some chemicals could be produced, stolen or acquired for use other than food. Agricultural chemicals, primarily pesticides and rodenticides, have been used to deliberately contaminate the food supply in numerous attacks, mainly in China. Although the U.S. Environmental Protection Agency and the World Health Organization have banned many of these chemicals, they are frequently used in developing countries where there is a lack of regulatory oversight. Moreover, deliberate contamination of the food supply with a chemical requires that they have organoleptic properties that would render them odorless, tasteless or heat resistant to be effective. Therefore, it is possible that terrorists could introduce non-explosive chemicals into the food supply to cause injury or death, or obtain some of the more readily available toxic chemicals (e.g. pesticides, insecticides, industrial chemicals) and introduce them into the food supply. Several examples of deliberate chemical contamination events perpetrated by terrorists or individuals are described in the next section, under “Food contamination with CBRN agents”.

Radiological and/or nuclear

Dissemination of nuclear material could take place either through the food chain, water supply or by placing a radioactive source in a public place. A "dirty bomb" is produced when an explosive device is combined with radioactive materials. Depending on the explosive component, the loss of life could be tremendous and the presence of radioactive material could potentially cause immense panic, contaminate property and have considerable economic consequences (Thornton et al., 2004). There are few recorded events of a terrorists using a dirty bomb. In the United States, authorities captured a terrorist who was allegedly planning to build and explode a dirty bomb in May of 2002 (Iserson & Pesik, 2003).

The use of radiological chemicals (e.g., polonium 210) to deliberately contaminate food at extreme concentrations may cause morbidity and mortality. However, only one confirmed case of deliberate contamination of food with radiological material resulting in death was identified in the literature.

Food Contamination Events with CBRN Agents

Intentional or deliberate use of food contaminated with CBRN agents to cause injury or promote terror on the public has been well documented through history. In this literature search, I compiled 64 confirmed incidents using CBRN agents to intentionally contaminate food. The chronological incidents, identified by CBRN agent, description of events, food item(s), country of origin, number of illnesses and deaths are shown on Table 1 for intentional food contamination, and Table 2 for unintentional food contamination.

Intentional food contamination

The data cover a 67–year period from 1946 to 2015, and document thousands of illnesses and hundreds of deaths (Table 1). There are 64 actual events recorded, with China and the U.S. tied at 18, followed by Japan at 7, the U.K. at 5, and numerous other countries reporting 1-3 events. The motive for the events range from unknown (n=15), political (n=9), disgruntled employees (n=9), competitor sabotage (n=7), revenge (n=7), terrorism (n=7), mental illness (n=3), resentment (n=2), extortion, and one each for disputes, sexual assault, theft and deliberate tampering (n=1). The major agent of choice for contamination is chemical (n=50), followed by unknown agent (n=15), biological (n=7) and radiological/nuclear (n=4). The most widely used chemical was rat poison, which were reported in most of China's deliberate food contamination events.

In reviewing the chronology of deliberate food contamination, the maximum number of casualties occurred in 1946, when several hundred German prisoner of war (POW) soldiers died and thousands became ill after consuming arsenic contaminated bread while being held at a U.S. POW camp in Nuremburg, Germany (Khan, Swerdlow, & Juranek, 2001). The motive was revenge and a Jewish extremist group (Nakam) claimed responsibility for the mass poisoning (Anon, 2009a). Nakam members were seeking retribution for war crimes by the prisoners, most of who were former Nazi SS (Anon, 2009).

Another important finding of this search revealed that the maximum number of illnesses from a single, deliberate contamination event of the food supply occurred in Oizumi, Gunma Prefecture, Japan in October of 2013. More than 2,800 people reported illnesses and 6.4 million packs of frozen food were recalled due to malathion poisoning

(Lui, 2014). A disgruntled plant worker was arrested for poisoning frozen food products with the pesticide malathion on four separate occasions during the same month (Anon., 2014). The motive behind the attacks was over the worker's (contractor) lack of payment. No fatalities were reported from this incident.

The next section summarizes confirmed deliberate attacks on the food supply system by country. A more thorough description for each event and the corresponding country is provided in Table 1.

<u>Afghanistan</u> *(n=3)* In March of 2000, two students died and hundreds became ill after exposure to food deliberately poisoned with an unknown agent at a religious school in Jalaludin, Afghanistan (Mohtadi & Murshid, 2007). The motive behind the event was never determined.

Two terrorism plots were uncovered in Afghanistan against the United States. In March of 2003, a high-level Al Qaida operative in Afghanistan was captured by the FBI with a spiral notebook describing a plot to poison U.S. military field rations with an unknown agent (Pinkerton, 2004). In 2001, U.S. forces seized documents at the Tarnak Farms an Al Qaeda training camp near Kandahar, Afghanistan, illustrating plans to poison U.S. drinking water and food supplies with an unknown agent (Forest, Howard, & Sheehan, 2013).

<u>Australia</u> *(n=1)* In November of 1978, several delegates at an international Assyrian Congress meeting in Sydney became ill after ingesting a food item that had been poisoned with mustine hydrochloride (Mohtadi & Murshid, 2006). The motive was determined to be political and it was alleged that the Iraqi delegation was responsible for

supplying the contaminated food. Two delegates who received contaminated food had previously criticized the Iraqi Government's use of violence. No fatalities were reported from this incident.

Bangladesh *(n=2)* Between the years of 2004 to 2006, approximately 142 individuals in Dhaka, Bangladesh, recalled buying or accepting food or drinks before losing consciousness. It is reported that the victims were deliberately poisoned with benzodiazepine (Majumder et al., 2008). The motive behind the attack was sexual assault and theft. No fatalities were reported from these incidents.

In July of 1999, elderly members of a group called Tablig Jamaat, became ill after eating food contaminated with an unknown agent at a mosque in Chandpur, Bangladesh (Mohtadi & Murshid, 2006). The motive behind the attack was theft. No fatalities were reported from this incident.

Belgium *(n=1)* A narrative for this event is provided under the Europe summary.

Canada *(n=2)* In May of 2000, an unknown perpetrator added arsenic to a coffee vending machine located at the Lavalis University Animal and Food Sciences department, where approximately 30 people became ill, and four were hospitalized due to treatment related complications (Anon, 2009a). The police said that the incident was probably deliberate though suppliers of the coffee were not suspected (Mohtadi & Murshid, 2006). No fatalities were reported from this incident.

In 1970, four university students in Canada became ill after consuming food intentionally contaminated with embryonated *Ascaris suum*, the swine roundworm (Phills, Harrold, Whiteman, & Perelmutter, 1972). A graduate student was charged with the attack due to a dispute involving unpaid rent. No fatalities were reported from this incident.

China *(n=18)* Due to the numerous deliberate contamination events that have occurred in this country, I will highlight some of the major cases. A more detailed description of events can be found in Table 1. The majority of intentional food contamination events were from rat poisoning and none were due to terrorism. In September of 2002, 38 people died and several became ill in Tangshan, China, when a disgruntled employee used rat poison "Dushuqiang" to contaminate a rival's breakfast snacks (Anon, 2009a; Sholl, 2004; U.S. Food and Drug Administration, 2004).

In 1992, more than 700 people became ill from arsenic-contaminated flour at the school's cafeteria in Zhengzhou, China (Torok et al., 1997). The motive behind the attack was revenge. A student was expelled from the University due to the incident. No fatalities resulted from this incident.

Europe In 1978, health officials in 18 countries received notification that imports of Jaffa oranges from Israel were injected with mercury. The Palestinian group called the Arab Revolutionary Army claimed responsibility for the attack to sow panic and wreck the economy (Mohtadi & Murshid, 2006; RAND, 2010). The Israeli Citrus Marketing Board suggested that the fruit may have been contaminated at the point of retail. It is also suggested that the oranges were spiked in Rotterdam, where they were shipped for repackaging and shipped to Europe (Mohtadi & Murshid, 2006). The contaminated oranges and lemons were discovered in six countries – Belgium, France, the Netherlands, United Kingdom (UK), West Germany and Sweden. In the Netherlands, five children became ill after consuming the contaminated oranges. In Israel, 12 children were hospitalized (Baines, Davies, Chadd, Manning, & Gregson, 2007; Sholl, 2004) after consuming contaminated oranges. An investigation by Ehud Sprinzak and Ely Karmon concluded that the culprits of the original contaminations were most likely German sympathizers of the Palestinian cause (Sprinzak, 2001). No fatalities were reported from these incidents.

France *(n=3)* A narrative for this event is provided under the Europe summary.

Germany *(n=1)* A narrative for this event is provided under the Europe summary.

India *(n=2)* In 2013, 23 children died and 24 became ill in Bihar state, India, after consuming a school lunch (rice and soya beans) deliberately contaminated with the pesticide monocrotophos (Anon, 2013). The school principal and her husband were blamed for the attack. The school chef claimed that she warned the principal that the cooking oil may have been contaminated due to its smell and appearance. The chef's boss apparently insisted that she cook the food with the suspicious oil (Gayle & Parry, 2013).

In June of 2000, six workers became ill and died in Punjab, India, after two of their colleagues had contaminated their food with an unknown pesticide. The two suspects were captured within hours of the incident (Anon, 2009a) and the motive was due to the employees being disgruntled.

Iraq *(n=3)* In January of 2008, four of ten individuals died after consuming cake contaminated with thallium in Baghdad, Iraq (Centers for Disease Control and Prevention, 2008). The motive behind the attack was determined to be for political reasons and the members of the Iraqi Air Force club were specifically targeted. Four fatalities resulted from this incident.

In October of 2006, at least ten Iraqi army and police officers died and four became ill at a base in Numaniyah from consuming chicken deliberately contaminated with cyanide (Paley, 2006). The event was considered a terrorism attack by Sunni insurgents because the officers were mostly Shi'I (Anon, 2009a). Several hundred victims were ill from the attack.

In March of 2005, three pilgrims in Al-Hillah were given food with an unknown agent by members of a terrorist group. The individuals suffered from food poisoning (Mohtadi & Murshid, 2006). No fatalities or illnesses were reported from this incident.

Israel *(n=2)* In 2002, a terrorism plot was discovered where three men were arrested in Jerusalem for allegedly planning a mass poisoning with an unknown agent of Israeli patrons at a café (U.S. Food and Drug Administration, 2004). No fatalities or illnesses were reported from this incident.

Italy *(n=3)* In April of 1988, grapefruit contaminated with an unknown agent were discovered in Naples and Rome. The poison turned out to be a substance which causes color tainting but was not determined to be harmful (RAND, 2010). A group claiming support for the Palestinians "The Organization of Metropolitan Proletariat and Oppressed Peoples" notified authorities that they injected poison into grapefruits imported from Israel. No fatalities or illnesses were reported from this incident.

Japan *(n=7)* Due to the numerous deliberate contamination events for this country, I will highlight some of the more dramatic cases. A more detailed description of events for this country can be found in Table 1. In October of 2013, more than 2,800 people reported illnesses after consuming frozen food contaminated with the pesticide malathion (Lui, 2014). A plant worker disgruntled over his pay was arrested in Oizumi, Gunma Prefecture, Japan for the incident. Moreover, he admitted to four separate occasions of poisoning food during the same month (Anon., 2014). No fatalities were reported from this incident.

In 1988, three people became ill after a worker deliberately added sodium azide and sodium cyanide into the sugar canister used for coffee and tea at the workplace break room (Dalziel, 2009). The resentful worker was said to be troubled about work, and the incident took place shortly after he returned to the office from a leave of absence. No fatalities were reported from this incident.

In 1936, one of the earliest cases of confirmed deliberate food contamination occurred when three people died and 17 became ill after ingesting salmon eggs contaminated with *S. typhi* at a party given in honor of one of the physicians at the hospital where Dr. Tei-Seburo Takahashi worked (Carus, 1998). The motive for this incident was reported to be retaliation, as Dr. Takahashi apparently hoped to infect one of the members of the staff with whom he disliked. No fatalities were reported from this incident.

<u>Netherlands</u> *(n=2)* In March of 2004, four people became ill after consuming various food products contaminated with pesticides, insecticides, and mouse poison. The motive was reported to be due to extortion when a Dutch man was convicted in an effort to extort money from food manufacturers (Mohtadi & Murshid, 2006). No fatalities were reported from this incident.

Nicaragua *(n=1)* In October of 1979, two policeman died and 12 became ill after consuming food contaminated with an unknown agent that was distributed by two individuals at a police station in Managua, Nicaragua. The motive was determined to be political because the two individuals responsible for the crime opposed the Sandinista government (Mohtadi & Murshid, 2006).

Philippines *(n=1)* In 2005, 28 schoolchildren died and 130 became ill after consuming cassava fritter laced with the organophosphate insecticide coumaphos, by one individual in Southeastern Philippines (Dalziel, 2009). Mental illness was reported to be the motive behind the attack. Reports indicate that a vendor was distraught due to several successive events that occurred immediately prior to the mass poisoning (Felongco, 2005).

Russia *(n=2)* In June of 2002, 60 students and teachers became ill after consuming an unknown food item contaminated with *salmonella typhi* toxin at a school in Volgograd, Russia (Mohtadi & Murshid, 2007). The motive behind the attack is unknown, however, there are few details and it is not clear if there was foul play, however criminal proceedings were instituted (Mohtadi & Murshid, 2006). No fatalities were reported from this incident.

In 1994, 9 Russian soldiers and 5 civilians died after drinking champagne laced with cyanide (Khan et al., 2001). It was determined that the motive was political because they were deliberately poisoned by the Tajik opposition group (Anon, 2009a).

Sweden *(n=1)* A narrative for this event is provided under the Europe summary.

Ukraine *(n=1)* In 2004, Viktor Yushchenko, President of Ukraine died after he claimed he was deliberately poisoned with dioxin in his food while having dinner with senior political officials (Dalziel, 2009). The motive behind the attack was political.

United Kingdom *(n=5)* Due to the numerous deliberate contamination events for this country, I will highlight some of the more dramatic cases. A more detailed description of events for this country can be found in Table 1. Only one fatality is known to have been definitely reported in the U.K. due to deliberate contamination of the food supply. The most notorious case occurred in November of 2006, when Alexander Litvinenko (a former officer of the KGB) died after Andrey Lugovoy (a former Russian officer) placed radioactive polonium-210 into his tea or sushi along with several former KGB officers who were also poisoned at a restaurant in London (Dalziel, 2009). The motive behind the attack was political and Litvinenko's deathbed allegation was about the misdeeds of the Russian government and he believed that President Vladimir Putin was behind the attack (Litvinenko, 2006). The incident resulted in four illnesses and 1 death.

In October of 2002, an obscure Islamic terrorist group tried to purchase the toxin saponin, in London, UK (Sholl, 2004; Syal, 2003). The terrorists indicated that the intent of the agent was “fire retardant on rice intended for human consumption”. No fatalities or illnesses were reported from this incident.

United States *(n=18)* Due to the numerous deliberate contamination events for this country, I will highlight some of the more dramatic cases. A more detailed description of events for this country can be found in Table 1. Only one successful deliberate food contamination event occurred for political reasons. In 1984, more than in 751 illnesses were reported after members of a religious commune intentionally contaminated 10 Oregon salad bars with the pathogenic bacteria *Salmonella Typhimurium* (Torok et al., 1997). The motive behind the attack was political influence in a local election. No casualties were reported from this incident.

While there have been many more unsuccessful attempts at deliberate food contamination with biological agents, four events have occurred in the U.S. where biological agents were used and reached their intended targets or destinations. One of the most notorious cases occurred in 1996, when more than 23 workers became ill after consuming muffins and doughnuts contaminated with the pathogenic bacteria *Shigella dysenteriae* Type 2 in a hospital breakroom in New Hampshire. A laboratory employee who had access to the locked room is suspected of the poisoning incident (Kolavic et al., 1997). The pastries were left there by a lab technician, Diane Thompson, who had access to the shigella cultures. On August 28, 1997, Ms. Thompson was indicted on three charges of food tampering. She was sentenced to 20 years in prison (Carus, 2002; Mohtadi & Murshid, 2006). The motive behind the attack was cited as a disgruntled employee. No fatalities were reported from this incident.

Only one fatality occurred in the U.S. due to deliberate contamination. In April of 2003, one person died and thirteen individuals presented symptoms and were admitted to the local emergency room after they were deliberately poisoned from drinking arsenic contaminated coffee at a local church gathering in rural Maine (Gensheimer, Rea, Mills, Montagna, & Simone, 2010). The motive for the attack was revenge. The person who was responsible for the event, determined to be a church member, committed suicide and left a note behind admitting his role in the poisonings.

The earliest confirmed case of deliberate food contamination in the U.S. occurred in October 1961, when 23 personnel were infected with Hepatitis A, after ingesting deliberately contaminated potato salad served at the officer's mess hall, at Cecil Field Naval Air Station, in Jacksonville, Florida (Mohtadi & Murshid, 2006). The motive behind the attack was mental illness. The individual had a history of psychological problems, and the investigators apparently believed that he might have deliberately contaminated the food by urinating into it (Carus, 1998). No fatalities were reported from this incident.

Three confirmed cases of deliberate contamination of the food supply with radiological/nuclear material have been reported in the U.S. There were no fatalities resulting from these incidents. The most notable case was in July of 1995, at the National Institute of Health (NIH) labs in Bethesda, MD. A pregnant researcher was intentionally poisoned after consuming food and drink (from a water cooler) that was contaminated with radioactive phosphorus-32 (Dalziel, 2009). The motive not known for certain, but the victim accused her supervisor of being responsible for the poisoning because her maternity leave would delay an important research project. The Nuclear Regulatory Commission cleared her boss of the incident (Anon, 1997). More than 27 co-workers became ill because they also stored their lunch in the same refrigerator.

In addition, unsuccessful attempts at food terrorism include plots (n=5), threats (n=3), possessions (n=2), hoaxes (n=2), and attempted acquisitions (n=1); no deaths or illnesses have resulted from these categories (see Table 1). There are several more notable cases that should especially be highlighted. Earlier, in 2004, the FBI learned of a plot to compromise the world's largest producer of Meals Ready to Eat (MREs), located in McAllen, Texas (Pinkerton, 2004). In 2003, the FBI warned that Al Qaeda terrorists might use poisons to contaminate U.S. food and water supplies (Forest et al., 2013); and in March of 1989, a telephone call was placed to the FDA claiming that Chilean fruit bound for the U.S. and Japan had been spiked with cyanide. The FDA later confirmed traces of cyanide in a small sample of grapes that had arrived from Chile. Since the acid in fruit quickly decomposes the poison, the original amount injected could have been much greater (Mohtadi & Murshid, 2006). This event led to the recall of all Chilean grapes distributed in Canada and the USA, and the publicity surrounding this incident resulted in a boycott by American consumers. The economic impact was considerable, leading to a loss in sales ranging at several hundred million dollars and more than 100 growers and shippers were forced into bankruptcy (Sholl, 2004).

Unintentional food contamination

In the United States, food borne illnesses resulting from food safety breakdowns are estimated to kill 3,000 and hospitalize 128,000 every year (Scharff, 2015). The DHS indicated that a failure on food safety (i.e. unintentional contamination) could have a major impact on public health and the U.S. economy, especially if terrorists were to attack the food supply system (U.S. Department of Homeland Security, 2007). Unintentional food contamination events show the vulnerability of the food sector and give terrorists ideas on how to reproduce these events for harm.

Contaminated food outbreaks occur naturally every year. However, since the focus of this dissertation is deliberate contamination of the food supply by terrorism, foodborne outbreaks are briefly addressed in this chapter. In actuality, foodborne outbreaks are more devastating than acts of food terrorism. For example, the findings of my review determined that more than 107 confirmed cases of foodborne outbreaks occurred globally between 1978 and 2014 (see Table 2). To illustrate the vulnerability of the food supply to contamination, in Shanghai, China, more than 30,000 became ill after ingesting clams contaminated with Hepatitis A. In the U.S., more than 1,400 people became ill and two people died after the *Salmonella* outbreak after people consumed contaminated jalapeno and serrano peppers, and tomatoes produced by companies in Mexico (Centers for Disease Control and Prevention, 2014b), causing an estimated $100 million dollars in losses. Finally, during late 2008 and early 2009, nine people died and at least 714 people in 46 states were poisoned after consuming peanut food contaminated with *Salmonella typhimurium* produced by the Peanut Corporation of America (PCA) at its Blakely, Georgia processing plant (Prevention, 2010). The FBI convicted the president of PCA and his brother on more than 71 criminal counts, including shipping a tainted product that should have been destroyed. Economic losses to the industry resulted in more than one billion dollars which largely affected the state of Georgia (Leighton, 2014).

The data on unintentional food contamination cover a 42 –year period from 1973 to 2015, with more than 82,000 illnesses and approximately 1,666 deaths (Table 2). There are 11 confirmed cases of illnesses due to unintentional food contamination. The U.S. and India are tied at 4 cases, followed by China, Iraq and Spain reporting 1 event. The following section consists of a summary of inadvertent food contamination. A more detailed description can be found in Table 2.

The highest number of casualties from one single event occurred in Spain in 1981, when 800 people died and over 20,000 became ill from cooking oil contaminated with refined aniline (McKay & Scharman, 2015; Sholl, 2004). It was determined that the chemical agent was added to oil for non-food use and illegally sold as cooking oil in the streets of Madrid, Spain.

The highest number of illnesses occurred in China in 2008, when more than 54,000 children became ill and three died after consuming infant formula contaminated with melamine (Chao, 2008). In this instance, competitive practices were cited as the motive because farmers and dairy companies in China deceitfully increased the supposed protein content of milk and milk powder by adding melamine to increase the total nitrogen content (W. Nganje, Dahl, Wilson, Siaplay, & Lewis, 2007).

Most of the unintentional food occurrences in India were due to pesticides where in 2002, 40 villagers became ill and three died after using empty pesticide containers for food storage (Dewan et al., 2004).

In examining the historical record for the United States, only four confirmed cases of unintentional food poisoning with a CBRN agent were identified. In 2009, six people became ill after drinking from a communal coffee pot that was contaminated with sodium azide. It was unknown at the time whether or not the poisoning was intentional (Schwarz et al., 2014). Although it is suspected that it was accidental due to the minimal amount in the coffee pot and the affected employees worked in a research lab which used the chemical (Gussow, 2010). In 2002, more than 150 students experienced gastrointestinal illness after ingesting chicken tenders that were contaminated with ammonia during a warehouse leak of refrigerant in Will County, Illinois. In 1985, over 1,300 people became ill after consuming watermelon grown in soil treated with aldicarb in California and over 483 cases in other states (McKay & Scharman, 2015). An estimated 9 million or more Michigan residents were affected, in 1973, when polybrominated biphenyl-contaminated feed was accidently mixed and consumed by farm animals bred for human consumption. The incident caused the quarantine of more than 500 farms and cattle, swine, sheep, chicken and food products were destroyed. The event resulted in emotional suffering, depressive symptoms and abnormal immunologic studies with uncertain significance (McKay & Scharman, 2015). The aftermath led to exposures for farmers, their families and workers.

In summation on deliberate food contamination events, this review has shown that no incidents led to mass fatalities, however, widespread illnesses occurred under these adverse circumstances. In examining the numerous events, the majority occurred in the subsequent food supply chain (i.e. home, workplace, schools, retail outlets, restaurants, military installations). The most obvious finding to emerge from this review is that events that occurred at the point of food distribution have the greatest impact on morbidity and mortality. An important assessment regarding the incidents cited, is that if the food supply system can breakdown due to inadvertent contamination, terrorists with nefarious intent could certainly manipulate it.

Food Defense Exercises

To enhance the nation's ability to prevent, protect from, respond to, and recover from acts of terrorism, the National Exercise Program (NEP) was developed by the DHS under the direction of the FEMA (U. S. Department of Homeland Security, 2011a). The NEP integrates various exercises at the state, local, territorial, and tribal levels that are an essential component of national preparedness. The NEP was established by the United States Code (USC), Title 6, Chapter 2, Subchapter II, Part A, Section 748(b)(1), based upon numerous policies including the Public Law 111-353, Section 208, National Security Presidential Directive 51/Homeland Security Presidential Directive 20, and Homeland Security Presidential Directive 8 (HSPD-8). HSPD-8 requires that all Federal departments and agencies identify their level of participation in national homeland security preparedness-related exercises. The NEP defines exercise as "the employment of personnel and resources in a controlled environment to test, validate, and/or improve a specific plan or capability in pursuit of a stated objective within the homeland security enterprise" (U. S. Department of Homeland Security, 2011a).

DHS established the Homeland Security Exercise and Evaluation Program (HSEEP) to provide standardized methods and techniques when developing and executing drills and exercises. DHS stated that the advantages of an exercise program included assessing and improving performance (U.S. Department of Homeland Security, 2013b).

There are seven types of exercises defined within HSEEP, each of which are divided into two categories: Discussion-Based Exercises, of which there are four types and Operations-Based Exercises of which there are three types. Discussions-based exercises help to familiarize participants with plans, policies, agreements and procedures, or may provide a form for developing new plans, agreements, training and procedures. The four types of discussion-based exercises include seminars, workshops, tabletops and games. Discussion-based exercises are less complicated than operations-based exercise and they do not involve deployment of resources.

Operations-based exercises are used to validate plans, policies, agreements and procedures, clarify roles and responsibilities, and identify resource gaps in an operational environment. They are also used to improve individual and team performances. In addition, they involve the deployment of resources and personnel and are more complex than discussion-based exercises. The three major discussion-based exercises include drills and both functional and full-scale exercises.

The description of each exercise, as defined by the DHS (U. S. Department of Homeland Security, 2014a), is discussed as follows:

> Full-Scale Exercises (FSEs): A multi-agency, multi-jurisdictional operations-based exercise involving actual deployment of resources in a coordinated response as if a real incident had occurred. A full-scale exercise tests many components of one or more capabilities within emergency response and recovery, and is typically used to assess plans and procedures under crisis conditions, and assess coordinated response under crisis conditions. Characteristics of an FSE include mobilized units, personnel, and equipment; a stressful, realistic environment; and scripted exercise scenario.
>
> Functional Exercise (FEs): A single- or multi-agency operations-based exercise designed to evaluate capabilities and multiple functions using a simulated response. Characteristics of a functional exercise include simulated deployment of resources and personnel, rapid problem solving, and a highly stressful environment.
>
> Games: A simulation of a model or models where operations using rules, data and procedures are used to depict an actual or assumed real systems.

Seminar: A discussion-based exercise designed to orient participants to new or updated plans, policies, or procedures through informal discussions.

Tabletop Exercises (TTXs): A discussion-based exercise intended to stimulate discussion of various issues regarding a hypothetical situation. Tabletop exercises can be used to assess plans, policies, and procedures or to assess types of systems needed to guide the prevention of, response to, or recovery from a defined incident. TTXs are typically aimed at facilitating understanding of concepts, identifying strengths and shortfalls, and/or achieving a change in attitude. Participants are encouraged to discuss issues in depth and develop decisions through slow-paced problem-solving rather than the rapid, spontaneous decision-making that occurs under actual or simulated emergency conditions. TTXs can be breakout (i.e., groups split into functional areas) or plenary (i.e., one large group).

Workshop: A type of discussion-based exercise focused on increased participant interaction and focusing on achieving or building a product (e.g., plans, policies). A workshop is typically used to test new ideas, processes, or procedures; train groups in coordinated activities; and obtain consensus. Workshops often use breakout sessions to explore parts of an issue with smaller groups.

In order to gain some sense of the scope of training exercises in the U.S. on topics related to chemical, biological and radiochemical threats to food and public health preparedness, the Homeland Security Digital Library (HSDL) database (U. S. Department of Homeland Security, 2014c) and scholarly literature was searched for training exercises related to food defense. Access to the HSDL database resources is not openly available to the public at large. The exercises described in this review were retrieved from the database using an authorized account to access full and restricted collections. The following keywords were employed in the search: *bioterrorism, food terrorism, food, public health preparedness, biological, chemical, radiochemical, radionuclear, nuclear, exercises, drills, simulation-based training, workshop* and *disaster*. Any Lessons Learned and/or After Action Reports (AARs) identified in the key word search were examined for relevance to the study and briefly reviewed to assess the specific topics of interest. The Lessons Learned and AARs were generated after each exercise to "help, advise and assist" participants from local, state, and federal departments and agencies. The reports provided confirmation of the participating agencies exercise performance, analyzed exercise results, generated a compendium for lessons learned and provided the basis for planning future exercises. The purpose of the exercises were to assess the impact of a food terrorism-related attack on the affected community and facilitate interaction, coordination, and problem solving among numerous public and private agencies charged with responding to this particular event. A more comprehensive list of all food terrorism exercises are presented in Table 3.

The search identified a total of 34 food terrorism exercises, of which tabletop (n=27) was the most frequent, followed by games (i.e. simulation modeling) (n=3), functional (n=1), and full scale (n=1). Additionally, two exercises incorporated a combination of exercise types (e.g., a TTX, seminar and workshop). One exercise used an international group of participants that met face-to-face for the event (Hennessey, Kennedy, & Busta, 2010). The majority of the exercises focused on evaluating or determining the readiness of local, state and federal agencies and the private sector to respond to emergencies involving food terrorism. The exercises represented a wide range of exercise types, geographic locations, agents evaluated, and resources used. The most widely used CBRN agent in the exercise was botulism in food (n=21), followed by unidentified agents (n=6), biologicals (n=21) and chemicals (n=2). Only one exercise used a live agent, the 2009 FoodEx (U. S. Department of Homeland Security, 2009). The majority of exercises were performed between December 1999 and May 2012. Some exercises did not provide a date. Most exercises were sponsored by a federal agency or state department of health and implemented at the regional, county or city level. In three instances, the exercises were implemented at a local university (Hennessey et al., 2010; Johnson et al., 2009; State of Georgia, 2009).

Full-Scale exercises focusing on food terrorism: HSDL Restricted Collection (n=1)

The full-scale exercise (FSE) “FoodEx 2009” occurred from August 7 to August 12, 2009 (U. S. Department of Homeland Security, 2009). This specific exercise is a main focus of this dissertation. The exercise was embedded within a cluster of parallel exercises taking place at two field locations on August 10, 2009, as well as in a number of agency offices and labs across Georgia between August 7 and August 10, 2009. The two field locations included a simulated terrorism lab in a private residence located in a training facility at the Federal Law Enforcement Training Center (FLETC) in Brunswick, Georgia, and a simulated food distribution warehouse located in a farmer's market facility in Jesup, Georgia, approximately 50 miles from the terrorism lab. The FSE simulated terrorists intentionally contaminating chicken nuggets with actual lethal doses of methyl parathion at a food processing plant. To my knowledge, this is the first operations-based exercise that used a “live” chemical terrorism agent. In the FSE, priority was placed on assessing emergency management capabilities under a scenario that has rapid escalation of morbidities and mortalities. The major lessons learned from this exercise included: participants were concerned about early warnings and information sharing; there should be standard operating procedures in public health, regulatory, and law enforcement agencies regarding inter-agency and Federal/State notification of any event that may ultimately be determined to be food related; there was uncertainty as to whether the FBI would assign a case number to the samples being sent to the labs (case-number assignment issues should be clarified and included in emergency operations plans); the primary focus should be on activities that truly have a bearing on the outcome of the incident, that is primarily saving lives.

Functional Exercises focusing on food terrorism (n=2): literature (n=1) and HSDL full (n=1)

Johnson et al. (2009) used a functional exercise based on a fictitious criminal tampering event where a former employee at a local cheese factory contaminated the cheese with Shiga toxin producing *E. coli* bacteria. The exercise was held on November 18th and 19th, 2008 at University of Illinois, located in Urbana, Illinois. The participants included the Illinois Department of Public Health central and regional office staff, the local and county public health district, staff from various state and local support agencies such as Illinois State Police, Illinois Emergency Management Agency, Illinois Department of Agriculture, University of Illinois police, FBI, DHS, local firefighters, and industry. The purpose of the exercise was to observe how the participants respond when faced with a stressful reality-based simulated exercise. Simulating a food-borne terrorism attack, the authors investigated the FE as a tool for evaluating the effectiveness of the food and emergency response plan and successfully demonstrated participating agencies preparedness to a food bioterrorism incident. The exercise evaluation was judgment based and relied on the opinions of the participants, not on actual performance. The participants responded to survey questions following the exercise. The participants did not feel strongly that the exercise allowed participating agencies to improve their responsiveness. However, the authors felt the exercise was a success in that it allowed for improved relationships among responders, and they felt the efficacy of the plans and capability of the personnel to implement the plans were adequately tested.

A joint TTX and FE occurred on May 2, 2012, in Dallas, Texas (U. S. Department of Homeland Security, 2014c). The participants included FEMA Region 6 and surrounding states, officials from USDA FSIS, APHIS Veterinary Services (VS) and USDA Office of the Inspector General Emergency Response Team. The purpose of the exercise was in response to a food security incident that involved an unknown contaminant in meat, poultry, dairy products and live animals associated with those products. The major lessons learned from this exercise included: responses to injects indicated that the proper discussions were occurring on how to deal with the live animals contaminated with the toxin; some of the Federal agencies did not engage in exercise planning or exercise play despite numerous attempt at involvement, therefore, these agencies did not receive the benefits gained during the planning phase of the exercise or the experience gained during exercise play. No reason was provided for their lack of involvement.

Game (modeling) exercises focusing on food terrorism: from literature (n=3)

Linton et al. (2011) developed a computer simulation model of the food supply chain where a contaminant was intentionally introduced into the food supply system and it was monitored for public health impacts. The model was developed as a hands-on education and assessment tool by several universities, as a graduate level interdisciplinary, evidence-based, and in-depth food safety and defense curriculum. The data for the model was collected from various food companies to create authentic scenarios of supply chain simulation. The model simulation ran each day and data derived from the output consisted of the supply chain produced food and distributed the product downstream and consumers purchased and consumed based on preference. An unknown "virtual" contaminant was introduced into the supply chain and the system was monitored for effects. The simulation showed that a long-term economic impact resulting from recalls was estimated in the hundreds of millions of dollars. The authors further showed that if companies involved in the recall of a short-shelf life product had released test results with the rest of the industry, then the longer shelf-life products could have been recalled sooner, resulting in reduced public health impacts. The results of the second data set showed that under a best-case scenario, the entire supply chain is aware of the contamination, and the participants waited for positive test results before conducting a recall. By improving the time to test the accuracy of the data, intervention strategies were implemented sooner rather than later, resulting in a lower public health impact. The authors noted that better training for food industry professionals in reviewing risks associated with allowing a potentially contaminated product to remain in the food supply could improve the responses to foodborne outbreaks.

Hartnett et al. (2009) developed a discrete event simulation model to estimate and define the coordination of response by the public health system based on the intentional contamination event of the food supply system. To illustrate the utility of the model in the public health system in responding to a deliberate contamination event on the food supply, two pathogens (e.g., *E. coli* and *Salmonella*) and three classes of food were analyzed. The three food vehicles were represented by: (1) a short shelf life product (e.g., a leafy green vegetable-fresh spinach), (2) a medium shelf-life product (e.g., deli meat- hotdogs), and (3) a shelf stable product (e.g., canned goods-peanut butter). The pathogen-specific variables used in the model and health symptoms associated with exposure were expressed as available data from patient reports. The results showed that after 1,000 simulations, the average number of *Salmonella* cases were 755, following 2,000 exposures in a short shelf life product. The model also resulted in 24 reported cases with an advisory-triggered 28 days after exposure. By the time the advisory was issued, most of the food (spinach) that was contaminated had been consumed, and all the exposures had already occurred. The findings were similar for the medium shelf life food (hot dogs), with only one case being averted. Regarding the stable shelf life food item (peanut butter), 125 exposures were averted by the advisory. The author's findings were similar with the *e. coli*-contaminated product. The authors contend that their model is applicable to bioterrorism events, due to expert judgment comparisons between different agents, different system reactions, and other assumptions within the system. Finally, the model provided the ability to analyze the impact of system changes, to compare scenarios and quantify the benefits of improvements with respect to averting exposures and risk reductions, and enhance our ability to understand and manage these threats.

Sholl (2004) recognized that government agencies needed a tool to assist in threat evaluation of a food contamination event and as part of his doctoral dissertation, conceptualized and described a computer based simulation model Predictive Modeling and Decision Making Tool (PMDM), that could be used to identify, quantify, and locate a contaminated food product in the supply chain. Furthermore, the model would estimate consumer exposure to a certain agent, project the chance of experiencing human illness and death, and evaluate various methods of interventions to protect the public. The scenario was based on produce (lettuce) as a potential vehicle for bioterrorism. The author used customer-shipping data collected from a produce supplier for lettuce, and distribution of the produce was derived from retail and wholesale distributors. A national market research firm provided the data on consumption and disease; morbidity and mortality was garnered from the literature or derived by clinical experts. The proposed system, if built, would consist of four components: 1) a PC-based predictive modeling tool that would examine "what if" scenario preparation, but could also be used during an actual outbreak as decision tool; 2) a trace forward and backward system to use the existing facility registration data collected by the FDA, as well as future technology such as Radio-Frequency Identification Device (RFID) for food tracking; 3) utilization of expert software to assist public health officials in early identification of outbreak occurrence of the food and agent; and finally 4) an early warning system based on monitoring certain early exposures based on more sensitive persons which will provide early detection of an adverse event.

The author estimated that the lettuce scenario showed that over 900,000 households would likely be exposed to some level of CBRN "*B. anthracis*" contamination. The morbidity count could result in 1 - 2 million victims needing treatment. The author concluded that models show that potential health effects of a terrorist attack are such that the providers of public health make serious attempts at countering terrorist threats.

Tabletop exercises focusing on food terrorism: from literature (n=3)

Abraham et al. (2012) conducted five TTX's, of which two demonstrated bioterrorism and threat preparedness on mass population exposures, in West Virginia. The participants in the tabletop scenarios were from the disciplines of public health nursing, medicine, emergency services, mental health, allied health, and pharmacy. The hypothetical scenarios of deliberate contamination were: 1) a student contaminated lettuce at a state university with *Shigella sonnei* and 2) a dismissed athlete contaminated ice at the basketball tournament with *Escherichia coli*. The purpose of the exercises was to establish contingency plans for communication and modification methods during a foodborne terror attack. Lessons learned from the exercise included: organizations should plan for when and how to activate a joint information center; a policy between public health and the first responder community should be established concerning pre-incident sharing; and educational institutions should update their emergency plans.

Hegle et al. (2011) conducted five exercises in North Carolina, between February and July of 2009, of which one dealt with food terrorism. The purpose of the exercise was to test response plans, define roles and responsibilities, assess capabilities, and make any necessary enhancements before a substantive event occurred. The 270 participants represented a variety of public health professionals from 10 counties across the state. The hypothetical scenario involved a bioterrorism attack with liquid anthrax in a meat processing plant. The participants used a joint exercise consisting of a seminar, workshop and TTX to discuss the food and agriculture safety and defense plans, communication activated during the response and appropriate isolation and quarantine procedures among the affected victims of the attack. The exercise yielded an important lesson: while there were numerous difficulties with communication systems in all of the exercises, the opportunity to test these systems, train public health practitioners and other response partners on their use and identify technological challenges resulted in valuable learning in preparation for a real-life emergencies. The participants noted that there was a failure in developing exercise scenarios that tested a coordinated regional response to an event, which reduced the potential effectiveness of the regional exercises. It was recommended that consideration should be given to collaborating with regional counterparts (e.g. emergency management regional response teams) in the planning and facilitation of regional exercises to further build these relationships and practice the interagency coordination needed in a real-world emergency.

Hennessey et al. (2010) performed a TTX “Demeter's Resilience” with an international impact by simulating an intentional attack on the food supply with an unknown agent from a poultry processing facility in the United States and shipped internationally. The exercise was held at The University of Minnesota located in St. Paul, Minnesota. The participants included numerous federal agencies, the University of Minnesota, six of the eight G8 countries, WHO, the European Commission and the private sector. The objective of the exercise was to promote discussion among the participants regarding threat posed by a deliberate attack on the food supply with distribution of the product internationally. Outcomes and recommendations included: the participants agreed that recognition of a foodborne disease outbreak is driven by the characteristics of the illnesses rather than actual numbers of ill individuals; effectiveness of international communication channels is greatest when communication is initiated as early as possible; multiple communication messages may be needed to reach different cultures or audiences; and there is a recognized need for increasing the knowledge of food safety and law enforcement response protocols both within and among nations.

Tabletop exercises focusing on food terrorism: from HSDL full database (n=7)

TTX "Operation Cherokee Rose" occurred on June 5, 2008, in Atlanta, Georgia and at the FSIS headquarters in Washington, DC. The participants included USDA and FSIS. The purpose of the exercise was "to test and validate operating guidelines and directives for responding to a non-routine incident" involving the intentional contamination of meat, poultry or egg products within an FSIS inspected facility. Recommendations and assessments included: numerous participants suggested that the exercise should have included EPA Region 4, Georgia Environmental Protection Division, consumer groups, Georgia Department of Homeland Security, state & local law enforcement and physicians/clinical lab; some felt that the epidemiological elements of the scenario were unrealistic, in that local public health would be continually learning new information during the course of real-life outbreak investigations; and, finally, some participants noted that the exercise illustrated the need to improve communication and coordination among all stakeholder groups, especially with regard to creating a unified message.

TTX "Operation Rocky Top" occurred on September 25, 2008, in Denver, Colorado and at the FSIS headquarters in Washington, DC (U. S. Department of Homeland Security, 2014c). The participants included USDA and FSIS. The purpose of the exercise was "to test and validate operating guidelines, policies, and procedures for responding to a non-routine incident" involving the intentional contamination of meat, poultry, or egg products with an unknown contaminant within an FSIS regulated facility.

Lessons learned included: a strong need to establish and expand command structure that offers coordination, communication and interoperability; a separate screen to track progress of the ICS; more involvement by local health departments in the scenario; and some participants noted that the exercise illustrated the need to improve communication and coordination among all stakeholder groups, especially with regard to creating unified messages.

TTX "Operation Wild Rose" occurred on October 30, 2008, in Des Moines, Iowa and at the FSIS headquarters in Washington, DC (U. S. Department of Homeland Security, 2014c). The participants included the USDA and FSIS. The purpose of the exercise was "to test and validate operating guidelines and directives for responding to a significant incident" activity involving the intentional contamination of food products with an unknown agent within an FSIS inspected facility. Assessments and recommendations included: the need for an EOC and Public Information Officer (PIO)/Joint Information Center (JIC); more stakeholders were needed from local government agencies, particularly public health departments, hospitals, HAZMAT and environmental agencies; the communication from government agencies to industry was limited and confusing; and there was consensus among the participants that government was not working as well with industry as possible.

TTX "Operation Apple Blossom" occurred on January 8, 2009, in Springdale, Arkansas and at FSIS headquarters in Washington, DC (U. S. Department of Homeland Security, 2014c). The participants included the USDA, FSIS, FBI, EPA, OSHA and the State Department of Environmental Quality (DEQ). The purpose of the exercise was "to test and validate operating guidelines and directives for responding to a significant incident activity involving" the intentional contamination of meat, poultry and egg products with an unknown agent within an FSIS regulated facility. In addition, the exercise simulated the emergency operations center (EOC) to move participants toward operations in line with the National Response Framework Incident Command/Unified Command System. Furthermore, the state DEQ addressed criminal investigation, product disposal and facility decontamination, and workplace protection. The major lesson learned from the exercise was that the participants stressed that clarification should be provided on how the Arkansas Department of Health can issue advisories to the public that are as timely as possible yet coordinated with messaging by federal agencies.

TTX "Operation Sunflower" occurred on February 26, 2009, in Lawrence, Kansas and at the FSIS headquarters in Washington, DC (U. S. Department of Homeland Security, 2014c). The participants included the USDA and the FSIS. The purpose of the exercise was "to test and validate operating guidelines and directives for responding to a significant incident involving" the intentional contamination of meat, poultry and egg products with an unknown agent within an FSIS regulated facility. The exercise yielded the following lessons: participants suggested adding times to each inject to provide a "real time" timeline versus the compressed time of the scenario; not all of the necessary participants were available for the exercise; and better notification/communication prior to the exercise may have helped to identify and encourage participation by representatives of these stakeholder groups.

TTX "Operation Magnolia" occurred on May 7, 2009, in Jackson, Mississippi and at the FSIS headquarters in Washington, DC (U. S. Department of Homeland Security, 2014c). The participants included the USDA and the Food Safety and Inspection Service

(FSIS). The purpose of the exercise was “to test and validate operating guidelines and directives for responding to a significant incident involving” the intentional contamination of meat, poultry and egg products with an unknown agent within an FSIS regulated facility. Lessons learned included: the exercise should be expanded to include more stakeholder groups; participants from industry commented that the exercise scenario did not accurately portray the food industry’s ability to provide large amounts of information in the early phases of the exercise, therefore real time coordination on critical information should improve the response capabilities for all stakeholder groups; and participants complained that they did not play out activation of Emergency Operations Center (EOC) or unified command structures.

A joint TTX and FE occurred on May 2, 2012, in Dallas, Texas (U. S. Department of Homeland Security, 2014c). See second paragraph, under FE section.

Tabletop exercises focusing on food terrorism: from the RAND report (n=4)

The Rand Corporation’s Public Health Preparedness database identified four tabletop exercises involving food contamination by terrorists (Shugarman et al., 2005). The authors of the report indicated that the organizations that supplied information regarding detailed knowledge on the exercise wanted to remain anonymous, therefore, specific information concerning person, place and time were de-identified in the RAND report.

TTX “TE1” occurred sometime between December 1999 and December 2004, in unknown city and state. No information is provided regarding the participants. The purpose of the exercise was to detect an outbreak of botulism in unknown food product and follow steps set up for an outbreak investigation. No lessons learned or after action report were included in the report.

TTX "TE5" occurred sometime between December 1999 and December 2004, in unknown city and state. No information is provided regarding the participants. The purpose of the exercise was to detect food contaminated with (Ergot - *claviceps purpurea* fungus) and demonstrate the ability to coordinate relations with other stakeholders, notify and work with public health organizations, prioritize and use public health resources, and obtain assistance and work cooperatively with other stakeholders. No assessments, recommendations or after action report were included in the report.

TTX "TE7" occurred sometime between December 1999 and December 2004, in unknown city and state. No information is provided regarding the participants. The purpose of the exercise was to detect food contaminated with *Salmonella* poisoning. Additionally, participants were tasked with practicing group problem solving and assess interagency coordination; discuss coordination/integration of forces, responsibilities, and disaster response plans; and acquaint key department personnel with one another and their mutual responsibilities. No action report or lists of lessons learned were included in the report.

TTX "TE11" occurred sometime between December 1999 and December 2004, in an unknown city and state. No participants' information was provided. The purpose of the exercise was to detect food contaminated with *Shigellosis*. Additionally, participants were tasked with identifying and understanding policy issues, certain performance measures, and gaps in the event of a bioterrorist attack. The report did not include the after action report or list of lessons learned.

Tabletop exercises focusing on food terrorism: not identified in any literature review (n=1)

TTX "Georgia Food Emergency Response Tabletop Exercise" occurred in May of 2008, at The University of Georgia, in Athens, Georgia (State of Georgia, 2009). The participants included 16 state and federal agencies. The purpose of the exercise was to simulate intentional contamination of seafood with ricin introduced at the point of production in an overseas country and entering the U.S. through the Atlanta airport. The lessons learned included the following: the participants indicated a willingness to continue building the capacity for information sharing among state agencies, such that agencies quickly become aware of emergent conditions; they encouraged continued capacity building for the rapid dissemination/sharing of epidemiological data between GA Division of Public Health, CDC, and other agencies; the need to identify a means by which to reduce uncertainty and facilitate a shorter time frame for the making of the decision to hold or recall products, e.g., moving information from labs to decision makers more quickly and bringing more labs into the analytical process during the crucial early hours of analysis; and pinpoint a means by which to confirm that some product in the food supply is safe while others are known/suspected to be contaminated.

Tabletop exercises focusing on food terrorism: from HSDL restricted database (n=2)

TTX "Liquid Food and Crop Contamination" occurred on April 29, 2008, in McClellan, California at the California Office of Homeland Security Training and Exercise Division offices. The participants included personnel from county and state agencies. The purpose of the exercise was to improve interagency collaboration during an attack on the food system where individuals became ill after drinking milk intentionally contaminated with an unidentified biological agent (U. S. Department of Homeland Security, 2014d). Lessons learned included: the ICS, Standardized Emergency Management System (SEMS) and National Incident Management System (NIMS) concepts for a food event need further practical application and exercise; and a large or intentional food contamination event would involve local, state and federal jurisdiction and resources from very early in the response, making coordinated dispatch and command and control potentially challenging.

TTX "Protect and Defend II" occurred on July 25, 2007, in Philadelphia, Pennsylvania. Approximately 140 participants from numerous federal, state and local agencies as well as local colleges and universities and the private sector food companies. The purpose of the exercise was to test and evaluate the ability of public and private agencies with responsibility for response, recovery, and mitigation endeavors during a natural or intentional interference of Pennsylvania's food delivery system. The exercise simulated consumers calling into super-markets and convenience stores complaining about feeling ill, consumers are asking if complaints about numerous food products including hamburger, hot dogs, fruits, salads, and milk have been reported. Local emergency rooms and hospitals report that numerous people are presenting with symptoms that are comparable to diazinon poisoning. Laboratory tests confirm that these illnesses were the result of diazinon poisoning. The exercise concludes when law enforcement arrest an employee of a local food processing plant after surveillance tapes show him placing something on the conveyor line. Assessments and recommendations included: participants indicated that more media training and media relations training to public and private organizations that have public information officers (PIOs) is needed;

private organizations need to be trained on how to interface with a Joint Information Center before an incident occurs; and public and private organizations need to be trained on Risk Communication.

Biological Weapons Tabletop Exercise (BWTTX) focusing on food terrorism: from HSDL restricted (n=10)

Seven TTX's were identified in the database identified as BWTTX008, BWTTX010, BWTTX017, BWTTX042, BWTTX064, BWTTX072, and BWTTX104. No dates or locations were given for these exercises. The number of participants and observers for each exercise ranged from 40 to 150 personnel representing local, state, and federal agencies participated in these exercises. The purpose of the BWTTX's were to assess the impact of a bioterrorist attack on the unidentified "AREA" and facilitate interaction, coordination, and problem solving among the numerous public and private agencies charged with responding to such an event. All seven exercises were sponsored by an unnamed federal entity that featured the contaminant botulinum toxin in food and they were all conducted as part of the Domestic Preparedness Program (DPP). The common lessons learned from all seven exercises included: a formal screening and reporting system is needed; the medical community should consider working with the state Department of Health to review the reliability and the validity of current daily health surveillance indicators and to establish a standardized monitoring system; response agencies should continue building a strong WMD response program through regular refresher training on chemical/biological agent recognition for first responders and support staff; current regulations governing the distribution of food should be reviewed and revised (as appropriate) to include provisions to mitigate the potential for a foodborne release of a WMD agent and provide a means for tracking possible sources; and until the medical community sees a statistically significant number of cases, they may not recognize the first victims of an attack as representing a subset of a potentially much larger number scenario unfolding.

TTX, "BWTTX074" no date or location given for the event. The exercise was sponsored by an unnamed federal entity that featured the contaminant *tularemia* in food and it was conducted as part of the Domestic Preparedness Program (DPP). Approximately 100 participants representing Federal, State, and local agencies participated in this exercise. The purpose of the exercise was to evaluate the impact of a bioterrorist attack on any community and to facilitate interaction, coordination, and problem solving among the numerous public agencies charged with responding to the event. The major lesson learned cited in the report stated that once activated, the health department and EOC should also jointly prepare procedures for hospitals and medical facilities to coordinate with the EOC, in support of a public health emergency or bioterrorist incident.

TTX, "BWTTX078" no date or location given for the event. No information is given regarding the number of participants and observers, however, representatives from local, state, and federal agencies participated in this exercise. The purpose of the BWTTX was to assess the impact of a bioterrorist attack on unknown city and to facilitate interaction, coordination, and problem solving among the numerous public agencies charged with responding to such an event. The exercise was sponsored by an unnamed federal entity that featured the contaminant *Vibrio cholera* in food and it was conducted as part of the Domestic Preparedness Program (DPP). The major lesson learned cited in the report stated that several emergency management participants were glad to have the opportunity to exercise their local response plans to ensure their effectiveness in dealing with bioterrorism.

TTX, “BWTTX104” no date or location given for the event. More than 70 participants representing Federal, State, and local agencies participated in this exercise. The purpose of the exercise was to assess the impact of a bioterrorist attack on the unknown city community and facilitate interaction, coordination, and problem solving among the numerous public agencies charged with responding to such a horrific act. The exercise was sponsored by an unnamed federal entity that featured the contaminant *Staphylococcal Enterotoxin B* (SEB) in food and it was conducted as part of the Domestic Preparedness Program (DPP). The major lessons learned cited in the report indicated that early detection diagnosis of unusual or suspicious disease outbreaks by local medical and public health personnel, acting in concert with first responders in their communities, would make a critical difference in that community’s ability to respond to and manage the particular dimensions of an actual bioterrorism incident or naturally occurring unusual disease outbreak.

Summary of Food Terrorism Exercises

The results of all the food defense exercises show that a bioterrorist incident may likely be characterized by the absence of a credible threat (because the incident will be temporally and geographically dispersed and the public health emergency will escalate without the traditional 9-1-1 call reporting a single major incident at a specific location). As a result, identification of the point of release may be difficult and delayed and, in fact, may never occur. A bioterrorist incident will create a major public health crisis, and emergency healthcare would take priority over all other response and recovery activities. Lastly, federal resources may not arrive until 12 to 36 hours after notification. Based on these characteristics, the foundation of the emergency response planning efforts should be focused on incident recognition, rapid response and mobilization, and integration of mutual-aid and federal assets.

The food defense section of the literature review set out to determine the quantity and magnitude of HSEEP exercises that utilized food contaminated with a CBRN agent in order to test and improve public health preparedness in response to such an event. The common themes resulting from the exercises revolved around early warning communication systems and pre-incident sharing; collaborating with external partners, especially law enforcement and regional partners; updated emergency response plans; policies between public health and first responders; cooperation with external stakeholders especially the food industry; the need for a Joint Information Center which would include an Emergency Operations Center, a Public Information Officer; more media training; and finally early detection and warning to minimize illnesses and loss of life.

There are more than 100 exercises for pathogens such as anthrax, smallpox, tularemia and pneumonic plague that were listed in the HSDL database and in the literature. In contrast, as discussed in this chapter, this review reflects the totality of foodborne contamination exercises and it is apparent that there are a limited number of preparedness assessment opportunities available to assess the effectiveness of public health response plans to an event of intentional contamination of food.

Cost of Illness

Segel (2006) defines the cost of illness as a measure of "the economic burden of a disease or diseases and estimate the maximum amount that could potentially be saved or gained if a disease were to be eradicated." This section of the literature review will address the history of research in this area, the methods researchers have used to calculate it, the types of costs they have included, and the approaches they have taken to measuring indirect costs. It provides two sections that focus on the cost of foodborne illness: an overview of studies, and a description of the main features in these analyses. It concludes by reviewing the three studies in the literature that assess the cost of illness from a bioterrorist attack.

History of cost of illness studies

Cost-of-illness studies first emerged in 1913 and were among the first economic evaluation studies (Chapin, 1913). Mushkin and Collings (1959) built on earlier work to clarify the costs concepts in cost of illness studies. Their classification of costs accounted for effects of illness "on the use, distribution, and quantity of economic resources". Rice (1967) developed a method for estimating the cost of illness by using existing data sets which would become the standard approach for cost of illness studies, with refinement by the original author in collaboration with others (Rice, Hodgson, & Kopstein, 1985).

In the 1970s and 1980s, policymakers began to use cost of illness studies to win support for more resources being devoted to health care (Drummond, 1992). In the 1990s, pharmaceutical companies began to use cost of illness studies to highlight the economic burden of a particular disease (Drummond, 1992). The studies were used was to justify the fact that more resources, i.e. the company's product, should be devoted to that particular disease. Currently, pharmaceutical companies, health care decision makers, and policy makers utilize these studies to guide decisions concerning health care resources (Rice, 2000).

Costs of illness methodology

Two methods have emerged to estimate the costs associated with a particular disease or illness: prevalence and incidence. Prevalence-based studies determine the costs incurred by all individuals (regardless of the date of onset) infected with the disease during a defined period, usually one year (Friesner, Rosenman, Lobb, & Tanne, 2011; Wolf & Colditz, 1998). An incidence-based study estimates the cost for each patient recently diagnosed with the disease, usually from diagnosis to cure or death (Sorensen et al., 2012; Zaloshnja, Miller, Lawrence, & Romano, 2005).

Researchers have also had to identify whose costs they will measure. One perspective measures the costs to society (societal perspective) (Birnbaum et al., 2009; Marchetti & Rossiter, 2013) and another one may take into account costs to the third party payer (payer perspective) (Lin, Lingohr-Smith, & Kwong, 2014; Murman, Von Eye, Sherwood, Liang, & Colenda, 2007). Researchers can also focus on costs to businesses, the government, and participants and their families (Rice, 2000).

Types of costs

If possible, the cost of illness estimate should include all costs of a disease. Measurement of cost of illness has addressed *direct* costs and *indirect* costs. Direct costs are those expended treating a disease. Indirect costs refer to productivity losses attributable to a disease and its treatment and the cost of a patient's pain and suffering. Research using a societal perspective encompasses both indirect and direct costs.

Rice and Hodgson (1982) identified two types of direct costs: medical and non-medical. The former include costs for hospital inpatient stays, emergency department visits, office-based medical visits, outpatient visits, prescription medication, nursing home care, hospice care, rehabilitation care, home health care, and cost for medical supplies. A study that takes a health care provider perspective typically only includes these direct medical costs (Finkelstein, Graham, & Malhotra, 2014; Owusu-Edusei et al., 2013). The latter include transportation to health care and residential care as a result of the illness or disease. Some studies have included family time spent caring for the illness and change in a patient's life pattern due to the illness among direct non-medical costs (Rice, 1967; Rice et al., 1985).

Indirect costs include: absenteeism from work, loss productivity while on the job, and mortality (cost of premature death due to the illness) (Hodgson & Meiners, 1982). They also include a patient's pain and suffering or intangible costs (Haddix, Teutsch, & Corso, 2003a). This cost is difficult to quantify in monetary terms and is usually not included in the cost of illness estimation (Segel, 2006). Studies that measured intangible costs for foodborne illness include (Batz, Hoffmann, & Morris, 2012; Hoffmann, Batz, &

Morris, 2012; Minor et al., 2014; Scharff, 2010, 2012, 2015) and shown on Table 4.

Measuring indirect costs

The two approaches to estimate indirect costs of illness that have emerged in the literature are the Human Capital approach (HCA) introduced by Klarman in 1965 to evaluate the economics of syphilis control (Dorfman, 1965) and the willingness to pay (WTP) approach used by Schelling in 1968 (Hodgson & Meiners, 1982). The HCA computes the value of lost productivity due to absences from work (labor market work force and housework), disability (morbidity costs), and/or death (mortality costs) for patients and care givers in terms of lost earnings over the course of the entire period of absence from work (Rice, 1967). If the patient/care giver's primary employment is unpaid, researchers calculate the value of their work as the cost of hiring a replacement from the labor market (Segel, 2006).

When using an HCA approach, the cost of mortality is the productivity loss due to premature deaths—the present value of future earnings, from age of death to life expectancy. A prevalence-based COI study using an HCA approach, calculates the cost of mortality in light of the number of years patients would be expected to live if not afflicted with the disease (Segel, 2006). Researchers estimate lost future earnings due to a medical condition by the total number of deaths due to a medical condition and the average annual wages of deceased individuals from the year they died to their life expectancies.

Researchers who favor the WTP approach point out that the HCA's use of wage rates and employment rates typically assigns lower value to people by age, sex, or race

(Segel, 2006). Segel (2006) defines the WTP approach as "the amount an individual would pay to reduce the probability of illness or mortality." Researchers using this approach calculate the costs of mortality using the Value of Statistical Life (VSL) to appraise the statistical probability of reduction in the number of deaths through regulation or policy change (Grosse & Krueger, 2011). The WTP approach to reduce mortality has been examined extensively and utilized to calculate the value of statistical life (Hoffmann et al., 2012). However, the practice is controversial because the estimates are sensitive to the study populations, type of risk, and level of risk so they may not be applicable if used in a different study (Buzby & Roberts, 2009).

In valuing the economic burden of mortality, most Federal agencies (EPA, DOT, FDA and USDA) (President of the United States, 2013) use a measure of WTP to reduce risk of death called the Value of a Statistical Life (VSL). The USDA estimates morbidity losses based on the VSL approach using a value of $8.7 million (in 2013 U.S. dollars) based on a U.S. Environmental Protection Agency (2010) review of existing estimates. EPA's National Center for Environmental Economics values all deaths at a constant VSL based on studies from a meta-analysis of 26 existing studies (based on stated preferences and hedonic analysis) (U.S. Environmental Protection Agency, 2010).

COI studies focusing on foodborne illness

The Economic Research Service (ERS) of the USDA conducted some of the earliest studies on the economic costs of foodborne illness in the United States (Buzby & Roberts, 2009). Over time, ERS has updated and expanded these analyses with improved estimation methods and better data. Each series of ERS estimates incorporated better information on disease incidence, more detailed data on the health consequences of foodborne illness, and advances in the economic methods for valuing health outcomes. The initial estimates reflected the limited information then available about the incidence of foodborne illness and used the COI method to tally expenditures on medical care and lost productivity because of nonfatal illness and premature death (Buzby & Roberts, 2009).

In 2007, ERS's online Foodborne Illness Cost Calculator began providing information on the assumptions behind foodborne illness cost estimates for *Salmonella* and *Escherichia coli* O157 (STEC O157), giving Internet users a chance to make their own assumptions and to calculate cost estimates themselves (Buzby & Roberts, 2009). In 2014, the calculator began providing information on 14 pathogens, which cause over 95 percent of foodborne illnesses acquired in the United States. The Center for Disease Control (CDC) established the Foodborne Diseases Active Surveillance Network (FoodNet) in 1996 to track the incidence of foodborne illness, and many subsequent studies have drawn on this research.

Buzby, Roberts, Lin, and MacDonald (1996) used five main data sources for incidence of acute foodborne illnesses to estimate the cost of illness from foodborne disease: (1) national surveys or databases such as those conducted and published by the National Center for Health Statistics (NCHS), (2) CDC data ranging from reports of foodborne disease to active surveillance studies, (3) risk models based on pathogens' prevalence in foods, and on infectious doses, (4) medical data on individual cases, often published in the literature as a case history, and (5) extrapolations by experts to obtain estimates of the total number of cases and the disease severity distributions, to develop one of the first COI estimates. The authors estimated the costs of human illness due to six bacterial pathogens (*Salmonella*, *Campylobacter jejuni*, *Escherichia coli O157:H7, Listeria monocytogenes*, *Staphylococcus aureus*, and *Clostridium perfringens*) at $9.3-$12.9 billion annually. They attributed $2.9-$6.7 billion to foodborne bacteria. Salmonella is the most costly ranging from $0.6 billion to $3.5 billion dollars, due mainly to the large number of cases and its virulence among specific subpopulations: the elderly, infants, and immunocompromised.

Frenzen, Drake, Angulo, and Group (2005) estimated the cost of foodborne illness related to O157 STEC, which can cause hemolytic uremic syndrome (HUS), the abnormal premature destruction of red blood cells. Using data from the FoodNet from 1999 to 2002, the authors estimated direct costs and indirect costs for morbidity and mortality by the HCA approach, using a modified VSL that takes age at death into account—the VSL of $6.9 million for patients up to the age of 40, $9.3 million for an infant less than 1 year of age, and $1.8 million for an adult older than 85. They estimated the annual cost of illness related to O157 STEC at $405 million in 2003 dollars, including $370 million for premature mortality, $30 million for medical care, and $5 million in lost productivity. Furthermore, the average cost per person ranged from $26 for a patient who did not seek medical attention to $6.2 million for a patient who died from HUS. The authors concluded that O157 STEC infections are very costly for society and that the state should dedicate more resources to prevent infections.

Based on the Hammitt and Haninger (2007) WTP survey for food safety and the CDC data on the age distribution of illness severities, Roberts (2007) estimated that the annual cost of foodborne illness in the United States was $357 billion–$1.4 trillion, for 76 million cases of food-borne illness. The author used CDC's (Scallan et al., 2011) recent foodborne-disease-incidence estimates and the HCA to value mortality and morbidity. For mortality values, the author used different values for adults, children, and the elderly. Adults were valued at $7 million each, based on Viscusi and Aldy's 2003 review of the VSL literature where the range is $4 million to $9 million. The elderly (those aged over 70), were valued at 30% less, or $5 million, based on Blomquist's review (2004). Children were valued more highly, based on Hammitt and Haninger's ratio for hospitalized cases, at $12 million. The results showed that the leading cost component in the WTP estimates is cases where no medical care is received. The cost estimates at $1.4 trillion do not include chronic sequalae and thus represent an underestimation of costs.

Ralston, Kite-Powell, and Beet (2011) used data from CDC's Outbreak Surveillance Summaries (1993 to 2006) and FoodNet to estimate the burden of illness due to marine-borne pathogens from seafood consumption and beach recreation in the USA, using the ERS COI calculator. They reported the annual costs on the order of $900 million. The reported results indicated that premature deaths contribute most to the total costs of seafood-borne illness ($306 million), with the remainder due to medical care ($25 million for physician visits and $6 million for hospitalizations) and lost productivity ($15 million). Direct medical and productivity losses were estimated using the HCA and mortality using the WTP approach with a VSL of $5 million dollars. This study identified *vibrio vulnificus* as the most costly marine-borne pathogen, which accounted for about a third of the total seafood-borne costs and over 85% of the costs of Vibrio infections from direct exposure. The authors did not provide the year for the cost estimates.

Batz et al. (2012) used data from CDC's online repository of foodborne outbreaks from 1999 to 2008 to estimate the burden of illness from the top 10 pathogen-food combinations, which reflected five pathogens (*Campylobacter, Listeria monocytogenes,* norovirus, *Salmonella*, and *Toxoplasma gondii*) in eight food categories (poultry, pork, deli meats, dairy, produce, beef, eggs, and complex foods). They estimated costs at $4.4–$33.0 billion. The authors concluded by calling for further research on the relationship between attribution of foodborne illness and food sources, particularly for *Toxoplasma, Campylobacter*, and *Salmonella*.

Hoffmann et al. (2012) used CDC's (Scallan et al., 2011) recent foodborne-disease-incidence estimates and FoodNet 2001–2004 to estimate illness from 14 major pathogens in the United States. The authors reported that although scientists have identified 31 pathogens, these 14 pathogens account for over 95 percent of the illnesses, hospitalizations, and deaths from foodborne illness. They used a cost-of-illness estimate for nonfatal outcomes and a WTP (for reducing deaths) measure for fatal outcomes, using a VSL of $7.9 million (in 2009 U.S. dollars), concluding that the pathogens they studied cost $14.1 billion (ranging from $4.4 billion to $33 billion) in 2009 dollars. They estimated for acute illnesses that $11 billion for premature mortality, $2 billion for medical care; and for chronic conditions, $363 million for medical costs and $740 million for premature deaths. The authors conclude that nontyphoidal *Salmonella* and *Toxoplasma gondii* are the first and second most costly foodborne pathogens, respectively, in the United States.

In an update of Hoffmann et al. (2012), Hoffmann, Maculloch, and Batz (2015) attributed $15.5 billion in 2013 dollars for 15 pathogens based on the same CDC source

(Scallan et al., 2011). The authors noted that this adjustment reflects inflation and income growth over time. The report also indicated that five pathogens cause 90 percent of this burden and that COI for pathogens ranged from $202 for *Cyclospora cayetanensis* to $3.3 million for *Vibrio vulnificus*. As in the earlier study, the authors used ERS COI calculator to estimate the burden of illness using the HCA for morbidity and productivity losses, and the WTP approach for mortality losses, value each death the same, using a VSL of $8.7 million (this time in 2013 U.S. dollars) based on a U.S. Environmental Protection Agency (2010) review of existing estimates. Premature deaths account for the majority of losses (84%), followed by medical cost (10%) and productivity losses (6%). The authors performed a sensitivity analysis using the mean CDC incidence estimates and the upper ($15.7 billion) and lower ($1.6 million) bound VSL estimates, resulting in an economic burden of the 15 pathogens that could be as low as $1.8 billion and as high as $63 billion.

Minor et al. (2014) used CDC's (Scallan et al., 2011) recent foodborne-disease-incidence estimates and estimated the cost of foodborne illness from 31 pathogens, including several biotoxins, foodborne allergies, and unspecified agents, at an average of $36 billion, in 2013 dollars, with a range of $14.74 to $72.6 billion foodborne illness from 31 pathogens. The HCA was used to estimate direct medical and productivity losses and mortality based on the WTP approach using a VSL of $8.3 million (in 2013 prices). The authors reported that, *Cronobacter spp.* is the most costly pathogen, causing society a total monetary loss of $7 million dollars.

Scharff (2010; 2012) estimated the cost of foodborne illness in the United States to be as high as $51 billion. The author included estimates for foodborne illnesses caused by 30 of 31 identifiable pathogens plus foodborne illnesses for which no pathogen source can be identified in CDC's recent (Scallan et al., 2011) foodborne-disease-incidence estimates. Direct medical and productivity losses were estimated using the HCA and mortality using the WTP approach with a VSL of $7.3 million dollars. This analysis attempted to address the total burden of U.S. foodborne illness and includes illnesses of both known and unknown pathogen origin. The author concluded that improving social welfare requires bringing the product of the cost per case and the number of cases averted above the expected cost of implementing a particular food safety program for society as a whole.

Scharff (2015), putting his national estimate on foodborne losses due to 31 pathogens at $55.5 billion in 2013 dollars. The study reports costs by state, finding a range from $106 million in Wyoming to 7.3 billion in California using the basic cost of illness method. Direct medical and productivity losses were estimated using the HCA and mortality using the WTP approach with a VSL of $8.3 million dollars. The author concluded that since costs associated with foodborne illness differ across the states, policymakers at the state level should use state estimates instead of the national estimates.

Methodology employed in the COI studies for foodborne illness

The following sections assess each of the above-mentioned studies with respect to the main features of a cost of illness analysis.

Source of data. In order to get data on resource use and cost, almost half of the studies used retrospective cohort study methodology. This involved asking patients about their utilization retrospectively (Batz et al., 2012; Buzby & Roberts, 1996; Frenzen et al., 2005; Hoffmann et al., 2012; Ralston et al., 2011; T. Roberts, 2007; Scharff, 2012), or employing medical databases providing individual information on healthcare utilization and cost (Hoffmann et al., 2015; Minor et al., 2014; Scharff, 2015) or both (Batz et al., 2012; Buzby & Roberts, 1996; Frenzen et al., 2005; Hoffmann et al., 2012; Ralston et al., 2011; T. Roberts, 2007; Scharff, 2012, 2015; Ted & Diane, 1997). Table 5 shows the list of the medical databases employed.

Perspective of the study. All ten studies used the societal perspective.

Cost categories. All studies included indirect costs in their analysis as well as direct costs. To estimate indirect costs, all studies used the HCA. None of the studies gave an estimation of indirect costs on a population level (employed or unemployed patients). All reported indirect costs were based on employed patients only. Table 4 shows specific cost categories used in these studies. The most frequent cost categories included in the analysis were outpatient treatment cost, costs for hospital treatment, drugs, and emergency room facilities. Studies conducted by (Frenzen et al., 2005; Hoffmann et al., 2012; Scharff, 2012, 2015) were the most comprehensive studies with respect to cost categories (approximately seven) included in the analysis.

Several studies (Batz et al., 2012; Hoffmann et al., 2012; Minor et al., 2014; Scharff, 2010, 2012, 2015) used monetized quality-adjusted life year (QALY) to account for pain and suffering caused by foodborne illness as well as the illnesses' impact on daily activities, such as employment. Two National Academy of Sciences committees and the U.S. Environmental Protection Agency's Scientific Advisory Board have advised against using this measurement, finding that current approaches to monetizing QALY loss are not reliable economic measures (Hoffmann et al., 2012). ERS cost of illness is an established practice recognized to be a reliable, though conservative, economic estimate of the burden of nonfatal illness. Therefore, this literature review does not include the cost of illness that use monetized QALYs as a valuation method.

Cost of illness due to a bioterrorist attack

The literature review did not yield any studies of the cost of illness resulting from an attack on the food supply. However, it identified three studies (in Table 6) of the cost illness from a bioterrorist attack using chemical, biological, radiological, or nuclear materials (CBRNs). Two address harm due to inhalation of biological agents (Kaufmann et al., 1997; Lee, Gordon, Moore, & Richardson, 2008) and one address the harm if a terrorist introduced biological agents into a public drinking water supply system (Parks, 2009).

Kaufmann et al. (1997) used a hypothetical population of 100,000 people and modeled the economic burden of illness from a hypothetical bioterror attack with inhaled agents (*Bacillus anthracis*, *Brucella melitensis*, and *Francisella tularensis*). The estimated costs ranged from $478 million to $26.2 billion, per 100,000 persons exposed to brucellosis to anthrax, respectively. The authors used the HCA to value mortality and morbidity, which premature human death valued at the present value of expected future earnings, weighted by the age and sex composition of the U.S. workforce. The stream of future earnings was discounted at 3% and 5%, to give values of $790,440 and $544,160, respectively. Their model showed that in the absence of any intervention, all three biologic agents would cause high rates of illness and death, and early intervention of antibiotics after an attack is essential to saving lives. Their estimates did not account for emergency department visits and long term illnesses.

Lee et al. (2008) used data from the National Football League's game attendance to estimate the economic impact due to a bioterrorist attack on a sports stadium in an urban area at $57 billion in 2003 dollars, positing 31,000 illnesses and more than 10,000 deaths, due to an unknown biological agent. The authors used the HCA for morbidity and the WTP approach for mortality losses, using a VSL of $5.4 million dollars. The estimated loss of a bio-terrorist attack on a stadium ranges from $62 billion to $73 billion. The largest loss comes from the loss of lives, followed by the reduced demand for sports stadium visits. Their estimates for outpatient visits and hospitalizations were based on arbitrary values, and they did not include productivity losses due to short and long-term morbidity or the cost of emergency department visits and long-term illnesses.

Parks (2009) used the Los Alamos National Laboratory’s Critical Infrastructure Protection Decision Support System (CIP/DSS) model integrated with EPANET (a water quality model developed by EPA), and a Geographical Information System (GIS) to examine the spread of a deliberate attack on the Dallas, Texas, water utilities to estimate the cost of illness from with ricin, anthrax, and cryptosporidium, for his master's research thesis. He used computerized simulations to model the spread of biological or chemical contaminants through a water distribution system, which would result in over 30,000 deaths and 61,000 injured based on a worst-case scenario. Using an early warning system based on using a sensor or sensors sensitive to the contaminant could result in a reduction of illnesses and deaths. The author used the HCA for morbidity and WTP approach for mortality losses, using a VSL of $6.2 million dollars. The cost of illness estimates showed that costs range from $171,021 to $49.3 million dollars for ricin, $1.8 million to $31 million dollars for anthrax, and $7.5 million to $25 million dollars for cryptosporidium, when an early warning system is implemented to minimize losses. The study did not account for productivity losses due to illnesses. However, as the next section will describe, Parks accounted for the worried well in his cost of illness estimates.

The Worried Well

Terrorism triggers fear. It produces overwhelming reports in the media. During a bioterrorism event, the "worried well" are individuals who believe that they have been infected by a CBRN and seek medical care although they are not affected (Good et al., 2013; Gougelet, Rea, Nicolalde, Geiling, & Swartz, 2010). A large-scale bioterrorist attack is likely to generate a public health catastrophe in which the number of affected victims would surpass current healthcare resources, making the worried well a significant burden (Burkle, 2002). Nor would the need for care for medical emergencies unrelated to the bioterrorist attack cease (Courtney, Toner, & Waldhorn, 2009). A bioterrorism event could also require the treatment (e.g., antibiotic prophylaxis) of non-exposed but susceptible persons to prevent illness (Burkle, 2002). A bioterrorist attack would require an intricate and organized emergency response action and healthcare resources will need to be appropriated promptly by parties across multiple local, state, and regional authorities to care for those sick or injured by the attack; unaffected individuals constitute a major source of strain.

The examination of peer-reviewed literature did not identify any bioterrorism studies that quantified the worried well population and their effect on the economy. Nor did it identify any studies that used the COI method to quantify the worried well population and their economic burden to the healthcare industry. However, numerous articles describe the number of worried well persons in a bioterrorism attack.

Estimates of the worried well and other non-affected patients burdening the healthcare system

Wick and Zanni (2008) reported that, in the normal course of healthcare provision, individuals with hypochondria or worried well consume at least 10% of healthcare costs and are a major source of frustration to practitioners. In a bioterrorism event, the worried well will likely seek medical care for unexplained symptoms that resemble CBRN exposures such as chronic fatigue syndrome, fibromyalgia, headaches, dizziness and nausea (Pastel & Richey, 2011). Burkle (2002) suggests that 5% to 15% of non-exposed (outside of the attack area) but susceptible persons will receive treatment (e.g., antibiotic prophylaxis) (Burkle, 2002). Ranges researchers propose for estimates of the worried well range from at least five and possibly as many as ten for every affected patient (Gougelet et al., 2010; U. S. Department of Homeland Security, 2006) to 100–1,000 worried well for every actual patient (Bruemmer, 2003). Putzer (2006) reported that the number of worried well individuals seeking care is subject to the enormity of the event and the number of individuals affected by the event.

Estimates of worried well in past events

Researchers addressing the number of worried well in past CBRN events report a range of estimates of the worried well. Stone (2007) referenced the three most commonly studied CBRN events (The Goiana Incident, The Aum Attack and the Anthrax Letters), noting that almost 120,000 people were labeled as worried well in the Goiana incident in Brazil; 73% - 85% of patients seen in hospitals during the Aum Shinrikyo attack of the Tokyo subway were classified as worried well; and 99 percent of patients that received treatment during the anthrax letters attack were classified as worried well.

Eason (2013) estimated that more than 5500 “worried well” asked for medical treatment at local hospitals during the Aum Shinrikyo attack, where seven people lost their lives and more than 550 became ill. During the 2009 H1N1 influenza outbreak, emergency departments across the United States were overwhelmed with record numbers of worried well patients pursuing medical attention (Holtry, Hung, & Lewis, 2010).

Analyses of the impact of the worried well in a bioterrorist attack

Bebber (2007) in his doctoral dissertation used a computer simulation model, which estimated that the response plan developed by a hospital in Florida for a bioterrorist attack would effectively accommodate the increased patient load included the worried well. Hupert, Mushlin, and Callahan (2002) also developed a computer simulation model to help anticipate staffing needs for entry, triage, medical evaluation, and antibiotic dispensing in a hypothetical distribution center range (low, medium, and high) bioterrorism attack. The authors assumed that 10% of the “noninfected population would either be worried well or would have true non-bioterrorism-related illnesses.” Their results showed that the distribution center operation required from 93 personnel to staff for the low-attack scenario to 111 personnel staff for the high-attack scenario to process approximately 1000 people per hour within the baseline model assumptions. The worried well patients were processed in less than six minutes in all 3 models. Because they were asymptomatic, they received oral medications and were dismissed, so that staff could have more time to treat symptomatic patients. The author’s computer model and simulations could allow local planners to develop templates or plans for the more effective allocation of resources as an event proceeds.

The model employed by Parks (2009) included effects of the worried well on the health and economic sectors, analyzing both a scenario with an early warning system (EWS) and without one. The author used a value of “10” (10 times the number of legitimate patients) for the worried well effect in his simulation model. His results showed that for all three toxins (ricin, anthrax and cryptosporidium), twice as many worried well patients presented at the hospital as affected patients. His results showed a clear burden but identified the value of a triage system to separate the worried well from sick patients. His analysis of the economic impact of consumer spending’s decline due to the attack showed that the worried well would cause 90 percent of the impact.

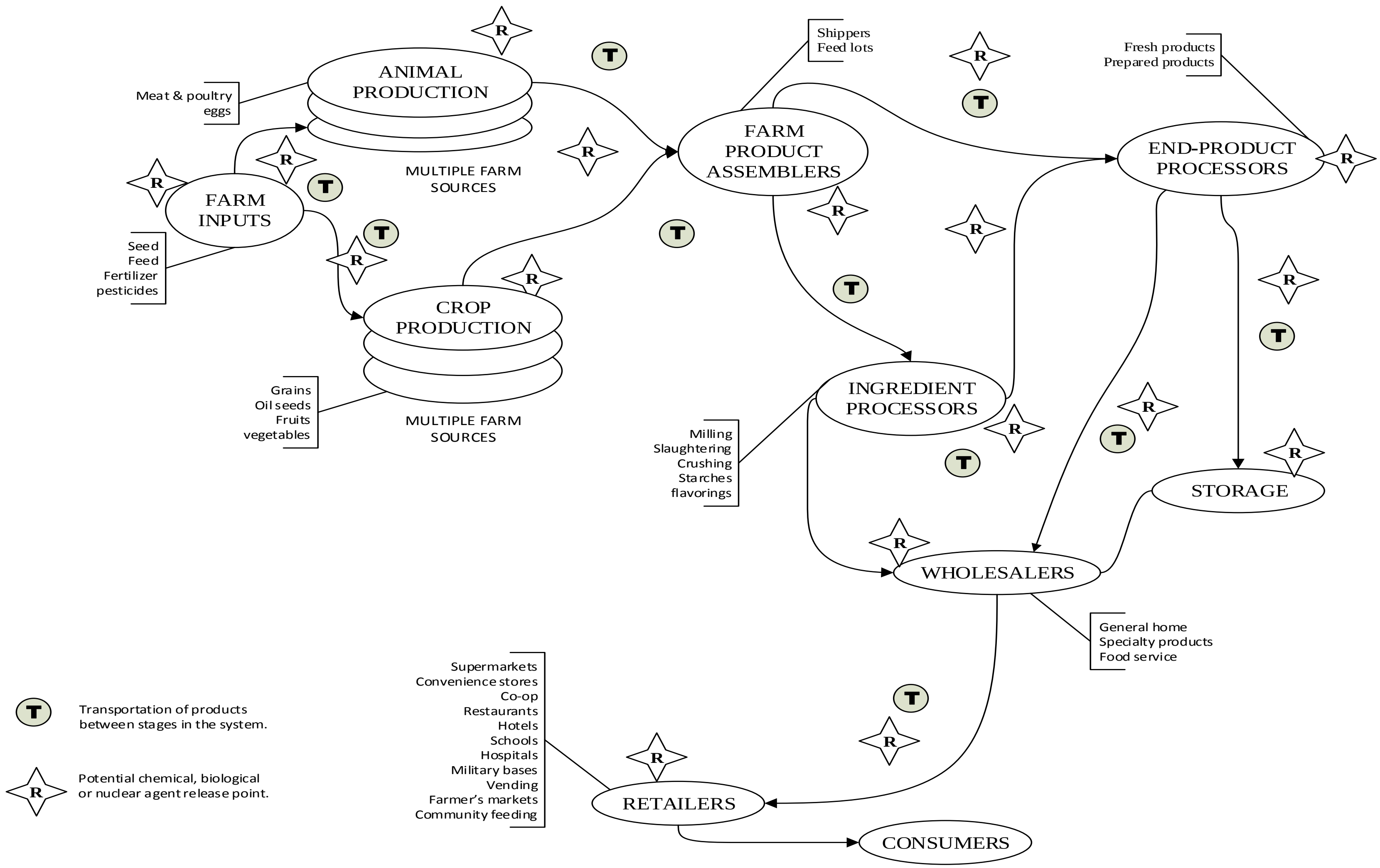

Figure 2. A schematic representation of the U.S. food supply, processing and distribution system. (Hope, 2004)

Table 1. Intentional Food Contamination Events, by country and date

Date	Agent	CBRN	Food	Description Of Event	Motive	Ill/Deaths
AFGHANISTAN (3 events**)**						
2003 March	Unknown	Unknown	Unknown	*Plot:* A high-level al Qaida operative in Afghanistan was captured by the FBI with a spiral notebook describing a plot to poison U.S. military field rations (Pinkerton, 2004).	Terrorism: Plot by Al Qaeda	N/A
2001	Unknown	Unknown	Unknown	*Plot:* U.S. forces seized documents at the Tarnak Farms Al Qaeda training camp near Kandahar, Afghanistan, illustrating plans to poison U.S. drinking water and food supplies (Forest, Howard, & Sheehan, 2013).	Terrorism: Plot by Al Qaeda	N/A
2000 March	Unknown	Unknown	Unknown	Two student died and hundreds were exposed to food deliberately poisoned at a religious school in Jalaludin, Afghanistan (Mohtadi & Murshid, 2007).	Unknown	Ill = Hundreds Deaths = 2

AUSTRALIA (1 event**)**						
1978 November	Mustine hydro-chloride	Chemical	Unknown	Delegates at an international Assyrian Congress meeting in Sydney were taken ill after ingesting food that had been poisoned with mustine hydrochloride. Mustine hydrochloride is an antineoplastic agent that produces vessication (blistering) (Mohtadi & Murshid, 2006).	Political: It was alleged that the Iraqi delegation was responsible for supplying the contaminated food. Two delegates who received contaminated food previously criticized the Iraqi Government's use of violence.	Ill = Several Deaths = 0
BANGLADESH (2 events**)**						
2004 – 2006	Benzodi azepine	Chemical	Unknown food & beverages	Approximately 142 individuals in Dhaka, Bangladesh, recalled buying or accepting food or drinks before losing consciousness, where poisoning with benzodiazepine is the suspected contaminant (Majumder et al., 2008).	Sexual assault and theft.	Ill = 142 Deaths = 0
1999 July	Unknow n agent	Unknown	Unknown food	Elderly members of a group called Tablig Jamaat, became ill after eating contaminated food at a mosque in Chandpur, Bangladesh (Mohtadi & Murshid, 2006)	Theft: Burglars tainted patron’s food, causing them to become unconscious, then took the victims' money and valuables	Ill = Several Deaths = 0

BELGIUM (1 event)						
1978 February	Mercury	Chemical	Fruit	Contaminated oranges were discovered in Belgium. A lemon injected with mercury was found in Belgium (Mohtadi & Murshid, 2006).	Terrorism: A Palestinian group (The Arab Revolutionary Group) claimed responsibility for the attack.	Ill = 0 Deaths = 0
CANADA (2 events)						
2000 May	Arsenic	Chemical	Coffee	An unknown perpetrator added arsenic to a coffee vending machine located at the Lavalis University Animal and Food Sciences department, approximately 30 people presented with symptoms of arsenic poisoning and, of these, four were hospitalized due to treatment related complications (Anon, 2009a).	Unknown: Police said that poison-ing was probably deliberate though suppliers of the coffee were not suspected (Mohtadi & Murshid, 2006).	Ill = 30 Deaths = 0
1970	*Ascaris suum*	Biological	Unknown food	Four university students in Canada were sickened after consuming food intentionally contaminated with embryonated Ascaris suum, the swine roundworm (Phills et al., 1972).	Sever	Ill = 4 Deaths = 0
CHINA (18 events)						
2013 December	Rat poison & herbicid e	Chemical	Yogurt	More than 15 children became ill and after consuming yogurt contaminated with rat poison and herbicide at a school in the Hunan Province of China (CNN, 2013)	Mental Illness: News reports state that the woman was suspected to be suffering from a	Ill = 19 Deaths = 0

					mental disorder (Beijing, 2013).	
2013 May	Rat poison	Chemical	Yogurt	Two nursery school children died after consuming yogurt that was deliberately contaminated with rat poison. The accused teacher to placed it on the street near her competitor's business, along with school supplies (Branigan, 2013).	Competitive sabotage: Police say that the head teacher spiked food with rat poison in an attempt to damage the reputation of rival institution.	Ill = 0 Deaths = 2
2007	Rat poison	Chemical	Rice	Three people died and nine were hospitalized after consuming rice laced with rat poison from a restaurant in Haikou, in Hainan, China (Dalziel, 2009).	Competitive sabotage: The incident was sparked by two men who worked for rival businesses.	Ill = 9 Deaths = 3
2007	Rat poison	Chemical	Noodles and soybean milk	One person died and eleven individuals became ill after eating noodles and soybean milk at the government department canteen in Xiantao City, Hubei Province in China (Dalziel, 2009)	Resentment: Police suspect that Hu's motive was resentment of her colleagues but the spokesman declined to elaborate.	Ill = 11 Deaths = 1

2003 November	Rat poison	Chemical	Breakfast food	Approximately 76 college students in Yizhou city of Guangxi Zhuang Autonous Region were ill after eating breakfast contaminated with rat poison (Sholl, 2004).	Unknown	Ill = 76 Deaths = 0
2003 October	Rat poison	Chemical	Unknown food	A woman poisoned 33 people with rat poison that were attending her husband's funeral. Ten people died and another 23 were hospitalized. (Mohtadi & Murshid, 2006).	Revenge: The act appears to have been motivated by revenge.	Ill = 33 Deaths = 10
2003 October	Rat poison	Chemical	Barbeque	Approximately 16 people in China were hospitalized after consuming barbecue poisoned with rat poisoning at a stand in Shaanxi Province. (Sholl, 2004).	Competitive sabotage: The business rival from a competing stand poisoned the food of his competitor	Ill = 16 Deaths = 0
2003 September	Tetra-methylene-disulfo-tetramine (Rat poison)	Chemical	Breakfast cake	More than 300 students and staff were poisoned after eating breakfast contaminated with rat poison at an elementary school in Yueyang, Hunan Province, China (Mohtadi & Murshid, 2007).	Competitive sabotage	Ill = 300 Deaths = 0

2002 September	Dushuqiang (rat poison)	Chemical	Pastry dough	A cousin and former employee of a soy milk shop in Tangshan, China, used a rat poison called" Dushuqiang" to contaminate a rivals breakfast snacks resulting in approximately 38 deaths (Sholl, 2004; U.S. Food and Drug Administration, 2004)	Disgruntled employee: The New York Times reported that the perpetrator sought only to cause illness, but fled in panic upon witnessing the violent deaths of several patrons (Anon, 2009a).	Ill = Several Deaths = 38
2002 January	Rat poison	Chemical	Unknown Food	92 children became ill after eating school lunch that contained rat poisoning in Linxian city, Hunan Province, China (Mohtadi & Murshid, 2007).	Disgruntled employee: It was later found to have been placed there by one of the teachers (Mohtadi & Murshid, 2006).	Ill = 92 Deaths = 0
2001 August	Rat poison	Chemical	Noodles	16 restaurants served noodles contaminated with rat poison making 120 customers ill in Ningxiang, Hunan Province, China (Mohtadi & Murshid, 2007).	Competitive sabotage: The incident was a deliberate attempt by a pair of men to sabotage the noodle factory as part of a business feud (Mohtadi & Murshid, 2006).	Ill = 120 Deaths = 0

2001 May	Dushuqiang (rat poison)	Chemical	Breakfast food	133 teachers and students at a middle school in Central China's Hubei Province were hospitalized after consuming breakfast containing the rat poison Dushuqiang at the school's cafeteria (Sholl, 2004).	Unknown	Ill = 133 Deaths = 0
1999 November	Rat poison	Chemical	Meat rolls	48 people became ill after consuming meat rolls deliberately contaminated with rat poison at a fast food restaurant in Deyang City, Sichuan Province, China (Mohtadi & Murshid, 2007).	Competitive sabotage: Police suspected a business rival of the restaurant owner (Mohtadi & Murshid, 2006).	Ill = 48 Deaths = 0
1999 March	Nitric acid	Chemical	Donkey meat soup	148 people were poisoned after consuming donkey meat soup contaminated with nitric acid from a restaurant in China by five of the worker (Mohtadi & Murshid, 2007).	Competitive sabotage: The perpetrators hoped to damage the business of the restaurant (Mohtadi & Murshid, 2006).	Ill = 148 Deaths = 0
1999 January	Unknown agent	Unknown	Unknown Food	Authorities arrested two suspects for the poisoning of 17 people, resulting in four deaths, in Ziyang county, China (Mohtadi & Murshid, 2006).	Unknown	Ill = 17 Deaths = 4

1999 January	Unknown agent	Unknown	Unknown Food	Nine children and three adults were hospitalized after eating poisoned sweets that someone had intentionally scattered over a five-square-mile area in Congzhou, Sichuan province, China (Mohtadi & Murshid, 2006).	Unknown	Ill = 12 Deaths = 0
1997 June	Insect-icide	Chemical	Pork	A farmer gave his fellow villagers Pork poisoned with insecticide. 44 people were taken ill, and there were no fatalities (Mohtadi & Murshid, 2006).	Revenge: A farmer retaliated against his fellow villagers after they called him a nut.	Ill = 44 Deaths = 0
1992	Arsenic	Chemical	Flour	More than 700 people became ill from arsenic-contaminated flour at the school's cafeteria in Zhengzhou, China (Torok et al., 1997).	Revenge: A student that was expelled from the University contaminated the flour.	Ill = 700 Deaths = 0
FRANCE (1 event)						
1978 February	Mercury	Chemical	Lemons	Contaminated oranges were discovered in France (Mohtadi & Murshid, 2006).	Terrorism: A Palestinian group—The Arab Revolutionary Group—claimed responsibility for the attack.	Ill = 0 Deaths = 0

GERMANY (2 events)						
1978 February	Mercury	Chemical	Oranges	A Palestinian group called the Arab Revolutionary Army claimed it injected exported Israel oranges with mercury to sow panic and wreck the country's economy (Mohtadi & Murshid, 2006; RAND, 2010).	Terrorism: A Palestinian group (The Arab Revol. Group claimed responsibility for the attack.	Ill = 0 Deaths = 0
1946 April	Arsenic	Chemical	Bread	Hundreds of German POW soldiers were killed and thousands were made ill from arsenic contaminated bread while held at a US prisoner-of-war camp in Nuremburg, Germany (Khan et al., 2001).	Revenge: A Jewish extremist group (Nakam), was responsible for the deliberate poisoni-ng. Nakam memb-ers, were seeking retribution for possible war crim-es by the prisoners, most of whom were former Nazi SS (Anon, 2009a).	Ill = Thousands Deaths = Hundreds
INDIA (2 events)						
2013	Mono-crotoph os	Chemical	Rice & soya beans	23 children died after consuming school lunch that was deliberately contaminated with the pesticide by the principal and her husband in Bihar state, India. The food was prepared with	Unknown. The school chef claimed that she warned the princ-pal that the oil may have conta-minated	Ill = 24 Deaths = 23

				cooking oil that contained the pesticide (Anon, 2013)	due to the smell and appearance. Her boss insisted that she cook the food with the oil (Gayle & Parry, 2013).	
2000 June	Pesticid e	Chemical	Unknown food	Six workers died in Punjab, India, after two of their colleagues had contaminated food with pesticide. Two suspects were captured within hours of the incident (Anon, 2009a).	Disgruntled employees	Ill = 6 Deaths = 6
IRAQ (3 events)						
2008 January	Thalliu m	Chemical	Cake	Four of ten individuals died after consuming cake contaminated with thallium in Baghdad, Iraq (Centers for Disease Control and Prevention, 2008).	Political: Thallium was used as a chem-ical poison for mass killing mainly for poli-tical reasons and the members of the Iraqi air force club were spec-ifically targeted.	Ill = 10 Deaths = 4

2006 October	Cyanide	Chemical	chicken	At least 10 people died and hundreds of Iraqi army and police officers were poisoned at a base in Numaniyah after eating chicken that was contaminated with cyanide (Paley, 2006).	Terrorism: Initial suspicions targ-eted Sunni insu-rgents as the perpe-trators, due mainly to the stricken officers being mostly Shi'I and their area of responsibility was a section of Bagh-dad known for attacks by Sunni insurgents (Anon, 2009a).	Ill = hundreds Deaths = 10
2005 March	Unknow n agent	Unknown	Unknown food	Three pilgrims in Al-Hillah were given poisoned food by members of a terrorist group. The individuals suffered from food poisoning. This attack was one of several on Shiite pilgrims in recent days (Mohtadi & Murshid, 2006).	Terrorism	Ill = 3 Deaths = 0
ISRAEL (2 events)						
2002	Unknow n agent	Unknown	Unknown food	*Plot:* Three people were arrested in Jerusalem for allegedly planning a mass poisoning of Israeli patrons at a café (U.S. Food and Drug Administration, 2004).	Terrorism (Plot)	Ill = 0 Deaths = 0

1978	Mercury	Chemical	Oranges	A radical Palestinian group "Arab Revolutionary Army-Palestine Command" poisoned Israeli citrus with mercury resulting in 12 children being hospitalized (Baines et al., 2007; Sholl, 2004). The oranges were injected with the poison at a Rotterdam port, and were found in Sweden, Netherlands and West Germany (Dalziel, 2009).	Political: An investigation by Ehud Sprinzak and Ely Karmon concluded that the culprits of the original contaminations were most likely German sympathizers of the Palestinian cause (Sprinzak, 2001).	Ill = 12 Deaths = 0
ITALY (1 event)						
1988 April	Unknown agent	Chemical	Grapefruit	Contaminated grapefruits were discovered in Naples and Rome and the government took all grapefruits off the market. The poison turned out to be a substance which causes color tainting but is not harmful (RAND, 2010)	Political: A group claiming support for the Palestinians "The Organization of Metropolitan Proletariat and Oppressed Peoples" notified authorities injected poison into grapefruits imported from Israel.	Ill = 0 Deaths = 0

JAPAN (7 events)						
2013 October	Mala-thion	Chemical	Frozen food products	A plant worker was arrested in Oizumi, Gunma Prefecture, Japan, for poisoning frozen food with the pesticide malathion 4 separate occasions during the same month (Anon., 2014). More than 2800 people reported illnesses and 6.4 million packs of frozen food were recalled (Lui, 2014).	Disgruntled worker: A contracted worker at Maruha Nichiro, disgruntled over his pay.	Ill = 2800 Deaths = 0
2002	Sodium azide & Sodium cyanide	Chemical	Sugar canister	A worker deliberately added sodium azide and sodium cyanide into the sugar canister used for coffee and tea at the workplace break room (Dalziel, 2009).	Disgruntled worker: The employee was troubled about work, the incident took place shortly after he returned to the office from leave of absence.	Ill = 3 Deaths = 0
1998	Arsenic	Chemical	Curry	Four people died and 63 were hospitalized after consuming arsenic contaminated curry prepared by a local woman for a summer festival in Wakayama, Japan (Dalziel, 2009).	Resentment: The courts were unable to determine Hayashi's motive, but prosecutors insisted she was "infuriated by feeling alienated from housewives in the neighborhood" when she went to where the curry was being prepared on the day of the	Ill = 63 Deaths = 4

					festival (Anon, 2009c).	
August 1998	Sodium azide	Chemical	Teapot	Someone deliberately added sodium azide to the contents of a teapot in Niigata, Japan, resulting in ten people becoming ill (Dalziel, 2009; Okumura, Ninomiya, & Ohta, 2003).	Unknown	Ill = 10 Deaths = 0
1995 January	Unknown agent	Unknown	Unknown food	*Potential Hoax:* The Japanese cult Aum Shinrikyo was presumed to have killed a number of dissident members by mixing toxic agents in their food however, no bodies were ever found (Sholl, 2004).	Unknown (hoax)	Ill = 0 Deaths = 0
1964 to 1966	Typhoid fever	Biological	Cake	It was reported that several outbreaks of typhoid fever and dysentery occurred in hospitals in Japan that were attributed to food contaminated by a research bacteriologist (Anon, 1966).	Revenge/Retaliation: Suzuki's motives are not clear. Motive might be related to his perceived ill-treatment by co-workers, also suggested that he may have been creating cases to further his academic research in bacteriology (Mohtadi & Murshid, 2006).	Ill = Several Deaths = 0

1936	*S. typhi*	Biological	Salmon eggs	Dr. Tei-Seburo Takahashi Infected 17 people, killing 3, using salmon eggs contaminated with S. typhi at a party given in honor of one of the physicians at the hospital where he worked (Carus, 1998).	Retaliation: Dr. Takahashi apparently hoped to infect one of the members of the staff who he disliked.	Ill = 17 Deaths = 3
			NETHERLANDS (2 events)			
2004 March	Pesti-cides, insect-icides, and mouse poison	Chemical	Unknown food	A Dutch man was convicted of contaminating various food products with pesticides, insecticides, and mouse poison, in an effort to extort money from food manufacturers. Four people were made ill as a result of the contamination (Mohtadi & Murshid, 2006).	Extortion	Ill = 4 Deaths = 0
1978 February	Mercury	Chemical	Fruit	Contaminated oranges were discovered in the Netherlands (Mohtadi & Murshid, 2006). Five children became ill.	Terrorism: A Palestinian group - The Arab Revolutionary Group—claimed responsibility for the attack.	Ill = 5 Deaths = 0

NICARAGUA (1 event)						
1979 October	Unknown Agent	Unknown	Hot tamales	Two individuals distributed poisoned food at a police station in Managua, Nicaragua. Two policeman died and more than 12 became ill (Mohtadi & Murshid, 2006).	Political: Individuals opposed to the Sandinista government	Ill = 12 Deaths = 2
PHILIPPINES (1 event)						
2005	Couma-phos (organo-phosphate)	Chemical	Cassava fritter	Twenty-eight schoolchildren died and 130 became ill after consuming cassava fritter laced with insecticide by one individual in Southeastern Philippines (Dalziel, 2009).	Mental illness: Reports said that at the vendor was distraught due to several successive events that occurred immediately prior to the mass poisoning (Felongco, 2005).	Ill = 130 Deaths = 28
RUSSIA (2 events)						
2002 June	*Salmon-ella typhi*	Biological	Unknown food	60 students and teachers were poisoned with the salmonella typhi toxin at a school in Volgograd, Russia (Mohtadi & Murshid, 2007).	Unknown: There are few details and it is not clear if there was foul play, however criminal proceedings were instituted (Mohtadi & Murshid, 2006).	Ill = 60 Deaths = 0

1994	Cyanide	Chemical	Cham-pagne	Nine Russian soldiers and five civilians died after drinking cyanide-contaminated champagne (Khan et al., 2001).	Political: Deliberately poisoned by the Tajik opposition group. Investigators hypothesized that the perpetrator(s)	Ill = 14 Deaths = 14
					had targeted Russian servicemen for attack (Anon, 2009a).	
SWEDEN (1 event)						
1978 February	Mercury	Chemical	Fruit	Contaminated oranges were discovered in six countries—Belgium, France, the Netherlands, West Germany, the UK and Sweden (Mohtadi & Murshid, 2006).	Terrorism: A Palestinian group—The Arab Revolutionary Group—claimed responsibility for the attack.	Ill = 0 Deaths = 0
UKRAINE (1 event)						
2004	Tetra-chloro-dibenzo-paradiox (TCDD)	Chemical	Food (possibly soup)	Viktor Yushchenko, President of Ukraine was deliberately poisoned with dioxin in his food while having dinner with senior political officials (Dalziel, 2009).	Political	Ill = 1 Deaths = 0

UNITED KINGDOM (5 events)						
2006 November	Poloniu m-210	Radiologic al	Tea or sushi	Alexander Litvinenko (a former officer of the KGB) died after Andrey Lugovoy (a former Russian officer) placed radioactive polonium-210 into his tea or sushi along with several former KGB officers who were also poisoned (Dalziel, 2009).	Political: Litvinenko's deathbed allegati-on about the misdeeds Russian govern-ment and Presid-ent Vladimir Putin was behind the attack (Litvinenko, 2006).	Ill = 4 Deaths = 1
2003 January	Ricin	Chemical	Unknown food	*Possession:* Seven Algerian terrorists were arrested for manuf ricin in a London apartment. They were planning to insert the ricin in food supply on British military base (Sholl, 2004; U.S. Food and Drug Administration, 2004).	Terrorism (Possession)	Ill = 0 Deaths = 0
2003	Unknow n agent		Beer	*Plot:* Several Islamic extremists from the UK prepare syringes to inject poisons into containers of beer at soccer games. They never followed through on the plot (U. S. Department of Homeland Security, 2008).	Terrorism (Plot)	Ill = 0 Deaths = 0
2002 October	Saponin	Chemical	Unknown food	*Attempted Acquisition:* An obscure Islamic terrorist group tried to purchase the toxin saponin, in London, UK (Sholl, 2004; Syal, 2003).	Terrorism (Atte-mpted Acquisition. Terrorists indicated intent of agent “fire retardant on rice intended for human consumption.	Ill = 0 Deaths = 0

1978 February	Mercury	Chemical	Fruit	Contaminated oranges were discovered in the UK. An orange injected with mercury was found in the UK (Mohtadi & Murshid, 2006).	Terrorism: A Palestinian group—The Arab Revolutionary Group—claimed responsibility for the attack.	Ill = 0 Deaths = 0
UNITED STATES (18 events**)**						
2008	Unknow n agent	Chemical	Unknown food	*Threat:* The U.S. Department of Homeland Security and FBI reported that the Mujahidin Poisons Handbook, which was posted on several Islamic websites and in existence for several years, describe techniques to attack the food supply (U. S. Department of Homeland Security, 2008).	Terrorism (Threat)	Ill = 0 Deaths = 0
2004	Unknow n agent	Unknown	Unknown food	*Plot:* The FBI learned of a plot to compromise the world's largest producer of Meals Ready to Eat, located in McAllen, Texas (Pinkerton, 2004) with an unknown poison.	Terrorism (Plot)	Ill = 0 Deaths = 0
2003 April	Arsenic	Chemical	Coffee	Thirteen individuals presented to the local emergency room after they were deliberately poisoned from drinking arsenic contaminated coffee at a local church gathering in rural Maine. One death occurred as a result of the intentional poisoning incident (Gensheimer et al., 2010).	Revenge: Person responsible, deter-mined to be a church member, committed suicide and left note behind admitting his role poisonings.	Ill = 13 Deaths = 1

2003 January	Black Leaf 40	Chemical	Ground beef	Ninety-two people reported illnesses after consuming ground beef purchased from a supermarket in Michigan contaminated with Black Leaf 40, an insecticide containing nicotine sulfate as the main active ingredient (Centers for Disease Control and Prevention, 2003).	Disgruntled Employee: An employee of the store was arrested and charged with the deliberate poisoning incident.	Ill = 92 Deaths = 0
2003	Unknow n agent	Unknown	Unknown food	*Threat:* The FBI warned that Al Qaeda terrorists might use poisons to contaminate U.S. food and water supplies (Forest et al., 2013).	Terrorism (Threat)	Ill = 0 Deaths = 0
2000 October	Rat poison	Chemical	Coffee	Seven employees of a company were hospitalized after drinking coffee contaminated with rat poison in Hernando, Tennessee (Mohtadi & Murshid, 2006).	Unknown: No arrests have been made in the deliberate poisoning incident.	Ill = 7 Deaths = 0
2000 September	Rat poison	Chemical	Salsa	In Jacksonville, Florida, two seventh graders allegedly contaminated the school cafeteria's salsa with rat poison, affecting 34 students (Mohtadi & Murshid, 2006).	Unknown: No motive for the poisoning.	Ill = 34 Deaths = 0

2000 May	Oven cleaner/ soil shield	Chemical	Fast food	Three teenagers were arrested and accused of tampering food served at a Rochester, New York, fast food restaurant where they were employed. Allegedly over an eight-month period from September 1999 to April 2000, they contaminated food with spit, urine, and household agents including oven cleaner, cleanser, and soil shield (Anon, 2009a).	Disgruntled employees	Ill = 0 Deaths = 0
2000	Thalliu m & arsenic	Chemical	Coffee	Twelve workers at a Midwestern auto plant ingested coffee contaminated with thallium and arsenic (Mohtadi & Murshid, 2006).	Unknown	Ill = 12 Deaths = 0
1998 March & September	Endrin	Chemical	Corn tortillas containing a meat filling	Five people consumed taquitos (corn tortillas containing a meat filling) in Orange County, California, that were deliberately contaminated with the pesticide endrin (Centers for Disease Control and Prevention, 1989; Sholl, 2004).	Deliberate Tampering: California Department of Health Services suspects deliberate tampering as the cause of the outbreak.	Ill = 5 Deaths = 0

1998	Iodine-125	Radio-logical	Chicken & vegetables	A Brown University graduate student fed two students (one of whom was his ex-girlfriend) a dish of chicken, vegetables that was contaminated with I-125 that he stole from the University's laboratory.	Revenge: The police Captain told the Associated Press that he believed the attack to be motivated by "some kind of love interest" (Anon, 1998).	Ill = 2 Deaths = 0
1996	*Shigella dysenteriae* Type 2	Biological	Muffins and doughnuts	Muffins and doughnuts contaminated with the pathogenic bacteria Shigella dysenteriae Type 2 were consumed by workers in a hospital in New Hampshire. A laboratory employee, who had access to the locked break room is suspected of the poisoning incident (Kolavic et al., 1997).	Deliberate Tampering/Disgruntled Employee: The pastries were left there by a lab technician, Diane Thompson, who had access to the shigella cultures. On August 28, 1997, Ms. Thompson was indicted on three charges of tampering food. She was sentenced to 20 years in prison (Carus, 2002). (Mohtadi & Murshid, 2006).	Ill = Several Deaths = 0

1995 August	Radio-active Phosphorus-32 (P-32)	Radio-logical	Unknown	A researcher at Massachusetts Institute of Technology in Boston, Massachusetts was deliberately poisoned with P-32 in his food or drink (Dalziel, 2009).	Unknown: Investigators believe that someone put P-32 in Yuqing Li's food or drink that was kept in a nearby room (Daly, 1995).	Ill = 1 Deaths = 0
1995 July	Radio-active Phosphorus-32 (P-32)	Radio-logical	Leftovers from a meal at a Chinese restaurant	At the National Institute of Health (NIH) labs in Bethesda, MD, a pregnant researcher was deliberately poisoned after consuming food and drink (from a water cooler) that was contaminated with P-32 (Dalziel, 2009).	Unknown: The victim accused her supervisor of being responsible for the poisoning because her maternity leave would delay an important research project. The NRC cleared her boss of the incident (Anon, 1997).	Ill = 27 Deaths = 0

1989 March	Cyanide	Chemical	Fruit	*Hoax*: A call placed to the FDA, claimed that Chilean fruit bound for the US and Japan had been spiked with cyanide. The Food and Drug Administration later confirmed traces of cyanide in a small sample of grapes that had arrived from Chile. Since the acid in fruit quickly decomposes the poison, the original amount injected could have been much greater (Mohtadi & Murshid, 2006).	Hoax: A caller to Radio Cooperativa in Chile claimed the incident in the name of the Israeli Ultranationalist Movement based on sabotage to harm the United States, because that country closed its ears to the Israeli warnings (RAND, 2010).	Ill = 0 Deaths = 0
1989	Cyanide	Chemical	Yogurt	One person died in New Jersey after consuming cyanide-contaminated yogurt (McKay & Scharman, 2015).	Unknown	Ill = 0 Deaths = 1
1984	*Salmonella Typhimurium*	Biological	Restaurant salad bars	Members of a religious commune intentionally contaminated Oregon salad bars with the pathogenic bacteria Salmonella Typhimurium (Torok et al., 1997). The attack resulted in 751 illnesses.	Political: Influence results in a local election.	Ill = 751 Deaths = 0

1961 October	Hepatitis A	Biological	Potato salad	A deliberate contamination of food served at the officer's mess, with Hepatitis A at Cecil Field, in Jacksonville, Florida. Twenty-three personnel were infected (Mohtadi & Murshid, 2006).	Mental illness: History of psychological problems, and investigators apparently believed that he might have deliberately contaminated the food by urinating into it (Carus, 1998).	Ill = 23 Deaths = 0

Table 2. Unintentional Food Contamination Events, by country and date

Date	Agent	CBRN	Food	Description of Event	Illnesses/Deaths
				CANADA (1 event**)**	
1985	*C. Botulism*	Biological	Restaurant Food	*Outbreak*: Outbreak occurred after people consumed botulism contaminated meals prepared at White Spot Restaurant located in Vancouver, British Columbia, Canada (Centers for Disease Control and Prevention, 1985b).	Ill = 32 Deaths = 0
				CHINA (2 events**)**	
2008	Melamine	Chemical	Infant formula	More than 54,000 children became ill and three died after consuming infant formula contaminated with melamine in China (Chao, 2008).	Ill = 54,000 Deaths = 3
1991	Hepatitis A	Biological	Clams	*Outbreak*: Over 30,000 people became ill with hepatitis A after consuming clams in Shanghai, China (Sholl, 2004).	Ill = 30,000 Deaths = 0
				DENMARK (1 event)	
1998	*Salmonella*	Biological	Mayonnaise	*Outbreak*: About 10,000 cases of salmonellosis were linked to the consumption of contaminated mayonnaise (Koukouliou, Ujevic, & Premstaller, 2010).	Ill = 10,000 Deaths = 0
				INDIA (4 events**)**	
2007	*Atropa acuminata*	Biological	Egg curry, wild plant, rice, roti	An outbreak of non-bacterial food poisoning in soldiers at high altitude, caused by accidental ingestion of a dish made out of *atropa acuminata* plant leaves containing atropine related alkaloids (Kushwaha, Aggarwal, Sharma, Singh, & Nimonkar, 2008).	Ill = 29 Deaths = 0
2002	Endosulfan	Chemical	Wheat flour	More than 40 villagers were poisoned by using empty pesticide containers for food storage (Dewan et al., 2004).	Ill = 40 Deaths = 3

2000	Endosulfan	Chemical	Unknown food	Forty four individuals consumed food which was accidentally contaminated by endosulfan in a rural area (Dewan et al., 2004).	Ill = 4 Deaths =1
1997	Malathion	Chemical	Chapatti, wheat flour	About 60 people became ill after eating lunch prepared at a local kitchen that had been sprayed with malathion (Dewan et al., 2004).	Ill = 69 Deaths = 0
			IRAQ (1 event)		
1971	Mercury	Chemical	Bread	More than 6500 people were hospitalized and 459 died after consuming bread made with mercury contaminated wheat (Koukouliou et al., 2010).	Ill = 6500 Deaths = 459
			ISRAEL (1 event)		
2003	Streptococcal Pharyngitis	Biological	Egg salad	*Outbreak*: A large food-borne outbreak occurred at a factory in Israel due to consumption of egg-mayonnaise salad contaminated with streptococcal pharyngitis by a worker leading to 212 illnesses (Kaluski et al., 2006).	Ill = 212 Deaths = 0
			JAPAN (1 event)		
1996	*E. coli* O157: H7	Biological	Radishes	*Outbreak*: Approximately 8,000 children became ill and several died after consuming radishes contaminated with E. coli O157:H7 during school lunch (Koukouliou et al., 2010).	Ill = 8,000 Deaths = Several
			SPAIN (1 event)		
1981	Refined aniline denaturant	Chemical	Cooking oil	Over 20,000 people became ill after a chemical agent was detected in illegal cooking oil made from oil that was for non-food use and sold in the streets of Madrid, Spain (McKay & Scharman, 2015; Sholl, 2004).	Ill = 20,000 Deaths = 400-800

THAILAND (1 event)					
2006	*C. Botulism*	Biological	Bamboo-shoots	*Outbreak*: More than 200 people became ill after consuming preserved bamboo-shoots contaminated with botulism that were served at a local festival(McKay & Scharman, 2015).	Ill = 200 Deaths = 0
UNITED STATES (101 events)					
2014	*Listeria monocytog enes*	Biological	caramel apples	*Outbreak*: More than thirty-one ill people have been hospitalized, and seven deaths have been reported due to consuming commercially produced, prepackaged caramel apples contaminated with listeria (Centers for Disease Control and Prevention, 2014b).	Ill = 32 Deaths = 3
2014	*Salmonella* Enteritidis	Biological	Bean sprouts	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated bean sprouts produced by Wonton Foods Inc. (Centers for Disease Control and Prevention, 2014b).	Ill = 115 Deaths = 0
2014	*Listeria monocytog enes*	Biological	Bean sprouts	*Outbreak:* Outbreak occurred after people consumed Listeria contaminated bean sprouts produced by Wholesome Soy Products, Inc. (Centers for Disease Control and Prevention, 2014b).	Ill = 5 Deaths = 2
2014	*Listeria monocytog enes*	Biological	Cheese	*Outbreak:* Outbreak occurred after people consumed listeria contaminated cheese produced by Oasis Brands Inc. (Centers for Disease Control and Prevention, 2014b).	Ill = 5 Deaths = 1
2014	*Cyclospora*	Biological	Cilantro	*Outbreak:* Outbreak occurred after people consumed cyclospora contaminated fresh cilantros from Peubla, Mexico (Centers for Disease Control and Prevention, 2014b).	Ill = 304 Deaths = 0

2014	*Salmonella* Braenderup	Biological	Nut butter	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated nut butter produced by nSpired Natural Foods (Centers for Disease Control and Prevention, 2014b).	Ill = 6 Deaths = 0
2014	*Salmonella* Newport, *Salmonella* Hartford, & *Salmonella* Oranienbur g	Biological	Chia powder & seeds	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated sprouted chia powder and seeds produced by Oriya Organics Superfood Protein Medley (Centers for Disease Control and Prevention, 2014b).	Ill = 31 Deaths = 0
2014	*Escherichi a coli* O121	Biological	Raw clover sprouts	*Outbreak:* Outbreak occurred after people consumed E. coli O121 contaminated raw clover sprouts produced by Evergreen Fresh Sprouts, LLC (Centers for Disease Control and Prevention, 2014b).	Ill = 19 Deaths = 0
2014	*Escherichi a coli* O157:H7	Biological	Ground beef	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated ground beef produced by Wolverine Packing Company (Centers for Disease Control and Prevention, 2014b).	Ill = 12 Deaths = 0
2014	*Listeria monocytog enes*	Biological	Cheese	*Outbreak:* Outbreak occurred after people consumed listeria contaminated cheese produced by Roos Foods (Centers for Disease Control and Prevention, 2014b).	Ill = 8 Deaths = 1
2014	*Salmonella* Heidelberg	Biological	Chicken	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated chicken produced by Tyson Foods, Inc. (Centers for Disease Control and Prevention, 2014b).	Ill = 9 Deaths = 0
2014	*Salmonella* Stanley	Biological	Cheese	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated raw cashew cheese produced by The	Ill = 17

				Cultured Kitchen (Centers for Disease Control and Prevention, 2014b).	Deaths = 0
2013	*Escherichia coli* O157:H7	Biological	Salad	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated Ready-to-Eat Salads produced by Glass Onion Catering (Centers for Disease Control and Prevention, 2014b).	Ill = 33 Deaths = 0
2013	*Salmonella* Heidelberg	Biological	Chicken	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated chicken produced by Foster Farms (Centers for Disease Control and Prevention, 2014b).	Ill = 134 Deaths = 0
2013	*Vibrio parahaemolyticus*	Biological	Shellfish	*Outbreak:* Outbreak occurred after people consumed Vibrio bacteria contaminated shellfish produced harvested along the Atlantic Coast (Centers for Disease Control and Prevention, 2014b).	Ill = 104 Deaths = 0
2013	*Cyclospora*	Biological	Fresh produce	*Outbreak:* Outbreak occurred after people consumed cyclosporiasis contaminated salad mix produced by Taylor Farms de Mexico (Centers for Disease Control and Prevention, 2014b).	Ill = 631 Deaths = 0
2013	*Listeria*	Biological	Cheeses	*Outbreak:* Outbreak occurred after people consumed listeria contaminated cheeses produced by Crave Brothers Farmstead Cheese Company (Centers for Disease Control and Prevention, 2014b).	Ill = 6 Deaths = 1
2013	Hepatitis A	Biological	Pomengranate seeds	*Outbreak:* Outbreak occurred after people consumed Hepatitis A contaminated pomegranate seeds from a company in Turkey, Goknur Foodstuffs Import Export Trading (Centers for Disease Control and Prevention, 2014b).	Ill = 165 Deaths = 0

2013	*Sal.* Montevideo & *Sal.* Mbandaka	Biological	Tahini sesame paste	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated tahini sesame paste produced by Krinos Foods (Centers for Disease Control and Prevention, 2014b).	Ill = 16 Deaths = 1
2013	*Salmonella* Saintpaul	Biological	Cucumbers	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated cucumbers supplied by Daniel Cardenas Izabal and Miracle Greenhouse of Culiacán, Mexico (Centers for Disease Control and Prevention, 2014b).	Ill = 84 Deaths = 0
2013	*Escherichia coli* O121	Biological	Frozen food products	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated frozen food products produced by Rich Products Corporation (Centers for Disease Control and Prevention, 2014b).	Ill = 35 Deaths = 0
2013	*Salmonella* Heidelberg	Biological	Chicken	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated chicken produced by Foster Farms (Centers for Disease Control and Prevention, 2014b).	Ill = 634 Deaths = 0
2013	*Salmonella* Typhimurium	Biological	Ground Beef	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated ground beef produced by Jouni Meats, Inc and Gab Halal Foods (Centers for Disease Control and Prevention, 2014b).	Ill = 22 Deaths = 0
2012	*Escherichia coli* O157:H7	Biological	Spinach and Spring Mix -	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated pre-packaged leafy greens produced by State Garden (Centers for Disease Control and Prevention, 2014b).	Ill = 33 Deaths = 0
2012	*Salmonella* Bredeney	Biological	Peanut Butter	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated peanut butter manufactured by Sunland, Inc. of Portales, New Mexico (Centers for Disease Control and Prevention, 2014b).	Ill = 42 Deaths = 0

2012	*Listeria monocytogenes*	Biological	Cheeses	*Outbreak:* Outbreak occurred after people consumed listeria contaminated cheese by Frescolina Marte brand ricotta salata cheese imported from Italy and distributed by Forever Cheese, Inc. (Centers for Disease Control and Prevention, 2014b).	Ill = 22 Deaths = 4
2012	*Salmonella* Braenderup	Biological	Mangoes	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated mangoes produced by Agricola Daniella of Mexico (Centers for Disease Control and Prevention, 2014b).	Ill = 127 Deaths = 0
2012	*Salmonella* Typhimurium and Newport	Biological	Cantaloupe	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated cantaloupe produced by Chamberlain Farms Produce, Inc (Centers for Disease Control and Prevention, 2014b).	Ill = 261 Deaths = 3
2012	*Salmonella* Enteritidis	Biological	Ground Beef	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated ground beef produced by Cargill Meat Solutions (Centers for Disease Control and Prevention, 2014b).	Ill = 46 Deaths = 0
2012	*Escherichia coli* O145	Biological	Unknown	*Outbreak:* Outbreak occurred after people consumed E. coli O145 contaminated food. A source for these infections was not identified. (Centers for Disease Control and Prevention, 2014b).	Ill = 18 Deaths = 1
2012	*Salmonella* Bareilly and *Salmonella* Nchanga	Biological	Ground Tuna Product	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated frozen raw yellow fin tuna product from Moon Marine USA Corporation (Centers for Disease Control and Prevention, 2014b).	Ill = 425 Deaths = 0

2012	*Escherichia coli* O26	Biological	Raw Clover Sprouts at Jimmy John's Restaurants	*Outbreak:* Outbreak occurred after people consumed E. coli O26 contaminated sprouts from Jimmy John's restaurants (Centers for Disease Control and Prevention, 2014b).	Ill = 29 Deaths = 0
2012	*Salmonella* Enteritidis	Biological	Mexican fast food	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated food from a Mexican-style fast food restaurant chain, Restaurant Chain A (Centers for Disease Control and Prevention, 2014b).	Ill = 68 Deaths = 0
2012	*C. Botulism* Botulism	Biological	Alcoholic beverage, Beets, Meat sauce	*Outbreak:* Summary of botulism cases reported in 2005 to CDC. Outbreaks occurred after people consumed botulism (A, B &E) contaminated pruno, an illicit alcoholic beverage brewed by prisoners, home-canned beets and home-canned pasta in meat sauce (Centers for Disease Control and Prevention, 2014c).	Ill = 25 Deaths = 1
2011	*Salmonella* Typhimurium	Biological	Ground Beef	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated ground beef purchased from Hannaford stores (Centers for Disease Control and Prevention, 2014b).	Ill = 20 Deaths = 0
2011	*Escherichia coli* O157:H7	Biological	Romaine Lettuce	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated romaine lettuce purchased from salad bars at grocery store Chain A (Centers for Disease Control and Prevention, 2014b).	Ill = 60 Deaths = 0
2011	*Salmonella* Heidelberg	Biological	Chicken Livers	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated kosher broiled chicken livers produced by Schreiber Processing Corporation (Centers for Disease Control and Prevention, 2014b).	Ill = 190 Deaths = 0

2011	*Salmonella* Enteritidis	Biological	Pine Nuts	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated Turkish Pine Nuts sold in bulk bins at Wegmans grocery stores (Centers for Disease Control and Prevention, 2014b).	Ill = 43 Deaths = 0
2011	*Listeria monocytog enes*	Biological	Cantaloupes	*Outbreak:* Outbreak occurred after people consumed listeria contaminated cantaloupes produced by Jensen Farms (Centers for Disease Control and Prevention, 2014b).	Ill = 147 Deaths = 33
2011	*Salmonella* Heidelberg	Biological	Ground Turkey	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated ground turkey produced by Cargill Meat Solutions Corporation (Centers for Disease Control and Prevention, 2014b).	Ill = 136 Deaths = 0
2011	*Salmonella* Agona	Biological	Papayas	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated whole, fresh imported papayas imported from Mexico by Agromod Produce, Inc. (Centers for Disease Control and Prevention, 2014b).	Ill = 106 Deaths = 0
2011	*Salmonella* Enteritidis	Biological	Sprouts	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated alfalfa and spicy sprouts produced by Evergreen Fresh Sprouts, LLC Alfalfa Sprouts and Spicy Sprouts (Centers for Disease Control and Prevention, 2014b).	Ill = 25 Deaths = 0
2011	Shiga toxin-producing *E. coli* O104	Biological	Raw sprouts	*Outbreak:* Outbreak occurred after people consumed E. coli O104 contaminated raw sprouts from one farm in Germany (Centers for Disease Control and Prevention, 2014b).	Ill = 6 Deaths = 1

2011	*Salmonella* Hadar	Biological	Turkey Burgers	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated turkey burgers produced by Jennie-O Turkey (Centers for Disease Control and Prevention, 2014b).	Ill = 12 Deaths = 0
2011	*Escherichi a coli* O157:H7	Biological	Lebanon Bologna	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated Lebanon bologna produced by Palmyra Bologna Company (Centers for Disease Control and Prevention, 2014b).	Ill = 14 Deaths = 0
2011	*Salmonella* Panama	Biological	Del Monte Cantaloupe	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated cantaloupe harvested from single farm in Guatemala (Centers for Disease Control and Prevention, 2014b).	Ill = 20 Deaths = 0
2011	*Escherichi a coli* O157:H7	Biological	Hazelnuts	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated in-shell hazelnuts produced by DeFranco & Sons (Centers for Disease Control and Prevention, 2014b).	Ill = 8 Deaths = 0
2011	*C. Botulism* Botulism	Biological	Alcoholic beverage, Salmon eggs	*Outbreak*: Summary of botulism cases reported in 2006 to CDC. Outbreaks occurred after people consumed botulism (A, B &E) contaminated salmon eggs) and the other with pruno, an illicit alcoholic beverage brewed by prisoners (Centers for Disease Control and Prevention, 2014c).	Ill = 20 Deaths = 0
2010	*Salmonella* serotype I 4	Biological	Alfalfa sprouts	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated alfalfa sprouts produced by Tiny Greens Alfalfa Sprouts or Spicy Sprouts (Centers for Disease Control and Prevention, 2014b).	Ill = 140 Deaths = 0

2010	*Salmonella* Enteritidis	Biological	Shell eggs	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated eggs traced back to Wright County Egg and Hillandale Farms both from Iowa (Centers for Disease Control and Prevention, 2014b).	Ill = 3,578 Deaths = 0
2010	*Escherichi a coli* O157:H7	Biological	Cheese	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated cheese produced by Bravo Farms (Centers for Disease Control and Prevention, 2014b).	Ill = 38 Deaths = 0
2010	*Salmonella* Chester	Biological	Cheesy Chicken Rice	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated Cheesy Chicken & Rice single-serve frozen entrées produced by Marie Callender's (Centers for Disease Control and Prevention, 2014b).	Ill = 44 Deaths = 0
2010	*Salmonella* Typhi	Biological	Fruit pulp	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated consuming frozen mamey fruit pulp in a milkshake or smoothie produced by Goya and La Nuestra .(Centers for Disease Control and Prevention, 2014b)	Ill = 9 Deaths = 0
2010	*Salmonella* Hartford and *Salmonella* Baildon	Biological	Food	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated food after eating at a Mexican-style fast food restaurant chain (Centers for Disease Control and Prevention, 2014b).	Ill = 19 Deaths = 2
2010	*Salmonella* Newport	Biological	Alfalfa sprouts	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated alfalfa sprouts produced by J.H. Caldwell and Sons Inc (Centers for Disease Control and Prevention, 2014b).	Ill = 44 Deaths = 0

2010	*Escherichia coli* O145	Biological	Romaine lettuce	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated shredded lettuce produced by Freshway Foods (Centers for Disease Control and Prevention, 2014b).	Ill = 26 Deaths = 2
2010	*Salmonella* Montevideo	Biological	Italian style meats	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated salami meats produced by various companies (Centers for Disease Control and Prevention, 2014b).	Ill = 272 Deaths = 0
2010	*Escherichia coli* O157:H7	Biological	Beef	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 beef produced by National Steak and Poultry (Centers for Disease Control and Prevention, 2014b).	Ill = 21 Deaths = 0
2010	*C. Botulism* Botulism	Biological	Seal blubber, Unknown food	*Outbreak*: Summary of botulism cases reported in 2005 to CDC. Outbreaks occurred after people consumed botulism (A, B &E) contaminated caused by seal blubber and the other by an unknown food vehicle (Centers for Disease Control and Prevention, 2014c).	Ill = 9 Deaths = 0
2009	*E. coli* O157:H7	Biological	Beef	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated ground beef produced by Fairbanks Farms (Centers for Disease Control and Prevention, 2014b).	Ill = 19 Deaths = 2
2009	*E. coli* O157:H7	Biological	Beef	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated ground beef from JBS Swift Beef Company (Centers for Disease Control and Prevention, 2014b).	Ill = 23 Deaths = 0
2009	*E. coli* O157:H7	Biological	Cookie dough	*Outbreak:* Outbreak occurred after people consumed E. coli O157:H7 contaminated raw, prepackaged cookie dough produced by Nestle (Centers for Disease Control and Prevention, 2014b).	Ill = 65 Deaths = 0

2009	*Salmonella* St. Paul	Biological	Alfalfa sprouts	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated alfalfa sprouts obtained from grocery stores and restaurants (Centers for Disease Control and Prevention, 2014b).	Ill = 235 Deaths = 0
2009	*Salmonella* (multiple types)	Biological	Pistachios	*Outbreak:* Outbreak occurred after people consumed salmonella contaminated pistachios produced by Setton Pistachio of Terra Bella Inc, (Centers for Disease Control and Prevention, 2014b).	Ill = 1 Deaths = 0
2009	Sodium azide	Chemical	Coffee	Six people became ill after drinking from a communal coffee pot that was contaminated with sodium azide. It is unknown whether or not the poisoning was intentional (Schwarz et al., 2014). It is suspected that is was accidental due to the minimal amount in the coffee pot and they worked in a research lab which used this chemical (Gussow, 2010).	Ill = 6 Deaths = 0
2009	*C. Botulism* Botulism	Biological	Green beans, asparagus, tuna	*Outbreak:* Summary of botulism cases reported in 2005 to CDC. Outbreaks occurred after people consumed botulism (A, B &E) contaminated home-canned green beans), home-canned asparagus and home-canned tuna (Centers for Disease Control and Prevention, 2014c).	Ill = 11 Deaths = 1
2009 & 2008	*Salmonella typhimuriu m*	Biological	Peanut butter, peanut paste, and peanut meal	*Outbreak:* In late 2008 and early 2009, nine people died and at least 714 people in 46 states were poisoned after consuming peanut food contaminated with Salmonella typhimurium produced by the Peanut Corporation of America (PCA) at its Blakely, Georgia processing plant (Prevention, 2010). The FDA reported that the company shipped tainted products under	Ill = 714 Deaths = 9

				three conditions: (1) without retesting, (2) before the re-test results came back from an outside company, and (3) after a second test showed no bacterial contamination. In all three cases, the initial positive result means that the product should have been destroyed (Anon, 2009b).	
2008	*C. Botulism* Botulism	Biological	Seal products, Green bean, Carrot mix	*Outbreak:* Summary of botulism cases reported in 2005 to CDC. Outbreaks occurred after people consumed botulism (A, B &E) contaminated seal products, home-canned green bean and carrot mix. (Centers for Disease Control and Prevention, 2014c).	Ill = 18 Deaths = 1
2008	*Salmonella* St. Paul	Biological	Jalapeno & serrano peppers, tomatoes	*Outbreak*: Outbreak occurred after people consumed salmonella contaminated jalapeno and serrano peppers, tomatoes produced by companies in Mexico (Centers for Disease Control and Prevention, 2014b).	Ill = 1,442 Deaths = 2
2008	*E. coli* O157:H7	Biological	Ground beef	*Outbreak*: Outbreak occurred after people consumed E. coli O157:H7 contaminated ground beef purchased at Kroger stores (Centers for Disease Control and Prevention, 2014b).	Ill = 49 Deaths = 0
2008	*Salmonella* Agona	Biological	Cereal	*Outbreak*: Outbreak occurred after people consumed salmonella contaminated cereal produced by Malt-O-Meal (Centers for Disease Control and Prevention, 2014b)	Ill = 28 Deaths = 0
2008	*Salmonella* Litchfield	Biological	Cantaloupe	*Outbreak*: Outbreak occurred after people consumed salmonella contaminated cantaloupe from Honduras (Centers for Disease Control and Prevention, 2014b).	Ill = 51 Deaths = 0

2007	*C. Botulism* Botulinum	Biological	Hot dog Chili sauce	*Outbreak*: At least 8 people in three states became ill after consuming undercooked chili sauce from a plant in Georgia produced by Castleberry Farms (McKay & Scharman, 2015).	Ill = 8 Deaths = 0
2007	*E. coli* O157:H7	Biological	Pizza	*Outbreak*: Outbreak occurred after people consumed E. coli O157:H7 contaminated frozen pizza produced by General Mills company under the brand names of Totino's or Jeno's (Centers for Disease Control and Prevention, 2014b).	Ill = 21 Deaths = 0
2007	*Salmonella*	Biological	Pot Pies	*Outbreak*: Outbreak occurred after people consumed salmonella contaminated Banquet pot pies produced by ConAgra Foods (Centers for Disease Control and Prevention, 2014b).	Ill = 272 Deaths = 0
2007	*E. coli* O157:H7	Biological	Ground beef patties	*Outbreak*: Outbreak occurred after people consumed E. coli O157:H7 contaminated ground beef patties produced by Topp's Brand (Centers for Disease Control and Prevention, 2014b).	Ill = 40 Deaths = 0
2007	*Salmonella* Wandswort h	Biological	Puffed rice & corn snack	*Outbreak*: Outbreak occurred after people consumed salmonella contaminated Veggie Booty produced by Robert's American Gourmet brand (Centers for Disease Control and Prevention, 2014b).	Ill = 65 Deaths = 0
2007	*Salmonella* Tennessee	Biological	Peanut butter	*Outbreak*: Outbreak occurred after people consumed salmonella contaminated peanut butter produced by Peter Pan and Great Value (Centers for Disease Control and Prevention, 2014b).	Ill = 425 Deaths = 0

2007	*Listeria monocytogenes*	Biological	Milk	*Outbreak*: Outbreak occurred after people consumed listeria contaminated pasteurized milk produced by Whittier Farms (Lavoie, 2008).	Ill = 5 Deaths = 3
2007	*C. Botulism* Botulism	Biological	Beaver tail, seal oil, white fish	*Outbreak:* Summary of botulism cases reported in 2005 to CDC. Outbreaks occurred after people consumed botulism (A, B &E) contaminated beaver tail, seal oil, and white fish (Centers for Disease Control and Prevention, 2014c).	Ill = 26 Deaths = 3
2006	*E. coli* O157:H7	Biological	Lettuce	*Outbreak*: Outbreak occurred after people consumed e. coli contaminated lettuce from Taco Bell restaurants (Centers for Disease Control and Prevention, 2014b).	Ill = 71 Deaths = 0
2006	*Salmonella typhimurium*	Biological	Tomatoes	*Outbreak*: Outbreak occurred after people consumed salmonella contaminated tomatoes from restaurants (Centers for Disease Control and Prevention, 2014b).	Ill = 183 Deaths = 0
2006	*E. coli* O157:H7	Biological	Spinach	*Outbreak*: Outbreak occurred after people consumed e. coli contaminated fresh spinach (Centers for Disease Control and Prevention, 2014b).	Ill = 183 Deaths = 1
2006	*C. Botulism* Botulism	Biological	Home canned carrots, commercial carrot juice, fish eggs, fermented tofu, canned chicken broth	*Outbreak:* Summary of botulism cases reported in 2006 to CDC. Outbreaks occurred after people consumed botulism (A, B &E) contaminated home canned carrots, commercial carrot juice, fish eggs, fermented tofu and canned chicken broth (Centers for Disease Control and Prevention, 2014c).	Ill = 19 Deaths = 0

2005	*C. Botulism* Botulism	Biological	Fish (type unspecified), stinkfish, stinkhead, and unknown food	*Outbreak:* Summary of botulism cases reported in 2005 to CDC. Outbreaks occurred after people consumed botulism (A, B &E) contaminated fish (type unspecified), stinkfish, stinkhead, and an unknown food, respectively (Centers for Disease Control and Prevention, 2014c).	Ill = 18 Deaths = 2
2004	*C. Botulism* Botulism	Biological	Alcoholic beverage, and home-canned mushrooms	*Outbreak:* Summary of botulism reported in 2004 to CDC. Outbreaks botulism (A, B &E) contaminated pruno, bootleg prison-made alcoholic beverage, home-canned mushrooms (Centers for Disease Control and Prevention, 2014c).	Ill = 14 Deaths = 0
2003	*C. Botulism* Botulism	Biological	Unknown food, fermented fish heads	*Outbreak:* Summary of botulism cases reported in 2003 to CDC. Outbreaks occurred after people consumed botulism (A, B &E) contaminated unknown food and fermented fish heads (Centers for Disease Control and Prevention, 2014c).	Ill = 8 Deaths = 2
2002	*C. Botulism* Botulism	Biological	Alaskan native foods	*Outbreak:* Summary of botulism cases reported in 2002 to CDC. Outbreaks occurred after people consumed botulism (A, B &E) contaminated Alaskan native foods (Centers for Disease Control and Prevention, 2014c).	Ill = 21 Deaths = 0
2002	Ammonia	Chemical	Chicken tenders	*Outbreak*: Outbreak of gastrointestinal illness occurred after students consumed chicken tenders that were contaminated with ammonia during a warehouse leak of refrigerant in Will County, Illinois (Dworkin et al., 2004).	Ill = 157 Deaths = 0
2001	*C. Botulism* Botulism	Biological	Unknown commercial product,	*Outbreak:* Summary of botulism cases reported in 2006 to CDC. Outbreaks occurred after people consumed botulism (A, B &E) contaminated unknown commercial product and Alaskan native foods (Centers for Disease Control and Prevention, 2014c).	Ill = 33 Deaths = 1

			Alaskan native foods.		
1999	*Listeria monocytogenes*	Biological	Hot dogs & deli meat	*Outbreak*: Outbreak occurred after people consumed listeria contaminated hot dogs and deli meat from the manufacturer, Bil Mar Foods (Centers for Disease Control and Prevention, 1999).	Ill = 75 Deaths = 17
1998	*Staphylococcus aureus*	Biological	Luncheon meat, fried chicken & rice	*Outbreak*: Over 145 police officers became ill after consuming boxed lunch items contaminated with *S. aureus* prepared by a caterer using improper holding temperature for food in Hawaii (Afton et al., 2005).	Ill = 145 Deaths = 0
1996	*Cyclospora* cayentanensis	Biological	Raspberries	*Outbreak*: A series of outbreaks in the U.S. and Canada due to Guatemalan raspberries possibly due to contaminated water (Manning et al., 2005).	Ill = 1465 Deaths = 0
1994	*Salmonella enteritidis*	Biological	Ice cream	*Outbreak*: Over 224,000 became ill after consuming ice cream from a transported a tanker truck that was unwashed after carrying raw eggs (Sholl, 2004).	Ill = 224,000 Deaths = 0
1992	*C. Botulism*	Biological	Salt-cured fish	*Outbreak*: Outbreak occurred after people consumed botulism contaminated uneviscerated salt-cured fish from a family member based on an ethnic preparation of fish known as moloha (Centers for Disease Control and Prevention, 1992).	Ill = 4 Deaths = 0
1985	Aldicarb	Chemical	Watermelon	*Outbreak*: Over 1300 people became ill after consuming watermelon grown in soil treated with aldicarb in California and over 483 cases in other states (McKay & Scharman, 2015).	Ill = 1300 Deaths = 0

1985	*Salmonella typhimurium*	Biological	Milk	*Outbreak*: Approximately 170,000 people became ill after consuming milk contaminated with *Salmonella typhimurium* from a pasteurization factory (the source was the interior of the pipes) (Koukouliou et al., 2010).	Ill = 170,000 Deaths = 0
1985	*Listeria monocytogenes*	Biological	Cheese	*Outbreak*: Outbreak occurred after people consumed listeria contaminated Mexican-style cheese manufactured by Jalisco Products, Inc., (Centers for Disease Control and Prevention, 1985a).	Ill = 142 Deaths = 48
1983	*C. Botulism*	Biological	Onions	*Outbreak*: Outbreak occurred after people consumed botulism contaminated sautéed onions patty-melt sandwiches from a local restaurant (Centers for Disease Control and Prevention, 1984).	Ill = 28 Deaths = 0
1978	*C. Botulism*	Biological	Restaurant Food	*Outbreak*: Outbreak occurred after people consumed botulism contaminated food at a restaurant (Mann, Lathrop, & Bannerman, 1983).	Ill = 34 Deaths = 0
1977	*C. Botulism*	Biological	Jalapeno peppers	*Outbreak*: Outbreak occurred after people consumed botulism contaminated home-canned jalapeno peppers at a Mexican restaurant (Terranova, Breman, Locey, & Speck, 1978).	Ill = 59 Deaths = 0

Table 3. Food Terrorism Exercises Identified in the Homeland Security Digital Library Database

Date		Exercise	Agent	Scenario	Lessons Learned/After Action Report
Homeland Security Digital Library Collection - Restricted (U. S. Department of Homeland Security, 2014b)					
Date and location unknown **HSDL RC**	TTX	BWTTX 008	Clostridium botulinum toxin type A / in food	Hundreds of individuals were exposed to Clostridium botulinum toxin type A in food from a local restaurant. A federal entity sponsored the exercise as part of the Domestic Preparedness Program (DPP).	Convene a meeting of representatives from each agency that participated in the response to discuss and analyze their actions and interactions to highlight positive aspects that should be followed by other communities and determine areas of improvement that could be addressed following the incident.
Date and location unknown **HSDL RC**	TTX	BWTTX 010	Clostridium botulinum toxin type A / in food	The scenario involved the contamination of food with Clostridium botulinum toxin type A. Approximately 500 people ingested the agent. The exercise was conducted as part of the DPP.	The group concluded that a formal screening and reporting system is needed. It was suggested that the CITY medical community should consider working with the HD and STATE Department of Health to review the reliability and the validity of current daily health surveillance indicators and to establish a standardized monitoring system.
Date and location unknown **HSDL RC**	TTX	BWTTX 017	Clostridium botulinum / in food	Hundreds of people were exposed to food contaminated with Clostridium botulinum at a city arena. The exercise was conducted as part of the DPP.	CITY response agencies should continue building a strong WMD response system based on lessons learned and through regular refresher training on C/B agent recognition for first responders and support staff.

Date and location unknown **HSDL RC**	TTX	BWTTX 042	Botulinum toxin / in food	Participants became ill after eating food contaminated with botulinum toxin being given away at a sporting event. The U.S. Army Soldier and SBCCOM sponsored the exercise as part of the DPP.	Participants discussed documenting the lessons learned from the response efforts to this crisis. This information would then be used to brief local, state, and federal officials on what had occurred in the CITY area. These lessons would also assist other communities with preparing to deal with a similar crisis in the future.
Date and location unknown **HSDL RC**	TTX	BWTTX 064	Botulinum toxin / in food	The scenario involved the contamination of samples of ice cream being given away at the CITY’S OUTDOOR SHOPPING AREA.	Current regulations governing the distribution of food should be reviewed and revised (as appropriate) to include provisions to mitigate the potential for a food-borne release of a WMD agent and provide a means for tracking possible sources.
Date and location unknown **HSDL RC**	TTX	BWTTX 068	Botulinum toxin / in food	Officials suspected bioterrorism after an extremist group sent a fax message to local news organizations claiming credit for the outbreak.	Current regulations governing the distribution of food should be reviewed and revised (as appropriate) to include provisions to mitigate the potential for a food-borne release of a WMD agent and provide a means for tracking possible sources.
Date and location unknown **HSDL RC**	TTX	BWTTX 072	Botulinum toxin / in food	The incident involved the release of a significant quantity of botulinum toxin and Clostridium botulinum bacteria at a fictitious biotechnology company’s picnic IN SUMMER. Approximately 1,000 people ingested a food-borne dose of the agent.	Until the medical community sees a statistically significant number of cases, they may not recog- nize the first victims of an attack as representing a subset of a potentially much larger number. Speed in analyzing epidemiological data and disseminating results is essential.

Date and location unknown **HSDL RC**	TTX	BWTTX 074	Tularemia in food	The scenario involved the release of a quantity of tularemia (Francisella tularensis) at the INDOOR MALL on A FALL weekend.	The health department and EOC also should jointly prepare procedures for hospitals and medical facilities to coordinate with the EOC, once activated, in support of a public health emergency or bioterrorist incident.
Date and location unknown **HSDL RC**	TTX	BWTTX 078	Vibrio cholera / in food	Several people become ill from food served at the Cardiologists Convention which was deliberately contaminated with Vibrio cholera. The U.S. Army Soldier and Biological Chemical Command sponsored the exercise as part of the DPP.	Several emergency management Participants were glad to have the opportunity to exercise their local response plans to ensure their effectiveness in dealing with bioterrorism.
Date and location unknown **HSDL RC**	TTX	BWTTX 104	Staphylococcal Enterotoxin B (SEB)	The scenario involved the intentional release of a quantity of SEB on August 4 at a “Quince” party.	There is no “school” solution to bioterrorism response, but early detection diagnosis of unusual or suspicious disease outbreaks by local medical and public health personnel, acting in concert with first responders in their communities, will make a critical difference in that community’s ability to respond to and manage the particular dimensions of an actual bioterrorism incident or naturally occurring unusual disease outbreak.

August 7, 2009 to August 10, 2009 **HSDL RC**	FS	Georgia FoodEx 2009 Full Scale Exercise	Methyl parathion in chicken nuggets	Exercise was performed where mass casualties resulted from an intentional food contamination event. The USDA sponsored the event and the Institute for Health Management and Mass Destruction Defense, College of Public Health at the University of Georgia (IHMD/UGA) conducted the event where multiple agencies participated from base office across the State of Georgia.	Concerns arose about early warnings and information sharing. There should be standard operating procedures in public health, regulatory, and law enforcement agencies regarding inter-agency and Federal/State notification of any event that may ultimately be determined to be food related. Early in the exercise there was uncertainty as to whether the FBI would assign a case number to the samples being sent to the labs. Case-number assignment issues should be clarified and included in emergency operations plans. Concentrate on activities that truly have a bearing on the outcome of the incident, primarily saving lives.
April 29, 2008 McClellanCA **HSDL RC**	TTX	Liquid Food and Crop Contamination Tabletop Exercise	Drinking milk intentionally contaminated with an unidentified biological agent	The California Office of Homeland Security Training and Exercise Division, conducted a tabletop exercise to improve interagency collaboration during an attack on the food system where individuals became ill after drinking milk intentionally contaminated with an unidentified biological agent.	Incident Command System (ICS), State Emergency Management System (SEMS) and National Incident Management System (NIMS) concepts for a food event need further practical application and exercise. A large or intentional food contamination event will involve local, state and federal jurisdiction and resources from very early in the response, making coordinated dispatch and command and control potentially challenging (U. S. Department of Homeland Security, 2014b).

July 25, 2007 Philadelphia, PA **HSDL RC**	TTX	Protect and Defend II" tabletop exercise	Diazinon in produce	Consumers are calling into supermarkets and convenience stores to complain about feeling ill, consumers are asking if complaints about numerous food products including hamburger, hot dogs, fruits, salads, and milk have been reported.	Provide media training and media relations training to public and private organizations that have public information officers (PIOs). In addition, private organizations need to be trained on how to interface with a Joint Information Center before an incident occurs. Furthermore, public and private organizations need to be trained on Risk Communication.
Homeland Security Digital Library Collection Full (HSDL F)					
May 2, 2012 Dallas, TX and surrounding states **HSDL F**	TTX FE	Food Security Exercise FEMA R VI	Contaminated meat, poultry, dairy products and live animals	FEMA Region 6, officials from USDA FSIS, APHIS Veterinary Services (VS) and USDA Office of the Inspector General Emergency Response Team and the surrounding states participated in a functional exercise and TTX in response to a food security incident that involved contaminated meat, poultry, dairy products and live animals associated with those products.	Responses to injects indicated that the proper discussions were occurring on how to deal with the live animals contaminated with the toxin. Decisions were made to form Unified Command organizations in those States where Federal/State personnel were playing in the exercise as a team. Some Federal agencies did not engage in exercise planning or exercise play despite numerous attempt at involvement. These agencies did not receive the benefits gained during the planning phase of the exercise or the experience gained during exercise play.
May 7, 2009 Jackson, MS	TTX	Operation Magnolia	Unknown agent in meat, poultry, eggs	U.S. Department of Agriculture (USDA) and the Food Safety and Inspection Service (FSIS) conducted a tabletop exercise, in Jackson, MS and at the FSIS headquarters in Washington, DC. The purpose of the exercise was	The scope of the emergency should be expanded to include more stakeholder groups. Participants from industry commented that the exercise scenario did not accurately portray the food industry's ability to provide large amounts of information in the early phases of the exercise. Therefore, real time coordination on critical

HSDL F				"to test and validate operating guidelines and directives for responding to a significant incident involving the intentional adulteration of meat products within an FSIS regulated facility.	information should improve the response capabilities for all stakeholder groups. Participants did not play out activation of EOC or unified command structures.
February 26, 2009 Lawrenc e,KS **HSDL F**	TTX	Operation Sunflower	Unknown agent in meat, poultry, eggs	USDA and FSIS conducted a tabletop exercise in Lawrence, KS and at the FSIS headquarters in Washington, DC. The purpose of the exercise was "to test and validate operating guidelines and directives for responding to a significant incident involving the intentional adulteration of meat products within an FSIS regulated facility.	Suggest adding times to each inject to provide a "real time" timeline versus the compressed time of the scenario. All of the needed participants were not available for the exercise. Better notification/communication prior to the exercise may have helped to identify and encourage participation by representatives of these stakeholder groups.
January 8, 2009 Springdal e, AR **HSDL F**	TTX	Operation Apple Blossom	Unknown agent in meat, poultry, eggs	USDA and FSIS conducted a tabletop exercise in Springdale, AR and at FSIS headquarters in Washington, DC. The purpose of the exercise was "to test and validate operating guidelines and directives for responding to a significant incident activity involving the intentional adulteration of meat products within an FSIS regulated facility.	A simulated Emergency Operations Center (EOC) was needed to move participants toward operations in line with the NRF Incident Command/Unified Command System. Include reps from FBI, EPA, OSHA and the state Department of Environmental Quality to address criminal investigation, product disposal and facility decontamination, and workplace protection. Clarify how Arkansas Dep. of Health can issue advisories to the public that are as timely as possible yet coordinated with messaging by federal agencies.

October 30, 2008 Des Moines, IA **HSDL F**	TTX	Operation Wild Rose	Unknown agent in food	USDA's FSIS conducted a tabletop exercise in Des Moines, IA and at the FSIS headquarters in Washington, DC. The purpose of the exercise was "to test and validate operating guidelines, and directives for responding to a significant incident activity involving the intentional adulteration of food products within an FSIS inspected facility.	A simulated Emergency Operations Center (EOC) and Public Information Officer (PIO)/Joint Information Center (JIC) were needed More stakeholders were needed from local government agencies, particularly public health departments, hospitals, HAZMAT, environmental agencies Communication from government agencies to industry was limited and confusing; there was a general sense that government was not working as well with industry as possible.
Septemb er 25, 2008 Denver, CO **HSDL F**	TTX	Rocky Top	Unknown agent in meat, poultry, eggs	USDA's FSIS conducted a tabletop exercise in Denver, CO and at the FSIS headquarters in Washington, DC. The purpose of the exercise was "to test and validate operating guidelines, policies, and procedures for responding to a non-routine incident involving the intentional adulteration of a meat, poultry, or egg product within an FSIS regulated facility and product distribution.	Need to first establish and expand command structure to afford coordination, communication and interoperability; and Have a separate screen to track progress of the ICS. More involvement by local health departments in scenario – e.g., suggest adding an inject to address local health departments being inundated by phone calls; and invite state epidemiologists and representatives from department of emergency management to participate. Several participants noted the exercise illustrated the need to improve communication and coordination among all stakeholder groups, especially with regard to creating unified messages.

June 5, 2008 Atlanta, GA **HSDL F**	TTX	Operation Cherokee Rose	Unknown agent in meat, poultry, eggs	USDA's Food Safety and Inspection Service (FSIS) conducted a tabletop exercise in Atlanta, GA and at the FSIS headquarters in Washington, DC. The purpose of the exercise was "to test and validate operating guidelines and directives for responding to a non-routine incident involving the intentional adulteration of food products within an FSIS inspected facility.	Several participants suggested that the exercise should have included: EPA;Environmental Protection Division of Georgia, Consumer groups; GA Homeland Security, state & local law enforcement; Physicians/clinical lab. The epidemiological elements of the scenario were unrealistic, in that local public health would be continually learning new information during the course of real-life outbreak investigations. Many participants noted that the exercise illustrated the need to improve communication and coordination among all stakeholder groups, especially with regard to creating a unified message.
RAND – RAND Technical Report					
Unknow n State Between 12 /1999 and 12/ 2004 **RAND**	TTX	TE1	Botulism in food	Detect an outbreak and follow steps set up for an outbreak investigation.	None listed.
Unknow n State Between	TTX	TE5	Ergotism Food contamination (Ergot - claviceps purpurea fungus)	Demonstrate the ability to coordinate relations with other stakeholders; notify and work with public health organizations; prioritize and use public health resources; and obtain assistance	None listed.

12 /1999 and 12/ 2004 **RAND**				and work cooperatively with other stakeholders.	
Unknown State Between 12 /1999 and 12/ 2004 **RAND**	TTX	TE7	Salmonella poisoning	Practice group problem solving and assess interagency coordination; discuss coordination/integration of forces, responsibilities, and disaster response plans; and acquaint key department personnel with one another and their mutual responsibilities.	None listed.
Unknown State & county Between 12 /1999 and 12/ 2004 **RAND**	TTX	TE11	Shigellosis	Identify and understand policy issues, measures to be performed, and gaps in the event of a bioterrorist attack.	None listed.

BWTTX – Biological Weapons Tabletop Exercise
FE – Functional Exercise
FSE – Full Scale Exercise
HSDL F - Homeland Security Digital Library Collection (Full)
HSDL RC – Homeland Security Digital Library Collection (Restricted)
RAND – RAND Technical Report (RAND, 2010)
SM - Seminar
TTX – Tabletop Exercise
WK - Workshop

Table 4. Cost categories included in cost of illness studies.

	Direct cost						**Indirect Costs**		
Authors	Outpatient	Inpatient	Medications	Rehabilitations (long term care)	ER	Non-medical	Productivity loss	Mortality - HCA	Mortality - WTP
Batz, Hoffmann, and Morris Jr (2012)	✓	✓			✓		✓		✓
Buzby and Roberts (1996)	✓	✓	✓	✓	✓		✓	✓	
Frenzen, Drake, Angulo, and Group (2005)	✓	✓	✓	✓	✓		✓	✓	
Hoffman, Batz, and Morris Jr (2012)	✓	✓	✓	✓	✓		✓		✓
Hoffmann, Maculloch, and Batz (2015)	✓	✓			✓	✓	✓		✓
Kaufmann et al. (1997)	✓	✓	✓				✓	✓	
Lee at al. (2008)	✓	✓						✓	✓
Minor et al. (2014)	✓	✓		✓	✓		✓		✓
Parks (2009)	✓	✓	✓		✓				
Ralston, Kite-Powell, and Beet (2011)	✓	✓					✓		✓
Roberts (2007)	✓	✓					✓		✓
Scharff (2012)	✓	✓	✓	✓		✓	✓		✓
Scharff (2015)	✓	✓	✓	✓		✓	✓		✓

ER = Emergency Room

HCA = Human Capital Approach

WTP = Willingness-to-Pay

Table 5. Data sources used in foodborne cost of illness studies

Authors	Data source
Batz, Hoffmann, and Morris Jr (2012)	-CDC's online repository of foodborne outbreaks (1999 through 2008) -Expert elicitation[1]
Buzby and Roberts (1996)	-National Center for Health Statistics (NCHS) -CDC reports of foodborne disease -Risk models based on pathogens' prevalence in foods, and on infectious doses -Medical data on individual cases, often published in the literature as a case history -Extrapolations by experts to obtain estimates of the total number of cases and the disease severity -Medicare reimbursement rates and per capita expenditures on physician services from the Health Care Financing Administration (HCFA) -American Hospital Association's Hospital Statistics, -National Center for Health Statistics' National Hospital Discharge Survey (NHDS) -National Mortality Follow-back Survey -VSL $11,867 to $1,584,605 in 1993 dollars
Frenzen, Drake, Angulo, and Group (2005)	-CDC's Foodborne Diseases Active Surveillance Network (FoodNet) -FoodNet Population Survey, 2002-2003 -National Health Accounts, 2000 -American Medical Association -Medical Expenditures Panel Survey (MEPS), 2001 -Nationwide Inpatient Sample file, 2001 -Current Population Survey, March 2001 -VISL $6.9 million, 2003 dollars; $9.3 million for infants; $1.8 million for adults >85
Hoffman, Batz, and Morris Jr (2012)	-CDC, 31 pathogens by Scallen et al 2011 -Nationwide Inpatient Sample (NIS) database, 2001 to 2003 -FoodNet data from 2001 to 2004 -VSL of $7.9 million (in 2009 U.S. dollars)
Hoffmann, Maculloch, and Batz (2015)	-CDC, 31 pathogens by Scallen et al 2011 -National Inpatient Sample (NIS) database and existing scientific literature -VSL of $8.7 million (in 2013 U.S. dollars)
Minor et al. (2014)	-CDC, 31 pathogens by Scallen et al 2011 -VISL $8.3 million (in 2013 prices)

Table 5, continued

Ralston, Kite-Powell, and Beet (2011)	-CDC Outbreak Surveillance Summaries, 1993-2006 -Cholera and Other Vibrio Illness Surveillance System (COVIS), -FoodNET -National Notifiable Disease Surveillance System (NNDS) -Economic Research Service (ERS) COI calculator -VSL of $5 million
Roberts (2007)	-CDC, 31 pathogens by Scallen et al 2006 -FoodNet -VSL adults ($7 million); children ($12 million), and the elderly ($5million)
Scharff (2012)	-CDC, 31 pathogens by Scallen et al 2011 -Healthcare Cost and Utilization Project (HCUP) database, years 2004-2008 -National Notifiable Diseases Surveillance System (NNDSS) data -FoodNet data from 2000 - 2001 -Bureau of Labor Standards, October 2010 -VSL of $7.3 million in 2010 dollars
Scharff (2015)	-CDC, 31 pathogens by Scallen et al 2011 -National Notifiable Diseases Surveillance System (NNDSS) data -Healthcare Cost and Utilization Project through 2012 -Medical Fees in the United States, 2014 edition -Bureau of Labor Statistics (BLS), 2013 -VSL updated to 2013 dollars

[1]Expert elicitation consists of a set of formal research methods used to characterize uncertainty research methods used to characterize uncertainty about existing scientific knowledge and to provide alternative parameter estimates when there are meaningful gaps in available data.

Table 6. Data sources used in bioterrorism cost of illness studies.

Authors	Data source
Kaufmann et al. (1997)	-Undiscounted average of future earnings is $1,688,595 -hospitalization was $875/day, in 1993 -Lost productivity valued at $65/day -Outpatient visit costs used the Medicare National Average Allowance -Population exposed, hypothetical at 100,000
Lee at al. (2008)	-National Football league (NFL) game attendance -Hazard Prediction and Assessment Capability (HPAC) modeling scenario -Cost-benefit study of counter measures against anthrax terrorism -Impact M for Planning (IMPLAN) data, 2003 -VSL of $5.4 million
Parks (2009)	-Dallas Water Utilities (DWU) distribution system -Critical Infrastructure Protection Decision Support System (CIPDSS) a computer simulation and decision analytic tool -EPANET - software that models water distribution piping systems -Cost data from Corso et al. 2003 -VSL of $6.2 million

CHAPTER 3

A BENCHMARK SYSTEM TO OPTIMIZE OUR DEFENSE AGAINST AN ATTACK ON THE U.S. FOOD SUPPLY UTILIZING THE RISK REDUCTION EFFECTIVENESS AND CAPABILITIES ASSESSMENT PROGRAM[3]

[3] Hodoh, O.B., Dallas, C.E., Williams, P., Jaine, A.M. and C.A. Harris. Accepted by *American Journal of Disaster Medicine*. Reprinted here with permission of the publisher.

Abstract

Objective: A predictive system was developed and tested in a series of exercises with the objective of evaluating the preparedness and effectiveness of the multi-agency response to food terrorism attacks.

Design: A computerized simulation model, Risk Reduction Effectiveness and Capabilities Assessment Program (RRECAP) was developed to identify the key factors that influence the outcomes of an attack and quantify the relative reduction of such outcomes caused by each factor.

Setting: The model was evaluated in a set of Tabletop and Full-Scale Exercises that simulate biological and chemical attacks on the food system.

Participants: Over 300 participants representing more than 60 federal, state, local and private sector agencies and organizations.

Results: The exercises showed that agencies could use RRECAP to identify and prioritize their advance preparation to mitigate such attacks with minimal expense. RRECAP also demonstrated the relative utility and limitations of the ability of medical resources to treat patients if responders do not recognize and mitigate the attack rapidly, and the exercise results showed that proper advance preparation would reduce these deficiencies.

Conclusions: Using computer simulation prediction of the medical outcomes of food supply attacks to identify optimal remediation activities and quantify the benefits of various measures provides a significant tool to agencies in both the public and private sector as they seek to prepare for such an attack.

Key words: Emergency response, Food terrorism, Simulation, Public health preparedness, Intervention, Food defense

INTRODUCTION

Food processing, distribution, and supply systems are essential elements of the U.S. economy and these systems present significant vulnerability to attack (Karwa et al., 2005; Smith DeWaal, 2004). Biological and chemical contamination of the food supply poses an enormous threat to human life and public health. Deliberate biological or chemical contamination of the food supply bears the risk of significant social disruption and diminished confidence in the food supply, widespread panic, economic collapse, and massive fatalities (Evans et al., 2002). The impact of H5N1 on the poultry industry (Onyango, Rimal, Miljkovic, & Hallman, 2009), bovine spongiform encephalopathy on the beef industry (Devadoss, Holland, Stodick, & Ghosh, 2006), and the 2008 melamine poisoning incident on the milk industry (Ingelfinger, 2008) suggest the scope of the risk.

Studies using predictive simulation modeling have suggested that prompt detection of food terrorism events will result in significant reductions in morbidity and mortality without fully quantifying the likely consequences of food terrorism (Hartnett et al., 2009; Wein, Liu, & Bloom, 2005). Jaine (2011) has developed the Risk Reduction Effectiveness and Capabilities Assessment Program (RRECAP)[4] as a computer simulation model to address this gap and provide greater detail as to how public health agencies, first responders, and private sector organizations might minimize these consequences. It does this by evaluating the operational and organizational characteristics that exist for federal, state, and private sectors responding to potential cases of food terrorism in light of superior quantification of consequences.

[4] Patent Pending

This article describes the evaluation of the RRECAP model in a large, multi-agency training operation named Georgia FoodEx 2009, (U. S. Department of Homeland Security, 2009) which comprised a Tabletop Exercise (TTX) and Full-Scale Exercise (FSE). The TTX simulated deliberate contamination of seafood with ricin and rapid consumption in the United States. The FSE simulated terrorists intentionally contaminating chicken nuggets with lethal doses of methyl parathion (MP) at a food processing plant. To our knowledge, this is the first operations-based exercise that used the actual chemical agent during the operation. The research complies with the Homeland Security Exercise and Evaluation Program (HSEEP), which uses discussion and operations-based exercises to measure and assess public health preparedness to respond to terrorist acts and manmade or natural disasters (U. S. Department of Homeland Security, 2011a; U.S. Department of Homeland Security, 2013b).

Among the objectives of the exercises were to utilize RRECAP to identify the key factors that determine the effectiveness of the response to each attack (the Key Performance Capabilities [KPCs]), evaluate the degree to which changes in capabilities affect the outcome of an attack (the Key Impact Metrics), and make recommendations of ways to optimize prioritization of KPC's to minimize the negative impact of the attack.

METHODS

Model Description

RRECAP is an innovation that can measure the effectiveness of federal, state, and private sectors in preventing and responding to attacks on various complex systems such as food, communication, and transportation. RRECAP is a predictive model designed to help government and industry improve their ability to respond to all forms of attacks through improving prevention and response. The program works by showing the geographic and temporal evolution of a simulated deliberate food contamination event using a geographic information system (GIS) map (see Figure 3). This map overlays distribution and consumption information with profiles of morbidity and mortality outcomes and displays the results in an animated map that depicts the temporal evolution of the consequences of the quantities and locations of morbidities and mortalities that result from the attack as they spread throughout the affected areas.

To improve prevention, the model addresses two components:

1) Applying principals of Organizational Performance Management as a means to identify partnerships between various levels of government and the private sector; and
2) Helping the private sector identify methods to reduce food vulnerabilities.

To improve response, it assesses five components:

1) Benchmarking preparedness via discussion and operations-based exercises;
2) Performing sensitivity analyses to determine which KPCs are influential in minimizing outcomes of an attack;
3) Quantifying the benefits of improving preparedness by rendering values for the key indicators (e.g. morbidities and mortalities) under different sets of values of the KPCs;
4) Prioritizing the relative benefit of investments in improving different capabilities;
5) Assisting organizations in developing Risk Management plans to enhance response effectiveness to all forms of attack.

In addition to showing the consequences of an event, the model demonstrates the effects of implementing interventions and changes in timing of interventions to minimize impacts of catastrophic incidents.

RRECAP Evaluation in Georgia 2007/2008 Tabletop Exercise

In the first of two exercises to test the effectiveness of RRECAP, a TTX was utilized to look at issues in prevention, protection, response and recovery during an attack on the U.S. food supply. The HSEEP compliant exercise was held in May 2008 in Atlanta, Georgia, with 16 state and federal agencies participating. The exercise simulated an intentional contamination of seafood with ricin introduced at the point of production in an overseas country and entering the United States through Hartsfield–Jackson Atlanta International Airport, a key entrance point for seafood imported into the country. The scenario assumed that people in several states rapidly consume the highly perishable seafood. The scenario incorporated an early notification that an Al-Qaeda affiliated terrorist group published a warning on the Internet of a planned attack on the food system.

The focus of the exercise was on decision-making before it became a massive international effort. The capabilities analyzed included: roles and responsibilities, conduct of operations, communications, and spatial awareness. Once the basic capabilities were understood in the TTX, they were used as the foundation for building the FSE.

RRECAP Evaluation in Georgia FoodEx 2009 Full-Scale Exercise

The second and by far the larger exercise using the RRECAP simulation evaluation included many of Homeland Security's 37 nationally identified Target

Capabilities and quantified the effectiveness of key capabilities in reducing attack consequences. The attack scenario involved chicken nuggets intentionally contaminated with a concentrated lethal pesticide distributed throughout the southeastern United States. The MP-scenario was validated by the Department of Homeland Security's, Chemical, Biological or Radiological Threat Risk Analysis Center as a plausible scenario.

Scenario Profile and Model Assumptions

The design of the FSE placed a priority on assessing emergency management capabilities under a scenario that has rapid escalation of morbidities and mortalities. The scenario involved contamination of approximately 20,000 lbs. of chicken nuggets with liquid MP (77% technical form) when terrorists sprayed it into open boxes at a distribution center in Jesup, Georgia. MP is a highly toxic organophosphorus pesticide used to kill insects on agricultural crops (U.S. Environmental Protection Agency, 2006). According to the World Health Organization, 200,000 – 250,000 deaths each year occur globally from MP poisoning, most of them suicides.(Balali-Mood & Abdollahi, 2014). Technical material is 80% pure and MP is colorless, odorless, and tasteless. In order to determine the likely time it would take to validate contamination with field measurements, we injected a controlled small sample of chicken with the pesticide so that a lethal dose actually was present. The chicken was divided into ¼ lb. servings and contaminated with the chemical at a level where 90% of people who consumed a serving would become ill (Infectious $Dose_{90}$ (ID_{90})) and 50% of them would die (Lethal $Dose_{50}$ (LD_{50})). The sample was taken under strict control to the exercise site for sampling in the field. The model outcomes include realistic time course data based on this exercise. Table 7 describes key parameters of this scenario.

Scenario Summary

The FSE took place from August 7 to August 12, 2009. The FoodEx 2009 exercise was embedded within a cluster of parallel exercises taking place at two field locations on August 10, 2009, as well as in a number of agency offices and labs across Georgia between August 7 and August 10, 2009. The two field locations included a simulated terrorism lab in a private residence located in a training facility at the Federal Law Enforcement Training Center (FLETC) in Brunswick, Georgia, and a simulated food distribution warehouse located in a farmer's market facility in Jesup, Georgia, approximately 50 miles from the terrorism lab. Table 8 and Figure 4 present the scenario timeline.

RRECAP was used to model the outcomes under a range of different scenarios. The first simulation depicts the outcomes that would have presented without any intervention. The subsequent simulations depicted the likely outcomes with response parameters set at the values that were observed during the exercise and the different interventions that the exercise participants invoked.

One of the activities of this exercise was to assess the levels to which responders were able to perform the identified key capabilities. When this assessment is made, the value (length of time that it takes to identify the correct vector with sufficient accuracy to enable an appropriate intervention to be invoked) is entered in the "Interventions" section of the model (see Figure 3). The "Indicators" table is generated as a part of the RRECAP scenario and shows various observable outcomes of the attack. Four indicators most influential in helping identify and mitigate a foodborne attack are:

1) Consumer Reports (*including those to the food producer*)

2) Medical Attentions

3) Reports to the Public Health Departments

4) Hospital Admissions

Sensitivity Analysis

A sensitivity analysis was performed after the results were determined from the FSE exercises to determine which KPCs were most influential in minimizing the outcomes of the attack.

RESULTS

RRECAP Evaluation in Georgia 2007/2008 Tabletop Exercise

This exercise used RRECAP to evaluate the profiles of morbidity and mortality presentation due to consumption of ricin-contaminated seafood. In the simulation, tens of thousands of servings of contaminated seafood were consumed in the United States resulting in thousands of morbidities and mortalities. Following the completion of the exercise an Improvement Plan was developed that identified several key areas in need of enhancement. This exercise revealed that the computerized simulation provides both evaluation of the effectiveness of various response activities and improves the focus and involvement of exercise participants. Other recommendations included:

1) Development of a Risk Management Plan with comprehensive public/ private training;

2) Development of an exercise program to nurture a public/private partnership;

3) Expand the modeling to measure the effectiveness of the Target Capabilities to mitigate the consequences of a variety of scenarios;

4) Evaluate medical surge and other resource management and spatial awareness capabilities.

RRECAP Evaluation in Georgia FoodEx 2009 Full-Scale Exercise

No Intervention

This RRECAP simulation investigated morbidity and mortality without any interventions. As the attack progressed, RRECAP illustrated the number of morbidities and mortalities expected to occur based on agent-specific parameters to a final end-point.

In the absence of any interventions, by 11:00 am on the 16^{th} day (371 hours) following the start of the exercise, just under 72,000 morbidities and 40,000 mortalities occurred (Figure 5). Just under 54,000 hospital beds existed in a 250-mile radius of the contamination area, but more than 66 percent of those beds are in constant use (based on the national average).(Centers for Disease Control and Prevention, 2013) The enormous number of casualties would cause an overwhelming demand on local and regional hospitals.

Stop Movement/Stop Sale Intervention

In the first simulation, RRECAP identified how event consequences grow over time under a worst-case scenario (i.e. when the event goes undetected). The primary goals of RRECAP are to identify the KPCs that are most effective in reducing event consequences. The scenario data used by RRECAP identifies the set of capabilities required for effective response of the modeled scenario known as “Key Capabilities.” The Stop Movement/Stop Sale Intervention simulation models the extent to which interventions precipitated by exercise participants would reduce these consequences.

The initiation of the exercise was that one of the terrorists had displayed signs of illness while at work and transported to the hospital, where he exhibited flaccid paralysis before becoming non-responsive. Simultaneously, local hospitals reported high numbers of ill individuals seeking medical attention, which triggered an immediate public health response led by local public health officials to suspect criminal activity. Since the hospital had no family contacts for the patient, the local epidemiologist went to the home, knocked on the door, observed lab materials when the door opened, was refused entry and immediately called the police. The police entered the home, saw a laboratory and called the local Special Weapons and Tactics (SWAT) team. The SWAT team saw the laboratory producing suspicious materials and called Georgia Emergency Management Agency (GEMA). GEMA alerted the State Operations Center and the 4th Civil Support Team (CST) in Georgia was activated to help identify the suspicious materials. While awaiting arrival of the CST the on-site Incident Command (IC) together with the Georgia Department of Agriculture (GDA) contacted the local staff of the food production company and found that some of their employees were reporting illness. This triggered the IC/GDA to order a Stop Movement of all product shipped from that location. During this part of the exercise, the GDA invoked two specific interventions: the identification of the product suspected of contamination at “Hour 84” following the start of the exercise, and at that time, he ordered the cessation of all movement and sale of that product, “Stop Movement.”

The time of the intervention, “84 Hours,” was entered in the Interventions table (Figure 3) and the simulation proceeded to run. During the first hours of the event, there were no interventions, so the evolution of consequences was identical to those generated in the previous scenario. The intervention occurs at "84 hours", and RRECAP continues to run the simulation modeling the effects of that "Stop Movement" intervention. When the evolution stopped, the consequences of the intervention were recorded showing the number of morbidities and mortalities.

The Stop Movement/Stop Sale Intervention reduced the number of morbidities to under 32,000 and the number of mortalities to 18,000, respectively (Figure 5). However, even at these levels, surrounding hospitals would still be unable to respond adequately to the affected victims, which would worsen considerably the extent and severity of morbidity.

Stop Movement/Stop Sale and Public Announcement Intervention

At "Hour 93" the 4th CST, which was on site with its mobile laboratory, confirmed the identity of the contamination agent from the samples brought under control, and the Assistant Commissioner ordered a Public Service Announcement of product contamination. The time of announcement, "93 Hours," was entered into the Interventions table (Figure 3) and the model proceeded to run. Displays showed when the intervention occurred, and recorded the number of morbidities and mortalities; RRECAP continued to run the simulation of the effects of the "Public Announcement" intervention. At the conclusion of the evolution, the number of morbidities and mortalities that resulted from the combined effects of both the Stop Movement/Stop Sale and the Public Announcement were recorded as just over 19,000 morbidities and under 10,000 mortalities, respectively (Figure 5). While these numbers of patients resulting from the attack would still overwhelm surrounding hospitals, the overall impact on public health would be significantly diminished relative to the 84-hour intervention data.

Analysis of Key Indicators

RRECAP displays the various observable outcomes of the attack in the "Indicators" section of the output (Figure 3). The consequences of the *No Interventions* scenario were approximately 200 Consumer Reports, 54,000 people seeking Medical Attention, 8,100 reports by Public Health Departments, and 20,000 people admitted to hospitals (Table 9). The consequences of the *Stop Movement/Stop Sale Intervention* reduced all these parameters by 55%, and the consequences of the *Public Announcement* further reduced Consumer reports by an additional 25% and the remaining indicators by 18%.

Sensitivity Analysis

RRECAP has the ability to monitor any number of capabilities. For this study, it was determined after the FSE that five KPCs were influential in identifying and mitigating a foodborne attack:

1) Spatial Awareness: The percentage of businesses that handled the product. This was captured by utilizing the Food and Agriculture System Criticality Assessment Tool (FAS-CAT) to identify critical nodes within the system;
2) Recall Effectiveness: If a recall was invoked, then the percentage of product that was returned due to that recall;
3) Recall/Stop Sale Time Span: If a stop sale or recall was invoked, then the amount of product that was stopped/recovered due to that action;
4) Announcement Effectiveness: If a public announcement was invoked, then the percentage of the product that was not yet consumed and was prevented from consumption by the public announcement;

5) Announcement Time Span: If a public announcement was invoked, then the length of time that it took for that announcement to be effective.

The scenario was based on a default response effectiveness at 50%. For the sensitivity analysis, three different percentages (25%, 50% and 75 %) were entered in the capabilities section of the model (Figure 3). Table 10 shows the results of the sensitivity analysis for the number of morbidities and mortalities. The combined effectiveness of the response strategies for the existing capabilities at increasing efficiencies reduced morbidities and mortalities by approximately 34%, 55% and 73%, respectively. Responding at lower efficiencies would negatively affect more people. Figures 6 and 7 show the results of the sensitivity analysis for the total number of people affected by the attack.

DISCUSSION

Incidents of intentional contamination of the food supply worldwide in the past fifty years suggest that terrorist groups understand the potential of such attacks to create social disruption, panic and death (Johnson et al., 2009; World Health Organization, 2008). In 1984, the Rajneeshee cult attempted to reduce voter turnout in a local election in Oregon by deliberately contaminating restaurant salad bars with *S. typhi*. While the group did not achieve its aim, 751 people were treated for salmonellosis, the local health department closed down all ten restaurant salad bars, and policy changes were implemented nationwide to prevent future attacks. Other examples include a plot, detailed in the notebook of a high-level Al-Qaeda operative detained in Afghanistan, to compromise the world's largest producer of Meals Ready to Eat (MREs) the food rations U.S. soldiers use during field operations, with poison (Pinkerton, 2004). In 2003, a church member in rural Maine poisoned thirteen individuals by contaminating coffee at a church gathering with arsenic (Gensheimer et al., 2010), and ninety-two people reported illnesses after consuming ground beef contaminated with an insecticide containing nicotine sulfate in Michigan (Centers for Disease Control and Prevention, 2003).

In 2004, President George W. Bush signed Homeland Security Presidential Directive 9, establishing a national policy concerning the protection of the food system from terrorists (U.S. Department of Homeland Security, 2004). A report by the U.S. Department of Homeland Security and the Federal Bureau of Investigation revealed that the "Mujahidin Poisons Handbook" appears on the websites of many radical Islamist groups describing techniques for attacks on the food supply (U. S. Department of Homeland Security, 2008). In a bulletin to the nations law enforcement officials, the FBI warned that Al-Qaeda might use poisons to contaminate the U.S. food and water supplies (Forest et al., 2013).

The current study addresses the results of such an attack by simulating a scenario that involved a food product both simulated and actually contaminated with a lethal pesticide distributed in the southeastern United States, and involving a live response including deployment of the 4th, 44th and 46th CST's and over 60 state, federal and private agencies. The RRECAP tool was used to measure the effectiveness of current capabilities and showed that if the attack had not been mitigated the consequences would have been over 70,000 morbidities and 40,000 mortalities in Georgia, Florida, and South Carolina (Figure 5). RRECAP showed the combined effects of the high levels of performance of key capabilities combined with the swiftness of high-level officials making key decisions would reduce morbidities by 30%. The Stop Movement/Stop Sale action reduced the number of morbidities and mortalities in half and the additional effect of the Public Announcement further reduced these by an additional 45%, as evaluated by the RRECAP tool. Additionally, RRECAP yielded a plan for improvement by identifying a set of capabilities that, if improved by a specified and achievable amount (50 percent), could reduce consequences from baseline by approximately 73%. RRECAP also showed that existing capabilities reduced the total number of cities that the incident would have affected from 73 to 36 (Figure 5), reducing the urban human health impact to a range much more manageable with immediately available healthcare resources, which are located in these metropolitan settings.

The RRECAP tool has certain essential data that is required to compute the levels of morbidity and mortality resulting from a catastrophic foodborne attack. Most measures are related to the time to perform specific response activities. The list (in the Methods section) could be extended almost indefinitely, but the objective of RRECAP is to assess the activities required to improve consequences of an attack. Thus, activities are only important to the extent that they can be reasonably expected to improve the consequences, the principal mechanism for which is often the time it takes to accomplish the activities. Therefore, the quality/quantity of performance is only significant if the timing of the performance is appropriate.

Limitations

The capability benchmarks RRECAP generates depend on implementation of a specific scenario and set of accompanying assumptions. Of course, in real-life events many other factors outside the control of responding agencies would play a significant mitigating or exacerbating role. Outbreaks may continue for longer than expected because key events fail to be recognized, while some are acknowledged quickly because of an incidental reason. For example, if the epidemiologist had delayed or failed to visit the terrorist's home, notification to law enforcement would have never occurred resulting in increased morbidity and mortality. The results RRECAP generates cannot be extrapolated to make specific projections of the consequences of different scenarios, or to real-life scenarios, and may only be used for relative comparisons.

Neither RRECAP nor any other currently known process can be expected to predict the actual outcomes of various scenarios in advance of the actual occurrence nor determine the extent and effectiveness of the responses, the precise effects of having specific levels of capability, or the exact success of interventions. These factors do not implicitly create uncertainty in RRECAP, as the objective is to determine the relative changes in outcome caused by differing values of various target capabilities. If the scenario values are maintained consistently across different exercises, the relative comparisons of results of those exercises are preserved, regardless of the absolute values.

CONCLUSIONS

RRECAP is a science-based predictive software system that enables users to quantify current levels of effectiveness of response to catastrophic attacks, provides focused guidance on optimal ways to achieve consequence reduction, and relatively quantifies benefits achieved through remediation activities. It provides a powerful tool to assess the effectiveness of preparedness projects currently implemented and under development, and to focus them to achieve various strategic plans for effective prevention, mitigation and response. It demonstrates the utility of computer simulation prediction to measure the relative benefit of policies and procedures that agencies might implement to prepare for deliberate attacks on the U.S. food supply.

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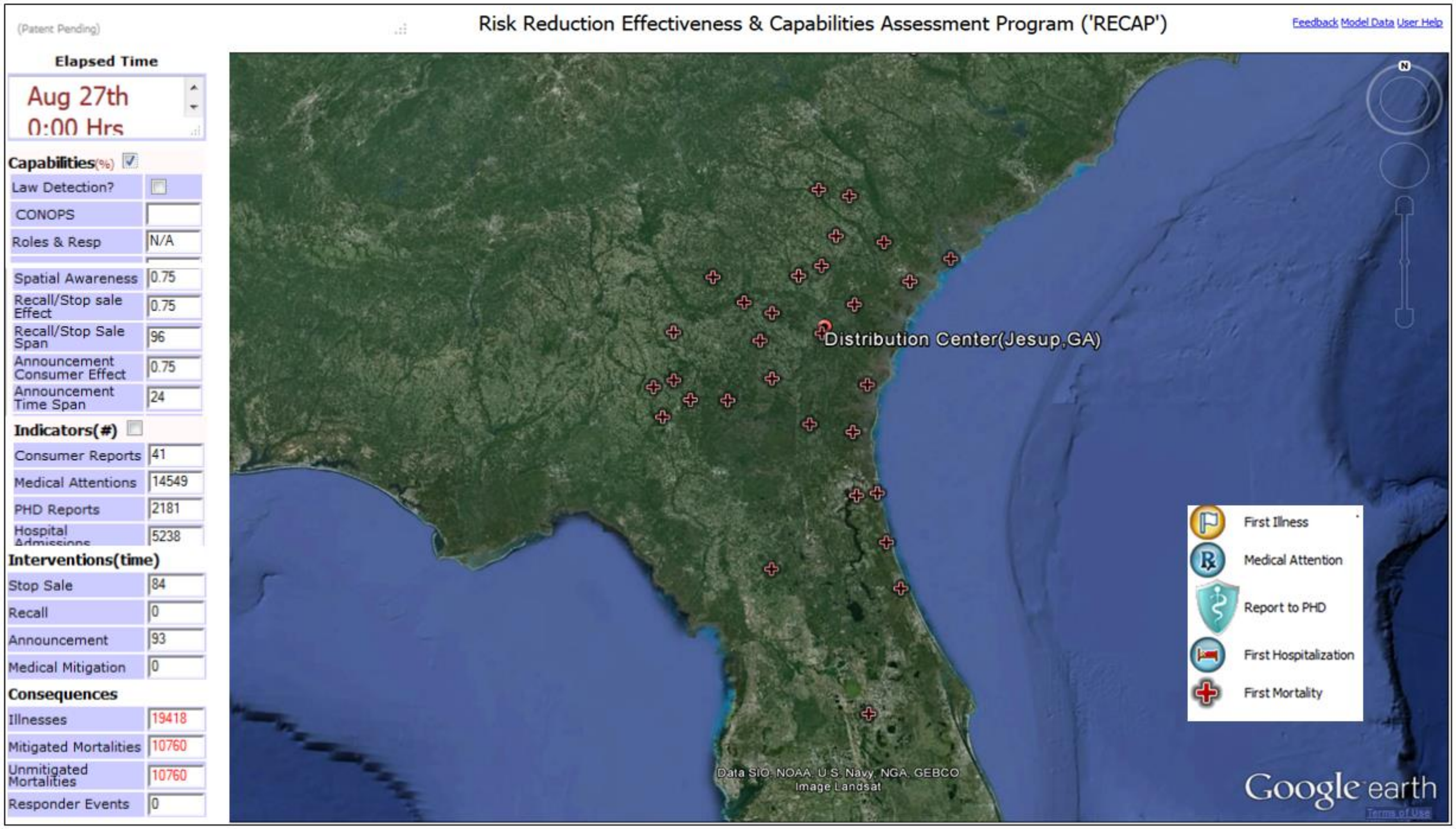

Figure 3. RRECAP Key Performance Capabilities

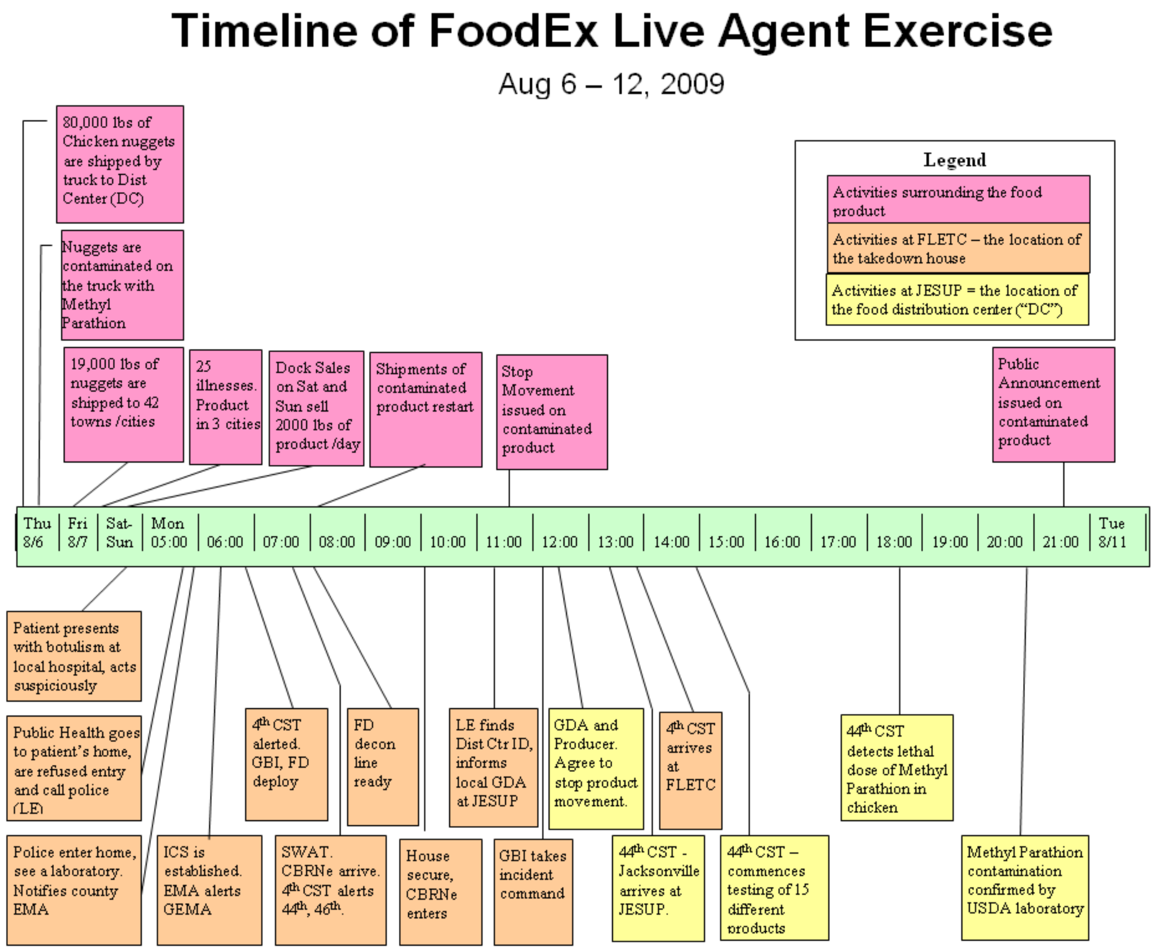

Figure 4. Timeline of FoodEx Live Agent Exercise

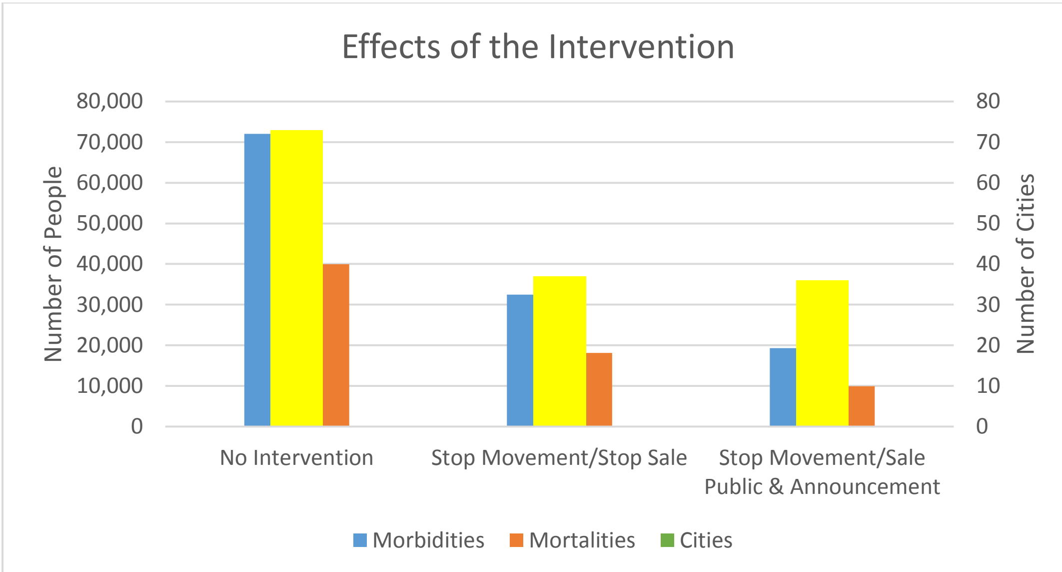

Figure 5. Combined effects of the intervention on the number of morbidities and mortalities.

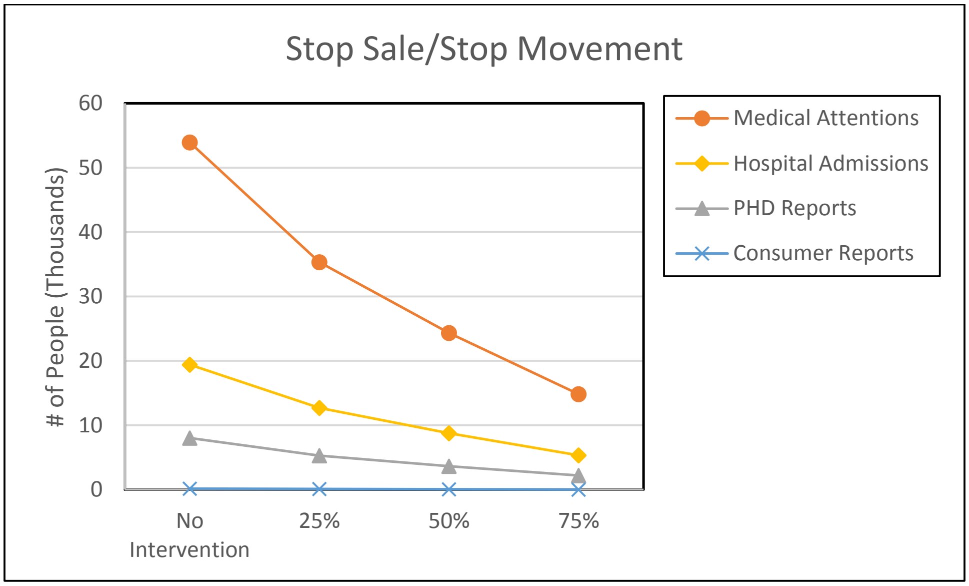

Figure 6. Comparison of Indicators (Observations) Modeled at 25%, 50% and 75% for Stop Sale/Stop Movement Intervention.

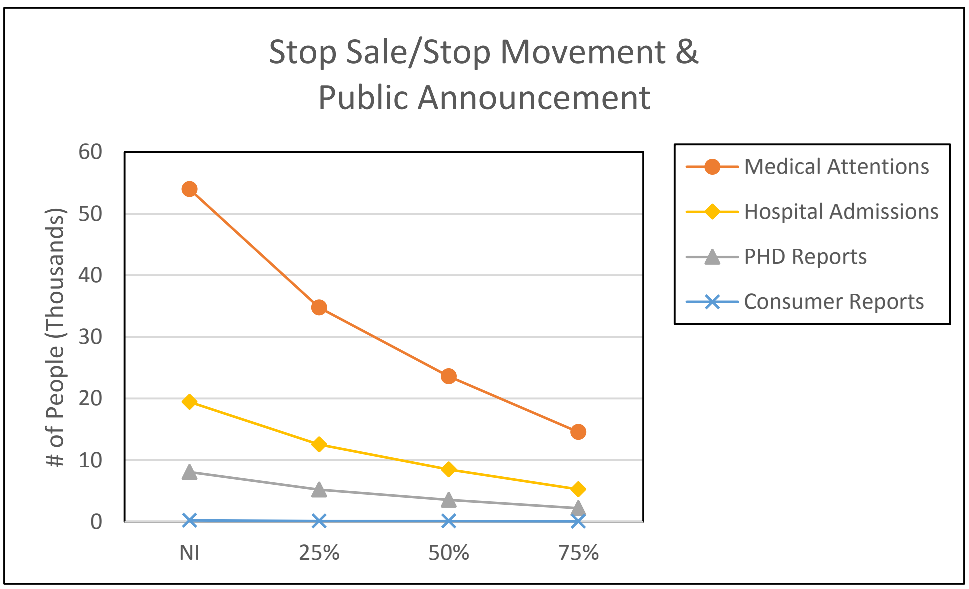

Figure 7. Comparison of Indicators (Observations) Modeled at 25%, 50% and 75% for the Stop Sale/Stop Movement and Public Announcement Intervention.

Table 7. RRECAP model parameters

Data Item	Value
Product Sourcing	
Contaminated quantity	80,000 lbs servings; 25,000 servings per million population in the state
Shipped per day	500,000 lbs/day
Product distribution	N(10 days, 2.9 days)
Shipping rate	1,900 servings/hour
Shipping days/week	5 days/week
Shipping hours/day	10 hours/day
Contaminated locations	100 individual locations per million population in state
Geographic spread of consumption	100% to homes within 200 – 250 mile radius of Jessup, GA
Consumer Handling and Consumption	
Serving size	One ¼ breast
Consumption amount	Uniformly consumed by all subpopulations
Consumption delay	1 – 3 days following arrival at consumption point
Consumption profile	N(36 hours, 9 hours); terminates at 72 hours
Agent Information	
Agent name	Methyl Parathion (77% Technical Material)
Patient Response Information	
Attack rate	90% (LD_{50} approximately 3 – 20 mg/kg)
Consumer reporting	$\bar{x}$ = 0.515 % (average level in severe illnesses)
Time from consumption to symptom onset	N(4.5 hours, 1.8 hours); min time symptom onset of 1 hour
Time from symptom onset to seeking medical care	$\bar{x}$ = 5 hours
Proportion seeking medical care	75%
Hospitalization	$\bar{x}$ = 8 hours following illness presentation
Proportion of hospitalizations	36% of ill will be admitted
Mortality level	50% of affected will die after consuming a single serving
Time-to-mortality	lnN ($\bar{x}$ = 72 hours, max = 204 hours)
Public Health Response	
Rate reporting to Public Health	minimum = 48 hours; $\bar{x}$ = 96 hours; max = 120 hours
Volume reporting to Public Health	15%
Surge capability	504 beds within 50 miles; 7646/100 miles; 14606/150 miles; 30473/200 miles; 53895/ 250 miles
Agency Response Information	
Outbreak consequence accuracy	Range of 0% to 100%
Outbreak consequence sensitivity	Range of 0 to 2; 0.25 (Default)
Intervention Information	
Recall time span	6 hours (Default)
Recall effectiveness	6 hours (Default)
Recall time span for non- identified companies	240 hours / 5 days (Default)
Public announcement time span	48 hours (Default)
Effectiveness of public announcement	50% (Default)
Effectiveness of Medical Mitigation	50% (Default)

Table 8. Timeline of events Georgia FoodEx 2009 Full-Scale Exercise.

Day	Event
Prior to Day-1	80,000 lbs of chicken nuggets are shipped by truck to the Distribution Center in Jesup, Georgia. Terrorists contaminate nuggets on the truck with liquid methyl parathion.
Day-1	The product is shipped to 42 towns and cities from the distribution center in Jesup.
Days-2 and 3	2,000 servings are sold per day as "Dock Sales".
Day-3	Georgia Department of Community Health's epidemiology group report thousands of patients admitted to local area hospitals with seasonal influenza symptoms, similar to one another yet uncharacteristic for late summer.
Day-4 (5:00 am)	The terrorist (plant employee), acting suspiciously is transported to local emergency room with botulism-like symptoms. Symptoms of organophosphate poisoning (e.g. excessive salivation, lacrimation, nausea and vomiting, diarrhea) are comparable to food-borne botulism symptoms (e.g. dizziness, dry mouth and diarrhea).
Day-4 (5:50 am)	Public health department goes to home of suspicious patient, are refused entry and call police. Police enter home, see a laboratory and notify the local Emergency Management Agency (EMA).
Day-4 (6:00 am)	Incident Command System (ICS) is established and EMA alerts the Georgia Emergency Management Agency. The Georgia Bureau of Investigation, Special Weapons and Tactics (SWAT)-CBRNE team arrive and begin pursuing investigation. The 4th CST alerts 44th and 46th.
Day-4 (8:00 am)	Shipments of contaminated product restart.
Day-4 (1:00 pm)	Stop Movement/Stop Sale issued by the Georgia Department of Agriculture (GDA) and the Incident Commander (IC) on the contaminated product.
Day-4 (2:55 pm)	44th CST detects lethal doses of methyl parathion in chicken.
Day-4 (8:00 pm)	Methyl parathion contamination confirmed by USDA laboratory.
Day-4 (9:00 pm)	Public Announcement issued IC and GDA on contaminated product.
Day-4 (11:00 pm)	Exercise ends.

Table 9. Changes in Key Indicators (Observations) because of the interventions.

	Interventions		
	No Intervention *	Stop Movement/ Stop Sale*	Stop Movement/Stop Sale and Public Announcement *
Observations			
Consumer Reports	196	87	38
Medical Attentions	53,962	24,331	14,491
Public Health Department Reports	8,048	3,650	2,173
Hospital Admissions	19,424	8,760	5,216

*The total number of people affected

Table 10. Comparison of Capabilities Modeled at 25%, 50% and 75%

		Intervention		
% Efficiency	Effect	No Intervention	Stop Movement	Stop Movement and Announcement
25	Illnesses	71,995	47,131	46,361
50	Illnesses	71,995	32,461	18,162
75	Illnesses	71,995	19,829	19,418
25	Mortalities	39,980	26,201	25,542
50	Mortalities	39,980	18,162	17,430
75	Mortalities	39,980	11,036	10,760

CHAPTER 4

ESTIMATING THE COST OF ILLNESS DUE TO A FOOD TERRORISM ATTACK USING THE RISK REDUCTION EFFECTIVENESS AND CAPABILITIES ASSESSMENT PROGRAM DATA[5]

[5] Hodoh, O.B., Dallas, C.E., Williams, P., Jaine, A.M., Corso, P.S. and C. A. Harris. To be submitted to *Journal of Food Protection.*

Abstract

Deliberate or intentional contamination of food has been rare in the United States to date, but food processing, distribution, and retail systems are all potentially vulnerable to food terrorism. A food terrorism event could devastate the economy, yet there is a paucity of studies that have estimated the potential cost of illness due to foodborne terror attack. This study seeks to estimate a total cost of illness due to a hypothetical foodborne attack where terrorists intentionally contaminate chicken nuggets with lethal doses of methyl parathion. We used the morbidity, hospitalization, and mortality data from the computerized simulation model Risk Reduction Effectiveness and Capabilities Assessment Program (RRECAP) to estimate the cost of illness, applying the Cost of Illness Calculator created by the U.S. Department of Agriculture's Economic Research Service. The model showed a cost ranging from $87 billion—if the head of the state agriculture issues a stop movement /stop sale and there is a public announcement intervention—to $349 billion if no interventions are invoked. Mortality costs drive the total cost estimates. Direct medical cost estimates of the attack ranged from $538 million to $2.2 billion, from outpatient and physician office visits and indirect costs resulting from lost workdays, and premature mortality costs ranged from $86 billion to $346 billion. The worried-but-well individuals represent 99% of the direct medical costs and productivity losses. The findings from this study support early intervention to reduce the economic burden from a foodborne terror attack. This provides justification to strengthen support for increased terrorism surveillance and public health preparedness by both government agencies and the private sector.

The World Health Organization defined food terrorism as “an act or threat of deliberate contamination of food for human consumption with biological, chemical and physical agents or radionuclear materials for the purpose of causing injury or death to civilian populations and/or disrupting social, economic or political stability”(World Health Organization, 2008). Deliberate contamination of the food supply represents a serious potential threat to public health, although it has been rare to date, when compared to other forms of terrorism. A successful food terror attack could cause social disruption and diminish confidence in the food supply. DeWaal indicated that if terrorists were to attack the U.S. food supply, it would erode confidence in the government’s ability to safely monitor food, just as confidence in airport security fell after September 11, 2001 (DeWaal, 2007). The U.S. Food and Drug Administration (FDA) concluded that food terrorism is likely, and that a significant number of people would be affected by serious foodborne illnesses (U.S. Food and Drug Administration, 2004). Due to the centralized food and distribution methods over large areas, including food processing and the increase of food imports, there are major concerns about the vulnerability of the United States to attacks on the water and food supply (Karwa et al., 2005; Smith DeWaal, 2004). The U.S. food supply system has numerous vulnerability points through which a terrorist could introduce a contaminant into the food processing and distribution system infrastructure (Hope, 2004). Terrorists could potentially attack food supply sources (food processing and distribution facilities) by gaining access via forced entry, or utilizing an insider to compromise the food.

One form that food terrorism might take is the deliberate delivery of chemical, biological, radiological, or nuclear (CBRN) agents, which would inflict illness and death among humans and intimidate communities and governments (Das & Kataria, 2010). The most well-known case of food terrorism for political gain in the United States is the deliberate contamination of salad bars with salmonella by the Rajneeshee group in 1984, which resulted in approximately 750 illnesses and numerous hospitalizations (Torok et al., 1997). Furthermore, the U.S. Department of Homeland Security has reported terrorist threats to the food supply targeting hotels and restaurants to the FDA and the U.S. Department of Agriculture (USDA) (Keteyian, 2010*)*; after investigation, the FBI revealed information regarding threats that had been posted on Muslim-affiliated websites for several years (U. S. Department of Homeland Security, 2008).

Food contamination can be costly to both consumers and businesses throughout a multitude of industries that include pre-farm inputs, transportation, processing, farming practices and wholesale distribution. Costs to consumers range from the utilization of medical care to treat foodborne illnesses and productivity losses because of illness, and loss of life. A food terrorism event in the United States would threaten local and national economies, and might overwhelm public health services (Manning et al., 2005); however, any costs that are substantiated due to an event are just a tiny fraction of all costs that might be incurred due to the interrelationships experienced in the industry. Many parts of the food processing, wholesale distribution and retail businesses are intertwined with other industries, such as healthcare and state and federal regulatory bodies. To assess these potential costs, this study used the cost-of-illness (COI) methodology, which presents the economic burden of illness that reflects either the lifetime (incidence-based) cost of disease, or the costs incurred during a specified period (prevalence-based) (Haddix, Teutsch, & Corso, 2003b). The COI method typically considers both direct and indirect costs. Direct costs of an illness or disease include two separate categories, direct medical expenditures and direct non-medical expenditures required to treat the illness or injury (Rice & Hodgson, 1982). Indirect costs, as defined in the COI method, are typically associated with productivity losses attributable to the disease or injury (Segel, 2006). Following the human capital (HC) approach developed by Rice in 1967 (Rice, 1967), productivity loss due to an illness is approximated by valuing the entire period of absence from work by average individual earnings. Productivity loss associated with premature mortality is approximated by the present value of future earnings, from age of death to age of average life expectancy, sometimes adjusted for household productivity losses and consumption.

Another alternative to measuring loss of life in the COI methodology is through the contingent valuation (CV) methodology using the willingness to pay (WTP) approach (Go et al., 2014). A contingent, or hypothetical market, is required because valuing reductions in mortality risk is not a market-based good, and thus, survey respondents are asked to consider mortality risk reductions contingent on a hypothetical scenario. The WTP approach presumes that people are willing to pay a certain amount to reduce the probability of an event to avoid a certain illness, disease, or death. There is considerable evidence to show that COI estimates using the WTP approach provide much higher estimates of economic burden relative to COI estimates using the HC approach (Grosse & Krueger, 2011; Hirth, Chernew, Miller, Fendrick, & Weissert, 2000).

A number of studies have measured COI associated with foodborne pathogens, using approaches such as the HC approach for measuring productivity losses or WTP to prevent mortality risk reductions (Frenzen et al., 2005; Hoffmann et al., 2012; Mann et al., 1983; Minor et al., 2014; Scharff, 2012, 2015). Minor et al. (2014) placed the cost of foodborne illness from 31 pathogens, including several biotoxins, foodborne allergies, and unspecified agents, at an average of $36 billion (in 2013 dollars), with a range of $14.74 to $72.6 billion, based on the WTP approach. More recently, Scharff (2015) revised his estimate on foodborne losses due to 31 pathogens from approximately $51 billion (2010 dollars) to $55.5 billion (2013 dollars), using the HC approach. The USDA (Hoffmann et al., 2015) recently updated their economic burden of illness on 14 pathogens from $14 billion (2009 dollars) to $15.5 billion (2013 dollars) for 15 pathogens, using the HC approach for direct medical and productivity losses and the WTP approach for estimating mortality losses.

For bioterrorism attacks specifically, two studies have examined the economic burden using the COI methodology (Kaufmann et al., 1997; Lee et al., 2008). Kaufman et al. (1997) modeled the economic burden of illness from a hypothetical bioterror attack with inhaled agents (*Bacillus anthracis*, *Brucella melitensis,* and *Francisella tularensis*) using the HC approach to estimate productivity losses. Estimated costs ranged from $478 million to $26.2 billion in 1997 US$, per 100,000 persons exposed to brucellosis and anthrax, respectively. Lee et al. (2008) estimated the economic impact due to a bioterrorist attack on a sports stadium in an urban area at $57 billion (2003 dollars), positing 31,000 illnesses and more than 10,000 deaths, using input-output modeling. While these studies provided the field with an understanding of the economic scale and scope of potential bioterrorism events, neither focused explicitly on attacks on the vulnerable food supply chain in the United States. In this study, we will estimate for the first time the potential economic burden of illness associated with a terrorist attack on the food supply, including modeling various interventions aimed at prevention and response that can mitigate these costs.

Materials and Methods

This study is based, in part, on a 2009 multi-agency training operation (U. S. Department of Homeland Security, 2009), which was comprised of a Tabletop Exercise (TTX) and a Full-Scale Exercise (FSE). The exercise simulated the intentional contamination of chicken nuggets with lethal doses of methyl parathion (MP) at a food processing plant. The attack scenario involved chicken nuggets contaminated with methyl parathion being distributed throughout the southeastern United States, with live response that included the deployment of three Civil Support Teams (CST) and over 60 state, federal, and private agencies. The FSE utilized the morbidity and mortality outcomes data from the Risk Reduction Effectiveness and Capabilities Assessment Program (RRECAP[6]) (Hodoh, in review; Jaine, 2011) to quantify the effectiveness of current capabilities based on mitigating activities. RRECAP is a computerized simulation model that measures the effectiveness of responding to food system attacks, based on current levels of performance (prevention, protection, response, and recovery) in reducing morbidities and mortalities resulting from a food terrorist attack. The current study also utilizes morbidity, hospitalization, and mortality data from a previous article currently under review (Hodoh, in review).

In the scenario utilized in this study, several terrorists employed at a poultry facility in Jesup, Georgia, contaminated 20,000 lbs. of chicken nuggets processed at the plant. The product was packaged into 80,000 servings that were shipped from the

[6] Patent Pending

distribution center at a rate of 20,000 servings per day. The terrorists contaminated each serving of the product with enough methyl parathion to make 90% of consumers ill (Infectious $Dose_{90}$ (ID_{90})) and cause death in 50% of consumers (Lethal $Dose_{50}$ (LD_{50})). Methyl parathion is a highly-toxic organophosphate pesticide (OP) (U. S. Environmental Protection Agency, 2012; U.S. Department of Health and Human Services, 2001), classified as a restricted-use pesticide by the U.S. Environmental Protection Agency (EPA) due to its acute toxicity in humans. According to the World Health Organization, MP-related poisoning causes 220,000-250,000 fatalities per year, and OPs have been used as chemical warfare nerve agents (e.g. sarin, VX, tabun) (Balali-Mood & Abdollahi, 2014).

The first RRECAP simulation modeled the food attack incident as it would evolve with no intervention. The second simulation included a Stop Movement/Sale Action, which reduced morbidities and mortalities sharply. During this part of the exercise, clusters and patterns of illness immediately activated the District and State Public Health Departments into a response. Initial reporting of ill individuals triggered an immediate public health response and led public health officials to suspect criminal activity. The Georgia Department of Agriculture (GDA) moved quickly to determine the types, amount, and location of food items distributed by the implicated facility (prior to confirming whether an agent was present), and placed a hold on food (Stop Sale) remaining at the warehouse and a Stop Movement on food that was en route for delivery. The third simulation included a rapid confirmation of the contamination by the mobile labs of the CST, which enabled the execution of a public announcement by GDA. At the end of each simulation, RRECAP generated three important observations for use in the current study: (a) the number of victims that seek medical care after consuming the level of agent in a single serving of the product; (b) the number of patients that become ill and admitted to a hospital; and (c) the number of victims that died as a result of consuming the contaminated chicken nuggets. Table 1 presents the estimated population that consumed the MP-contaminated chicken nuggets, broken down by the various RRECAP modeling scenarios, and the estimated number of patients who sought medical care resulting in acute illness, hospitalizations, and deaths. The RRECAP model estimated the number of patients who experienced moderate or severe symptoms and sought medical care after consuming the contaminated chicken nuggets to be in the range of 5,216 to 53,962 (Table 1). The RRECAP model also provided estimates of the number of hospital admissions resulting from the foodborne attack, to be in the range of 5,216 to 19,424, based on the various scenarios listed in Table 1. The number of premature deaths estimated by the model ranged from 9,967 to 39,980.

A food terrorist event would create a class of worried-but-well individuals (ranging from 1,101,316 to 4,101,112), who would have an effect on healthcare utilization (DeBacker, 2003). These individuals would believe that they might become ill or die if they do not seek medical care because of the overwhelming reports in the media. During a food terrorism attack, the worried-but-well will seek medical treatment in their doctors' offices, emergency departments, and urgent care clinics, overwhelming the healthcare system without any medically-identifiable or emergent condition. For this study, it was conservatively assumed that for every one sick person that sought medical treatment, approximately 75 of the non-exposed population would feel that they are susceptible and seek treatment. This value is based on two factors: a study suggesting that worried-but-well patients would comprise at least 100 for each legitimate patient and could comprise 1,000 in the aftermath of a biologic attack (Bruemmer, 2003), and an estimate of the proportion of the U.S. population (between the ages of 2 and 150 years old) who actually consume chicken nuggets (U.S. Department of Health and Human Services, 2008).

Cost of illness estimation. The goal of this study was to estimate the COI resulting from each of the 3 scenarios resulting from a foodborne terrorist attack. Table 2 presents the parameters used in the COI calculations. The standard COI methodology, which is consistent with the U.S. Department of Agriculture, Economic Research Service (ERS) (Buzby & Roberts, 1996; U. S. Department of Agriculture, 2014) recommendation, is represented by:

$$\text{COI} = \sum (\text{Direct medical costs} + \text{Direct non-medical costs} + \text{Indirect Costs}).$$

Estimation of direct costs. Direct medical costs include: physician and hospital services, supplies, medications, and special procedures required for treating the foodborne attack patient. Direct non-medical costs include transportation to health care and residential care as a result of the foodborne attack (Buzby & Roberts, 2009). We adjusted all direct costs to 2013 U.S. dollars using the medical care component of the US Consumer Price Index (U.S. Department of Labor, 2014). The costs to consumers who experienced no health symptoms from the foodborne attack, and did not seek medical care, are set at zero.

The USDA ERS cost of foodborne illness calculator supplied the average unit costs for office-based physician ($136), outpatient visits ($659), and emergency department (ED) visits without hospitalization ($573) (U. S. Department of Agriculture, 2014). It was assumed that the ERS foodborne illness accurately estimated the average number of visits per case, including a follow-up visit with a physician for patients discharged from the hospital.

Patients enter the ED one of two ways, via either ambulance or self-transport/walk-in. Based on a report by the Centers for Disease Control and Prevention for ED visits for abdominal pain, it was assumed that 12.6% of patients affected by the foodborne attack arrived via ambulance (Bhuiya F, 2010). The median 2010 Medicare reimbursement for an ambulance run, obtained from a Government Accountability Office report as $469 (U.S. Government Accountability Office, 2012), was adjusted upward (U.S. Department of Labor, 2012).

We used mean hospital costs data ($8,362) taken directly from the 2012 Healthcare Cost and Utilization Project (HCUP) National Inpatient Sample (NIS) database for ICD-9-CM code 989.3, toxic effect of organophosphate and carbamate (U. S. Department of Health and Human Services, 2015b), as a proxy for foodborne-related associated illness. This ICD-9-CM code is the best approximation of the illness experienced by this type of foodborne attack illness scenario. HCUP estimated the average length of stay in the hospital for this type of diagnosis at 3.3 days. It was assumed that each patient was admitted only once for treatment of the ill effects of the foodborne attack. The analysis does not include estimates for long-term health care costs due to lack of sufficient data on methyl parathion poisoning.

Estimation of indirect costs. Following ERS, we used the human capital (HC) approach to estimate indirect costs pertaining to losses in productivity from lost employment by a sick individual or family member caring for the sick individual

(Hodgson & Meiners, 1982) and the willingness-to-pay (WTP) approach for estimating mortality losses.(premature death from consuming MP-contaminated chicken). For patients with an ED, physician, or outpatient visit, we estimated an absence of work of 1.67 days following the USDA ERS COI calculator estimates for salmonella (U. S. Department of Agriculture, 2014). For patients with an inpatient admission, we estimated work loss of 9.3 days. This reflects 3.3 days during the admission, based on the 2012 HCUP NIS data (U. S. Department of Health and Human Services, 2015b), and 6 days post-hospitalization recovery—assuming that for each day of hospitalization, a patient needs an equal amount of time to recover at home from the foodborne attack (Haddix et al., 2003a). The lost days of work were multiplied by the mean wage value of a lost day ($258), taken directly from the USDA ERS calculator (U. S. Department of Agriculture, 2014) and adjusted for the employment rate.

Due to data limitations, the RRECAP model does not provide the ages of the attack victims. Thus, this research cannot estimate premature death by the HC approach. Therefore, we used the WTP approach in the ERS calculator to estimate the value of death resulting from consuming MP-contaminated chicken nuggets. It is important to calculate a cost of illness through the lens of the Value of Statistical Life (VSL). VSL examines a specific amount that people are willing to pay in order to reduce mortality risks. In this instance, the COI calculator applied a VSL using the WTP approach of $8.7 million, based on EPA’s value of $7.4 million (in 2006 dollars) (U.S. Environmental Protection Agency, 2015). EPA’s National Center for Environmental Economics values all deaths at a constant VSL based on studies from a meta-analysis of twenty-six existing estimates (U.S. Environmental Protection Agency, 2010).

A one-way sensitivity analysis was performed on the lowest intervention/ lowest cost/ and highest intervention/ highest cost/ estimates by varying the value of one variable at a time while keeping the other variables constant. All cost parameters were increased and decreased by 20% of their original value due to the absence of specific data from published literature. The purpose of this analysis was to help identify variables having the greatest effect on direct and indirect costs as well as determining the extent to which these variations in these variables impact the total efficacy of the interventions. The sensitivity analysis was performed with MS Excel 2013.

Results

The cost of illness estimates resulting from a foodborne terrorism attack are based on three intervention scenarios: (a) No Intervention, (b) Stop Movement/Stop Sale Intervention, and (c) Stop Movement/Stop Sale and Public Announcement Intervention. For each intervention scenario, the RRECAP model recorded the number of victims affected by the attack at the end of each simulation (Table 1). The cost estimates are reported in 2013 dollars.

No intervention. In the absence of any interventions, the model suggests the total costs of illness resulting from the foodborne attack would be $349 billion dollars, including $346.1 billion for premature deaths, $2 billion for medical care, and $834 million for lost productivity (Table 4). Table 3 further breaks down direct and indirect costs, showing that outpatient clinic visits (40.6%) and physician office visits (39.2%) drive direct costs, followed by ED visits (11.9%) and hospitalizations (8.1%).

Stop movement/Stop sale intervention. This intervention reduced the total costs of illness resulting from the foodborne attack to $158 billion dollars, including $157.2

billion for premature deaths, $904 million for medical care, and $376 million for lost productivity. Table 3 further breaks down direct and indirect costs; the majority of direct medical costs on a percent basis were the same as the No Intervention scenario.

Stop movement/Stop sale and public announcement interventions. This intervention reduced the total costs of illness resulting from the foodborne attack to $87 billion dollars, including $86.3 billion for premature deaths, $538 million for medical care, and $223 million for lost productivity. Table 3 further breaks down direct and indirect costs; the majority of direct medical costs on a percent basis were the same as the No Intervention scenario.

One-way sensitivity analyses were then conducted in order to determine which variables have the greatest effect on direct and indirect costs, as well as the extent to which these variations in these variables impact the total efficacy of the interventions. First, with regard to the one-way sensitivity analysis conducted in relation to the minimum intervention/highest cost and the maximum intervention/highest cost (based on a 75% efficiency of the key capabilities), the new total expenditures were found to range from a minimum of $94 billion to a maximum of $418 billion. These minimum and maximum values were associated with 20% reductions and increases in premature death, indicating that variations relating to this factor had the largest impact upon the total cost of illness. Figures 8 and 9 illustrate the results of this analysis.

Following this, a second one-way sensitivity analysis was conducted in relation to the minimum intervention/lowest cost and the maximum intervention/highest cost (bases on a 25% efficiency of the key capabilities). In this analysis, new total expenditures were found to range from a minimum of $178 billion to a maximum of $349.4 billion. These minimum and maximum values were also associated with the variations relating to premature death, again indicating that variations relating to this factor had the largest impact upon the total cost of illness. Figure 10 and 11 illustrate the results of this analysis.

Discussion

The current study estimated the burden of illness resulting from a foodborne terror attack using the human capital approach for morbidity and the WTP approach for mortality. Current literature has presented a wide range of estimates for the costs of foodborne illness, ranging from $617 million to $1.4 trillion. This inconsistency across the cost-of-illness studies might be due to variation in the methods used in the calculation of costs, and the number of foodborne pathogens evaluated. Using the WTP approach, (T. Roberts, 2007) estimated the cost of illness for all foodborne disease at $1.4 trillion. Hoffman et al. (2012) estimated that 14 foodborne pathogens resulted in a total cost of illness at $14 billion (in 2009 dollars) using the ERS COI method.

The RRECAP simulation model showed that a foodborne terrorism attack could cause high rates of illness and death. In the absence of any intervention, the foodborne attack could cause $349 billion in cost of illness due to 72,000 illnesses and 39,000 deaths; the Stop Movement/Stop Sale Intervention could reduce the cost of illness to $158 billion, due to 34,000 illness and 17,000 deaths; finally, the combined intervention of Stop Movement/Stop Sale and Public Announcement could decrease the overall cost of illness to $87 billion, with 12,000 illnesses and 9,998 deaths. Compared to the $312.6 billion (in 2009) in annual cost for heart disease, $216.6 billion (in 2009) for cancer and

$188 billion (in 2009) for diabetes, a foodborne attack with a lethal agent is a potentially more costly illness (Book, 2012).

The speed of interventions is crucial to minimize the effects and economic burden of the illness. The large differences in morbidity and mortality for each intervention reflect the differences between direct medical costs and productivity losses. It should be noted that the total cost estimates were driven by the mortality costs. If interventions are initiated early, the Stop Movement/Stop Sale Intervention could reduce the economic burden for illness by 55%. As evaluated by the RRECAP model, the Public Announcement further reduced the burden of illness by an additional 45%.

Outpatient visits and physician office visits drove direct medical costs for the foodborne attack, with ED visits representing a sizeable percentage as well. Hospitalizations and ambulance transports comprised the smallest percentage of direct medical costs. Mortality caused the largest percentage of the indirect cost components for the foodborne terror attack, and the smallest percentage was due to missed workdays.

Stone reported that 99% of patients that received treatment during the 2001 anthrax letters attack were classified as “worried well” (Stone, 2007). The large number of worried well patients after a foodborne attack would further burden the healthcare system by seeking medical treatment. Most hospitals are not equipped with enough staff, beds, equipment, or supplies to handle a mass influx of patients from a terrorism event (Stone, 2007), in addition to caring for those injured by the attack and those who need routine or other non-terror attack-related medical emergencies. Furthermore, the worried well patients in the current study monopolize 99% of direct medical costs and productivity losses.

This study puts the cost of illness due to food terror attack at $349 billion when the No Intervention scenario is invoked and at $87 billion when interventions are combined to minimize public health impacts. Based on the data measured, lost lives impose the largest portion of the total economic impact. Results suggest that early intervention after an attack is essential to minimizing the cost of illness.

This study has some limitations. Computer simulation modeling was used in order to determine the number of illnesses and deaths from a foodborne attack, based on interventions by responding agencies, and then to determine the economic burden. The model does not generate ranges for morbidity, hospitalizations, and mortality estimates; it provides only point estimates. Other studies have had similar limitations. Kaufman et al. (1997) estimated the economic impact due to inhaled anthrax based on the human capital approach using modeling, as did Lee et al.’s (2008) estimate of the economic impact from a bioterrorism attack at a sports stadium, which used the human capital for morbidity and WTP approach for mortality losses. Moreover, Lee et al.'s estimates for outpatient visits and hospitalizations were based on arbitrary values, without measuring productivity losses due to short and long-term morbidity. Researchers analyzing healthcare issues have not used modeling to the extent that other fields have, which makes it difficult to compare the assumptions in the current study to previous efforts. Another major limitation of this study is that it does not include costs from the long-term health consequences associated with consuming MP-contaminated food, because reliable sources were not available in the literature. The HCUP data on which estimates were based also may not include all U.S. hospitals. In addition, HCUP does not include data on those who seek care outside of a hospital, and there may be differences in the coding used by hospitals for reporting the illnesses. Further, we had no way to include those who do not seek medical care, but who incur cost from over-the-counter medicine to treat GI distress. In addition, using the WTP approach the VSL varies among the federal agencies, ranging from the U.S. Department of Transportation's $6.2 million, FDA's $7.9 million, and the U.S. Occupational Safety and Health Administration's $8.7 million (President of the United States, 2013).

It is also important to note that, industry losses associated with production downtime and trade implication were not included in this estimate, and neither were federal, state, and local agencies costs in responding to the food terrorism event. This is not necessarily a limitation; however, should serve as a reminder when conducting future research.

Cost-of-illness studies are particularly useful for measuring the potential savings of averting a case of an illness. To this end, they can aid in cost-effectiveness analysis, benefit cost analysis, or illness prevention analysis by providing the baseline costs of maintaining the status quo. Moreover, the estimates from this study may be used in a benefit cost analyses to determine the feasibility of programs or interventions aimed at prevention and response.

Conclusion

The FY2016 budget submitted to Congress included a request by President Obama of $1.5 billion to support FDA's food safety through the Food Safety and Modernization Act, reflecting an increase of $109.5 million above FY2015 for implementation (U.S. Department of Health and Human Services, 2015b). However, the

U.S. House Appropriations Committee only approved an increase of $41.5 million; according to the Congressional Budget Office, the agency's ability to implement the food safety provision would have a funding gap of $166 million (U.S. Department of Health and Human Services, 2015b). At the same time, funding for Public Health Emergency Preparedness, administered by the Centers for Disease and Control (CDC), decreased from $9 billion in 2003 to $617 million in 2015 (U.S. Department of Health and Human Services, 2015a). Part of the funding shift can be attributed to new and emerging biologic threats—i.e., H1N1 in 2009 and Ebola in 2014—that have taken priority from the other public health preparedness funds for low probability/high risk events such as deliberate contamination of the food supply with CBRN agents. The field of disaster management is reactionary rather than proactive; therefore, new and emerging threats have shifted funding as well. The natural source of funding to prepare professionals in the field of emergency preparedness and response to bioterrorism would be federal grants. However, appropriations for public health emergency preparedness and response planning have been declining since 2002, forcing agencies into constant competition for the reduced funds. This creates a situation in which, in order to successfully compete for limited funding, evidence and performance-based public health preparedness exercises that demonstrate reductions in morbidity and mortality are more likely to receive these resources. Given this, studies like the current one are particularly urgent. Limited research has addressed the economic burden caused by food terrorism (Liu & Wein, 2008), or how public health agencies, first responders, and the private sector can minimize the outcomes of an attack by recognizing and responding to bioterror events in a timely manner.

The implications of this study will be useful to healthcare policy makers, who can use these findings to plan future resource allocation to efforts geared at reducing the effects of bioterrorism-related foodborne illnesses. Using the cost estimates derived from the interventions of this study, a benefit cost analysis approach could promote future disaster management planning that provides the maximum societal benefit for every public health preparedness dollar invested. This research could also be useful to state, local, and tribal agencies when applying for Public Health Disaster Preparedness grants because federal agencies may use cost of illness studies when making decisions on the allocation of research funding (U. S. Department of Health and Human Services, 2015a). Since one of the goals of disaster preparedness is to minimize economic disruption, the findings could prevent the worst-case scenario, in which the United States suffers $349 billion in losses, should have particular resonance.

Table 11. Estimated number of cases, foodborne attack, by scenario

Intervention Scenario	Worried Well[a]	Illnesses[b]	Physician, Outpatient, or Emergency Department visits; recovered[b]	Hospitalizations[b]	Post-hospitalization recovery[b]	Deaths[b]
No Intervention	4,047,150	71,995	4,101,112	19,424	19,424	39,980
Stop Movement/ Stop Sale	1,827,075	32,461	1,851,436	8,760	8,760	18,162
Stop Movement/ Stop Sale and Public Announcement	1,086,825	19,340	1,101,316	5,216	5,216	9,967

[a]The numbers of worried well patients are based on the assumption that for every sick patient there are 100 asymptomatic patients seeking medical treatment upon hearing of the foodborne terror attack.
[b]Data from RRECAP simulation run output.

Table 12. Parameter estimates for calculating cost of illness from foodborne terrorism

	Doctor visit; recovered	Hospitalized	Post-hospitalization recovery	Died
Direct Costs				
Physician office visits				
Average visit/case	1.4[a]	0.7[a]	1[a]	-
Average cost/visit	$137.85[a]	$137.85[a]	$137.85[a]	-
Outpatient clinic visit				
Average visit/case	0.3[a]	0.2[a]	-	-
Average cost/visit	$688.84[a]	$688.84[a]	-	-
Emergency Room Visits				
Average visit/case	0.1[a]	0.3[a]	0	-
Average cost/visit	$598.94[a]	$598.94[a]	$0	-
Ambulance runs				
No. of ambulance runs	0.1[a]	0.3[a]	-	-
Average cost/run	$488.63[b]	$488.63[b]	-	-
Inpatient admissions				
Average admission/case	-	1	-	-
Average cost/hospitalization	$0	$8,469[c]	$0	-
Average length of stay (days)	-	3.3[c]	-	-
Indirect Costs				
Proportion of cases employed	0.46[a]	0.43[a]	0.43[a]	0.43[a]
Average number of work days lost	1.67[a]	3.30[a]	6.00[a]	-
Average daily earnings	$258[a]	$260[a]	$267[a]	$267[a]
Premature death				
Low value per death	-	-	-	$1.5[d] million
Average value per death	-	-	-	$8.7[d] million
High value per death	-	-	-	$15.4[d] million

[a]USDA-ERS foodborne illness calculator
[b]US GAO, Ambulance Providers: Costs and Medicare Margins Varied Widely; Transports of Beneficiaries Have Increased
[c]HCUPnet Outcomes by ICD-9-CM Code 989.3 Toxic effect of organophosphate and carbamate.
[d]USEPA, National Center for Environmental Economics

Table 13. Direct and Indirect cost of illness from foodborne terrorism in 2013 dollars, (millions)

	Physician, Outpatient, or Emergency Department visit; recovered (percent of total)	Hospitalized (percent of total)	Post-hospitalization recovery	Total medical (costs total as percent of total across category)	Mortality
No Intervention					
Direct medical costs					
Physician office visits	781 (42.7%)	1.85 (1.1%)	2.64	785 (39.2%)	N/A
Emergency room visits	233 (12.8%)	3.3 (1.95%)	N/A	238 (11.9%)	N/A
Ambulance transport	3.3 (0.2%)	1.2 (0.7%)	N/A	4.5 (0.23%)	N/A
Outpatient clinic visits	810 (44.3%)	2.56 (1.5%)	N/A	813 (40.6%)	N/A
Hospitalizations	N/A	162 (94.8%)	N/A	162 (8.1%)	N/A
Total medical cost by outcome	1,829	171	2.64	2,003	N/A
Indirect costs					
Productivity loss, nonfatal cases	813.2	7.17	13.3	N/A	N/A
Premature death	N/A	N/A	N/A	N/A	348,959
Total cost of illness by outcome	2,643	178	16	N/A	348,959
Stop Movement/Stop Sale Intervention					
Direct medical costs					
Physician office visits	352 (42.7%)	0.833 (1.1%)	1.19	354 (39.2%)	N/A
Emergency room visits	106 (12.9%	1.51 (1.95%)	N/A	107.6 (11.9%)	N/A
Ambulance transport	1.5 (0.2%)	0.539 (0.7%)	N/A	2.04 (0.23%)	N/A
Outpatient clinic visits	366 (44.3%)	1.15 (1.49%)	N/A	367 (40.6%)	N/A
Hospitalizations	N/A	73.2 (94.8%)	N/A	73 (8.1%)	N/A
Total medical cost by outcome	826	77.3	1.19	$904.6	N/A
Indirect costs					

Productivity loss, nonfatal cases	367	3.23	6.04	N/A	N/A

Table 13, continued

Premature death	N/A	N/A	N/A	N/A	157,235
Total cost of illness by outcome	1,193	80.5	7.2		157,235
Stop Movement/Stop Sale & Public Announcement Intervention					
Direct medical costs					
Physician office visits	210 (42.7%)	0.496 (1.08%)	0.709	210.9 (39.2%)	N/A
Emergency room visits	63 (12.9%)	0.897 (1.95%)	N/A	64 (11.9%)	N/A
Ambulance transport	0.892 (0.18%)	0.321 (0.7%)	N/A	1.2 (0.23%)	N/A
Outpatient clinic visits	217 (44.3%)	0.687 (1.5%)	N/A	218.5 (40.6%)	N/A
Hospitalizations	N/A	43.6 (94.8%)	N/A	43.6 (8.1%)	N/A
Total medical cost by outcome	491.4	46	0.709	N/A	N/A
Indirect costs					
Productivity loss, nonfatal cases	218	1.92	3.6	N/A	N/A
Premature death	N/A	N/A	N/A	N/A	86,287
Total cost of illness by outcome	710	48	4.3		86,287

*Percentages may not add to 100 percent due to rounding

Table 14. Summary of total cost of illness from foodborne terrorism in 2013 dollars, in millions

	Medical costs (percent of total cost)	Productivity loss (percent of total costs)	Mortality (percent of total cost)	Total
No Intervention	$2,003 (0.57%)	$833 (0.24%)	$346,121 (99.19%)	$347,958 (100%)
Stop Movement/Stop Sale	$904 (0.57%)	$376 (0.24%)	$157,234 (99.2%)	$158,515 (100%)
Stop Movement/Stop Sale & Public Announcement	$538 (0.62%)	$223 (0.26%)	$86,287 (99.1%)	$87,049 (100%)

*Percentages may not add to 100 percent due to rounding.

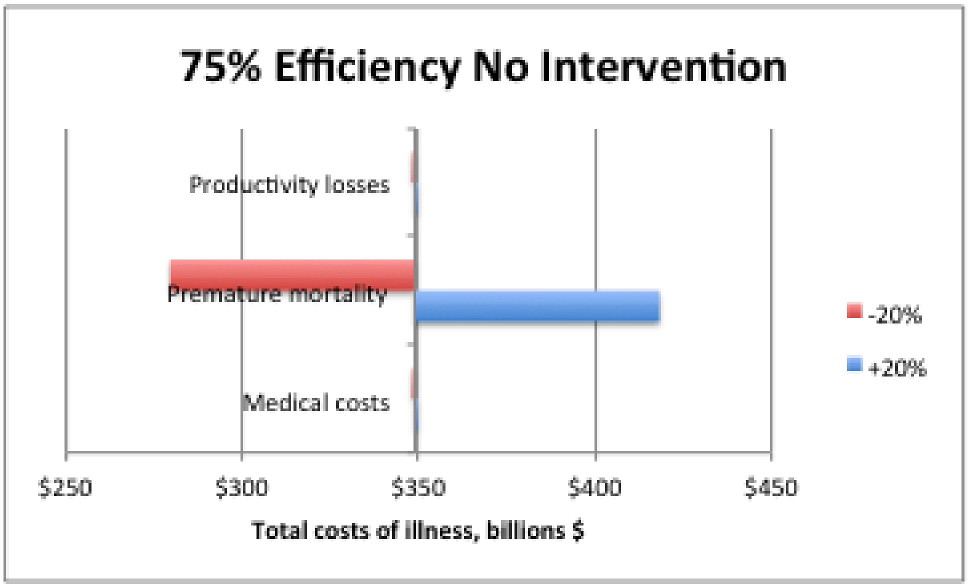

Figure 8. One-way sensitivity analysis of the minimum intervention/highest cost.

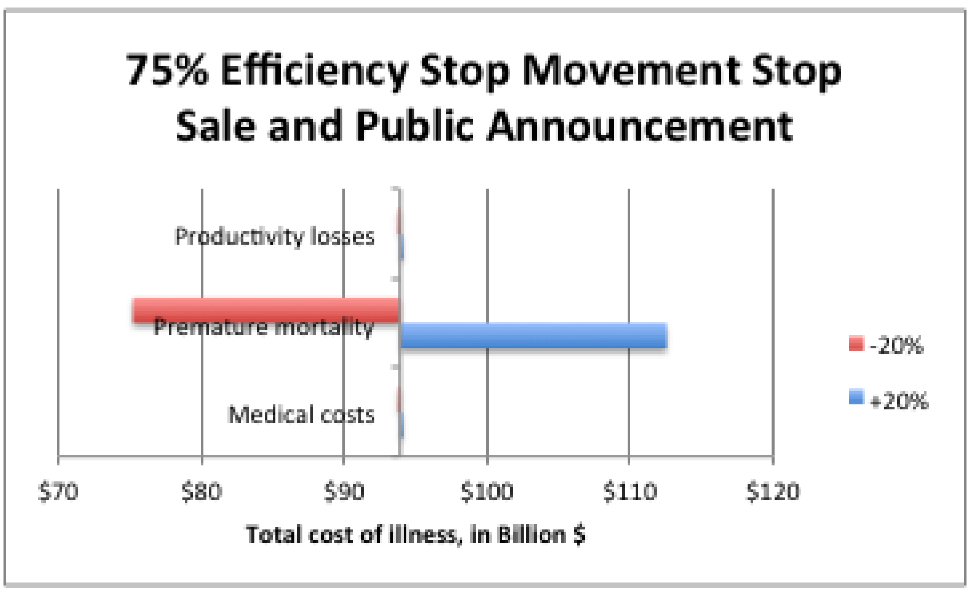

Figure 9. One-way sensitivity analysis of the maximum intervention/lowest cost.

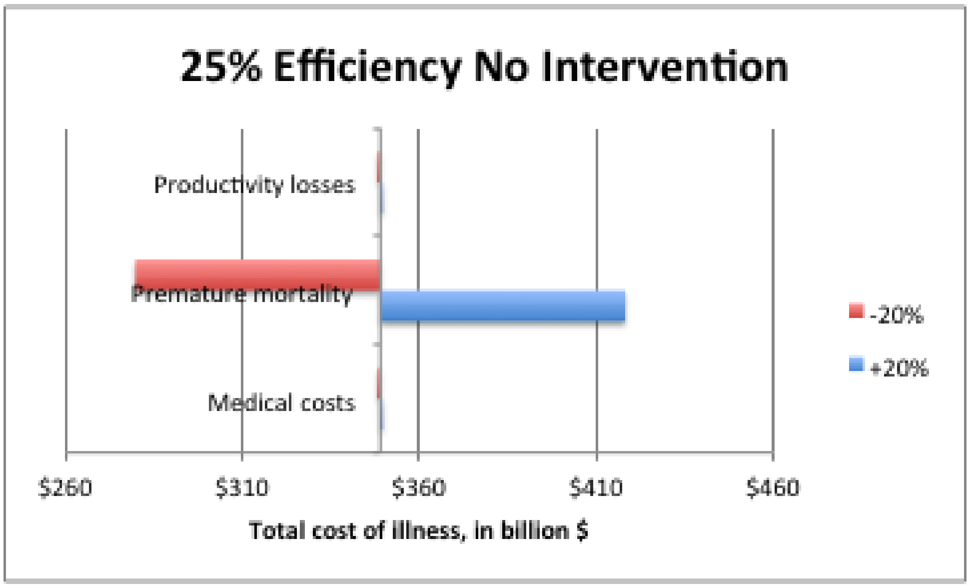

Figure 10. One-way sensitivity analysis of the minimum intervention/highest cost.

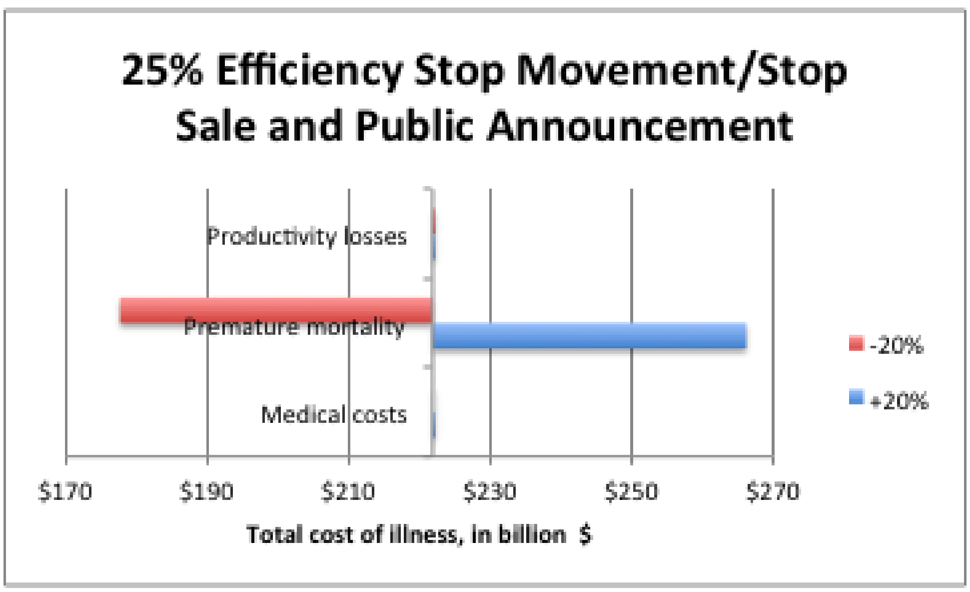

Figure 11. One-way sensitivity analysis of the maximum intervention/lowest cost

CHAPTER 5

SUMMARY and CONCLUSIONS

In the wake of raised awareness of threats to national security, federal food-safety regulatory agencies, mainly FDA and USDA recognize foodborne terrorism as a threat to social, economic and political stability. Incidents of chemical, biological and/or radiological/nuclear contamination of the food supply have caused various degrees of morbidity, mortality, and economic damage to date. A large-scale, deliberate attack on the food supply system such as the United States has never seen would have costs ranging from healthcare to treat food-related illnesses, productivity losses because of the illness, and mortality. This final chapter discusses and summarizes the results of this study, including its investigation of options to mitigate foodborne attacks. It also supplies limitations, public health implications, and recommendations for further research.

The conceptual framework for response used in this investigation is based on FEMA's National Response Framework, which guides how the nation conducts all-hazards response. The premise underlying this framework is that local authorities usually manage hazardous incidents and emergencies. Response to and recovery from an attack depends on local, well-trained professionals that have rehearsed through drills and exercises. The research therefore considered two Homeland Security Exercise Evaluation Program-compliant exercises built around benchmarks of possible outbreak related management activities, one discussion-based (Georgia 2007/2008 Tabletop Exercise) and the other operations-based (Georgia FoodEx 2009 Full-Scale Exercise.

The Public Health Preparedness Logic Model developed by M. A. Stoto et al. (2005) and M. Stoto (2013), which emphasizes capacity-building activities during a public health emergency, also provides background for this research, and the study includes a comparison between the results of their studies and the research findings.

Using these frameworks, the research employed an original computerized simulation model, the Risk Reduction Effectiveness and Capabilities Assessment Program (RRECAP[7]), to identify the key factors that influence the outcomes of an attack and quantify the relative reduction of such outcomes caused by each factor. This model was used in a set of exercises that simulate biological or chemical attacks on the food system to quantify the current capabilities to respond and recommend changes to preparedness training to optimize those capabilities.

To assess the burden of illness, this study used the human capital approach (HCA) to measure COI, developed by Rice in 1967 (Rice, 1967). In designing a framework, we had scant literature on which to draw. No existing cost of illness study for terrorism has focused on a foodborne terror attack. Kaufmann et al. (1997) modeled the economic burden of illness from a hypothetical bioterror attack with inhaled agents (*Bacillus anthracis*, *Brucella melitensis*, and *Francisella tularensis*). Estimated costs ranged from $478 million to $26.2 billion, per 100,000 persons exposed to brucellosis to anthrax, respectively, in 1997, using the human capital approach to account for cost of illness. Lee

[7] Patent pending

et al. (2008) estimated the economic impact due to a bioterrorist attack on a sports stadium in an urban area at $57 billion (2003 dollars), positing 31,000 illnesses and more than 10,000 deaths.

Review of the Research Objectives

Research Objective 1*: Quantify public health consequences (i.e. morbidity and mortality)*

resulting from a food terrorism incident and a lack of bioterrorism response by emergency managers in the public and private sectors using the RRECAP model. The primary attack scenario involved the distribution of a food product contaminated with a highly concentrated lethal pesticide throughout the southeastern United States, with live response consisting of deployment of three Civil Support Teams (CST's) and more than 60 agencies. We used RRECAP to measure the effectiveness of current capabilities, and showed that with no intervention, the attack would cause more than 70,000 illnesses and 40,000 mortalities spread across three southeastern states. The exercises simulated a severe but plausible attack on the food supply, and showed that: a) such an attack, if not recognized and mitigated rapidly, would overwhelm the medical resources available to patients; b) proper advance preparation would reduce these deficiencies adequately to handle all affected patients; and c) computer models provide an inexpensive and effective way for agencies to identify and prioritize their advance preparation to mitigate such attacks effectively. The operational effectiveness of public and private sectors to prevent and respond to attacks can be significantly improved by using computer simulation models to identify optimal remediation activities and quantifying the benefits that can be achieved through such activities.

The results of the RRECAP model agree with the findings of M. A. Stoto et al. (2005) and M. Stoto (2013). First, capacity-building activities (i.e., After Action Report and evaluation, development of partnerships with healthcare organizations and law enforcement, economic measures) and the functional capabilities (i.e., surveillance, epidemiological investigation, coordination and communication with first responders) support the objectives of early detection, early and effective response, and early recovery and return to normal function. Second, these objectives, in turn support the broad goal of mitigating mortality, morbidity, and economic consequences of a terrorist attack or other public health emergency.

Research Objective 2: *Determine the economic impact of a food attack, specifically, indirect costs including cost of medical care for worried well, government costs, and downtime costs.* At the present time, the economic impact model analysis of RRECAP is incomplete. In order to avoid delays with this dissertation, we deviated from the research prospectus and performed an economic burden of illness estimation from the foodborne terror attack.

Estimates of the cost of illness from victims consuming methyl parathion-contaminated chicken nuggets used the morbidity, hospitalization, and mortality data from the RRECAP model. As a result, the perspective of this cost of illness analysis represents cost incurred during a specified period (prevalence-based). The key finding from this study showed that, based on the various intervention scenarios it examined, the cost of illness due to foodborne terror attack ranged from $87 billion to $349 billion, depending on whether multiple interventions, a single intervention, or no intervention mitigates the cost. Mortality costs drive the total cost estimates. Direct medical cost estimates of the attack ranged from $538 million to $2 billion, from outpatient and physician office visits and indirect costs resulting from lost workdays, and premature mortality costs ranged from $86.2 billion to $346 billion. The analysis included the economic burden from the worried-but-well individuals who would have an effect on healthcare utilization during a foodborne terror attack, the first such analysis to do so. Cost of illness studies of foodborne pathogens (none of which address a terrorist event) has not encompassed these costs (Hoffmann et al., 2015; Minor et al., 2014; Scharff, 2015) (Batz et al., 2012; Buzby & Roberts, 2009; Buzby et al., 1996; Frenzen et al., 2005; Hoffmann et al., 2012; Scharff, 2012, 2015). This group drove 99% of direct health care cost by seeking treatment without any medically-identifiable or emergent health condition.

The cost of illness presented here is the first one ever conducted using the Healthcare Cost and Utilization Project National Inpatient Sample database for ICD-9-CM code 989.3, toxic effect of organophosphate and carbamate, as a proxy for a foodborne-related associated illness. The study utilized a comprehensive methodology and the USDA's ERS cost of illness calculator to estimate the cost of illness from a foodborne terror attack based on direct medical costs and indirect costs. Direct medical costs included office-based visits, urgent-care visits, emergency room visits, and in-patient hospitalizations. Indirect costs for morbidity and mortality include bed days and productivity losses (missed work days). These components of cost of illness for foodborne terror attack encompass all such costs prior research has identified, except for intangible costs.

The high estimate of $349 billion far exceeds the annual cost of heart disease ($312.6 billion), cancer ($216.6 billion) and diabetes ($188 billion) (Gaskin & Richard, 2012). The methodology utilized and described in this study are reproducible, reliable, and comprehensive. As with this study, future cost of illness studies should continue to follow the methodology outlined by Dr. Dorothy Rice (1967).

***Research Objective 3**: Identify recommendations for helping organizations determine which Key Performance Capabilities are most influential in minimizing outcomes of attacks.* RRECAP was designed to identify the set of capabilities required for effective response to any attack, to assess the level to which responders would be able to address the attack, to identify how to change the training of responders to improve their effectiveness, and to identify the set of capabilities effective response would require. The combined effects of the high levels of performance of key capabilities combined with the swiftness of high level officials making key decisions was shown by RRECAP to reduce morbidities by 30%. The Stop Movement/Stop Sale action reduced the number of morbidities and mortalities in half and the additional effect of the Public Announcement further reduced these by an additional 45%, as evaluated by the RRECAP tool. Additionally, RRECAP yielded a plan for improvement by identifying a set of capabilities that, if improved by a specified and achievable amount (50 percent), could reduce consequences from baseline by approximately 73%. RRECAP also showed that existing capabilities reduced the total number of cities that would have been involved in the incident from 73 to 36, reducing the urban human health impact to a range much more manageable with immediately available healthcare resources, which are located in these metropolitan settings.

The second major finding was that a catastrophic event is clearly possible. Hence, responding agencies should immediately take steps to ensure that they are prepared to identify and address a foodborne terrorist attack. Given current resources, hospitals would likely need to identify and exercise non-hospital and non-doctor resources that could handle overload. Advance preparation can and will improve the quality of response, might obviate the need for such overload, as well.

Unfortunately, agencies and healthcare organizations that would be responsible for responding to a foodborne terrorist attack may have severe weaknesses in their understanding of the factors that would determine their successful response. They do not have the time, money, or resources to plan and prepare for every possible attack using current techniques. By employing a computer simulation model, this study has provided an inexpensive and effective way to identify and quantify the probable outcomes of attacks on various targets, how the responding agencies should prepare to mitigate such attacks, and how to prioritize the preparation activities. The findings of this study highlight the need to encourage and fund public health agencies, first responders and healthcare organizations to develop and implement plans to prepare for a foodborne attack, and RRECAP provides a tool by which such entities might exercise thousands of different incident profiles at very little cost.

Training programs, tabletop, and field exercises should be conducted on a regular basis so that the personnel become familiar with the procedures (Sincavage, 2003). More importantly, the problems in training programs and exercises can be identified and resolved prior to a bioterrorism attack, which allows little room for error (Sincavage, 2003).

The implications of this study will be useful to healthcare policy makers, who can use these findings to plan future resource allocation to efforts geared at reducing the effects of bioterrorism-related foodborne illnesses. This research could also be useful to state, local, and tribal agencies when applying for Public Health Disaster Preparedness grants because federal agencies may use cost of illness studies when making decisions on the allocation of research funding (U. S. Department of Health and Human Services, 2015a). Since one of the goals of disaster preparedness is to minimize economic disruption, the findings could prevent the worst-case scenario, in which the United States suffers $349 billion in losses, should have particular resonance.

Limitations

This study is limited in a number of respects. The capability benchmarks generated by RRECAP depend on implementation of a specific scenario and set of accompanying assumptions. Of course, in real-life other factors outside the control of responding agencies can play a significant mitigating or exacerbating role. Outbreaks may continue for longer than expected if personnel do not recognize them from the start, and an incidental reason may trigger early detection. The results generated by RRECAP cannot be extrapolated to make specific projections of the consequences of different scenarios, or to real-life scenarios, and may only be used for relative comparisons.

Neither RRECAP nor any other currently known process can predict with certainty the actual outcomes of various scenarios. Factors such as the extent and effectiveness of the responses, the precise effects of having specific levels of capability, or the exact success of interventions do not implicitly create uncertainty in RRECAP. The model can only determine the relative changes in outcome caused by differing values of various target capabilities. If the scenario values are maintained consistently across different exercises, the relative comparisons of results of those exercises are preserved, regardless of the absolute values, but the results cannot be extrapolated to make specific projections of the consequences of different scenarios, or to real-life scenarios, and may only be used for relative comparisons. The fact that few researchers analyzing healthcare issues have used computer modeling as this project does presents another limitation, in that it is difficult to compare the assumptions in the current study to previous efforts.

A number of limitations suggest that the results of the current study may be underestimated. First, being limited to point estimates for morbidity, hospitalizations, and mortality estimates, this study lacks low and high estimates for determining economic burden of illness. It also does not include costs from the long-term health consequences associated with consuming MP-contaminated food, because the literature lacks reliable sources. Further, the use of HCUP data for inpatient hospitalization costs presented a couple of limitations. First, it was not possible to include data on those who seek care outside of a hospital or who use over-the-counter medicine to treat GI distress but do not seek medical care. Second, there may be differences in the coding hospitals use for reporting the illnesses. The study also did not address industry losses associated with production downtime and trade implication or costs for federal, state, and local agencies in responding to the food terrorism event.

Finally, time constraints in producing this dissertation prevented further, in-depth analysis on the economic impact to the poultry industry in Georgia due to the food terror attack with MP-contaminated chicken nuggets.

Future Work

The United States has a vested interest in evaluating the preparedness and effectiveness of a multi-agency response to food terrorism attack and identifying indicators that should be used to measure that effectiveness. Future research might employ computer simulation modeling as this dissertation does, as the method is reliable, inexpensive, and effective. Future research might apply RRECAP to any number of tests and scenarios, including foodborne pathogens not related to terrorism and other types of bioterrorist attacks. The work involved in this dissertation generated volumes of data that future research will use to make further explorations of the question of economic impact resulting from a bioterror event.

Issues future work might address include the following:

- An attack might involve multiple CBRN agents released simultaneously. How does RRECAP perform in analyzing such an event? Different agents would require different procedures, including contact precautions, isolation, and decontamination of patients. Healthcare providers may need to adapt to different scenarios at the same time. Different response plans based on the nature of the attack may be necessary to mitigate this additional strain on resources.
- RRECAP provided patient data on three scenarios—Emergency Department visits, in-patient hospitalizations, and mortality. Future research might include further breakdown of patient data by severity of illness, describing the disease progression resulting in recovery, death or long-term sequelae. For example, the number of victims who get no medical care and die or the number of patients who die in spite of hospitalization.

- The economic impact the study addressed was limited to the cost of illness. Future research might address direct farm costs, company/processor costs, distribution chain costs, international trade costs, and other areas.
- Further research could usefully explore standard templates and scenarios to apply RRECAP to a selected range of high priority commodity areas.
- Future research could explore, through subject matter experts, the key capabilities that optimal response to bioterrorist attacks and the level of granularity of performance of each capability.
- Modifying RRECAP to convert the acquired exercise data into a prioritized set of recommendations for capability remediation, and a corresponding Exercise after Action Report also poses an area for future research.

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