Selman C.A., and Guzewich J.J. (2014) Public Health Measures: Environmental Assessment in Outbreak Investigations. In: Motarjemi Y. (ed.) Encyclopedia of Food Safety, Volume 4, pp. 98--106. Waltham, MA: Academic Press.

Public Health Measures: Environmental Assessment in Outbreak Investigations

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Glossary

Contributing factors: These are determinants that directly or indirectly cause an outbreak. A contributing factor can be biological, behavioral, or attitudinal; or an element of the physical or social environment; or the result of policies related to the problem. Examples include retort, pasteurization, or cooking temperatures that do not destroy or reduce pathogens, poor personal hygiene of food workers, or cross-contamination. Contributing factors are what happened to cause a foodborne outbreak.

Critical control point (CCP): A step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level.

Critical limit (CL): A criterion that separates acceptability from unacceptability.

Environmental antecedents: These are supporting factors for the contamination, survival, or increase of biological or chemical agents in food. They may be related to people, equipment, food process, food type, economics, or other circumstances. In other words, antecedents are the reason why the contributing factors occur. Antecedents are sometimes referred to as root causes of foodborne outbreaks.

Environmental investigation: It is a generic term used to refer to all aspects of the environmental component of a foodborne illness outbreak (FBIO) response. It encompasses the environmental assessment and/or traceback activities.

Foodborne illness outbreak (FBIO) environmental assessment (EA): The systems-based component of an FBIO response that fully describes how the environment contributed to the introduction and/or transmission of agents that cause illness or could cause illness. Environment is everything external to the host, including air, food, water, animals, plants, climate, etc., as well as people and the social and built environments. All aspects of the external environment can be listed as variables that, in relation to transmission, are neutral, conducive, or protective. From this description, contributing factors and environmental antecedents to an outbreak can be determined.

Hazard analysis critical control point (HACCP) plan: A document prepared in accordance with the principles of HACCP to ensure control of hazards that are significant for food safety in the segment of the food chain under consideration.

Traceback investigation: An investigation activity that is conducted to support the epidemiological investigation in determining the likely food vehicle and/or the location of the food contamination, such as the point of final service, production, food source, etc.

Introduction

For decades, public health and food regulatory agencies have been investigating foodborne illness outbreaks (FBIOs) to identify and understand their etiology. There are three critical components of an outbreak investigation: epidemiological, laboratory, and environmental. The epidemiological and laboratory investigations have typically focused on identifying the pattern of illness, the pathogen, and the food associated with the outbreak. There are accepted epidemiological and laboratory procedures and methods for conducting these components of FBIO investigations. Some organizations have compiled and published the findings from these investigations. Data from these reports are sometimes used to measure the burden of foodborne disease within a population, to characterize the agents involved, and to suggest food safety priorities. The epidemiological and laboratory components of a foodborne outbreak investigation are discussed in more detail elsewhere within this encyclopedia.

Investigations of FBIOs are historically conducted by local and state/provincial public health agencies. FBIO response requires a multidisciplinary approach involving laboratorians, epidemiologists/communicable disease control authorities, and environmental health/food regulatory personnel. This multidisciplinary team's focus is to:

- stop an outbreak quickly if it is ongoing;
- understand what happened to cause the outbreak (i.e., contributing factors);
- implement immediate measures to prevent the ongoing contamination of food;
- understand why the outbreak occurred (i.e., environmental antecedents);
- implement long-term measures to prevent future outbreaks in the establishment; and
- use the information from the outbreak investigation to inform public policy on preventing future outbreaks.

The team may include – in addition to epidemiologists, clinical and environmental laboratorians, and environmental public health professionals – microbiologists, food technologists, engineers, hydrologists, geologists, veterinarians, and others, as outbreak circumstances warrant.

Detection of FBIOs is accomplished through laboratory-based surveillance for reportable diseases and through consumer complaint follow-ups. In the USA, more FBIOs are identified through consumer complaints than through laboratory surveillance. In either instance, once an outbreak has been detected, epidemiological investigations with laboratory support are conducted to verify that an outbreak has occurred and to determine the outbreak agent and vehicle. Other investigation activities, such as environmental or traceback investigations or other environmental activities, may follow.

Environmental assessments (root cause analysis) determine the contributing factors and environmental antecedents that led to the outbreak and/or to support the epidemiological investigation as needed. Traceback investigations support the epidemiological investigation when the source of contamination, such as the point of final service, production, etc., has not been determined or when there is a need to assist epidemiologists in determining the likely vehicle. Traceback investigations may follow the vehicle back through the farm-to-fork continuum to determine the source of contamination; when the food vehicle has not been identified; such investigations involve detailed food ingredient menu item reviews at the point of final service.

Other activities, such as regulatory/enforcement actions, can involve recalls, public alerts, and legal actions when indicated. Prevention/research activities may be initiated on the basis of investigation findings to permit a further understanding of the agent, the mode of transmission, and contributing factors, as well as to permit identification of ways to prevent similar outbreaks from occurring in the future. Research addressing data gaps may also be conducted by industry, academia, and government agencies.

FBIO Environmental Investigations

The processes and or methods of all aspects of a foodborne outbreak investigation have evolved over decades. A routine inspection using the current regulations as a guide provided the first approach to FBIO environmental investigations. This often produced a list of violations of the regulations, but often missed the true causes. During the late 1970s and early 1980s, published articles by Dr. Frank Bryan and others called for a focus on the factors that caused outbreaks rather than regulation violations during FBIO environmental investigations. In more recent years, hazard analysis critical control point (HACCP) principles, such as identifying hazards, critical limits (CLs), and critical control points (CCPs), are employed in FBIO environmental investigations. The addition of systems theory as an additional tool to understand why outbreaks occur represents the latest step in the evolution of the FBIO environmental investigation process.

Unfortunately, the FBIO environmental investigation is carried out less frequently and with less insight than other activities during an outbreak investigation. In many instances, these investigations are conducted by food safety regulatory agencies that often conduct regulatory inspections in response to outbreaks, rather than making epidemiologically, laboratory data-driven/systems-based environmental assessments to identify both contributing factors and environmental antecedents.

The findings from FBIO environmental investigations are also less frequently compiled and shared. As a result, there is often a lack of data from the environmental component of an investigation. In addition, there are doubts regarding the quality of the data that are reported, as those data relate to actual contributing factors. An example of such findings is the suggestion that improper food holding temperatures are a possible contributing factor for norovirus illness outbreaks. This is an unlikely relationship for an agent that does not reproduce outside a host cell. Improper food holding temperatures are a common violation in food inspection work; yet, such food holding temperatures are not an appropriate contributing factor to report in a viral FBIO.

To identify and understand the environmental causes of FBIOs, an investigator must conduct a systems-based environmental assessment, informed by available epidemiological and laboratory data, seeking to identify both contributing factors and their environmental antecedents. The FBIO environmental assessments will be covered in the remainder of this article. Developing an understanding of FBIO environmental assessments requires a basic understanding of a few general systems theory concepts, and an understanding of the food chain and its corresponding systems.

General Systems Theory

Systems theory is not new. It was first proposed in the 1940s by biologist Ludwig von Bertalanffy. He is recognized as one of the founders of general systems theory. His theory has been applied to a number of fields and served as the source of inspiration for those working to understand and influence complex systems.

Some of the basic concepts Bertalanffy proposed are especially helpful in framing the complexity of food facilities in such a way that food safety managers and foodborne outbreak investigators can become more effective in managing risk and understanding why outbreak events unfold, thus providing a basis for improved risk management. Those concepts include:

- understanding that the deep underlying interactions of all forces that make up a system is key to influencing or changing that system;
- all systems have 'set points' or set outcomes that are predetermined by the nature of these underlying interactions;
- changes to complex systems require a great deal of information about the nature of these underlying interactions; and
- unless this deeper understanding is achieved, efforts to change the system will ultimately fail and the system will return to its 'set point.'

Whether a facility food safety manager, regulatory inspector, or outbreak investigator, all have experienced either the cycle of making a food safety correction, only to see it occur repeatedly or having the same food facility involved in more than one or two foodborne outbreak investigations. Using Bertalanffy's concepts can help move foodborne outbreak investigation and food safety programs away from these cycles that do not support food safety.

Farm-to-Fork Continuum and Food Systems

The FBIO environmental assessment occurs within the context of the farm-to-fork continuum, sometimes referred to as the food chain. The farm-to-fork continuum represents how food flows from its source through processing or manufacturing, distribution, and finally to the point of final service, which may be a retail establishment such as a restaurant or a consumer's home. The source is where the food originates. It may include a farm where produce is grown or a sea where fish are harvested. Processing or manufacturing includes all the steps along the continuum that prepare the food for distribution. This point in the continuum may be as simple as washing whole produce or as complex as pasteurization or low-acid canning. Distribution includes everything from storage and warehousing to repacking, reprocessing, and transporting to the next point in the continuum. Sometimes distribution involves multiple points along the farm-to-fork continuum. Finally, the concept of point of final service includes any points where foods are purchased and/or consumed, such as grocery stores, restaurants, and delis, or the home.

Each point in the farm-to-fork continuum represents its own unique system (Figure 1). Although the systems themselves are unique, they all consist of the same components:

- Inputs – items that enter the system.
- Processes, steps, and methods to which the inputs are subjected.
- Internal system variables – factors that exert positive, negative, and neutral effects on all other aspects of the system.
- Outputs – immediate results of the system.
- Outcomes – what happens as a result of the outputs.
- Feedback to that particular system on the basis of the outcomes (Figure 2).

Food Systems

Inputs and Processes

At the source, inputs might include the weather, soil conditions, and the hydrology of the watershed as it relates to irrigation source water, type or breed of animal, organisms, and/or chemicals inherent to the product or from the environment.

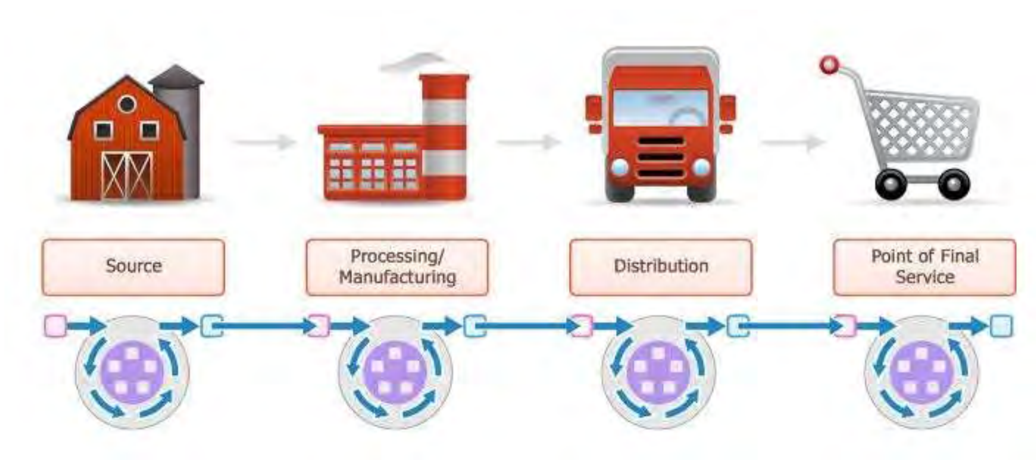

Figure 1. Farm-to-fork continuum

Inputs at subsequent points along the farm-to-fork continuum will include much more than circumstances directly related to food safety such as ingredients for the final product that include organisms or chemicals that may or may not be harmful if consumed. They could include infusions of financial and human capital or other elements that are less obvious, such as management structures that do not support a food safety culture within the establishment.

The flow of food through such processes as storing, cooking, etc. to which inputs are subjected at different points along the farm-to-fork continuum provides a road map for the environmental assessment at that particular point in the continuum. It is essential to describe the related processes step by step, from receipt of ingredients through disposition of the final product or output, whether that is shipping the product to the next stop on the farm-to-fork continuum or to final service or consumption. There may be a few processes involved or many, depending on the complexity of the food product. Using the establishment's HACCP plan, if there is one, also helps identify potential or real hazards, CCPs, and CLs along the way. Mapping the flow of food through processes is necessary for identification of contributing factors (Figure 3).

This basic mapping of the flow of food through the establishment's food processes is the total extent of many foodborne outbreak environmental assessments. However, to understand the environmental antecedents, the internal system variables must be examined.

Internal System Variables

Understanding internal system variables and especially their interactions with each other is important to understand how the system operates and why it operates the way it does. Knowledge of these variables and their interactions can also lead to an informed analysis of the degree of control exerted over critical food safety hazards. It can also explain how, in various circumstances, that degree of control may change. Although no system is completely safe or unsafe, properly managing internal system variables helps to influence the system's outcome toward a safe product.

Internal system variables include:

- People
- Equipment
- Processes
- Foods
- Economics (Figure 2).

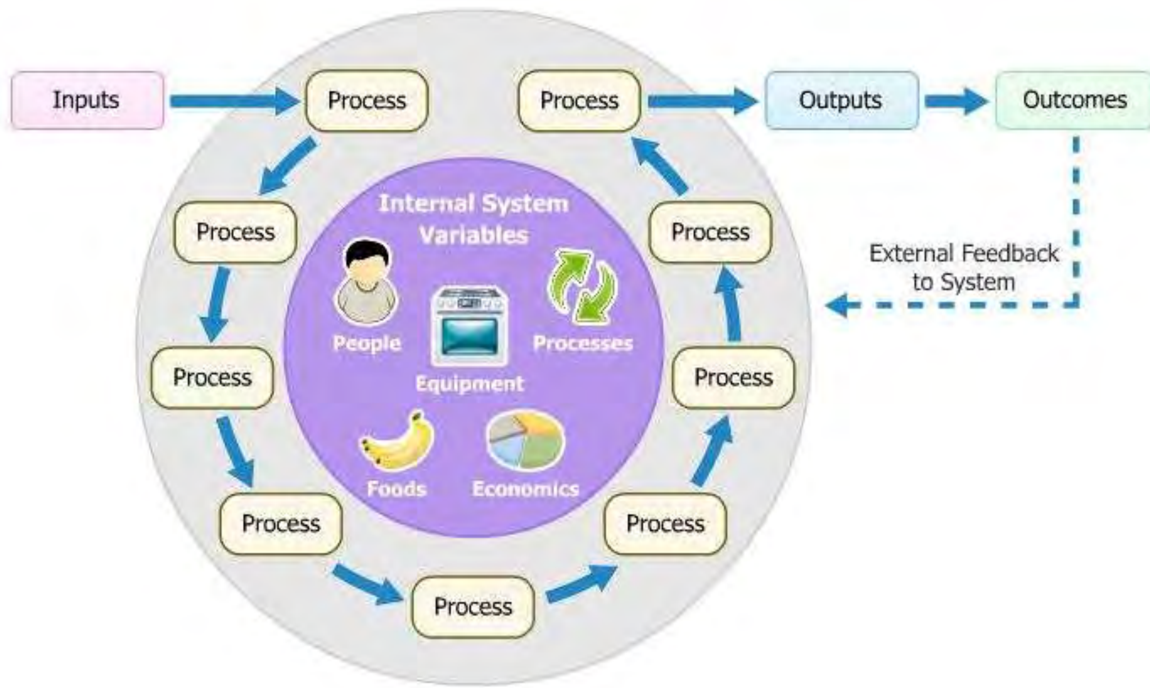

Figure 2. System Components

These are variables currently recognized as having the greatest influence on food safety. Understanding these variables and their influences helps in determining why the outbreaks occurred. The internal system variables and their potential influences on food safety are complex; on any given day, they may have a positive, negative, or neutral influence on food safety within a particular system in the farm-to-fork continuum. The environmental assessment team must determine the role of these variables during its investigation.

The people, as an internal variable, exert the greatest influence on all aspects of the system at any point in the farm-to-fork continuum, from inputs through outcomes. This internal system variable refers to the individuals working at any point in the continuum and the food safety culture within which they work. The food safety culture at any point in the farm-to-fork continuum is reflected by such things as the owner's/manager's/ supervisor's knowledge and commitment to food safety, the existing written standard operating procedures, HACCP plans that include monitoring, the recordkeeping and corrective actions, the supervision of employees, etc. The people variable also refers to how an individual is inclined to behave and how an individual interprets standard operating procedures. For example, some food workers are not inclined to view diarrhea as an illness, and therefore they do not report it to management.

The internal system variable equipment refers to the physical layout of the facility and the equipment appropriate to that point in the farm-to-fork continuum. To support safe food practices, the equipment must be properly designed and constructed for its intended purpose. It must be properly located, not only for its proper operation but also for its facilitation of the most efficient work flow for the processes involved. Proper installation also requires adequate space in the facility to accommodate both the equipment and the work flow in the facility. In

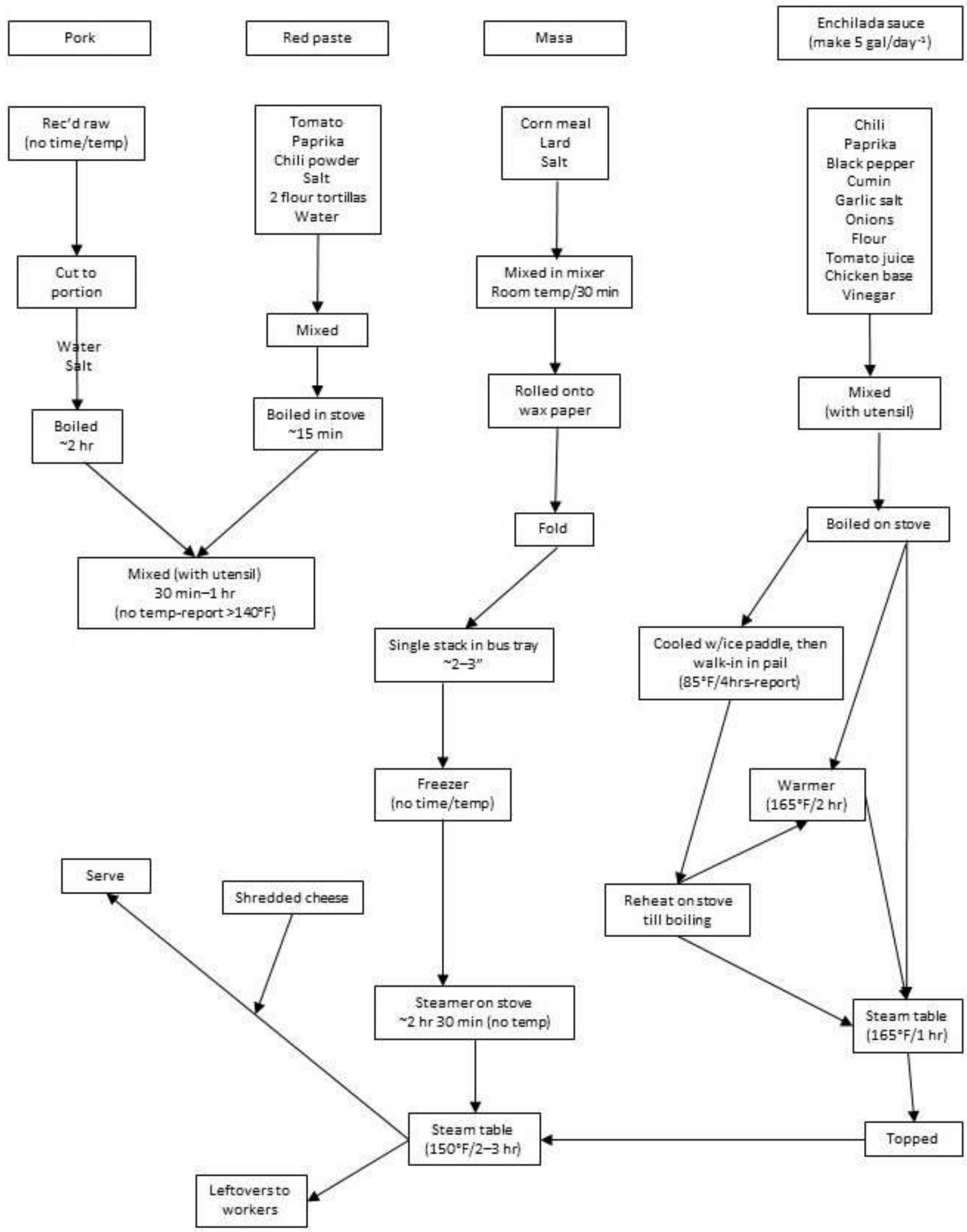

Figure 3. **Food flow**

addition, equipment that is not properly maintained can potentially exert a negative influence on food practices and CLs. Finally, poorly located or maintained equipment may also influence workers to develop procedures independently to work around the problems caused, thus negatively influencing CLs (Figure 4).

The internal system variable processes refer to the inherent qualities of processes but not to such actual food processing steps as cooking, holding, storing, etc., as depicted in the flow of food at any point along the farm-to-fork continuum. Although a process may be capable of delivering a safe end result, the inherent nature of the process may pose circumstances that

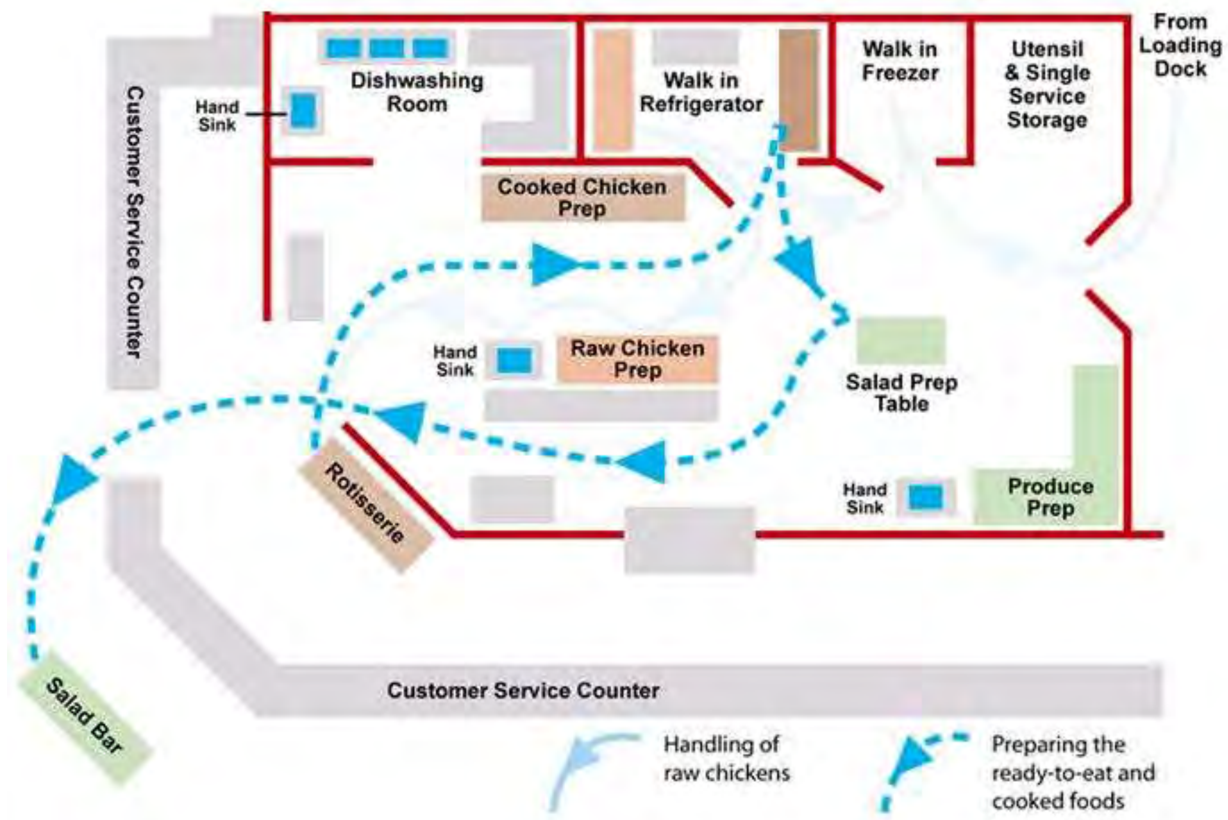

Figure 4. Physical Facility Layout

negatively influence the safety of the system. An example is the complexity of the process. A process that is highly complex may pose many risks for contamination or for survival or proliferation of the agents that cause foodborne illness. Industry efforts to reduce the complexity of processes can be found at many points along the farm-to-fork continuum. For example, a manufacturer or restaurant manager may remove steps from a complex process to make it as simple as possible. By changing the inherent nature of the process from complex to simple, a manufacturer or restaurant manager reduces opportunities for contamination or for survival or proliferation of agents. However, complexity of a process is more obvious than other examples, such as the influence of traditions in food processing or when pathogens change rendering the inherent properties of a process from safe to unsafe. A good example is the ability of *Salmonella* to develop a protective barrier that renders low water activity of a process to be ineffective in reducing pathogens.

The internal system variable food refers to the inherent qualities of food that may positively or negatively influence food safety. These qualities include pH, water activity, texture, and viscosity. For example, the texture of leafy greens renders them difficult to clean; the thickness of such a food as refried beans may require specialized cooling practices.

The internal system variable economics refers to issues affecting the costs and profit margins at any point along the farm-to-fork continuum. For example, a restaurant may be required to change its menus to accommodate changes in food trends, and doing so can potentially affect costs and profit margins. Adequate profit margins may allow any point along the farm-to- fork continuum to maintain itself in a way that promotes safe food practices, whereas poor profit margins may contribute to inadequate staffing, training, or maintenance of equipment, all of which can negatively influence food safety.

People, equipment, processes, foods, and economics are the internal system variables currently recognized as being related to food safety. Overtime well-conducted FBIO environmental assessments will identify other important variables.

Outputs, Outcomes, Feedback

The last three system components along the farm-to-fork continuum are outputs, outcomes, and feedback. Outputs are represented by the final food item that moves from one point in the continuum to the next, ultimately including the final product that is consumed by customers. Outcomes include such elements as customer satisfaction, profit, and customer health. These are only a few of the outcomes of the individual systems represented along the farm-to-fork continuum, but they may be most closely related to public health.

Outcomes spark results that are fed back into each system in one way or another. The feedback may prompt changes within an individual system or in the larger farm-to-fork continuum. For example, feedback on customer satisfaction may trigger a change in menu at a restaurant, or a change in the production of a particular food at manufacturing; feedback on profits may trigger a change in practices or processes at any point along the continuum. Finally, feedback from large foodborne outbreak events can result in system changes at each point in the farm-to-fork continuum.

Although the individual food systems along the farm-to-fork continuum are unique, they are interrelated. Each point affects food safety of any subsequent points along the continuum. A breakdown in food safety at any point along the continuum can contribute to an outbreak of foodborne illness (Figure 1).

Internal System Variable Interaction

It is important to understand all the components within an individual system, whether that system resides at the farm, the manufacturing plant, in the distribution, or at the point of final service. But it is especially important to understand the internal system variables, because these variables exert such strong influences on every aspect of the individual food system, from inputs through outcomes, including customer health. Specifically, the internal variables can pull the system toward a safe or an unsafe outcome – or sometimes, in varying degrees, toward both a safe and an unsafe outcome. Understanding these variables, and especially their interactions with each other, is pivotal to understanding how an individual system operates and why it operates the way it does. Knowledge of these variables and their interactions can also lead to an informed analysis of the degree of control that system managers have over food safety hazards. It can also facilitate an analysis of how, in various circumstances, that degree of control may change. Properly managing the underlying variables helps to pull the individual system's outcome toward a safe product. But it is important to understand that no individual food system is ever completely safe or unsafe. Instead, the system 'tends' to be safe or unsafe. A simple analogy can clarify this point.

If a room's thermostat is set at 70 F, then 70° is the system's set point, the point the system will attempt to maintain. The heating and cooling mechanisms will work to keep the temperature at 70°. It will try to maintain this temperature in spite of the negative effects of some of the system's internal variables, such as insufficient attic or window insulation or improperly sealed doors.

If it is cold outside and a door is opened, the temperature may temporarily drop to 65°. That is because opening the door overwhelms the set point of the system. However, once the door is closed, the system works to regain the set point in spite of its internal variables' negative influences.

Understanding a system and how it reacts to internal variables is important. In the case of a room with a heating and cooling system, an open window will not change the thermostat setting. The thermostat will try to help the room regain its set point, which is what all systems do. It is important to understand that the system's set point is one condition that, together with internal variables, is influenced by positive and negative factors. Successfully changing the system's set point, if that is necessary, requires understanding these variables and their influences.

The internal variables influence the individual food systems described along the farm-to-fork continuum. Each of these variables may have a positive, negative, or neutral influence on food safety at any given point in time, and yet the food system works to remain at its set point. However, if the negative effects of one or more variables overwhelm the other variables' positive or neutral influences, the result can be contamination and/or survival or proliferation of an etiologic agent in food, to such an extent that an FBIO occurs.

For one to determine contributing factors and environmental antecedents, the interactions of these variables with each other and within the individual food system itself must be understood. Such an understanding provides the information required to strengthen internal system variables and if necessary change the food safety system's set points, thus reducing the opportunity for a similar outbreak to occur. Over time, data from foodborne outbreak environmental assessments can be compiled, analyzed, and trends determined and provided to decision makers to inform food safety policy development.

Environmental Assessment

Environmental assessment, as a part of an FBIO investigation, is different from other environmental/food safety inspection activities at food establishments. An FBIO environmental assessment reconstructs past events. It is triggered by an outbreak of foodborne illness. It describes the outbreak influences of people, equipment, processes, food, and economics on variables that may have contributed to the outbreak. This assessment identifies contributing factors and environmental antecedents to the outbreak. It is a forensic process that looks at clues and data to develop a hypothesis regarding the cause of the outbreak and to implement appropriate controls to prevent future outbreaks.

By contrast, routine regulatory inspections involve the present – what an inspector can observe or measure at the time of the visit and what violations of regulations can be cited. Routine regulatory inspections involve documenting current conditions at the establishment to provide snapshots of observable conditions at the time of the inspection. It may be risk based – that is, focused on risks that are most likely to cause foodborne illness – and it is conducted when specific information is not available to suggest that any process is out of control. This activity should also be based on an environmental assessment, one that is conducted in the present.

A plan review/HACCP development inspection focuses on future operations at a facility. It identifies potential problems before they lead to a foodborne illness, and it identifies control points for preventing foodborne illness in the future. It allows the facility to evaluate plans and procedures. This activity should also be based on an environmental assessment, one that is conducted on the basis of expectations of the future.

FBIO Environmental Assessment

An FBIO environmental assessment is an in-depth, multidisciplinary, systems-based approach to determine how the environment contributed to the introduction and/or transmission of the agent that caused illness. The environment can include everything external to the host, including air, food, water, animals, plants, climate, etc., as well as people and social and built environments.

The objectives of an assessment are to identify contributing factors and environmental antecedents, as well as to generate recommendations for informed interventions. Contributing factors are divided into three categories:

- Contamination
- Survival
- Proliferation/amplification

Contamination factors refer to how an etiologic agent got onto or into the food vehicle. Examples of contamination factors include a contaminated ingredient or bare-hand contact by a food handler/worker/preparer suspected to be infectious.

Survival factors refer to processes or steps that would have eliminated or reduced an etiologic agent if conducted properly. Although survival factors primarily relate to bacterial outbreaks, under limited circumstances they may be appropriately cited in viral outbreaks as well. For example, although norovirus is more heat resistant than most bacteria, it can be inactivated by cooking processes (185°F/85°C for 5 min or boiling for 1 min). As a result, depending on the cooking processes involved, citing survival of the agent as a contributing factor in an outbreak can be appropriate. Examples of survival factors include insufficient time and/or temperature during cooking/heat processing or insufficient time and/or temperature during reheating.

Proliferation/amplification factors identify how an etiologic agent was able to increase in number and/or produce toxic products before the vehicle's being ingested. These factors relate only to bacterial outbreaks. Examples of proliferation/amplification factors include improper cold or hot holding of foods or inadequate processing, such as acidification, water activity, or fermentation.

Environmental antecedents are directly related to contributing factors. They explain why the outbreak occurred and are often referred to as the root causes of outbreaks. For example, a worker who cooks food may not speak the native or primary language of food managers or supervisors. This language barrier may limit the worker's ability to understand food safety training properly, thus resulting in improper cooking of food.

FBIO environmental assessments are best accomplished with a team approach. Team members will vary depending on the setting and the expertise needed, but the team can include such specialists as microbiologists, epidemiologists, water experts, environmental health specialists, food technologists, and veterinarians. The team must understand the farm-to-fork continuum, the systems that make up each point along the continuum, and the interrelationship between different points on the continuum. They must be able to think critically as they filter through information once it evolves over the course of the outbreak investigation, describe each system relevant to the outbreak event, determine the most likely contributing factors and environmental antecedents, and provide recommendations for informed interventions.

Recommendations for informed intervention are based on the findings of the FBIO environmental assessment. These recommendations may be implemented during the environmental assessment in order to stop the outbreak and prevent the further spread of the agent, and/or they may result in the development of longer term strategies to reduce the likelihood of future outbreaks. Immediate steps taken might include destroying food or taking steps to stop its distribution, excluding food workers who are ill, or closing the facility. Longer term strategies might include development and implementation of an HACCP plan or updating and implementing policies regarding identifying and managing food workers who are ill with such symptoms as diarrhea, vomiting, and/or fever.

Challenges Encountered in an FBIO Environmental Assessment

There are four important challenges sometimes encountered in the course of conducting an environmental assessment: the ability to think critically; timing; distinguishing between regulatory violations and factors and antecedents that contribute to foodborne outbreaks; and the seasonal nature of growing foods.

The foodborne outbreak environmental assessment is complex, requiring a high level of critical thinking skill among team members to determine the most likely contributing factors and environmental antecedents in an outbreak event. Each point along the farm-to-fork continuum represents its own unique individual food system, but the systems are interrelated. Therefore, an outbreak of foodborne illness that appears related to one part of the continuum can actually be the result of a food safety breakdown in another part of the continuum. The team must continuously assess an outbreak event, not only in terms of the immediate system under scrutiny but also in terms of the other systems in the farm-to-fork continuum. Such an assessment requires a continuous and iterative analysis and assessment of current thinking within the team as information is gathered and premises are revisited until the team is convinced that the best possible conclusions have been reached. Objectively and continuously evaluating a hypothesis based on information gathered at a point in time during a foodborne outbreak event is one of the most challenging aspects of critical thinking during an environmental assessment. Developing such a hypothesis requires giving equal weight to information that weakens a favored hypothesis and information that supports it. After all, human nature renders it difficult to prove yourself wrong. Therefore, evidence that conflicts with assumptions tends to be discounted. During an environmental assessment, it is human nature to seek information that confirms a hypothesis, rather than information that refutes it. There is a tendency to believe what is expected to be believed. Such a tendency can lead to flawed or inaccurate conclusions.

Another important challenge is timing. Agencies may become aware of an FBIO when it is over or nearly over. Affected persons may no longer be sick, and they may have a hard time remembering what they ate, thereby making it difficult for epidemiologists to identify the vehicle. Food preparation may have been days or weeks earlier, and management and food workers may have a difficult time remembering what actions they took. Investigators try to reconstruct what happened and why food workers acted the way they did, but the workers may not be able to give investigators a complete picture. Therefore, agencies must act quickly when they receive a report that an outbreak may have occurred.

Differentiating between violations of regulations and variables that may have led to an outbreak represents another significant challenge. A food establishment system has its own set point at which some level of regulatory compliance occurs on a day-to-day basis. At any point in time, violations of regulations may be present, but such violations may not result in an FBIO. An

FBIO is usually the result of a convergence of factors, and investigators must focus on determining the specific system variables that led to the outbreak. These variables are often associated with a regulatory requirement, but some variables may not be. At the same time, there may be multiple regulatory violations that are unrelated to the FBIO event. For example, floors, walls, and ceilings of a food establishment that are in poor repair or are dirty are likely violations of food regulatory requirements and are likely to be noted during a routine inspection. However, during an environmental assessment, these things may be noted as part of a general description of the establishment, but they are not at all likely, for instance, to be related to a *Clostridium perfringens* or a *Staphylococcus aureus* outbreak.

Finally, the growing, harvesting, and processing activities for implicated commodities may have ceased for seasonal operations by the time an environmental assessment is being started. Such a cessation means that investigators cannot observe operations or conditions that might have contributed to the outbreak.

Conclusion

Although there have been improvements in FBIO investigation and reporting, the reports still leave many questions regarding environmental causes of outbreaks. Environmental assessments are a critical part of the FBIO response. Unfortunately, information from FBIO environmental assessments, if they are conducted, is sometimes missing or minimally supplied in subsequent publications on specific FBIOs or in outbreak surveillance systems. A compilation and analysis of environmental causes of FBIOs provides the data needed to inform public policies, procedures, and training at the point(s) involved along the farm-to-fork continuum; such a compilation also identifies research gaps and evaluates the impact of food safety programs in reducing the risks of FBIOs. All these benefits, however, depend on a standard method or approach to conducting an FBIO environmental assessment and to reporting and analyzing the data from FBIOs.

In 1999, the US Centers for Disease Control and Prevention (CDC) began to explore using a systems approach, as described in this article, during FBIO environmental assessments. This approach was further explored by state and local food safety programs participating in the CDC Environmental Health Specialists Network and by the US Food and Drug Administration (FDA). As a result, the US FDA began conducting systems- based environmental assessments in 2011 during that agency's foodborne outbreak responses. In 2002, the US National Park Service Public Health Program began its exploration of a systems approach for its field assessments of foodservice establishments. The Park Service continues to work with this approach to determine if it can help regulators and food managers gain additional control over food safety issues. In 2013, CDC will launch an e-learning program on how to conduct an FBIO environmental assessment. This training program will be required of participants who report assessment data to the National Voluntary Environmental Assessment Information System (NVEAIS), an expansion of the existing CDC FBIO reporting system. This new reporting system is expected to help identify factors that can be routinely monitored to prevent or reduce the risk for FBIOs. By building on the foundation of a standard method for FBIO environmental assessments, NVEAIS provides a basis for understanding and preventing future outbreaks, as opposed to simply responding to them.

See also: Food Safety Assurance Systems: Essentials of Crisis Management; Investigation of Incidents in Industry; Root Cause Analysis of Incidents. Public Health Measures: Foodborne Disease Outbreak Investigation; Surveillance of Foodborne Diseases

Further Reading

Bertalanffy L (1968) The Meaning of General Systems Theory. New York: George Braziller.

Bryan R (1978) Factors that contribute to outbreaks of foodborne disease. Journal of Food Protection 41: 816–827.

Bryan F (1981) Hazard analysis critical control point approach: Epidemiologic rationale and application to food service operations. Journal of Environmental Health 44(1): 7–14.

Cassady JD, Higgins C, Mainzer HM, et al. (2006) Beyond compliance: Environmental health problem solving, interagency collaboration, and risk assessment to prevent waterborne disease outbreaks. Journal of Epidemiology and Community Health 60(8): 672–674.

Council to Improve Foodborne Illness Outbreak Response (CIFOR) (2009) Guidelines for Foodborne Disease Outbreak Response. Atlanta: Council of State and Territorial Epidemiologists. Available at: www.cifor.us

Higgins CL and Hartfield BS (2004) A systems-based food safety evaluation: An experimental approach. Journal of Environmental Health 67(4): 9–14.

Todd ECD, Bartleson CA, Guzewich JJ, et al. (2011) Procedures to Investigate Foodborne Illness, 6th edn. Des Moines: International Association for Food Protection.

World Health Organization (WHO) (2008) Foodborne Disease Outbreaks Guidelines for Investigation and Control. Geneva: WHO Press.

Yiannis F (2009) Food Safety Culture: Creating a Behavior-based Food Safety Management System. New York, NY: Springer Publishing.

Relevant Websites

http://www.fda.gov/Food/FoodSafety/FoodborneIllness/ucm235425.htm — Environmental Assessments (US FDA).

http://www.cdc.gov/nceh/ehs/EHSNet/default.htm — Environmental Health Specialists Network (US CDC).

http://www.cdc.gov/nceh/ehs/eLearn/EA_FIO/index.htm — e-Learning on How To Conduct A Foodborne Illness Outbreak Environmental Assessment (US CDC).

http://www.cdc.gov/nceh/ehs/EHSNet/nveais.htm — National Voluntary Environmental Assessment Information System (US CDC).