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# Risk Assessment of Malicious Biocontamination of Food

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## ABSTRACT

Throughout the last decades of the 20th century, the biological threat evolved from primarily a government-controlled weapon to a tool of terrorism. One of the consequences of this trend is the near impossibility of foreseeing when and how an act of bioterrorism will occur. The suitability of food products for such an act stems from the multitude of microorganisms that may be used for contamination and the vulnerability of the products during and after processing. Tests that would enable the detection of a large variety of microorganisms quickly, reliably, and economically should also provide satisfactory means to prevent acts of malicious biocontamination of food products. Until such means become available, a priority-based approach to the problem is probably the most practical. Priorities should be determined based on a systematic risk assessment to define the relative likelihood of a certain microorganism being used in an act of malicious food contamination. Criteria to be evaluated are availability, weaponization processes, delivery of an effective dose, probability of early detection, and the microorganism's resistance to the conditions to which it will be exposed. Because the results of such an assessment may vary according to prevailing conditions, the assessment must be based on the existing circumstances. The results of the assessment should then be applied to the various procedures of food processing, which should further reduce the number of potential microbial threats. Existing methods of screening food for contaminating microorganisms and existing food safety and security procedures such as hazard analysis and critical control point programs may have to be modified to become suitable for the detection of acts of bioterrorism.

Pathogenic microorganisms have been utilized as agents of warfare in various conflicts throughout history. The first documented event is probably the catapulting of corpses of plague victims into the besieged town of Kaffa on the Black Sea, an event that might have started the Black Death in Europe in the 14th century *(6).* During the last decades, the debate on the possible use of microbial agents as weapons, previously dealt with in special classified forums, has moved to the center of public interest and the attention of the media. One of the more noteworthy effects of this development is the increased public pressure on the relevant authorities to establish methods for determining whether occurrences of food contamination are deliberate malicious acts *(2).* A much more dire scenario is the acquisition of biological weapons by various clandestine organizations *(2).* While under governmental control, these agents have been maintained as weapons of war and thus their potential use has been considered to be limited to well-defined circumstances. Although accidents such as the Sverdlovsk incident *(8)* have occurred, the use of biological weapons outside these specific conditions has been considered unlikely and thus generally predictable. This assumption has changed radically within the last decades. State-sponsored and other terrorist groups and even isolated individuals are now able to prepare home-made biological weapons, the use of which is highly unpredictable. Although these weapons are less sophisticated than those developed by governments, their detection is often more difficult, depending on the resources used in their preparation and the efficiency of the intelligence services.

One of the principal aims of terrorist organizations is to disrupt the normal lifestyle of the target population. The means to achieve this objective may be physical injury, psychological pressure, and/or economic damage. Only the first of these methods involves the actual dissemination of a microbial agent.

Episodes of malicious contamination of food have occurred *(14).* Two of the most notorious cases are the contamination of salad bars with *Salmonella* Typhimurium in 1984, resulting in 751 cases of salmonellosis *(13),* and the contamination of food with *Shigella dysenteriae* by a laboratory worker who infected 12 of his colleagues *(5).* Although morbidity was relatively limited in these cases, the morbidity associated with episodes of unintentional food contamination indicates the potential magnitude of such incidents: in 1985, 170,000 people in the United States were infected by *Salmonella* Typhimurium after consuming contaminated milk *(12),* and in 1991 contaminated clams caused 300,000 cases of hepatitis A in China *(4).*

The main topics related to acts of biological (and other) acts of terrorism are prevention and, should this fail, readiness and response. Because risk assessment is related primarily to prevention, this article is focused mainly on this subject.

One of the most difficult topics associated with terrorism in general and food bioterrorism in particular is the necessity of finding a satisfactory compromise between declassifying information indispensable for preventing the of-

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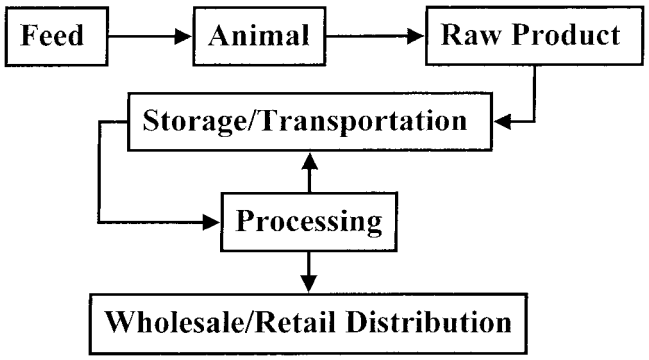


FIGURE 1. *Stable-to-table chain of food products.*

fensive act and the danger of providing essential data to the terrorist. In most cases, these two aspects are sides of the same coin; naming the microorganisms most suitable for an act of food bioterrorism is likely to help the producers improve their methods of prevention and detection while providing guidance to the terrorists. The compromise should be based on balancing the potential damage caused by lack of knowledge and the possibility of facilitating the terrorists (taking into consideration the abundance of information currently available in the public domain). Thus, examples in this review are kept to a strict minimum.

## THE THREAT

One of the most daunting aspects of bioterrorism in general and malicious food biocontamination in particular is the very large number of various microorganisms that could be used in such an act. The Centers for Disease Control and Prevention has published a list of such microorganisms, which have been divided into three groups (A, B, and C) *(11)* based on such criteria as threat to national security, public health impact, ease of dissemination, and psychological impact on the public. This report includes all the microorganisms that could be used in an act of bioterrorism, and all the microorganisms that pose a threat to the food industry are included as a single set in group B, without further elaboration. Because it is one of the most important topics associated with bioterrorism, the prevention of malicious biocontamination of food warrants a more detailed examination.

## RISK ASSESSMENT

The ideal tool for the detection of food contamination, malicious or not, would be a quick, low-cost, easy-to-use, and highly sensitive and specific system to detect every possible material or microorganism extraneous to the food product. Until such systems become available in the (maybe not so distant) future *(10)*, it is necessary to deal with the problem of food contamination using a priority-based approach based on the relative risk associated with relevant microorganisms and the ''stable-to-table'' processing chain *(14)* (Fig. 1).

## MICROBIAL RISK ASSESSMENT

Several factors have an impact on the risk assessment associated with microorganisms and frequently interact with one another.

**Availability.** The ease with which the microorganism can be acquired may vary among geographic regions, according to the prevalence of specific microorganisms. Acquisition of more sophisticated microorganisms is likely to be easier for state-sponsored terrorist groups and more difficult for smaller organizations. As the infrastructure complexity likely to be required for the weaponization of the these microorganisms increases, so does the risk of detection. Thus, the capabilities of and support for the suspect organizations play an important role in assessing the relative risk of a given microorganism.

**Means of weaponization.** Even if readily available, the microorganism must be cultured to reach the dose required to instigate an act of terrorism, and additional procedures may be necessary in the preparation of the final product. If the equipment required for production, the containment of the microorganism, and the provision of a reasonable level of safety during preparation are difficult or complex, the risk of discovery increases (unless the final product is provided by a sponsoring government) and thus the probability that this microorganism will be used is reduced.

**Delivery.** The delivery of the microorganism at an effective dose would have to be inconspicuous (e.g., no noticeable means of transport required). The effective dose is influenced by the microorganism's virulence, contagiousness, and ability to multiply after dissemination. Thus, a more virulent microorganism may have a lower effective dose, but its containment during the weaponization process is likely to be more complex. Likewise, a contagious microorganism may be disseminated at lower doses because it will spread in secondary waves of infection following its multiplication in the infected hosts. Another factor to be considered is the microorganism's population dynamics between dissemination and infection. Microorganisms resistant to environmental conditions will not decrease significantly in population between dissemination and infection, and those that might increase in population under these conditions are likely to pose a higher risk.

**Likelihood of detection between dissemination and infection.** Microorganisms inducing organoleptic changes in the contaminated product, such as changes in its appearance (e.g., decay) and odor, are less likely to be used.

## PRODUCT-ASSOCIATED RISK ASSESSMENT

A detailed examination of food safety and security topics such as access limitation, surveillance, personnel security, and tampering are beyond the scope of this review. However, several topics are important for risk assessment of malicious biological food contamination.

**Geopolitical factors.** If the food consumed by the target population is analogous to an item consumed by the population the terrorists deem themselves to be a part of, the risk of contamination for this food is likely to decrease. However, personnel security problems can arise because individuals cannot be barred from working in the food industry on the basis of population affiliation.

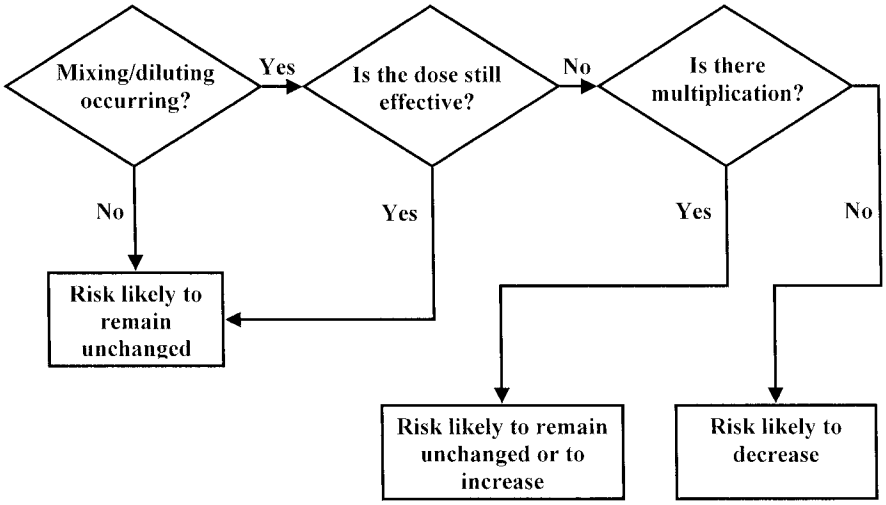


FIGURE 2. *Effect of mixing and diluting on risk assessment.*

**Specific consumer populations.** Risk assessment should take into consideration cases in which food items are to be consumed by specific groups of people, such as infants, whose susceptibility to infections is higher than average, or ethnic groups who consume particular food items. Food contamination might also be used as a tool of propaganda. For example, the Pentagon warned that the Taliban might try to poison food supplied by the United States as relief to Afghan refugees *(9).*

**Psychological effect.** Risk assessment should consider the fact that contamination of certain food items, such as those used in religious ceremonies for example, may have a more significant psychological impact than contamination of other items.

**Mixing or diluting.** These procedures may have an impact on the risk assessment associated with the product. The possible consequences are presented in Figure 2.

## PROCESSING CHAIN–RELATED RISK ASSESSMENT

A typical stable-to-table food chain is presented in Figure 1. Specific vulnerabilities are inherent at each stage of this chain. Raw products may be contaminated directly or by infecting the producing animal through its feed or environment; however, the only microorganisms suitable for such an action are those that cause no clinical signs in the animal. For example, *Bacillus anthracis*, one of the more frequently mentioned agents of bioterrorism, would be unsuitable for animal contamination because infected animals produce almost no milk and show obvious clinical signs of illness, which would probably prevent their meat from reaching consumers (although not necessarily in all countries) *(9).* However, other infectious agents may cause more subtle symptoms that may disappear unnoticed after a few days *(3),* creating carrier animals that could be a source for contamination of the food chain.

Because animals may obtain the majority of these microorganisms through natural infection, routine inspections should be able to detect infected animals. However, inspections should be extended to unexpected microorganisms because those used for bioterrorism may not be the same ones that are routinely isolated.

Through the implementation of hazard analysis and critical control point (HACCP) practices, inspectors should be able to detect food contaminated during processing *(15).* However, HACCP programs are oriented toward providing guidance to prevent unintentional contamination resulting from human error or ignorance. To prevent intentional contamination, control measures should be emphasized.

Disregarding pathogens that are unable to survive a certain processing stage may significantly reduce the number of microorganisms that must be screened as potential threats. For example, in products pasteurized before shipping, all the microorganisms destroyed by pasteurization may be eliminated from the risk assessment up to that point in the chain and should be included only from that point onward.

In assessing the risk of end-product contamination, the consideration of contagious microorganisms is of special importance. Although the number of contaminated items may be limited, the ensuing spread of the microorganism is likely to have severe consequences.

## SUMMARY

Resources allocated to prevent the intentional biological contamination of food should be priority based and preceded by a thorough assessment of the risks. The necessity to prioritize resource allocations has spurred attempts to devise mathematical formulas to quantify the weapons potential of a microbe *(1)* and the food safety risks *(7).* Although these efforts are certainly steps in the right direction, the results of such a risk assessment depend on the prevailing circumstances, which may differ under different conditions (such as the geopolitical situation and the relevant epidemiology) but may also change over time. Consequently, individual risk assessments must be performed for given circumstances and must be periodically reexamined and updated. Existing methods devised for the prevention of involuntary food contamination may have to be modified before applying them in the fight against bioterrorism.

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