

Risk Communication Strategies for Bt-based Public Health Interventions

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Abstract Bt-based public health interventions represent a significant advancement in disease control and vector management, leveraging the biological insecticidal properties of *Bacillus thuringiensis* (Bt). This study aims to analyze the risk communication strategies employed in Bt-based public health initiatives. We explore the principles and mechanisms of Bt interventions and set forth the objectives of this study to enhance public understanding and acceptance. Theoretical frameworks underpinning risk communication are discussed, encompassing key concepts, models, and ethical considerations. We detail strategies for identifying target audiences, crafting effective messages, and addressing public misconceptions. Through case studies of successful Bt interventions, we identify best practices and common challenges in risk communication. The review evaluates the effectiveness of these strategies using various metrics and emphasizes the need for continuous feedback and improvement. Finally, we discuss the implications for integrating risk communication into public health planning, offer policy recommendations, and propose future research directions. Effective risk communication is crucial for the success of Bt-based interventions, ensuring public trust and cooperation, ultimately contributing to improved public health outcomes.

Keywords Bt-based interventions; Risk communication; Public health; Vector management; *Bacillus thuringiensis*

1 Introduction

Bacillus thuringiensis (Bt) is a Gram-positive bacterium widely recognized for its insecticidal properties, particularly against dipteran insects, which include many vectors of human diseases such as mosquitoes (Zhou et al., 2020). The use of Bt-based interventions in public health has gained significant attention due to their effectiveness and environmental safety.

Bt-based interventions have been employed in various public health initiatives to control mosquito populations, which are vectors for diseases such as malaria, dengue, and Zika virus. The bacterium produces δ -endotoxins during its sporulation phase, which are highly toxic to insect larvae upon ingestion (Raymond et al., 2010), leading to their death (Nair et al., 2020). Bt subsp. israelensis (Bti) is particularly effective against mosquito larvae and has been used in community-based larval source management (LSM) programs to reduce mosquito populations and, consequently, the incidence of mosquito-borne diseases (Ingabire et al., 2017).

The primary mechanism of Bt's insecticidal action involves the production of Cry and Cyt proteins, which form crystalline inclusions during sporulation (Ralte et al., 2012). These proteins are ingested by insect larvae, where they bind to specific receptors in the gut, causing cell lysis and death (Sanchis and Bourguet, 2011; Zhang et al., 2021). Bt-based bioinsecticides are considered environmentally friendly as they specifically target insect larvae without harming non-target organisms, including humans and other animals (Sanchis, 2011; Mendoza-Almanza et al., 2020). The effectiveness of Bt interventions can be influenced by factors such as the strain of Bt used, the method of application, and environmental conditions (Patil et al., 2011).

The objectives of this study are to examine the current state of Bt-based public health interventions, identify the key challenges and barriers to their implementation, and propose effective risk communication strategies to enhance community acceptance and participation. By synthesizing findings from various studies, this study aims to provide a comprehensive understanding of the socio-economic and operational factors that influence the success of Bt interventions and offer recommendations for future scale-up and integration into public health policies.

2 Theoretical Frameworks of Risk Communication

2.1 Definition and key concepts of risk communication

Risk communication is the process of exchanging information about risks between decision-makers and the public (Savoia et al., 2017). It aims to inform and educate individuals about potential hazards, enabling them to make informed decisions and take appropriate actions to mitigate those risks. Effective risk communication involves understanding the audience's perceptions, beliefs, and attitudes towards risk, and tailoring messages to address these factors (Fitzpatrick-Lewis et al., 2010).

2.2 Theories and models in risk communication

Several theories and models underpin the practice of risk communication. One prominent model is the risk information seeking and processing (RISP) model, which integrates concepts from the heuristic-systematic model of information processing and the theory of planned behavior. The RISP model emphasizes the role of information sufficiency, channel beliefs, and perceived information-gathering capacity in shaping how individuals seek and process risk information (Griffin, 2013).

Another important framework is the conceptual model for evaluating emergency risk communication, developed in collaboration with the centers for disease control and prevention (CDC). This model outlines key constructs for assessing internal processes and outcomes of emergency risk communication, such as changes in knowledge, attitudes, beliefs, and behaviors (Seeger et al., 2018).

Additionally, the landscape of risk communication research highlights the interdisciplinary nature of the field, with roots in psychology, social sciences, medicine, and environmental sciences (Schmälzle et al., 2017). This research domain has evolved to address various applied contexts, including public health, environmental hazards, and emergency response (Goerlandt et al., 2020).

2.3 Ethical considerations in risk communication

Ethical considerations are paramount in risk communication, as the process often involves conveying information that can significantly impact individuals' lives and well-being. Ethical failures in risk communication can arise from inadequate theoretical understanding of the ethical assumptions embedded in risk discourses or from conflicts between ethical purposes, such as improving decision-making effectiveness, empowering recipients, or ensuring informed consent (Thompson, 2012).

The ethical motivation for risk communication may vary, but it generally aims to ensure that individuals are adequately informed about risks and can make decisions consistent with ethical criteria (Coyle and Gillies, 2020). Philosophical theories of ethics provide a useful framework for understanding these differences and guiding ethical risk communication practices (Thompson, 2012). Moreover, the fairness of risk distribution across social groups and the use of persuasion in risk communication are critical ethical issues (Dickmann, 2013). Communicators must strive to present information transparently and equitably, avoiding manipulation or coercion (Trakoli, 2015).

In summary, theoretical frameworks in risk communication encompass a range of models and ethical considerations that guide the effective and responsible dissemination of risk information. These frameworks help practitioners understand the complex dynamics of risk perception and communication, ultimately supporting informed decision-making and public health interventions.

3 Risk Communication Strategies and Methods

3.1 Identifying and understanding target audiences

Understanding the target audience is the first step in effective risk communication. It involves recognizing the audience's knowledge, perceptions, concerns, and beliefs about the health risks and interventions being communicated. Studies have shown that risk perception is influenced by personal experiences, cultural and social factors, and trust in information sources (Fitzpatrick-Lewis et al., 2010). For instance, the public's response to COVID-19 risk communication was shaped by factors such as immediacy, uncertainty, and trust in institutions

(Malecki et al., 2020). Similarly, engaging communities in the development of messaging and understanding their literacy levels can significantly improve the effectiveness of communication (Ghio et al., 2021; Lindsey et al., 2022).

3.2 Crafting clear and relevant messages

Crafting messages that are clear, relevant, and tailored to the audience's needs is crucial. Effective messages should be fact-based, transparent, and empathetic (Leurer et al., 2022). They should also be delivered by credible sources and framed to increase understanding, social responsibility, and personal control (Ghio et al., 2021). Multi-media approaches, combining text and diagrams, have been found to be more effective than single media approaches. Additionally, messages should address both the hazard and the outrage components of risk perception, as these shape public acceptance and adherence to health interventions (Figure 1).

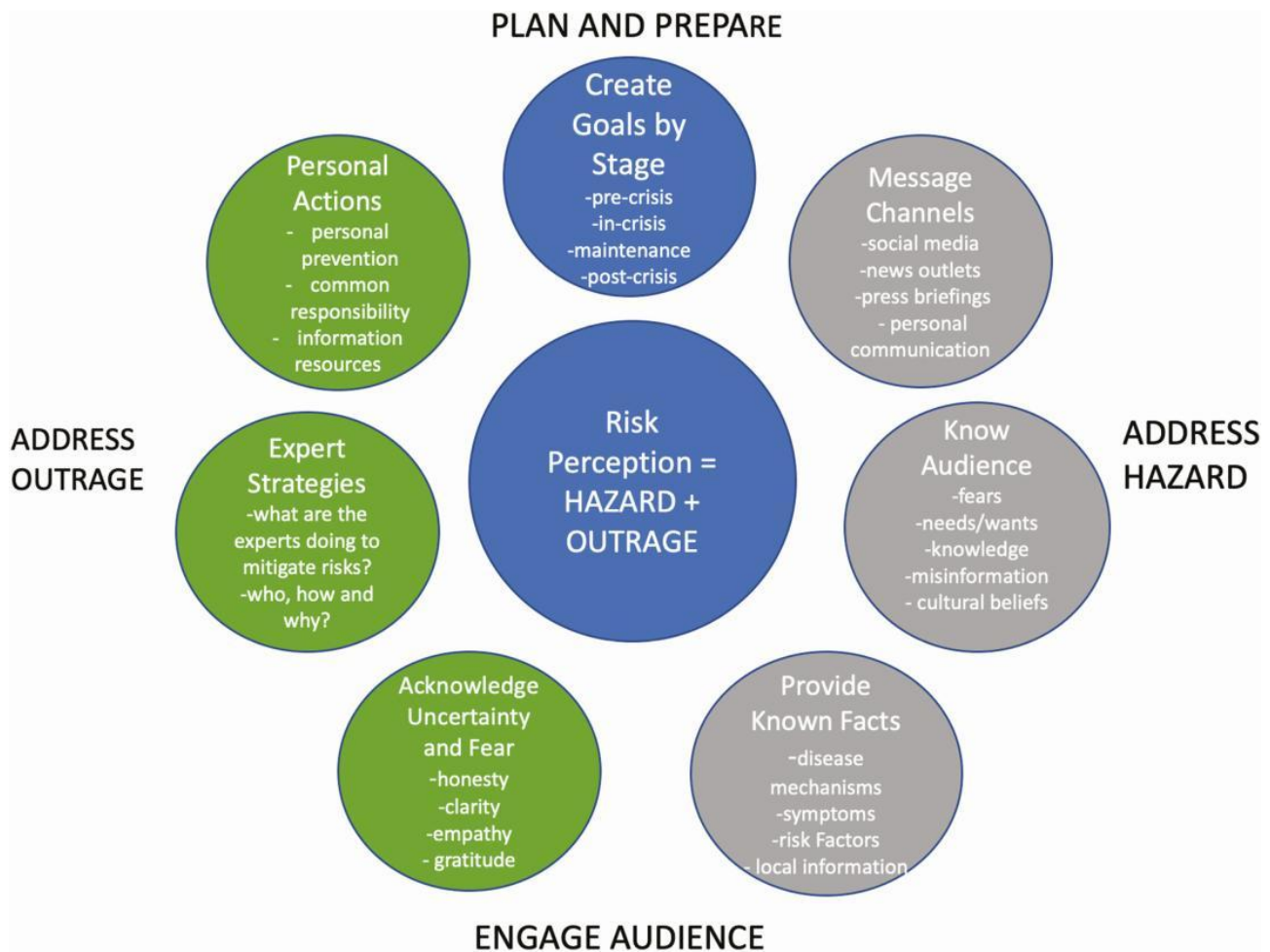


Figure 1 Crisis communication: addressing hazard+outrage during the COVID 19 pandemic (Adopted from Malecki et al., 2020)

The research of Malecki et al. (2020) outlines an effective framework for crisis communication during the COVID-19 pandemic, emphasizing the need to address both hazard and public outrage to manage risk perception. Central to the framework is the formula: Risk Perception = Hazard + Outrage. The model advocates for a comprehensive approach divided into four main strategies: Plan and Prepare, Address Outrage, Address Hazard, and Engage Audience. In the Plan and Prepare phase, it is crucial to set goals tailored to different crisis stages (pre-crisis, in-crisis, maintenance, post-crisis) and select appropriate message channels like social media, news outlets, and personal communication. Addressing outrage involves acknowledging public fears and uncertainties with honesty, clarity, empathy, and gratitude, while communicating expert strategies to mitigate risks effectively. Addressing the hazard requires providing accurate information about the crisis, including disease mechanisms, symptoms, and risk factors. Engaging the audience involves understanding their fears, needs, and cultural beliefs,

and combating misinformation through clear, accurate information. This holistic approach builds trust and encourages proactive behaviors during a crisis.

3.3 Addressing misconceptions and public concerns

Addressing misconceptions and public concerns is a critical component of risk communication. Misinformation can significantly hinder public health efforts, as seen in historical and contemporary health campaigns. Effective strategies include aggressively addressing misinformation, ensuring consistent messaging, and leveraging social media to quickly convey accurate information. Moreover, understanding and addressing the public's misperceptions by using plain language and providing actionable solutions can improve comprehension and response to health risks (Shrivastava et al., 2016).

In conclusion, effective risk communication for Bt-based public health interventions requires a comprehensive understanding of the target audience, the development of clear and relevant messages, and proactive addressing of misconceptions and public concerns (Su et al., 2022). By incorporating these strategies, public health officials can enhance the uptake and success of health interventions.

4 Case Studies in Bt-based Public Health Interventions

4.1 Successful Bt interventions and their communication strategies

Successful Bt-based public health interventions have demonstrated the importance of effective risk communication strategies. For instance, the community water fluoridation campaign in Saskatoon, Canada, during 1953/54, utilized extensive community outreach, involvement of local experts, and aggressive addressing of misinformation to gain public support (Leurer et al., 2022). Similarly, the Romanian Orthodox Church's involvement in COVID-19 mitigation efforts in Romania highlights the positive outcomes of productive consultations between public health authorities and religious institutions, emphasizing the importance of engaging faith-based communities in public health initiatives (Dascalu et al., 2021). These examples underscore the necessity of tailored communication strategies that involve local stakeholders and address community-specific concerns.

4.2 Challenges faced in risk communication

Despite the successes, several challenges have been encountered in risk communication for Bt-based public health interventions. The COVID-19 pandemic has revealed significant issues, such as delayed decision-making and limited information disclosure, which hindered effective communication in Wuhan, China (Figure 2) (Zhang et al., 2020). Additionally, the analysis of government communication in the United States during the COVID-19 pandemic highlighted the consequences of ineffective communication, including public confusion and misunderstanding, which prolonged the health crisis (Kim and Kreps, 2020). These challenges illustrate the critical need for timely, transparent (Rooney et al., 2020), and accurate communication to build public trust and ensure compliance with health interventions.

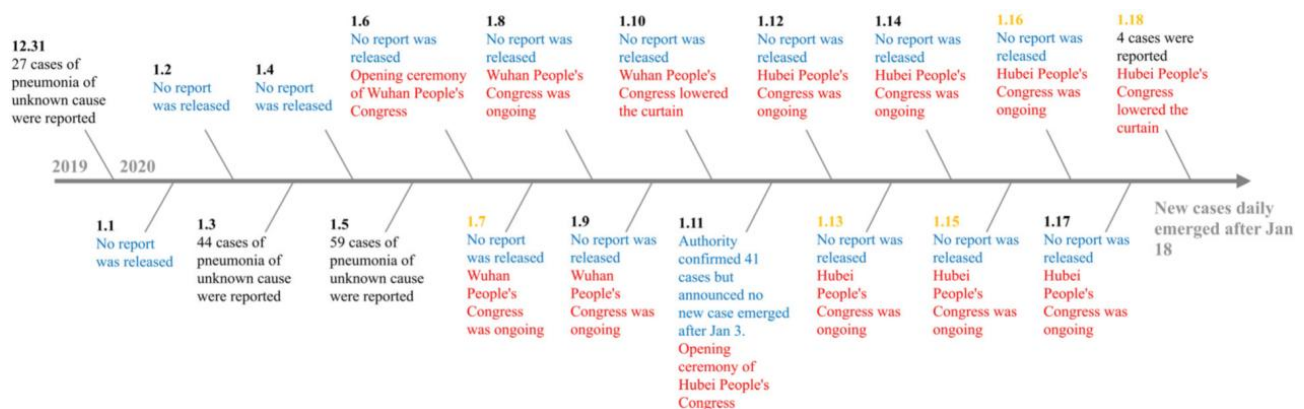


Figure 2 Timeline of official reports about infected cases by the Wuhan Health Commission (Adopted from Zhang et al., 2020)

Image caption: Blue represents "No report"; Red represents Wuhan and Hubei's Congress; Date in yellow represents confirmed infected case of medical worker (Adopted from Zhang et al., 2020)

The timeline in the research of Zhang et al. (2020) presents the sequence of events and official reports related to pneumonia cases of unknown cause in Wuhan, China, at the onset of the COVID-19 pandemic. Starting on December 31, 2019, with the initial report of 27 cases, the timeline highlights significant gaps in reporting, especially during the period when the Wuhan and Hubei People's Congress sessions were ongoing. Notably, from January 1 to January 17, 2020, multiple days passed without any reports being released, even as the number of pneumonia cases increased to 59 by January 5. On January 11, authorities confirmed 41 cases but stated that no new cases had emerged since January 3. It wasn't until January 18, when the People's Congress sessions concluded, that new cases were reported daily. This timeline underscores potential delays and inconsistencies in public health reporting, possibly influenced by political events, which may have impacted early responses to the outbreak. The emphasis on the lack of reporting during the People's Congress suggests a critical period where transparency and timely communication were crucial yet lacking.

4.3 Lessons learned from case studies

From these case studies, several key lessons can be drawn to improve future Bt-based public health interventions. First, the importance of community engagement and the involvement of local experts cannot be overstated, as demonstrated by the successful fluoridation campaign in Saskatoon. Second, the need for a collaborative approach that includes diverse stakeholders, such as religious institutions, can enhance the effectiveness of public health measures, as seen in Romania (Dascalu et al., 2021). Third, the experiences from the COVID-19 pandemic highlight the necessity of timely and transparent communication to prevent public confusion and ensure effective response to health crises (Warren and Lofstedt, 2021). Lastly, the use of social media and other modern communication tools should be integrated with traditional methods to reach a broader audience and address misinformation effectively (Toppenberg-Pejcic et al., 2019; Arije et al., 2023).

By incorporating these lessons, future Bt-based public health interventions can be better equipped to navigate the complexities of risk communication and achieve greater public support and compliance.

5 Evaluating the Effectiveness of Risk Communication

Evaluating the effectiveness of risk communication strategies for Bt-based public health interventions is crucial to ensure that the intended messages are accurately received and acted upon by the target audience. This evaluation can be broken down into three main components: metrics and indicators of success, feedback mechanisms, and continuous improvement.

5.1 Metrics and indicators of success

To measure the success of risk communication strategies, it is essential to establish clear metrics and indicators. These can include changes in awareness, knowledge, attitudes, and behaviors among the target population. For instance, a systematic review highlighted that multi-media approaches and printed materials combining text and diagrams are more effective in enhancing public understanding and response to environmental health risks (Fitzpatrick-Lewis et al., 2010). Additionally, the effectiveness of health-risk assessments with feedback has been demonstrated in worksite health promotion programs, where improvements in health behaviors and physiological estimates were observed (Soler et al., 2010). Metrics such as the rate of early detection, response times, and coordination efficiency during public health emergencies can also serve as indicators of successful risk communication (Dickmann et al., 2015).

5.2 Feedback mechanisms

Feedback mechanisms are vital for assessing the impact of risk communication and making necessary adjustments. These mechanisms can include surveys, focus groups, and direct feedback from the community (Brehaut et al., 2016). For example, patient-mediated interventions, such as patient-reported health information and patient education, have been shown to improve healthcare professionals' adherence to clinical practice guidelines, indicating the importance of incorporating patient feedback into communication strategies (Fønhus et al., 2016). Moreover, tailored risk feedback and message framing have been found to correct risk perceptions and increase behavioral intentions, underscoring the need for personalized feedback mechanisms (Goh et al., 2021).

5.3 Continuous improvement

Continuous improvement of risk communication strategies involves regularly updating and refining messages based on feedback and new evidence. This iterative process ensures that communication remains relevant and effective. A systematic review of personalized disease risk communication found that presenting risk information alone does not produce strong behavioral changes, suggesting the need for integrating additional behavior change techniques and theoretical frameworks (French et al., 2017). Furthermore, the development of high-quality communication tools that match patients' numerical abilities and provide clear, understandable information is essential for improving decision-making processes (Zipkin et al., 2014). By continuously evaluating and improving risk communication strategies, public health interventions can achieve better outcomes and foster greater trust and engagement within the community (Valle et al., 2018).

In conclusion, evaluating the effectiveness of risk communication for Bt-based public health interventions requires a comprehensive approach that includes defining clear metrics, implementing robust feedback mechanisms, and committing to continuous improvement. By leveraging these strategies, public health practitioners can enhance the impact of their communication efforts and better protect public health.

6 Implications for Future Bt-based Public Health Programs

6.1 Integrating risk communication into public health planning

Effective risk communication is essential for the success of Bt-based public health interventions. Research indicates that a multi-media approach, which combines various types of information delivery such as text, diagrams, and visual aids, is more effective than single-method approaches (Fitzpatrick-Lewis et al., 2010). Additionally, integrating emergency risk communication (ERC) into public health systems can enhance preparedness and response activities by reforming leadership structures, modifying organizational factors, and removing regulatory obstacles (Jha et al., 2018). For Bt-based interventions, it is crucial to incorporate these strategies into public health planning to ensure that the target audience receives and understands the risk messages, thereby improving compliance and trust in public health measures (Warren and Lofstedt, 2021).

6.2 Policy recommendations

To optimize the effectiveness of Bt-based public health programs, several policy recommendations can be made. First, policies should mandate the use of multi-faceted risk communication strategies that address the diverse needs of the target population (Fitzpatrick-Lewis et al., 2010). Second, it is important to establish networks, task forces, and committees that facilitate information sharing and coordination across different organizations and levels of response (Jha et al., 2018). Third, policies should encourage the engagement of local stakeholders to ensure the flow of information and build trust within communities (Scholz et al., 2021). Finally, integrating social science intelligence into epidemiologic risk assessments can provide a more comprehensive understanding of public perceptions and improve the design of risk communication strategies (Dickmann et al., 2016).

6.3 Future research directions

Future research should focus on several key areas to enhance the effectiveness of Bt-based public health interventions. First, there is a need for more empirical studies, particularly in low- and middle-income countries, to understand the specific challenges and opportunities in these settings (Jha et al., 2018). Second, research should explore the impact of personalized risk communication on behavior change, as current evidence suggests that personalized risk information alone does not produce strong or consistent effects (French et al., 2017). Third, studies should investigate the effectiveness of community-based and participatory interventions, especially in low-resource settings, to determine their potential for improving public health outcomes (Hale et al., 2014; Schiavo et al., 2014). Finally, research should address the gaps in evaluating the cost-effectiveness and health equity implications of risk communication strategies to inform better policy and practice (Meng et al., 2016).

By addressing these areas, future Bt-based public health programs can be better equipped to communicate risks effectively, engage communities, and achieve desired health outcomes.

7 Concluding Remarks

The review of literature on risk communication strategies for Bt-based public health interventions highlights several critical elements for effective communication. Effective public health messaging is characterized by delivery from credible sources, community engagement, and increasing awareness and knowledge, which are essential for managing risks and preventing infectious diseases. Multi-media approaches and printed materials combining text and diagrams are more effective than single media approaches. Additionally, integrating social science intelligence into epidemiologic risk assessments and strengthening multisectoral collaboration are crucial for improving risk communication. Trust in information sources, such as the WHO, significantly influences public adherence to preventive measures.

Effective risk communication is paramount in public health interventions as it fosters public trust, compliance, and support for non-pharmaceutical interventions (NPIs). It is essential for managing public perceptions and behaviors during health crises, such as the COVID-19 pandemic. Effective communication strategies can mitigate misinformation, enhance public understanding of health threats, and promote social responsibility and personal control. Moreover, integrating emergency risk communication (ERC) into public health systems ensures timely and accurate information dissemination, which is vital for preparedness and response activities.

Stakeholders should prioritize engaging communities in the development of public health messages to ensure they are acceptable and increase understanding and perceived susceptibility to health threats. It is recommended to address uncertainty immediately and with transparency to build and maintain public trust. Utilizing a multi-media approach and combining different types of information in printed materials can enhance the effectiveness of communication strategies. Strengthening multisectoral collaboration, including with local organizations, is essential for a cohesive and comprehensive risk communication strategy. Regular feedback from the public on their familiarity and compliance with preventive measures should be sought to adapt and improve communication strategies as the situation evolves. Finally, stakeholders should ensure that risk communication strategies are proactive, participatory, and multisectoral to facilitate better governance and collaboration.

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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