Abstract of the Problem Statement

Food safety remains a critical concern across food processing units, restaurants, street food sectors, storage facilities, and supply chains. The presence of harmful bacteria in food is a major cause of foodborne illnesses, leading to serious health risks, loss of consumer trust, regulatory penalties, and economic losses for food businesses. Despite increased awareness and regulatory standards, effective monitoring of bacterial contamination at the point of food handling continues to be a significant challenge. Currently, detection of bacterial contamination in food relies largely on laboratory-based testing methods such as culture techniques and biochemical analysis. While these methods are accurate, they are time-consuming, require skilled personnel, and involve sample collection and transport to laboratories. The time delay between sampling and results often ranges from several hours to days, during which contaminated food may already be consumed or distributed, limiting timely decision-making and corrective action.

Key limitations of existing detection practices include:

- ✓ Dependence on centralized laboratory infrastructure
- ✓ Long turnaround time between testing and results
- ✓ Requirement of trained personnel and controlled environments

Another major drawback of current practices is their invasive nature. Food samples must be collected, processed, and sometimes destroyed for testing, which is not always feasible in small food establishments, street food environments, or during large-scale food distribution. Frequent sampling increases operational costs and disrupts routine food handling processes, resulting in limited adoption of continuous monitoring, particularly in cost-sensitive settings.

From an operational standpoint, food businesses require rapid, on-site methods to assess food hygiene without interrupting workflows. However, most available detection systems are:

- ✓ Bulky and expensive
- ✓ Designed for laboratory or industrial use
- ✓ Inaccessible to small and medium food vendors and catering services

This creates a gap between food safety regulations and their practical implementation across decentralized food outlets.

Environmental factors such as temperature, humidity, storage conditions, and improper handling further contribute to bacterial growth in food. Despite this, there is limited capability to assess contamination risk in real time at the point of food preparation or storage. Without immediate feedback:

- ✓ Preventive action cannot be taken early
- ✓ Contamination progresses unnoticed
- ✓ The likelihood of foodborne outbreaks increases

Regulatory bodies emphasize preventive monitoring and hazard analysis; however, compliance remains challenging due to the lack of simple, rapid, and non-invasive detection tools. Existing inspection mechanisms are periodic and fail to reflect continuous hygiene

conditions, reducing the effectiveness of enforcement and shifting focus toward post-incident investigation rather than prevention.

Additional challenges include:

- Lack of real-time food safety verification for vendors and consumers
- Limited transparency in food hygiene practices
- Absence of accessible tools for non-laboratory environments

Industries involved in food processing, storage, and distribution increasingly seek technologies that enable faster decision-making, reduce dependence on centralized laboratories, and improve compliance with safety standards. However, the market currently lacks cost-effective and portable systems capable of detecting bacterial contamination quickly and non-invasively while maintaining acceptable reliability.

The problem is further compounded in rural and semi-urban areas where laboratory facilities are limited or inaccessible. Delays in testing and reporting are common, increasing the risk of contaminated food entering the supply chain and reaching consumers.

At its core, the problem lies in the absence of rapid, non-invasive, and on-site bacterial contamination assessment methods that can be deployed across the food ecosystem. Existing approaches are slow, invasive, resource-intensive, and poorly suited for continuous monitoring, restricting preventive food safety practices and increasing health, economic, and regulatory risks. Addressing this challenge requires focused research and collaborative efforts to enable faster, accessible, and field-deployable food safety assessment mechanisms. Bridging the gap between laboratory accuracy and real-world usability is essential to improve food hygiene standards, protect public health, and strengthen trust across the food supply chain.