



Environment-Linked Enteric Disease: Environmental Determinants, Surveillance Challenges, and One Health Priorities in Kosovo

Abdurrahim Gerguri^{1,2}, Arlinda Maloku^{1,3*}

¹*Pediatric Clinic, University Clinical Centre of Kosovo, Prishtina, Kosovo.*

²*AAB College, Prishtina, Kosovo.*

³*Faculty of Medicine, University of Prishtina "Hasan Prishtina", Kosovo.*

ABSTRACT

Environment-linked enteric disease remains an important environmental and public-health challenge shaped by contaminated food and water, sanitation, food handling, climate variability, and host susceptibility. Updated World Health Organization (WHO) estimates indicate that foodborne transmission of 42 infectious and chemical hazards caused approximately 866 million illnesses, 1.52 million deaths, and 57.1 million disability-adjusted life-years in 2021; children younger than five years experienced a disproportionate burden. This narrative review synthesizes international evidence and examines publicly available surveillance and outbreak information relevant to Kosovo, focusing on environmental determinants, laboratory capacity, food-chain monitoring, antimicrobial resistance (AMR), climate-related risks, and One Health approaches. The literature indicates that effective prevention requires coordinated surveillance across human health, veterinary services, food safety, and environmental monitoring. Public reporting on the July 2026 Prishtina outbreak described 74 epidemiologically linked cases, 29 hospitalizations, and *Salmonella* Enteritidis detected in patient samples; food and environmental samples were reported as negative, and the definitive source was not established in the available report (Telegrafi, 2026). The event illustrates the importance of rapid detection, timely sampling, source tracing, and transparent risk communication. Priorities for Kosovo include strengthening laboratory and epidemiological capacity, improving data interoperability, expanding food-chain surveillance, and developing climate-sensitive, genomic, and One Health approaches appropriate to national resources.

Keywords: Foodborne disease, Environmental health, *Salmonella*, Food safety, Disease surveillance, One health

Corresponding author: Arlinda Maloku

e-mail ✉ arlindamaloku@yahoo.com

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INTRODUCTION

Foodborne and waterborne enteric diseases arise through exposure to pathogens or chemical hazards in food, drinking water, and the wider environment. Transmission is influenced by sanitation, wastewater management, food production and handling, temperature control, environmental contamination, and host susceptibility. The 2026 World Health Organization (WHO) burden synthesis estimated that foodborne transmission of 42 infectious and chemical hazards caused 866 million illnesses, 1.52 million deaths, and 57.1 million disability-adjusted life-years (DALYs) in 2021. The incidence in children younger than five years was estimated to be 2.7 times that in older age groups, with a particularly high rate of DALYs (Lake *et al.*, 2026; WHO, 2026). These estimates include both infectious and chemical hazards and should not be interpreted as a count of clinically confirmed cases in any single country.

Food safety is a system-wide responsibility. Pathogens may enter the food chain during primary production, processing, transport, retail, preparation, or consumption. Water contamination and inadequate sanitation can amplify exposure, while warming temperatures, heavy precipitation, flooding, and drought may change pathogen ecology and the reliability of

water and food systems (WHO, 2021; Intergovernmental Panel on Climate Change [IPCC], 2022; Dietrich *et al.*, 2023; Mirón *et al.*, 2023; Semenza & Ko, 2023; WHO, 2023b). *Salmonella*, *Campylobacter*, Shiga toxin-producing *Escherichia coli* (STEC), norovirus, and *Shigella* are among the relevant enteric hazards, although the distribution of pathogens varies by setting and exposure route (European Food Safety Authority [EFSA] & European Centre for Disease Prevention and Control [ECDC], 2024; Li *et al.*, 2024; EFSA & ECDC, 2025).

For Kosovo, a useful response requires surveillance that connects clinical notifications, laboratory results, food-safety inspections, veterinary data, water quality, and environmental information. WHO guidance places foodborne disease surveillance within broader public-health preparedness and the International Health Regulations, and emphasizes collaboration between epidemiology, laboratories, environmental health, and food-safety authorities (WHO, 2016, 2025a, 2025b, 2025c, 2025d, 2025e). ECDC's 2026 country visit report also identifies communicable-disease surveillance and One Health coordination as relevant areas for technical cooperation in Kosovo (ECDC, 2026). This review summarizes the evidence and identifies practical priorities rather than claiming to provide a systematic review or a complete assessment of national surveillance performance.

MATERIALS AND METHODS

A narrative literature review was conducted to summarize evidence on environmental determinants of enteric disease and surveillance approaches relevant to Kosovo. The review covered literature published from January 2005 through July 2026. Searches were framed around PubMed, Scopus, Web of Science, and Google Scholar, alongside targeted searches of the World Health Organization (WHO), European Centre for Disease Prevention and Control (ECDC), European Food Safety Authority (EFSA), Food and Agriculture Organization of the United Nations (FAO), Codex Alimentarius, and other public-health agency resources. Search concepts included combinations of “foodborne disease,” “waterborne disease,” “enteric infection,” “food safety,” “sanitation,” “climate change,” “antimicrobial resistance,” “One Health,” “whole-genome sequencing,” “Kosovo,” and “outbreak surveillance.” Peer-reviewed studies, systematic reviews, authoritative surveillance reports, official guidance, and directly relevant public reporting were prioritized. Evidence was synthesized narratively according to environmental determinants, clinical and epidemiological features, surveillance, antimicrobial resistance, climate risks, and One Health. Publicly available information was used for the Kosovo case study. No formal risk-of-bias tool, duplicate independent screening, or meta-analysis was undertaken; accordingly, the findings should be interpreted as a narrative synthesis rather than a systematic review.

RESULTS AND DISCUSSION

Causes and clinical features

Enteric disease can be caused by bacteria, viruses, parasites, and toxins or chemicals transmitted through food and water. Common symptoms include diarrhea, vomiting, abdominal pain, and fever. Disease severity depends on the causative hazard, exposure dose, age, underlying health, and access to supportive care. Young children, older adults, pregnant people, and immunocompromised individuals may face greater risk of severe outcomes. The global burden estimates demonstrate that foodborne hazards include not only acute infections but also non-communicable outcomes associated with chemical exposure (Newell *et al.*, 2010; CDC, 2011; Scallan *et al.*, 2011; Grace, 2015; Havelaar *et al.*, 2015; WHO, 2015, 2024a; Lake *et al.*, 2026). Organism-specific information on *Salmonella*, *Campylobacter*, *STEC*, and norovirus is also provided in public-health guidance (Centers for Disease Control and Prevention [CDC], n.d.-a, n.d.-b, n.d.-c, n.d.-e). Food-vehicle attribution requires epidemiological and traceability evidence rather than symptom patterns alone (Hoffmann *et al.*, 2017). Selected pathogens and their usual exposure routes are summarized in **Table 1**. Incubation periods are approximate and vary by strain, inoculum, and host factors.

Table 1. Selected foodborne pathogens, exposure routes, clinical features, and prevention measures.

Pathogen/hazard	Common exposure route	Typical incubation	Main clinical features	Important complications	Key prevention
<i>Clostridium botulinum</i>	Improperly processed or preserved foods	Often 12–36 h; variable	Visual disturbance, weakness, bulbar symptoms	Descending paralysis, respiratory failure	Validated canning and preservation; discard unsafe products
<i>STEC</i> (e.g., <i>E. coli</i> O157)	Undercooked ground beef, produce, contaminated water, animal contact	Usually 3–4 days; range varies	Severe cramps, diarrhea that may become bloody	Hemolytic uremic syndrome	Safe cooking, prevent cross-contamination, safe water
<i>Campylobacter</i> spp.	Poultry, unpasteurized milk, contaminated water	Usually 2–5 days	Diarrhea, abdominal pain, fever	Reactive arthritis; Guillain-Barré syndrome in a minority	Cook poultry thoroughly; pasteurize milk; hand hygiene
<i>Shigella</i> spp.	Person-to-person spread; contaminated food or water	Usually 1–2 days	Fever, diarrhea, sometimes blood or mucus	Dehydration; complications in severe disease	Hand hygiene, sanitation, safe water and food handling
Norovirus	Contaminated ready-to-eat foods, shellfish, water; infected handlers	Usually 12–48 h	Acute vomiting and diarrhea	Dehydration, particularly in vulnerable groups	Handwashing, exclusion of ill food handlers, effective cleaning
<i>Salmonella enterica</i>	Eggs, poultry, meat, produce, cross-contaminated foods	Often 6 h–6 days	Diarrhea, fever, abdominal cramps	Bacteremia or invasive infection in vulnerable people	Safe cooking, cold-chain control, prevent cross-contamination

Environmental determinants

Environmental conditions affect pathogen introduction, persistence, amplification, and human exposure. Inadequate sanitation can permit fecal contamination of water and food; poorly managed wastewater can contaminate recreational waters and agricultural environments; and unsafe food handling can transfer pathogens between raw and ready-to-eat foods. Insufficient refrigeration and prolonged storage at permissive temperatures can increase the risk of bacterial multiplication. Safe drinking water, sanitation, and food hygiene are foundational barriers against enteric disease (WHO, 2022a, 2023c, 2024d, 2025c; FAO & WHO, 2023; CDC, n.d.-d). The

relative contribution of each pathway is context-specific and should be assessed through local epidemiological and environmental evidence rather than assumed from symptoms alone. Key pathways are summarized in **Table 2**.

Food-system resilience is also relevant to enteric disease prevention. Disruptions to production, storage, transport, and household access can increase reliance on informal or poorly controlled food channels, although food insecurity should not be treated as a direct proxy for contamination. Global assessments of food security and nutrition provide context for strengthening resilient supply chains and ensuring that food-safety measures remain accessible across populations (FAO *et al.*, 2022, 2023).

Table 2. Environmental determinants of enteric disease and corresponding public-health responses.

Determinant	Potential pathway or impact	Public-health response
Sanitation and wastewater	Fecal contamination of water, soil, food-growing areas, and household environments	Improve sanitation coverage, wastewater treatment, and safe sludge management
Drinking-water quality	Waterborne transmission and contamination of food during washing or preparation	Routine water-quality monitoring, rapid notification, and risk-based sampling
Food handling and hygiene	Cross-contamination during production, transport, retail, or household preparation	Good hygiene practices, staff training, inspection, and traceability
Cold chain and storage	Growth of susceptible pathogens when foods are held at unsafe temperatures	Temperature monitoring, validated storage practices, and rapid corrective action
Climate variability	Changes in water availability, flooding, temperature, and pathogen survival or distribution	Climate-informed surveillance, contingency planning, and resilient water systems
Animal and agricultural interfaces	Zoonotic transmission through livestock, animal products, manure, and contaminated environments	Veterinary surveillance, biosecurity, food-chain controls, and One Health data sharing

Climate change should be treated as a risk modifier rather than a uniform cause of all enteric infections. Temperature and precipitation effects vary by organism, geography, season, water infrastructure, and human behavior. Reviews have identified associations between meteorological conditions and several bacterial foodborne infections, while emphasizing uncertainty and the need for location-specific analyses (FAO & WHO, 2022; Dietrich *et al.*, 2023; Mirón *et al.*, 2023). For Kosovo, integrating meteorological indicators with routine enteric disease surveillance could support risk assessment, but such models should be evaluated prospectively before they are used for operational alerts.

Surveillance and outbreak response

Effective surveillance combines timely clinical reporting, laboratory confirmation, epidemiological investigation, and food or environmental sampling. Indicator-based surveillance can identify increases in expected disease notifications, while event-based surveillance can detect signals from clinicians, laboratories, food inspectors, or the public. Outbreak investigation should establish a case definition, construct a line list, describe cases by person, place, and time, develop and test hypotheses, collect suitable specimens, trace implicated products, and document control measures. WHO's updated manuals emphasize coordinated action across epidemiology, laboratory, environmental, and food-safety functions (WHO, 2025a, 2025b, 2025c, 2025d, 2025e).

Laboratory capacity affects both case confirmation and source attribution. Standardized culture and molecular testing, appropriate specimen transport, quality assurance, antimicrobial susceptibility testing, and interoperable reporting are foundational. Whole-genome sequencing (WGS) can help distinguish related isolates, identify clusters, and compare clinical, food, and animal isolates, but its usefulness depends on

representative sampling, validated analytical pipelines, metadata quality, and access to bioinformatics expertise (Schadron *et al.*, 2024). WGS is therefore best understood as a complement to, not a replacement for, field epidemiology and food-chain traceability.

Kosovo case study

Public reporting by Telegrafi, citing the National Institute of Public Health of Kosovo (IKSHPK), stated that by 14 July 2026, 74 cases had been identified in an outbreak epidemiologically linked to food consumed at several locations operated by the same food business in Prishtina. Of these, 29 patients were hospitalized and 45 received outpatient care. Salmonella Enteritidis was reported in patient samples, while food samples and environmental swabs collected during the investigation were negative. The report described a rapid rise in cases, with a peak on 10 July, followed by a decline (Telegrafi, 2026). These figures are presented as publicly reported information, not as an independently audited dataset; the key details are summarized in **Table 3**.

Negative food or environmental samples collected after an exposure do not necessarily exclude a contaminated food source, particularly if the implicated batch is no longer available or contamination is heterogeneous. Conversely, a plausible epidemiological link should not be presented as definitive source attribution without supporting investigation findings. The publicly available report indicated that the final assessment would integrate laboratory, clinical, epidemiological, and food-traceability evidence (Telegrafi, 2026). The outbreak therefore illustrates the value of timely sampling, detailed exposure histories, traceability records, rapid information exchange, and clear communication about what is known and what remains uncertain.

Table 3. Summary of the publicly reported July 2026 Prishtina food-associated outbreak.

Reported event	Year	Agent	Cases	Hospitalizations	Interpretation
Prishtina food-associated outbreak, as reported by Telegrafi citing IKSHPK	2026	Salmonella Enteritidis detected in patient samples	74	29	Food-associated epidemiological link reported; food and environmental samples were negative and definitive source attribution was not established in the public report

Antimicrobial resistance and one health

Antimicrobial resistance (AMR) in foodborne bacteria can emerge and spread across human, animal, food-production, and environmental interfaces. Antimicrobial use in human medicine and animal production, transmission through food chains, and environmental dissemination can all contribute to the problem. Integrated surveillance should therefore link clinical isolates and susceptibility results with veterinary and food-chain monitoring, while preserving clear data governance and laboratory standards (United Nations Environment Programme [UNEP], 2023; WHO, 2023a; Bosman *et al.*, 2024; Mahindroo *et al.*, 2024; WHO, 2024c). Antimicrobial therapy should be selected according to the likely pathogen, clinical severity, and relevant susceptibility data; antibiotics are not indicated for every enteric infection and can be harmful in certain conditions, including suspected STEC infection. Clinical management must follow current national guidance and clinician assessment.

One Health coordination is especially relevant where zoonotic pathogens circulate between people, animals, food, and the environment. The EFSA–ECDC One Health zoonoses reports demonstrate the value of combining data from human cases, food, animals, and feed to interpret trends and identify priorities (EFSA & ECDC, 2021, 2022, 2023, 2024, 2025; WHO, FAO, UNEP, & WOA, 2022). For Kosovo, feasible early steps include agreeing on a shared event-notification protocol, standardizing minimum outbreak data, clarifying responsibilities for specimen collection and food tracing, and conducting joint after-action reviews following significant outbreaks (WHO *et al.*, 2022; ECDC, 2026).

Prevention and policy priorities

Prevention requires a combination of household, industry, regulatory, and infrastructure interventions (Li *et al.*, 2025). The WHO food-safety strategy emphasizes evidence-based governance, stronger food-control systems, risk communication, stakeholder engagement, and the use of new technologies (WHO, 2022b, 2024b; FAO & WHO, 2023; FAO & WHO, 2022; CDC, n.d.-d). Food-system resilience and food security are also relevant to safe and reliable access to food, particularly where economic or environmental shocks disrupt supply chains (FAO *et al.*, 2022, 2023). Priority actions for Kosovo include:

Strengthen surveillance infrastructure, laboratory quality systems, specimen transport, and timely reporting of laboratory-confirmed cases.

Integrate human, veterinary, food, water, and environmental information through a practical One Health coordination mechanism.

Improve food-chain traceability and risk-based inspection, including temperature control, hygiene, and rapid access to supplier and distribution records.

Develop outbreak protocols that define roles, sampling timelines, communication channels, and public communication responsibilities.

Consider climate-sensitive surveillance indicators where local data support their use, and evaluate any alert model before operational deployment.

Assess the feasibility of WGS through regional reference laboratories or partnerships, with attention to quality assurance, data sharing, and bioinformatics.

Expand public education on hand hygiene, safe cooking,

separation of raw and ready-to-eat foods, safe water, and appropriate refrigeration (Huber *et al.*, 2025).

Limitations

This is a narrative review and does not provide a reproducible systematic review with formal study selection or risk-of-bias assessment. The Kosovo case study relies on publicly available media reporting that cites the national public-health institute; the underlying full outbreak investigation report was not available for independent review. The manuscript does not infer a definitive food vehicle from the available report. Climate-related associations and genomic surveillance opportunities are discussed at a general level and require local evaluation before specific operational recommendations can be made.

CONCLUSION

Environment-linked enteric disease remains a major environmental and public-health challenge with implications for health systems, food safety, and community resilience. The updated WHO estimates indicate a substantial global burden from foodborne infectious and chemical hazards, with disproportionate impacts on young children (Lake *et al.*, 2026). Public reporting on the July 2026 Prishtina outbreak demonstrates the importance of rapid detection, laboratory confirmation, coordinated epidemiological investigation, and food-chain traceability, while also showing why source attribution must remain cautious when environmental and food samples are negative. For Kosovo, strengthening laboratory capacity, integrating surveillance across human health, veterinary services, food safety, and environmental health, and improving risk communication are practical priorities. Climate-sensitive monitoring and WGS may provide additional value where infrastructure, data quality, and sustainable expertise are available.

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