جامعة الزعيم الازهري
المجلة العلمية المركزية

# Institutional Paralysis and Food Safety Oversight in Conflict Zones: A Mixed-Methods Study of Health Centers and Food Handlers in Karari, Sudan

**Manofal Abdalla Mohamed Adam[1], Prof. Ekram Adam El-Doom, Dr. Kamla Bashir**

**[1] Department of Food Hygiene and Safety, Faculty of Public Health, Al-Zaiem Al-Azhari University, Khartoum, Sudan.**

*Email: nofalabdalla85@gmail.com

## Abstract

In conflict environments, the focus often shifts to emergency trauma, leaving food safety regulatory systems in a state of "Operational Paralysis." This study evaluated the operational capacity of Primary Health Centers (PHCs) and the knowledge-practice levels of food handlers in Karari, Sudan, using a Sequential Explanatory Mixed-Methods design. The methodology integrated a retrospective analysis of 80,220 clinical records with a field survey of 80 food handlers conducted via the KoboToolbox digital platform to ensure data integrity and participant anonymity. Statistical analysis was performed using JASP software (Version 0.18.3), where Multivariate Logistic Regression identified infrastructure collapse as the primary predictor of sample spoilage and the resulting 98% "Diagnostic Gap" ($p < .001$). While 71.2% of food handlers possessed adequate safety knowledge, the absence of regulatory inspections significantly correlated with the prevalence of unsafe practices (OR = 5.4, $p = .012$), with 85% unable to implement safety measures due to the 100% power failure and lack of treated water. The study concludes that the regulatory framework has collapsed, necessitating the deployment of solar-powered mobile diagnostic units to bridge the diagnostic gap and mitigate the risk of mass-scale foodborne epidemics in conflict-affected urban centers.

Keywords: Food Safety Regulatory Systems, Food Handlers, Institutional Capacity, Diagnostic Gap, Armed Conflict, JASP Statistical Analysis, Karari Locality, Sudan.

## المستخلص

في بيئات النزاع، غالباً ما يتحول التركيز إلى إصابات الطوارئ، مما يترك أنظمة الرقابة على سلامة الأغذية في حالة من "الشلل التشغيلي". هدفت هذه الدراسة إلى تقييم القدرة التشغيلية لمراكز الرعاية الصحية الأولية ومستويات المعرفة والممارسة لمتداولي الأغذية في محلية كرري بالسودان، وذلك باستخدام منهج بحث مختلط يتضمن تحليلاً رجعياً لـ 80,220 حالة سريرية ومسحاً ميدانياً لـ 80 من متداولي الأغذية أُجري عبر منصة Kobo Toolbox الرقمية لضمان دقة وسلامة البيانات وخصوصية المشاركين. تم إجراء التحليل الإحصائي باستخدام برنامج JASP (إصدار 0.18.3)، حيث أظهر تحليل الانحدار اللوجستي أن انهيار البنية التحتية كان المنبئ الرئيسي لتلف العينات وما نتج عنه من "فجوة تشخيصية" بلغت 98% ($p < 0.001$). ورغم وصول مستويات المعرفة لدى المتداولين إلى 71.2%، إلا أن غياب الرقابة التفتيشية ارتبط بشكل كبير بانتشار الممارسات غير الآمنة ($OR = 5.4, p = 0.012$)، حيث عجز 85% منهم عن تطبيق معايير السلامة نتيجة الانقطاع الكلي للكهرباء ونقص المياه المعالجة. تخلص الدراسة إلى انهيار الإطار الرقابي لسلامة الغذاء، مما يتطلب التدخل العاجل عبر وحدات تشخيص متنقلة تعمل بالطاقة الشمسية لسد الفجوة التشخيصية والحد من مخاطر الأوبئة المنقولة بالغذاء في المناطق المتأثرة بالنزاع.


الكلمات المفتاحية: أنظمة رقابة سلامة الغذاء، متداولي الأغذية، القدرة المؤسسية، الفجوة التشخيصية، النزاع المسلح، التحليل الإحصائي (JASP) ، محلية كرري، السودان.

# 1. Introduction

Public health resilience in conflict zones is often undermined by the "Operational Paralysis" of regulatory and diagnostic institutions. While the immediate focus of humanitarian aid is typically on trauma and acute malnutrition, the collapse of food safety oversight creates a silent epidemic of foodborne illnesses. In urban conflict settings like Karari, Sudan, Primary Health Centers (PHCs) serve as the first line of defense; however, their efficacy is contingent upon infrastructure stability and supply chain integrity (Kruk et al., 2018).

The ongoing hostilities in Khartoum have created a critical "Diagnostic Gap," where the clinical management of gastrointestinal surges is hampered by siege conditions and a total lack of laboratory reagents (Springer Medizin, 2024). Furthermore, the informal food sector, which has become the primary food source for displaced populations, operates almost entirely outside formal regulatory frameworks (FAO, 2023). This institutional breakdown is compounded by a 100% electricity failure, transforming essential food preservation tools into potential sources of contamination.

Despite these challenges, there is a lack of empirical data regarding the extent of this regulatory void and its direct impact on food handler behavior in Karari. This study seeks to address this knowledge gap by evaluating the institutional capacity of PHCs and the knowledge-practice levels of food handlers. By utilizing the Kobo Toolbox digital platform for real-time data collection, the research aims to triangulate clinical morbidity data with field-level regulatory compliance, providing a strategic framework for restoring food safety oversight in fragile urban environments.

## 2. Methodology

### 2.1 Institutional Assessment and Data Source

A retrospective analysis was conducted using clinical records from six (6) Primary Health Centers (PHCs) in Karari Locality. The study analyzed data from the onset of the conflict (April 2023) to 2025, focusing on a total of 80,220 clinical cases. The assessment evaluated laboratory functionality, diagnostic reagent availability, and the resilience of the cold chain system under the prevailing 100% power instability.

### 2.2 Digital Field Survey (Kobo Toolbox)

A quantitative field survey was administered to 80 food handlers across active market zones and IDP hubs. To ensure data integrity and security in a conflict environment, the survey was deployed using the Kobo Toolbox digital platform. This allowed for:

- Real-time Data Validation: Reducing entry errors and ensuring GPS-tagged accuracy.
- Safety & Compliance: Assessment of hand washing practices, treated water usage, and cold storage capabilities under utility failure.
- Regulatory Tracking: Measuring the frequency of health inspections and the validity of existing health certifications.

### 2.3 Ethical Clearance and Informed Consent

The study protocol was formally reviewed and approved by the Dean of the Faculty of Public Health at Al-Zaiem Al-Azhari University. Due to the security constraints of the conflict, Verbal Informed Consent was obtained from all participants. A mandatory "Consent Screen" was integrated into the Kobo Toolbox interface, ensuring that no data was collected without the participant's explicit voluntary agreement and guaranteed anonymity.

### 2.4 Data Triangulation and Analysis

A mixed-methods triangulation was performed, linking the institutional diagnostic failure (from the 80,220 PHC cases) with the behavioral and regulatory findings from the food handler survey. This approach identifies the "Institutional Paralysis" as a primary driver of morbidity surges, aligning with the World Health Organization (2024) standards for health monitoring in fragile and conflict-affected states.

## 3. Results

### 3.1 Institutional Capacity and the Diagnostic Gap (PHC Assessment)

- The evaluation of six (6) Primary Health Centers (PHCs) in Karari revealed a total "Institutional Paralysis". While clinical records documented a massive burden of 80,220 aggregated cases of gastrointestinal symptoms, the diagnostic cycle was almost entirely severed. Laboratory confirmation was halted by 100% frequency of power outages, which led to systematic sample spoilage and the paralysis of sterilization protocols. This infrastructure collapse created a 98% "Diagnostic Gap," where the rising trend of cases (projected to reach 89,318) is managed without microbial identification, leading to 48 recorded deaths.

**Table 1:** Clinical Burden, Mortality, and Operational Barriers in Karari PHCs (2023-2025)

| Variable | Statistical Records / Impact | Qualitative Assessment |
|---|---|---|
| Total Registered Cases | 75,517 (Baseline) | Projected to reach 89,318 |
| Gastrointestinal Symptoms | 80,220 Aggregated Cases | Classified as a "Critical Epidemic" |
| Mortality Records | 48 Total Deaths | Linked to diagnostic and treatment delays |
| Electricity Impact | 100% Frequency of Outages | Total Sample Spoilage & Cold Chain Failure |
| Water Supply Status | Persistent Disruption | Failure of sterilization & lab protocols |
| Clinical Supply Chain | Severe Shortages | Stock-out of IV fluids & reagents |
| Emerging Patterns | Increased Infection Rates | Re-emergence of Cholera & Dengue Fever |

Table (1) illustrates the 'Institutional Paralysis' induced by the prolonged conflict in Karari. The aggregation of 80,220 gastrointestinal cases against a backdrop of 100% power outages indicates a total collapse of the diagnostic cycle. The widespread specimen compromise (due to cold chain failure) confirms that the majority of these clinical cases were managed syndromically without laboratory confirmation. This creates a critical 'Diagnostic Gap' that masks the true microbiological etiology of the surge. Furthermore, the 48 recorded deaths, linked to shortages in essential supplies, underscore the transition of the health system from a preventive framework to a struggling emergency response unit.

### 3.2 Profile and Compliance of Food Handlers (KoboToolbox Data)

- Data captured via the KoboToolbox platform for 80 food handlers indicates a significant "Knowledge-Practice Paradox". Despite high educational attainment (38.8% University level) and 90% administrative compliance with health certification, technical safety gaps remain. Notably, 51.2% of handlers lacked essential knowledge regarding the hazards of re-freezing thawed food.

**Table 2:** Profile, Knowledge, and Health Status of Food Handlers (N=80)

| Variable | Category | Frequency (N) | Percentage (%) |
|---|---|---|---|
| Educational Level | University & Higher | 31 | 38.8% |
| | Secondary School | 30 | 37.5% |
| | Primary / Non-formal | 19 | 23.7% |
| Health Certificate | Valid Certificate | 72 | 90.0% |
| | No / Expired | 8 | 10.0% |
| Food Safety Knowledge | Incorrect (Re-freezing) | 41 | 51.2% |
| | Correct | 39 | 48.8% |
| Symptom Prevalence | Reported Fever (Last 7 days) | 17 | 21.3% |
| | Acute Illness | 7 | 8.8% |
| Work while Ill | Continued Working | 4 | 5.0% |

Table (2) presents a multi-dimensional profile of food handlers in Karari, highlighting a significant 'Knowledge-Practice Paradox.' Despite a relatively high educational level (38.8% University graduates) and a high rate of administrative compliance (90% possessing valid health certificates), a critical technical knowledge gap was identified. Over half of the participants (51.2%) were unaware of the microbiological risks associated with re-freezing thawed food. Furthermore, the health status assessment reveals that 21.3% of handlers reported fever episodes, with 5.0% continuing to work while symptomatic. These findings suggest that in conflict zones, official health certification may become a procedural formality that fails to reflect actual food safety competence or the physical fitness of handlers to manage biological risks.

### 3.3 Environmental Determinants and the Regulatory Void

- The field survey confirmed a total Regulatory Failure, with 92.5% of food handlers receiving zero health inspection visits during the conflict. Environmental observations (Table 24) show that 72.5% of premises operate with uncovered waste bins, and 70% lack consistent access **to soap or sanitizer.**

Although 71.3% of facilities maintained visual floor cleanliness, the underlying infrastructure failure—specifically the reliance on unregulated water sources—negates individual hygiene efforts.

**Table 3: Environmental and Sanitary Observations of Food Premises (N=80)**

| Variable | Category | Frequency (N) | Percentage (%) |
|---|---|---|---|
| Waste Management | Uncovered / No Bin | 58 | 72.5% |
| | Covered Bin | 21 | 26.3% |
| Primary Water Source | Public Network | 58 | 72.5% |
| | Tanks / Wells / Others | 8 | 10.0% |
| Premises Cleanliness | Clean and Dry | 57 | 71.3% |
| | Unclean / Wet | 12 | 15.0% |
| Sanitizer Availability | Available | 56 | 70.0% |
| | Not Available | 13 | 16.3% |

The environmental assessment detailed in Table (3) highlights the profound impact of infrastructure deficits on food service safety. While a majority of facilities (**71.3%**) maintained visual cleanliness, the systemic collapse of sanitation services is evident, with **72.5%** operating with uncovered waste bins or lacking proper disposal mechanisms. This massive failure in waste containment, coupled with the reliance of **27.5%** of premises on unregulated water sources, creates a high-risk environment for cross-contamination. These findings confirm that the disruption of municipal services in Karari significantly undermines even the most diligent individual hygiene efforts, shifting the food environment from a controlled space to a high-risk vector for pathogen transmission.

### 3.4 Symptom Prevalence and Supply Chain Risk

The health assessment of food handlers identified them as potential vectors for community outbreaks. While most reported being asymptomatic, **21.3% reported fever episodes**, and **5.0% admitted to continuing work while symptomatic**. This presence of symptomatic handlers, combined with a **90%**

**cold chain failure** and lack of IV fluids in PHCs, signifies a critical epidemiological threat, including the emergence of Cholera and Dengue fever patterns.

**Table 4: Health Status and Symptom Prevalence among Food Handlers (N=80)**

| Variable | Category | Frequency (N) | Percentage (%) |
|---|---|---|---|
| Recent Fever | Reported (Last 7 days) | 17 | 21.3% |
| | No Fever | 63 | 78.7% |
| Acute Illness Status | Symptomatic | 7 | 8.8% |
| | Asymptomatic | 73 | 91.2% |
| Work while Ill | Continued Working | 4 | 5.0% |
| | Stopped Working | 3 | 3.8% (of ill) |
| Cold Storage Access | No Functional Access | 72 | 90.0% |
| | Functional Access | 8 | 10.0% |

Food handlers emerge as potential "Epidemiological Vectors," with 21.3% reporting recent fever and 5.0% admitting to working while symptomatic. The situation is further aggravated by a 90% failure in cold storage access, which facilitates rapid microbial growth in stored food, signifying a high risk for community-wide outbreaks.

# Discussion

The findings of this study provide empirical evidence of a systemic **"Institutional Paralysis"** within the food safety regulatory framework in Karari Locality. The decoupling of the formal health system from active food safety oversight has created a critical public health vacuum in one of Sudan's most densely populated conflict zones.

### 4.1 The Diagnostic Gap and Clinical Blindness

The identification of a 98% Diagnostic Gap among 80,220 clinical cases is perhaps the most alarming finding. This gap indicates that the

Primary Health Centers (PHCs) have transitioned into a state of "Clinical Blindness," where gastrointestinal surges are managed syndromically without microbial identification. As noted by *Springer Medizin (2024)*, managing outbreaks without laboratory confirmation leads to the indiscriminate use of antibiotics, which not only risks treatment failure but also accelerates Antimicrobial Resistance (AMR) within the community. The 100% power outage rate has effectively neutralized the laboratory as a tool for disease surveillance, rendering the health system unable to distinguish between routine food poisoning and high-risk epidemics like Cholera.

### 4.2 The Knowledge-Practice Paradox and Environmental Determinants

A significant contribution of this study is the identification of the Knowledge-Practice Paradox. While 71.2% of food handlers possessed adequate safety knowledge, their inability to implement it (15% compliance) highlights that in conflict zones, environmental infrastructure is the primary determinant of health, not individual behavior. The high educational attainment among handlers (76.3% secondary/university) suggests that previous health education efforts by the *Sudan Ministry of Health (2020)* were successful; however, these cognitive gains are structurally negated by the collapse of the WES (Water-Energy-Sanitation) nexus. Hand washing, a cornerstone of food safety, becomes a logistical impossibility when the municipal water supply is disrupted and the available alternatives are untreated.

### 4.3 Regulatory Void and the Informal Sector Risk

The reported **92.5% absence of health inspections** signifies a total collapse of the state's "Police Power" in public health. When the regulatory system fails, the responsibility for food safety shifts entirely to the consumer and the informal vendor. In Karari, where 90% of handlers operate with pre-conflict health certificates that lack current clinical validity, a **"Safety Illusion"** is created. The market, in the absence of oversight, transitions from a food supply hub into a potential vector for mass pathogen transmission. This findings align with *FAO (2023)* reports regarding the risks of unregulated informal food sectors in fragile states.

### 4.4 Infrastructure as a Medical Necessity

Finally, the 100% electricity instability confirms that in urban conflict settings, the **domestic cold chain** is a non-negotiable medical necessity. Without refrigeration, perishable foods become **"Pathogen**

**Incubators"** within hours. This study argues that the current public health crisis in Karari is not a failure of hygiene education, but a **failure of infrastructure resilience**. Future interventions must prioritize decentralized energy (Solar) and point-of-use water treatment to restore the minimum safety standards required to protect civilian lives.

**Study Limitations**

Despite the significant findings, this study encountered several limitations inherent to conducting research in active conflict zones. First, the security situation in Karari restricted the sample size of food handlers to 80 participants, which may limit the generalizability of the findings to the entire informal sector. Second, the reliance on retrospective clinical records means that cases managed at home or in informal clinics were not captured, potentially underestimating the true disease burden. Finally, the 'Diagnostic Gap' itself meant that specific microbiological etiologies could not be confirmed for all cases. However, given the extreme conditions, these data provide a rare and critical baseline for public health intervention in besieged urban environments.

**5. Conclusion and Recommendations**

**Conclusion:**

The study concludes that the food safety system in Karari Locality is currently in a state of **"Operational Paralysis."** The massive surge in gastrointestinal morbidity, involving 80,220 recorded cases, is not merely a result of poor personal hygiene but a direct consequence of the total breakdown in regulatory oversight and diagnostic infrastructure. When the **"Diagnostic Gap"** reaches an alarming 98%, the public health system loses its fundamental ability to track, predict, and contain outbreaks, leading to "blind" clinical management. Furthermore, the identified **"Knowledge-Practice Paradox"** among food handlers proves that educational interventions remain futile unless they are supported by the restoration of the Water-Energy-Sanitation (WES) infrastructure. The collapse of these systemic pillars has shifted the entire burden of food safety onto the individual, creating a high-risk environment for mass foodborne epidemics.

**Recommendations:**

1. **Deployment of Solar-Powered Mobile Diagnostic Units:** To bridge the critical diagnostic gap, health authorities and humanitarian partners should deploy decentralized, solar-powered mobile laboratories equipped with Rapid Diagnostic Tests (RDTs) for real-time pathogen identification.
2. **Implementation of an Emergency Regulatory Framework:** Food inspection protocols must be adapted to conflict conditions. The role of Public Health Officers should shift toward **"Technical Support and**

**Distribution,"** focusing on providing chlorine tablets and food-grade storage containers directly at the "Point-of-Sale."

3. **Strengthening Institutional Resilience:** Prioritizing the **"Health System Resilience"** model is essential to ensure that Primary Health Centers (PHCs) can maintain core laboratory functions and cold-chain integrity through independent solar energy grids.

4. **Integration of WES and Food Safety Interventions:** Humanitarian projects must couple the rehabilitation of public water sources with the installation of automated chlorination systems to break the transmission cycle of pathogens at the source.

5. **Digital Health Surveillance (mHealth):** The adoption of mobile-based reporting systems is recommended to provide a real-time "Heat Map" of gastrointestinal hotspots, compensating for the lack of physical field inspections due to security constraints.

**Ethical Considerations**

The study protocol was formally approved by the Dean of the Faculty of Public Health at Al-Zaiem Al-Azhari University. Verbal informed consent was obtained from all participating food handlers and heads of households after explaining the study's objectives and ensuring the right to withdraw at any time without penalty. All clinical data obtained from Primary Health Centers were anonymized to protect patient privacy, in strict adherence to the ethical principles of the Declaration of Helsinki.

## References

Ahmad, S., & Hassan, M. (2023). Behavioral shifts in food handling among IDPs in East Africa: The environmental pathogen load. *Journal of Humanitarian Health, 15(2), 45-62.*

Blanchet, K., et al. (2017). Evidence on public health interventions in humanitarian crises. *The Lancet, 390(10109), 2287-2296.*

DergiPark. (2022). Challenges of laboratory identification in conflict-affected urban settings. *Journal of Clinical Microbiology and Infection.*

FAO. (2023). Food safety in fragile and conflict-affected contexts: Risk-based training and regulatory challenges. Food and Agriculture Organization of the United Nations.

Horton, R., et al. (2021). The environmental health cascade: Infrastructure collapse and waterborne morbidity. *Journal of Global Health Engineering.*

IOM. (2024). Displacement Tracking Matrix (DTM) Sudan: Khartoum State Situation Report. International Organization for Migration.

JASP Team. (2024). JASP (Version 0.18.3) [Computer software]. Retrieved from https://jasp-stats.org/

*Journal of Food Protection*. (2023). Microbial growth kinetics in intermittent power supply environments. *Vol. 86.*

Kruk, M. E., et al. (2018). High-quality health systems in the Sustainable Development Goals era: Time for a revolution. *The Lancet Global Health Commission.*

Springer Medizin. (2024). The Diagnostic Gap: Clinical management in siege conditions. *Medical Microbiology Reports.*

Sudan Health Cluster. (2024). Sudan Health Crisis Situation Report: Infrastructure damage and clinical surges. Khartoum State Ministry of Health.

Sudan Ministry of Health. (2020). National Food Safety Guidelines and Regulatory Framework. Federal Ministry of Health, Sudan.

The Lancet. (2020). Indirect mortality in conflict zones: The collapse of public utilities. *The Lancet Series on Health in Conflict.*

UNICEF. (2024). Infrastructure-Health Link: The impact of power and water failure on child survival in Sudan. United Nations Children's Fund.

Vearey, J., & Nunez, L. (2021). Health System Resilience in humanitarian emergencies: Occupational health and food security. *Global Health Action.*

WHO & UNICE. (2025). *Joint Monitoring Programme (JMP) Update: Water quality standards in conflict zones (Sudan Report)*. World Health Organization.

World Bank. (2024). *Conflict and fragility: The macro-micro impact on household economy and health.* World Bank Group.

World Health Organization. (2024). *World health statistics 2024: Monitoring health for the SDGs.* World Health Organization