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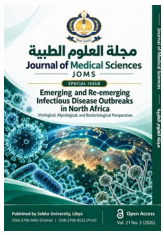

Infectious Disease Threats and Outbreak Preparedness in Southern Libya (Fezzan): A Narrative Review of Two Decades of Local Evidence

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A B S T R A C T

Southern Libya (Fezzan) lies on the main overland corridor between the Sahel and the Mediterranean, yet its infectious disease evidence is scattered across small local studies that are rarely read together. This narrative review assembles locally generated evidence published between 2005 and 2026, drawn mainly from the Journal of Medical Sciences of Sebha University and allied Libyan journals, and reads it as a preparedness question: what can the south currently detect, and what would it miss? Five bodies of work anchor the synthesis: malaria diagnosis at Sebha Medical Centre and among migrant workers, house flies as mechanical carriers of intestinal protozoa, opportunistic fungi in hospital dust, the haematological and hepatic effects of smoking among men in Brack, and microscopy-based diagnosis of bacterial vaginosis. Together they describe a region receptive to malaria reintroduction, now that *Anopheles stephensi* has reached Sudanese states bordering Libya and southern Niger; enteric transmission sustained by environmental pathways; critical-care units whose dust and surfaces carry *Aspergillus*, non-albicans *Candida*, *Burkholderia cepacia* complex and metallo-β-lactamase producers; and a heavily smoking male population whose raised inflammatory and hepatic markers may influence both severity and the reading of routine results. Diagnosis throughout rests on microscopy, rapid antigen tests and biochemical identification, which detect common pathogens adequately but cannot resolve species, resistance mechanism, strain relatedness or place of acquisition, the data an outbreak investigation needs first. The review closes by matching each priority question to the laboratory capacity Sebha already has, so that useful studies can begin before molecular platforms arrive.

التهديدات المعدية والجاهزية لمواجهة الفاشيات في جنوب ليبيا (فزان): مراجعة سردية لعقدين من الأدلة المحلية

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الملخص

تقع منطقة فزان في جنوب ليبيا على الممر البري الرئيس بين الساحل الإفريقي والبحر المتوسط، غير أن الأدلة المتعلقة بالأمراض المعدية فيها موزعة على دراسات محلية صغيرة قلّما تُقرأ مجتمعة. تجمع هذه المراجعة السردية الأدلة المنشورة محلياً بين عامي 2005 و2026، ومعظمها من مجلة العلوم الطبية بجامعة سبها والمجلات الليبية المناظرة، وتقرؤها من زاوية الجاهزية: ما الذي يستطيع الجنوب اكتشافه حالياً، وما الذي قد يفوته؟ ترتكز المراجعة على خمسة محاور: تشخيص الملاريا في مركز سبها الطبي وبين العمالة الوافدة، والذباب المنزلي ناقلاً آلياً للأوالي المعوية، والفطريات الانتهازية في غبار المستشفى، والتأثيرات الدموية والكبدية للتدخين لدى رجال مدينة براك، والتشخيص المجهري لالتهاب المهبل البكتيري. وتكشف القراءة المجتمعة لهذه المحاور منطقةً قابلة لعودة سراية الملاريا بعد رصد البعوضة الغازية Anopheles stephensi في ولايات سودانية متاخمة لليبيا وفي جنوب النيجر، وسرايةً معوية تدعمها مسارات بيئية، ووحداتٍ للعناية الحرجة يحمل غبارها وأسطحها فطريات Aspergillus وأنواع Candida غير البيضاء ومعقد Burkholderia cepacia وبكتيريا منتجة لإنزيمات الميتالو-بيتا-لاكتاماز، إضافة إلى شريحة واسعة من الرجال المدخنين ترتفع لديهم المؤشرات الالتهابية والكبدية بما قد يؤثر في شدة المرض وفي تفسير الفحوص المخبرية الروتينية. ويعتمد التشخيص في جميع هذه المحاور على المجهر والاختبارات السريعة والتعريف الكيموحيوي، وهي وسائل تكشف المسببات الشائعة لكنها لا تحدد النوع ولا آلية المقاومة ولا القرابة بين السلالات ولا مكان اكتساب العدوى. وتختتم المراجعة بربط كل سؤال ذي أولوية بالإمكانات المخبرية المتاحة فعلاً في سبها، بحيث يمكن البدء بدراسات مفيدة قبل وصول المنصات الجزيئية.

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1. Introduction

Outbreak preparedness in arid and thinly populated regions depends less on the number of hospital beds than on the ability to notice an unusual signal early, confirm it in a laboratory and trace where it came from. Diagnostics are the weakest link in that chain across low- and middle-income settings, and primary care is where the shortfall is greatest [1]. In North Africa, several infections described as emerging were present long before laboratories looked for them, so that outbreaks often surface late through travel surveillance abroad, single-hospital studies or reference laboratories rather than through routine national reporting [2].

Fezzan, the south-western region of Libya, makes this problem concrete. Sebha is its largest city, and the oasis towns of Brack and the Wadi Al-Shati valley, Ubari, Murzuq, Ghat and Al-Qatrun are spread across a desert that borders Niger, Chad and Algeria. The region is the first stop for people travelling north from the Sahel and the Horn of Africa towards the coast [3]. Its history includes epidemic malaria carried along caravan routes [4] and freshwater snail hosts of schistosomiasis recorded in Ghat [5]. In 2020 Sebha was the first part of Libya where the COVID-19 epidemic became prominent [6]. The public health system has meanwhile been weakened by more than a decade of instability: the national service availability and readiness assessment found 17% of hospitals and 20.1% of primary health care facilities closed, and identified diagnostics and essential medicines as the domains in greatest need [7].

Researchers at Sebha University, Sebha Medical Centre and neighbouring institutions have nonetheless produced a steady body of local evidence. Their methods reflect the laboratories available to them: Giemsa-stained blood films and rapid diagnostic tests for malaria, saline and iodine preparations of stool and of washings from flies, culture of settled dust from hospital wards, biochemical comparisons of smokers and non-smokers, and wet-smear and Gram-stain microscopy of vaginal discharge [4,8-11]. Much of this work appeared in regional journals, part of it only recently assigned DOIs, and it is seldom cited alongside the international literature on the same organisms.

Each of these studies answers a narrow prevalence question, and none was designed to ask what the region could detect if an outbreak began tomorrow. Read side by side, however, they describe the same system from different angles: who arrives and what they carry, which insects and environmental reservoirs move pathogens, which hosts are likely to become severely ill, and which laboratories would have to recognise the event. This review aims to synthesise two decades of local evidence from Fezzan into an account of infectious disease threats and detection capacity in the region, and to set out the priority studies that the laboratory resources now present in the south are sufficient to deliver.

2. Approach to the literature

This is a narrative review rather than a systematic one, chosen because the local evidence base is small, methodologically heterogeneous and largely published outside the major indexing databases. The archive of the Journal of Medical Sciences of Sebha University (JOMS), including back issues from 2009 to 2013 that were recently registered with Crossref, and the Sebha University Journal of Pure and Applied Sciences were searched issue by issue. PubMed, Google Scholar, OpenAlex and Crossref were searched with place names (Sebha or Sabha, Fezzan, Brack or Brak, Wadi Al-Shati, Ubari, Murzuq, Ghat, Al-Qatrun, Ghudduwah) combined with malaria, *Anopheles*, parasites, flies, fungi, nosocomial, resistance, hepatitis, tuberculosis, smoking and vaginosis. The window ran from January 2005 to November 2026; older work was retained when it explained present-day receptivity, such as historical vector surveys. Studies were eligible when they reported primary data collected in southern Libya or from populations moving through it. Libyan studies from other regions, and regional or international studies, were used to supply comparison, mechanism and context. Each cited record was checked against its publisher page or Crossref entry. Two limitations shape what follows. National surveillance reports are rarely public, so some events, such as the 2015 malaria cases in Wadi Al-Shati, are known only through secondary accounts. Several local studies also contain internal numerical inconsistencies between text and tables; these are noted where they affect interpretation. Ethical approval was not required, because the review draws only on published literature and publicly available reports.

3. Vector-borne threats: malaria at the edge of reintroduction

3.1. What the southern case series show

Libya recorded its last indigenous malaria case in 1973, and malaria diagnosed in the country since then has been classified as imported [12]. The largest hospital series from the south was collected at Sebha Medical Centre between November 2012 and February 2015. Of 220 patients with suspected malaria, 43 were positive by an immunochromatographic test confirmed on thick and thin Giemsa films; 39 infections were *Plasmodium falciparum* and 4 *P. vivax*, and 35 of the positive patients lived in Sebha city [4]. The finding that has received least attention is that 41 of the 43 positive patients were Libyan nationals. Travel histories were not recorded, so the series cannot show whether these were Libyans infected while travelling south or something that should have triggered a case investigation. That single missing variable is the most consequential weakness in

the southern malaria record.

Surveys of migrant workers give a different picture of the same problem. Among 135 asymptomatic expatriate workers tested in Sebha in February and March 2020, 20 (14.8%) were positive by rapid diagnostic test [13]. A larger survey of 363 expatriate workers found 141 positives (38.8%), with the highest rates among workers from Chad and Niger [12,14]. In centres for irregular migrants in Brack Al-Shati, Sebha and Bergen, 195 of 303 people tested positive, most of them within ten months of arrival and most originating from Ghana, Niger and Bangladesh [15]. These figures need careful reading. Histidine-rich protein 2 can remain detectable for weeks after successful treatment, and antibody-based tests record past exposure rather than current infection [12]. They therefore describe the exposure load entering the region more reliably than the size of the infectious reservoir (Table 1).

Table 1. Malaria testing in southern Libya and the nearest documented non-imported events, 2012–2026

Study	Setting and period	Population (n)	Test	Positive	What the design cannot establish
Hamid et al. [4]	Sebha Medical Centre, Nov 2012–Feb 2015	Patients with suspected malaria (220)	ICT (Pf/Pv) confirmed by Giemsa films	43 (19.5%); 39 *P. falciparum*, 4 *P. vivax*; 41 Libyan nationals	Travel history; imported versus locally acquired
Alhaddad and El-Salem [13]	Sebha health care centre, Feb–Mar 2020	Asymptomatic expatriate workers (135)	RDT	20 (14.8%)	Current versus recent infection; species confirmation
Al-Haddad and Elsalem [14]	Sebha city	Expatriate workers (363)	RDT (Pf/Pan antigen)	141 (38.8%); highest among workers from Chad and Niger	Antigen persistence after treatment; no microscopy or PCR confirmation
Mahanay et al. [15]	Migrant centres in Brack Al-Shati, Sebha and Bergen	Irregular migrants (303)	Antibody-based test	195 (64.4%); most within 10 months of arrival	Past exposure only; infectious reservoir unknown
Wadi Al-Shati event [12]	Al-Disa, 2015	Two Libyan residents without foreign travel	Not published	2 cases	Investigation unpublished; classed as probable introduced
Alarbi et al. [16]	Benghazi (northern comparator), 2024	Family cluster	Microscopy; entomology	4 *P. falciparum*, 1 death; no *Anopheles* trapped	Shows what a complete investigation can establish

ICT, immunochromatographic test; RDT, rapid diagnostic test; Pf, *Plasmodium falciparum*; Pv, *P. vivax*; PCR, polymerase chain reaction.

Table 1 shows positivity rising as the population tested moves from febrile hospital patients to asymptomatic workers and then to irregular migrants, while the diagnostic specificity falls in the same direction, because the highest figures come from tests that cannot confirm current parasitaemia. No southern study has reported species-level polymerase chain reaction (PCR), gametocyte carriage or a structured travel itinerary. The south has repeatedly demonstrated that parasites arrive frequently; it has never shown whether arriving parasites reach local mosquitoes.

3.2. Receptivity and the *Anopheles stephensi* frontier

Fezzan has never lost its malaria vectors. *An. sergentii* and *An. multicolor*, the two species that critical reappraisal identified as relevant to Libyan transmission, persist in oasis habitats [12,17], and serological work in the 1980s documented past exposure in the population [18]. Two events show what happens when cases arise without travel. In 2015 two Libyans in Al-Disa, Wadi Al-Shati, were diagnosed with malaria without having travelled abroad; female *Anopheles* were reported locally, but the investigation was never published and the episode remains classed as probable introduced malaria [12]. In 2024 a cluster of four *P. falciparum* infections, one fatal, near Benina airport in Benghazi was investigated in full; light-trap collections found no *Anopheles*, and the cluster was attributed to airport malaria [16]. The contrast is instructive: the northern event was characterised and published within two years, whereas the southern one is known only from secondary reports.

The arrival of *An. stephensi* changes the meaning of receptivity. This Asian vector was first recorded in Africa in Djibouti in 2012 [19]. In Sudan it has been confirmed across the country, including states bordering Libya, Chad and Egypt [20], and in 2025 it was detected in rural southern Niger, resting indoors alongside *An. coluzzii*, *An. gambiae* and *An. arabiensis* [21]. Unlike the native desert anophelines, it breeds in artificial containers, tolerates high temperatures and thrives in towns; habitat modelling suggests that more than 126 million urban Africans could be exposed if it spreads [22]. Water tanks, cisterns and construction sites in the oasis towns of Fezzan are exactly the habitats WHO lists as surveillance priorities [23]. The Sahara has acted as a barrier mainly because native vectors are sparse and short-lived in desert conditions. A container-breeding urban vector removes part of that barrier. The 2007 outbreak at Tinzaouatine in southern Algeria, where 26 autochthonous *P. falciparum* cases occurred near the Malian border and *An. gambiae* larvae were found for the first time in the country, is the Saharan precedent [24]. No Libyan anopheline has yet been tested for *Plasmodium* infection or insecticide susceptibility [12].

3.3. Weaker signals: arboviruses and schistosomiasis

Other vector- and snail-borne signals are thinner but share a feature with malaria. *Aedes albopictus* has been present in the Maghreb and Libya for at least eight years, West Nile virus transmission is

documented in Libya, and dengue and chikungunya have not been reported as locally acquired, although reported case counts cannot separate low transmission from non-detection [25]. In Fezzan, *Bulinus* snails were identified in Ghat in 1957 and sporadic urinary schistosomiasis is still diagnosed in Sebha [5]. Each of these infections would be recognised in the south only if a clinician thought to request a specific test that few local laboratories can perform.

4. Enteric and parasitic infections and mechanical vectors

Community parasitology in Sebha has been measured with reasonable consistency. Of 1,526 stool samples examined at Sebha Central Laboratory during 2014, 14.8% contained intestinal protozoa; *Blastocystis hominis* accounted for 9.8%, *Entamoeba histolytica/E. dispar* for 3.1% and *Giardia lamblia* for 1.5% [26]. When culture was added to direct microscopy among 380 outpatients, *Blastocystis* prevalence rose to 22.1%, and infection was associated with gastrointestinal symptoms (35.3% versus 13.2%) [27]. Among 100 children with diarrhoea at Sebha Medical Centre, modified Ziehl-Neelsen staining detected *Cryptosporidium* oocysts in 10%, and in 21.9% of those aged one to five years [28].

The house-fly study placed this human data in an environmental frame. Flies were trapped in two districts of Sebha, Al-Mahdia and Al-Jadeed, washed in saline and examined microscopically. Protozoa were recovered from the external surfaces of 28 of 90 flies: *B. hominis* from 15.55%, *E. coli* from 8.88%, *E. histolytica/E. dispar* from 5.55%, and eggs of *Hymenolepis nana* from a single fly in Al-Mahdia [8]. This was the first Libyan study of parasites carried on flies. The spectrum on the insects mirrors the spectrum in human stools from the same city, with *Blastocystis* dominant and *E. histolytica/E. dispar* second in both. The concordance suggests a shared faecal and environmental pool, but without *Blastocystis* subtyping it cannot show that flies carry the strains that infect people. Microscopy also cannot separate pathogenic *E. histolytica* from commensal *E. dispar*, so every amoebiasis figure in these datasets should be read as an upper bound.

The bacterial side of fly carriage has not been studied in the south, although it has elsewhere in Libya. In Misurata, flies trapped in a hospital, in streets and at an abattoir carried multiple-antibiotic-resistant Enterobacteriaceae and methicillin-resistant *Staphylococcus aureus*, and hospital flies carried the most resistant isolates [29]. A systematic review has catalogued more than 130 pathogens on house flies, many of them resistant [30], and a controlled intervention among soldiers showed that fly control reduced the incidence of shigellosis [31]. Given the resistance documented inside Sebha Medical Centre, discussed below, flies are a plausible bridge between hospital and community that no southern study has yet sampled. Conditions favouring that bridge recur: the floods that struck Ghat in March 2026 coincided with collapsed infrastructure and delayed referrals [32], the kind of setting in which waste accumulates, fly breeding increases and diarrhoeal outbreaks tend to amplify.

5. Hospital environmental reservoirs and healthcare-associated infections

The study of fungi in hospital dust at Sebha Medical Centre remains the only systematic environmental mycology survey from a southern hospital. Fifty duplicate dust samples were collected from operating theatres, intensive care units and neonatal wards between March and June 2012, yielding 202 fungal colonies, of which 83.7% were moulds. The intensive care unit had the highest load (89 CFU/g, against 65 CFU/g in theatres and 48 CFU/g in neonatal wards). *Aspergillus* made up 52.47% of isolates, *Penicillium* 22.27% and *Candida* 16.3%, and 30 of 34 yeasts (88.24%) were non-albicans species; *Fusarium*, *Bipolaris*, *Curvularia* and *Exophiala* were recovered from all three units [9].

Three features make this finding more important than its modest design suggests. The highest loads were in the units holding the patients least able to tolerate exposure. Settled spores become airborne again during cleaning, renovation and the dust storms common in Fezzan; desert dust carries fungal and bacterial load over long distances [33], and investigations of nosocomial aspergillosis outbreaks repeatedly trace the source to construction and ventilation [34]. Fungi recovered from intensive care units and operating rooms in Assiut, Egypt, produced proteolytic enzymes and mycotoxins [35], so environmental isolates of this kind cannot be dismissed as harmless contaminants. The predominance of non-albicans *Candida* is also relevant, because reduced azole susceptibility is more frequent outside *C. albicans* and because *Candidozyma (Candida) auris*, a critical-priority pathogen [36], is misidentified by the biochemical systems used in most Libyan laboratories. Its absence from southern reports therefore cannot be read as absence from southern hospitals [2]. The limits are equally clear: counts per gram of dust are not airborne concentrations, the survey was not repeated, and no environmental isolate was compared with a clinical one.

Bacterial reservoirs in the same hospital have since been characterised with similar methods. Of 200 environmental and clinical swabs from three Sebha facilities, 47 yielded *Burkholderia cepacia* complex, 40 of them from Sebha Medical Centre; nine species were distinguished, led by *B. cepacia* (29.8%) and *B. cenocepacia* (23.4%), and 89% of isolates formed biofilm [37]. In the intensive care unit, 456 swabs from surfaces, air, equipment, staff hands, shoe covers and nasal sites yielded 36 Gram-negative bacilli, all multidrug resistant, and 11 produced metallo-β-lactamase by

EDTA double-disc synergy [38]. At national level, a meta-analysis of 62 studies and 31,439 isolates estimated that Fezzan had the steepest rise in resistance and the highest antimicrobial-resistance-attributable disability-adjusted life-year rate by 2024, while noting that surveillance coverage reached near-national scope only in 2021 to 2024 [39].

Healthcare can also amplify bloodborne infection. In Ghudduwah, a village south of Sebha, a 2018 serosurvey of 352 residents found hepatitis B surface antigen in 2.8% and anti-HCV antibodies in 22.4%, with HCV associated with dental treatment, blood transfusion and wet cupping [40]. The national survey of 2008 had estimated HCV prevalence at 1.2% [41]. A village prevalence close to twenty times the national figure, tied to dental care and transfusion, points to procedures rather than community behaviour as the main route, and it is consistent with the weak infection-control environment documented in the hospital studies (Table 2).

Table 2. Healthcare and environmental reservoir evidence from Sebha and the south

Study	Setting and period	Samples	Methods	Main findings	Main limitation
Al Tayyar [9]	Sebha Medical Centre theatres, ICU, neonatal wards; Mar–Jun 2012	50 duplicate dust samples	Fungal culture, morphology, germ-tube test	202 colonies; *Aspergillus* 52.5%; ICU 89 CFU/g; 88.2% of yeasts non-albicans	No air sampling; no clinical matching
Shamsi et al. [37]	Sebha Medical Centre and two other facilities	200 swabs	Selective media, biochemical tests, USP <60> scheme	47 *B. cepacia* complex isolates (40 from Sebha Medical Centre); nine species; 89% biofilm-forming	Phenotypic species assignment; no typing
Alrbee et al. [38]	Sebha Medical Centre ICU; Feb–Apr 2017	456 swabs (surfaces, air, equipment, hands, nasal)	Culture, API 20E, EDTA double-disc synergy	36 MDR Gram-negative bacilli; 11 MBL producers	No carbapenemase genes identified
Khalaf et al. [40]	Ghudduwah village; 2018	352 residents	Serology	HBsAg 2.8%; anti-HCV 22.4%; HCV linked to dental care, transfusion, wet cupping	Cross-sectional; timing of exposures unknown
Bleiblo et al. [39]	National meta-analysis, 1970–2024	62 studies; 31,439 isolates	Pooled estimates and projections	Fezzan: steepest rise in resistance and highest AMR-attributable DALY rate by 2024	Southern surveillance coverage began late

ICU, intensive care unit; MDR, multidrug resistant; MBL, metallo-β-lactamase; AMR, antimicrobial resistance; DALY, disability-adjusted life-year; USP, United States Pharmacopeia.

The studies in Table 2 share a design and therefore share a blind spot. All are cross-sectional snapshots, all used phenotypic identification, and none linked an environmental isolate to a patient isolate or repeated sampling over time. Together they show that Sebha Medical Centre has harboured fungal, *Burkholderia* and carbapenemase-producing reservoirs across 2012 to 2017, but they do not yet show how often those reservoirs produce infections.

6. Host factors that shape severity

Brack, the main town of Wadi Al-Shati, has produced the clearest local data on smoking. In a comparison of 50 male smokers and 50 non-smoking male controls, alkaline phosphatase, aspartate aminotransferase and alanine aminotransferase were all significantly higher in the smokers, as were mean corpuscular volume and the leucocyte count, and alanine aminotransferase was higher still among men who had smoked for more than ten years [10]. An earlier study of 200 men in the same region found that C-reactive protein and leucocyte counts rose with daily cigarette consumption and years of smoking [42]. Both studies are small, unadjusted and confined to one area, so the magnitudes need confirmation in larger samples; the direction of effect, however, matches the international literature.

Smoking is common enough in Libya for these effects to matter at population level. Half of Libyan men (49.6%) smoked in the 2009 national risk-factor survey [43], and more than 40% of respondents identified as smokers in the 2022 to 2023 survey [44]. Smoking impairs mucociliary clearance and macrophage function, raises the risk of tuberculosis [45] and of bacterial and viral respiratory infection more broadly [46], and was associated with progression of COVID-19 [47]. Waterpipe use adds an exposure route of its own, because shared mouthpieces, hoses and water reservoirs can carry microorganisms between users [48]. Diabetes, also common in Libya, independently raises the risk of active tuberculosis [49] and of infection in general [50].

The Brack data carry a second implication that is easily overlooked. If smokers in the south carry higher baseline leucocyte counts and transaminase levels, then a mildly raised count or enzyme level in a febrile smoker is less informative for malaria, viral hepatitis or early sepsis than the same result in a non-smoker. Southern laboratories report against reference intervals derived elsewhere, and no smoker-stratified local intervals exist. During an outbreak, when triage relies heavily on simple blood tests, this matters.

Two epidemics show how host vulnerability and weak detection interact. When COVID-19 reached Sebha, the first two cases were confirmed on 26 May 2020 and 407 had been reported by 7 July, by which time the city was the epicentre of the national outbreak [6,51]. For tuberculosis, the Sebha sub-centre was among the five that together reported 86.8% of national pulmonary cases in an earlier period, and treatment success was lower among immigrants than

among Libyans (48.6% versus 68.1%) [52]. Between 2015 and 2024, however, the south had the lowest notification rates in Libya, with low-rate clusters in Ghat and Wadi Al-Hayaa [53]. Low notification in a region with high mobility, heavy smoking and limited diagnostics is more plausibly a sign of under-ascertainment than of low incidence, a hypothesis that a modest prevalence study could test.

7. Laboratory capacity in the south: what microscopy can and cannot see

Bacterial vaginosis offers a clean test of what a microscopy-based laboratory can achieve. In the study published in JOMS in 2010, 300 symptomatic women attending a gynaecology clinic were assessed by Amsel's clinical criteria, which combine discharge appearance, the whiff test and clue cells on a saline wet smear, and by Nugent scoring of a Gram-stained smear [11,54,55]. Prevalence by Gram stain was 25.1%. Against the Gram stain, Amsel's criteria had a sensitivity of 67.8% and a specificity of 97.7%, and vaginal douching was strongly associated with infection [11]. It remains the JOMS benchmark for the microscopy repertoire on which southern laboratories rely. In Brack, direct microscopy of 234 vaginal swabs detected *Candida* in 13.7% and *Trichomonas vaginalis* in 5.6% of married women [56], and a 2026 study from Tripoli again identified douching as the dominant risk factor [57]. Bacterial vaginosis is more than a nuisance diagnosis: it is associated with increased risk of HIV acquisition [58].

The lesson extends well beyond gynaecology. A carefully read Gram stain reaches near-reference performance for a syndromic diagnosis at almost no cost, whereas a wet-smear-only approach misses roughly one case in three. The same pattern holds across the threats reviewed here. Immunochromatography with Giemsa films detects malaria [4]; modified Ziehl-Neelsen staining detects *Cryptosporidium* [28]; selective media and biochemical keys assign isolates to the *B. cepacia* complex [37]; EDTA synergy flags metallo-β-lactamase production [38]. Each method gives a dependable answer about the presence of a common target, and each stops short of species, genotype, resistance mechanism or relatedness (Table 3).

Table 3. Diagnostic methods used in the reviewed southern studies and the information they cannot provide

Target	Method used	What it resolves	What it cannot resolve	Minimum feasible upgrade
Malaria [4,13]	RDT or ICT; Giemsa thick and thin films	Presence; *P. falciparum* versus other species; parasite density	Mixed species; *hrp2/hrp3* deletions; gametocytes; place of acquisition	Travel and residence form; dried blood spots for reference PCR
Intestinal protozoa [8,26]	Saline and iodine smears; formalin-ether concentration	Morphological identification	*E. histolytica* versus *E. dispar*; *Blastocystis* subtype	Antigen ELISA; reference PCR on a stored subset
Cryptosporidium [28]	Modified Ziehl-Neelsen	Oocyst detection	Species (*C. hominis* or *C. parvum*); zoonotic source	Antigen test; referral of positives
Bacterial vaginosis [11,56]	Wet smear, whiff test, Gram stain (Nugent)	Syndromic diagnosis; Nugent close to reference	Specific anaerobes; recurrence; resistance	Inter-laboratory Nugent quality assurance
Hospital fungi [9]	Culture; germ-tube test	Genus; *C. albicans* versus non-albicans	Species; *C. auris*; azole resistance	Chromogenic agar; referral identification and susceptibility testing
Gram-negative bacteria [37,38]	Biochemical keys, API 20E, disc diffusion, EDTA synergy	MDR phenotype; MBL presence; *B. cepacia* complex membership	Carbapenemase gene; clonal relatedness; *Burkholderia* species by sequence	Lateral-flow carbapenemase test; referral sequencing of clusters

RDT, rapid diagnostic test; ICT, immunochromatographic test; PCR, polymerase chain reaction; ELISA, enzyme-linked immunosorbent assay; MDR, multidrug resistant; MBL, metallo-β-lactamase.

Table 3 locates the region's diagnostic ceiling precisely. Southern laboratories are competent at detection and limited at characterisation, and outbreak investigation begins with characterisation: is this the same organism in several patients, where was it acquired, and which mechanism makes it resistant? The constraint is systemic. Primary care facilities nationally reached a general readiness score of only 45% [7], and a 2026 field report from Ghat described chronic diagnostic shortages, no serial electrolyte monitoring, no intensive care and critical referral delays after floods [32]. Under these conditions an outbreak in Fezzan is more likely to be recognised through deaths, clusters noticed by clinicians or samples sent abroad than through laboratory surveillance, which is the pattern described for North Africa as a whole [2].

8. Reading the evidence together

The five bodies of work reviewed here were produced independently, yet they fit a single sequence of exposure, amplification, host susceptibility and detection (Figure 1). Mobility along the Sahel corridor introduces *Plasmodium*, and probably hepatitis viruses and resistant bacteria, at a rate that local surveys have measured repeatedly [14,15,40]. Vectors and the environment then carry or sustain pathogens: native anophelines persist, an invasive urban vector is approaching from two directions, and flies and dust move protozoa and fungi through towns and hospitals [8,9,20,21]. Hospitals and procedures amplify what arrives, as shown by fungal, *Burkholderia* and metallo-β-lactamase reservoirs in one referral hospital and by a village HCV prevalence linked to dental care [37,38,40]. Host factors, above all heavy smoking, shape who

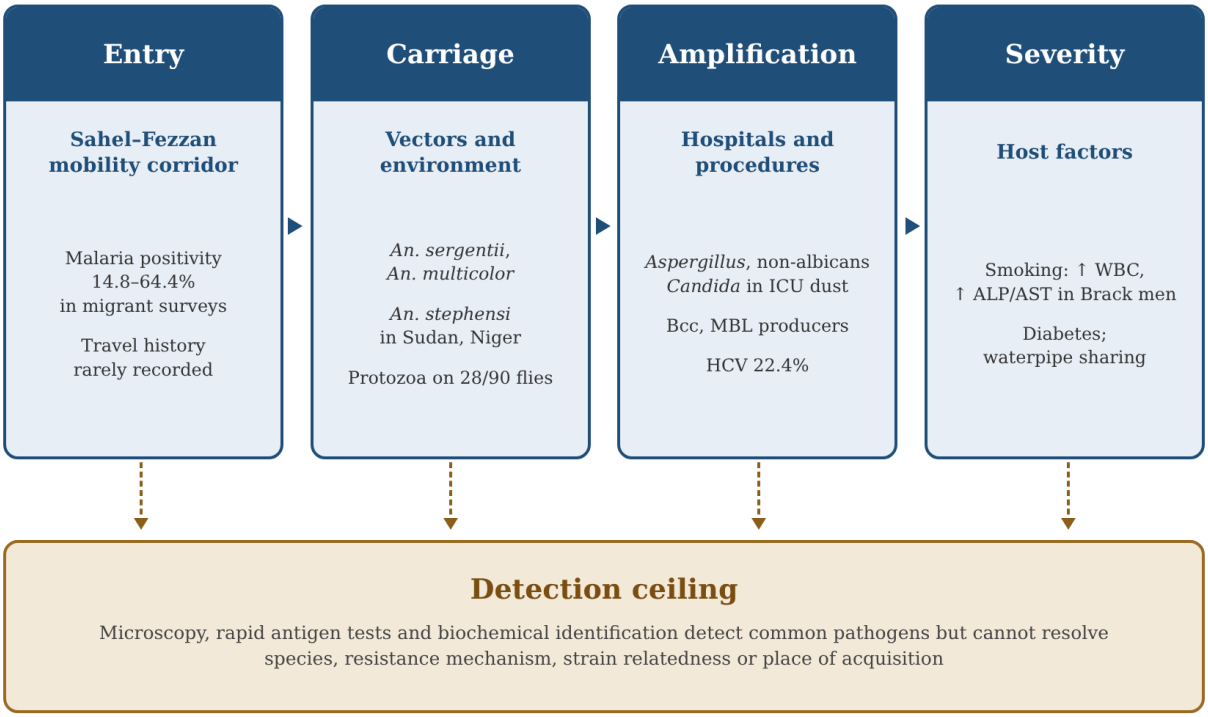

Fig. 1. Framework linking the reviewed evidence from Fezzan. Mobility introduces pathogens, vectors and the environment carry and sustain them, healthcare procedures amplify them and host factors shape severity; all four layers sit above a detection ceiling set by microscopy, rapid tests and biochemical identification. Evidence cited in each layer is drawn from local studies reviewed in the text.

becomes severely ill and blur the laboratory signals used in triage [10,42].

Running beneath all four layers is the detection ceiling set out above, and this is where the synthesis leads. Every exposure pathway in Figure 1 has been documented at least once in Fezzan, but none has been followed long enough, or characterised finely enough, to provide the baseline against which an outbreak could be recognised. The evidence is also geographically concentrated: most of it comes from Sebha city and from a single hospital, with Brack the only other town contributing several studies, and Ubari, Murzuq, Ghat and Al-Qatrun almost absent from the peer-reviewed record. For the south, the binding constraint on preparedness is therefore the detection layer and the distribution of research effort, rather than any single pathogen.

Two features give this synthesis its weight, and two restrict it. It is the first account to read the southern Libyan evidence as one body of work, and it rests on an issue-by-issue search of journal archives that are only now acquiring persistent identifiers, with every record checked against its publisher page or Crossref entry. Against that, a narrative method applies no formal appraisal of bias and pools nothing quantitatively, so the prevalence figures reported here should be read as individual study results rather than regional estimates. The primary studies are also mostly small, cross-sectional and single-centre, and several carry numerical inconsistencies between text and tables. The assessment of detection capacity is drawn from the methods these studies describe rather than from a facility survey, which would be the natural next measurement.

9. Priority studies the south can carry out now

The priorities below are organised by what each study requires, because the most common reason local research stalls is that the question chosen needs equipment the laboratory does not have. Research laboratories in Sebha often lack PCR, electrophoresis or even an autoclave, but they do have microscopes, incubators, culture media, rapid tests and trained staff. Several high-value questions can be answered with exactly those resources, provided that samples are stored for later referral and that study designs record the variables earlier studies omitted (Table 4).

Table 4. Priority questions for Fezzan matched to current laboratory capacity

Priority question	Suggested design	Feasible with current southern capacity	Partner required	Builds on
Are malaria cases in Libyan nationals imported or locally acquired?	Prospective case series at Sebha Medical Centre with a standard travel and residence form and dried blood spots	Yes	Reference PCR for species and genotype	[4,12]
Has *An. stephensi* reached Fezzan oasis towns?	Larval surveys of tanks, cisterns and construction sites in Sebha, Ubari, Murzuq, Al-Qatrun and Ghat	Yes (collection and morphology)	COI sequencing of a subset	[20,21]
Do flies link hospital and community resistance?	Paired fly sampling at markets, abattoir and hospital; bacterial culture and susceptibility testing	Yes	None for the core study	[8,29]
Which *Entamoeba* species and *Blastocystis* subtypes circulate in people and flies?	Stored subset of human and fly samples	Sample collection only	Reference PCR	[26,27]
Does airborne fungal load in critical care follow dust storms, and does it match clinical isolates?	Monthly settle plates in ICU and theatres for one year; species identification of clinical moulds and yeasts	Settle plates and culture	Species identification and antifungal susceptibility	[9]
What is the burden of healthcare-associated infection and which carbapenemases circulate?	Point-prevalence survey with lateral-flow carbapenemase testing	Partly	Gene confirmation	[38,39]
Do smokers in Wadi Al-Shati have more or more severe respiratory infections?	Prospective cohort; smoking-stratified reference intervals	Yes	None	[10,42]
How consistent is vaginal-smear microscopy across southern laboratories?	Blinded slide exchange with Nugent scoring	Yes	None	[11,56]
Is low tuberculosis notification in the south under-ascertainment?	Audit of presumptive tuberculosis at primary care with molecular testing at referral	Partly	Molecular testing	[52,53]
Does dental care or cupping transmit HCV in southern villages?	Repeat serosurvey with infection-control audit of clinics	Serology	HCV RNA confirmation	[40]

PCR, polymerase chain reaction; COI, cytochrome oxidase I; ICU, intensive care unit; HCV, hepatitis C virus.

The most urgent item is also the cheapest. Repeating the Sebha Medical Centre malaria design with a one-page travel and residence form, and storing a dried blood spot from every positive patient, would convert a prevalence series into evidence on importation versus local acquisition within a single transmission season [4]. Larval surveys of water tanks, cisterns and construction sites in Sebha, Ubari, Murzuq, Al-Qatrun and Ghat require only dippers, trays and a dissecting microscope; morphological identification of *An. stephensi* is straightforward, and a subset of specimens can be sent for cytochrome oxidase I sequencing [21,23]. The fly study can be carried forward by culturing bacteria from the same washings and testing their susceptibility, which would test directly whether flies connect the resistance seen in hospital wards with the community [8,29].

In the hospital, the dust survey should be repeated with monthly settle plates in intensive care units and theatres across a full dust-storm season and paired with species identification of clinical mould and yeast isolates, so that environmental and clinical data can be compared for the first time [9]. A point-prevalence survey of healthcare-associated infection in Sebha hospitals, combined with lateral-flow carbapenemase detection, would cost little and would place the reservoir studies in a clinical frame [38,39]. In Wadi Al-Shati, the smoking studies can grow into a prospective cohort that records respiratory infections and hospital admissions, and into a reference-interval study stratified by smoking status [10,42]. Inter-laboratory quality assurance for Gram-stain reading, using blinded slides circulated among southern laboratories, would strengthen every microscopy-based diagnosis in the region at negligible cost [11,55].

Some questions cannot be answered without partners. Differentiating *E. histolytica* from *E. dispar*, subtyping *Blastocystis*, sequencing carbapenemase genes and genotyping *Plasmodium* all require a reference laboratory, which could be national or regional. Testing whether the low tuberculosis notification rates in the south reflect under-ascertainment requires access to molecular testing at referral level [53]. The obstacles are practical: unstable electricity and reagent supply, staff migration, insecurity on roads between towns, and ethical safeguards for research involving migrants held in detention, whose consent and confidentiality need particular protection. A further obstacle is visibility. Much of the evidence reviewed here appeared in local journals that are only now being indexed; publishing future southern studies with complete methods, open data and structured reporting would allow them to enter regional syntheses and to be cited where decisions are made.

10. Conclusions

Two decades of local research show that southern Libya is receptive to malaria reintroduction, sustains enteric transmission through environmental pathways, harbours fungal and multidrug-resistant bacterial reservoirs in its main referral hospital, and has a heavily

smoking male population whose baseline laboratory values differ from those assumed in routine reference intervals. The invasive vector *An. stephensi* is now recorded in neighbouring Sudan and Niger. What the evidence does not yet show is how often these threats produce disease, because southern laboratories can detect common pathogens but cannot characterise them. Preparedness in Fezzan will improve fastest by recording travel and residence for every notifiable infection, storing samples for referral, extending surveillance beyond Sebha, and choosing research questions that current laboratories can answer now.

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Declarations

Author contributions: F.A.A.: Conceptualization, Methodology, Investigation (literature search and screening of malaria, vector and enteric parasite sources), Data curation (Tables 1 and 3), Visualization (Fig. 1), Writing – original draft (Abstract, sections 1 to 4 and 9, Conclusions), Project administration. G.F.M.: Conceptualization, Methodology, Investigation (literature search and screening of hospital environment, smoking and laboratory diagnosis sources), Data curation (Tables 2 and 4), Writing – original draft (sections 5 to 8), Validation (reference checking against publisher records and Crossref). Both authors contributed equally to the work, and both reviewed, edited and approved the final manuscript.

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