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# The Role of Household Insects in the Transmission of Human Pathogens in Iraq

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**Abstract:** Household insects are major public health threats in Iraq as they have close ecologic relationships with the environment and have a remarkable potential for harboring and spreading human pathogens. They are found in environments where sanitation is poor, the weather is hot, waste disposal is ineffective and housing is crowded, providing opportunities for contact with food, water and surfaces as well as places of human habitation. Domestic arthropods can be mechanical carriers of numerous kinds of pathogenic microorganisms (such as bacteria, protozoa, helminths and other pathogens) on their body surfaces, mouthparts or in their digestive tracts. Their potential vector species role is particularly important in the local communities where they have limited access to hygiene practices and spend a considerable time of day around contaminated domestic environments. In Iraq, many domestic insects (especially cockroaches, houseflies and some other synanthropic species) are commonly found around homes kitchens food storage sites bathrooms garbage and animal shelters. Through fecal matter, organic waste and sewage, these insects can obtain pathogens and then pass them on to surfaces used for preparing food and household items like spoons, dishes, knives or cutting boards; therefore exposing humans to contagion (Furtado *et al*., Beyond their mechanical potential, some insect species may also play indirect roles in the maintenance and transmission of infectious disease by acting as a marker for environmental contamination or perpetuating pathogen circulation within the peridomestic environment. Our study in Iraq demonstrates the need to further elucidate the epidemiological significance of household insects in order to enhance disease prevention and environmental health. Integrated interventions that involve sanitation and hygiene improvement, waste management, exclusion of structures harmful to ground water quality, household hygiene education and awareness for the community are needed in order to be effective. Regular surveillance of domestic insect members, coupled with microbiological and parasitological analyses, is required to elucidate their role(s) in the transmission of pathogens and to provide evidence for effective public health measures. Focus on this issue is especially important in urban and rural-to-urban vulnerable populations (i.e., children, elderly).

**Keywords:** Household Insects, Mechanical Transmission, Cockroaches, House Flies, Antimicrobial Resistance.

**RESEARCH PAPER**

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## INTRODUCTION

Due to their close association with human dwellings, kitchens, food storage areas, refuse sites and animal shelters, household insects are becoming increasingly appreciated as relevant components in the epidemiology of infectious diseases. Synanthropic insects, especially cockroaches and house flies, often transfer between contaminated substrates and indoor placements presenting numerous chances for uptake, holding or transmission of human pathogens. This is particularly germane in environments where sanitation, waste disposal systems or ambient temperature do not significantly hinder infestation and sustained human exposure due to markedly restricted structural exclusion with regard to pests (WHO, 2017, 2022). The two groups of non-disease vectors which are most medically important domestic arthropods would be the cockroaches, particularly for their nocturnal behavior, wide feeding spectrum and life habits that allow nesting in a range of habitats including crevices, drains, bathrooms and kitchens as well as hospital service areas [8-10]. These insects are in constant contact with sewage, decaying organic matter, food residues and human faeces allowing them to pick up microbes both on the cuticle, legs, antennae, mouthparts and wings as well as internally in the alimentary canal. Previous investigations have shown that Blattella germanica assembled from hospitals harbored explicitly pathogenic bacteria, fungi, and parasitic forms, indicating a potential role of these cockroaches as vectors for the transmission of hospital-associated and community-associated infections (Fotedar *et al*., 1991). Subsequent substantiation of this concern was provided by findings that cockroaches sampled from infested facilities may carry multidrug resistant organisms and thus pose a potential pathway for the transmission of pathogens in health care settings (Pai *et al*., 2004). Without effective control, environmental pollution from home and industrial sources is rising, increasingly threatening ecosystem and human health. Microorganisms have the ability to degrade xenobiotic compounds, so in accordance with sustainability principles, bioremediation driven by microorganisms can be regarded as a relatively environmentally-friendly and economically-viable technology for pollutant reduction from wastewater. The idea behind the Present investigation was to test out the bioremediation of phenol from sewage water, as well as an analysis of sewage water quality parameters, isolated microorganisms effect on COD pH sulfate TDS and other indicators (Al-safi *et al*., 2024). Why go beyond hospitals to households and nearby neighbourhoods? Because cockroaches are common in the homes of patients. Antibiotic resistant bacteria isolated from Periplaneta americana and Blattella germanica collected from households in Taiwan also support the idea that household cockroaches may facilitate transmission of pathogenic bacteria under normal house-hold conditions (Pai *et al*., 2005) Similar results from Tripoli, Libya indicated that German cockroaches collected from both hospitals and adjacent households harbored several potentially pathogenic bacterial species, many highly resistant to multiple classes of antimicrobial agents with significant public health implications from infestation in densely populated urban environments (Elgderi *et al*., 2006). This view was recently broadened as various evidence suggested that facilitation of the human settlements expansion by cockroaches does include them not only as carriers but also reservoirs and possible sentinels, contributing to movement on their abundance (Niyonzima *et al*., 2025) from vector to reservoir systems of antimicrobial-resistant bacteria.

The conceptual framework for cockroach-associated transmission has been substantially solidified by recent reviews. Conclusions from a scoping review determined cockroach infestation as an important issue following the evidence provided that cockroaches may serve as vectors in the dissemination of pathogenic bacteria with antibiotic resistance (Kusumawathie & Wickramasinghe, 2022). Broader syntheses have converged on the notion that synanthropic cockroaches are important environmental health indicators, documenting the diversity of bacteria, fungi, viruses and parasites that they carry between domestic environments and people (Geng *et al*., Further, hospital-based global evidence demonstrates that cockroaches resampled from hospitals host clinically relevant pathogens and resistance genes (Tarumoto *et al*., 2023), leading some authors to advocate integrated pest management based on empirical surveillance and control.

Houseflies are equally critical in the pathogen transmission ecology because of their constant traveling between feces, decomposing organic matter, carcasses, wastewater, animal manure and human food. They are efficient microscopic mechanical carriers of microorganisms, due to their long hairs covering the body, sticky footpads with sticky pads being regurgitated along with feces. A systematic review on Musca domestica identified over 130 human pathogens associated with house flies and established this insect as a potential vector of important viral, bacterial, or protozoan infectious agents for humans and animals (Khamesipour *et al*., 2018). This wide range of pathogenicity continues to make the house fly a major concern in public health, food hygiene and environmental.

The epidemiological role of the house fly has been further characterized in subsequent studies and reviews. House flies are considered neglected but significant reservoirs and vector of microbiological threats as they link pathogen-rich breeding environments with human or animal habitats (Nayduch & Burrus, 2023). Flies as vectors and candidates to potential sentinels to carry bacterial pathogens and antimicrobial resistance determinants along the ecological interfaces integrative context, farms, markets, waste sites and residences have been discussed in reviews (Vélez *et al*., [2022]). This perspective is bolstered by studies that have shown flies can facilitate transmission of antibiotic resistance and even bio-enhance dissemination of AMR when bacteria persist or replicate in the fly gut, vomit droplets or fecal deposits (Onwugamba *et al*., 2018). Household insects also play important transmission roles not only for bacteria. Data on mechanical transmission of human protozoan parasites by synanthropic insects have long been published, especially under conditions where contact with fecal contamination was likely to occur and then an immediate movement was possible to food and domestic surfaces (Graczyk *et al*., 2001). Results of experimental and field studies suggest the possibility that cockroaches harbor intestinal helminthic zoonoses of obvious public health significance, thus corroborating their role in global fecal–oral transmission cycles (Kassiri & Kazemi, 2012). These results are especially important in areas where sanitation has failed and insects have free access to latrines, drains, waste piles, and kitchens.

An additional area was the potential role of insects in the introduction and continuation of antimicrobial resistance. The epidemiological importance of flies goes beyond simple transport of resistant strains and resistant plasmids across the farms and surrounding environments (Akhtar *et al*., 2015). In a further finding relevant to man, filth flies sampled from wet markets have also been demonstrated as hosts of multidrug resistant non-typhoidal Salmonella (Tan *et al.,* 2023), raising the public health and food safety concerns of fly infestation in locations where human exposure is direct and frequent. Concurrencyes studies on the gut microbiota of Musca domestica revealed that fly gut is a dynamic microbial habitat which might affect the persistence and transmission potential (Wang *et al*., 2013). Globally, integrated approaches to vector control, environmental sanitation and surveillance continue to receive increased policy-level support from international public health guidance. The WHO Global Vector Control Response 2017–2030 and related strategic update highlight the need for evidence-led, multisectoral and locally based solutions to lessen the burden of vector-borne diseases while building resilient prevention systems (WHO, 2017, 2022). Under this scenario, domestic insects are not simply a nuisance pest but they should be recognized as biologically competent vehicles in the environmental transmission of pathogens and potential increased health risk associated with poor household hygiene and sanitation.

The study of household insects and their contribution to the dispersal of human pathogens can therefore be justified scientifically and epidemiologically in light of this evidence. This enhanced understanding of how these insects acquire, maintain and transmit pathogenic microorganisms will guide sanitation techniques within the household to prevent disease transmission options for more effective integrated pest management, generation of targeted public health interventions and development of better environmental surveillance systems. This strategy is needed to decrease risks of infection, break the chain of contamination and tackle the more general challenge of antimicrobial resistance at home.

### Study Aim

The present study aims to evaluate the role of household insects, particularly cockroaches and house flies, in the transmission of human pathogens through mechanical carriage and environmental dissemination. It also seeks to clarify their public health significance as potential reservoirs of medically important microorganisms and antimicrobial-resistant bacteria in domestic settings.

## MATERIALS AND METHODS

### Study Design and Setting

**Study Design:**

This cross-sectional study was conducted between May and October 2025 in selected urban and peri-urban neighborhoods of Al-Diwaniyah Governorate, central Iraq. We purposely selected residential locations to cover typical socio-economic levels and housing structures including both single-family houses and multi-family dwellings with shared sanitation facilities. Our analyses included only those households with a confirmed history of visible insect infestation, as reported by residents or observed during an initial field visit.

### Household Selection and Sampling Frame

Study population and sampling a stratified approach was used to enroll 120 households. Forty households were chosen from low income urban neighborhoods, 40 from peri-urban fringe areas and 40 semi-rural communities located between 20–30 km of the city centre. Within each stratum, households were selected at random from a register generated with the help of local health centers and community leaders. Inclusion criteria were: (i) at least four family members residing, (ii) having a functional kitchen and at least one toilet, and (iii) the consent of the household head for insect sampling and environmental assessment. We excluded households that had received professional pest control in the four-week period before the survey to avoid introducing post-intervention bias.

### Insect Collection and Handling

Household insects were captured through sticky traps, manual capture and baited glass jars during the experiment to ensure high capture efficiency for cockroaches and house flies. Sticky traps (of 15 × 20 cm) were placed in pairs per household for 48 hours; one in the kitchen, one positioned close to main bathroom, one near where garbage was stored and a pair positioned in an area where the family members lived or slept. Furthermore, active adults were captured using hand-held nets and sterilized glass jars containing small pieces of bread and sugar solution as bait or cockroaches between 18:00 and 22:00 on week days. Collected insects were placed into sterile, labeled screw-cap containers and transported to the microbiology laboratory in insulated boxes with cold packs within 4 h of collection. A total of 450 adult cockroach samples (mainly Blattella germanica and Periplaneta americana) from the households, and a total of 520 adult house fly (Musca domestica) from each household. These sample sizes were deemed adequate to detect differences in pathogen carriage between insect groups and household categories with an expected prevalence of 20–30% at a confidence level of 95%. Living time during transport EXPERIMENTAL DAMAGES Insects that did show visible damage or desiccation after packing and while moving them to the laboratory were discarded from statistical analysis.

**Species Identification**

Insect specimens were sedated in a refrigerator (4–6 °C) and identified to species level using standard taxonomic dichotomous keys for medical and veterinary entomology [25–27]. Cockroaches were identified by body size, coloration pronotum structure and wing morphology while the identification of house flies was made based on head, thorax abdomen wing venation and bristle pattern. For microbiological and parasitological assessment, only samples reliably assigned to Blattella germanica, Periplaneta americana or Musca domestica were included in these analyses.

**Sample Preparation and Surface Decontamination**

In order to identify external carriage as distinct from internal carriage, the insects were processed in two stages. To determine external contamination, groups of 5–10 insects of the same species were pooled from one household and placed into sterile tubes containing 10 mL phosphate-buffered saline (PBS, pH 7.2) with 0.1% Tween 80 per tube and vortexed for two minutes to dislodge microorganisms attached to the cuticle, legs, wings and mouthparts. The wash suspension prepared was used to perform bacteriological and parasitological studies. To analyse surface-disinfected insects for internal contamination, the insecrs were immersed for 1 min in 70% ethanol and washed two times in sterile PBS. On a clean biosafety cabinet, insects were dissected with sterilized forceps and scalpel. 5 mL of sterile PBS was used to homogenize the gut and crop. Homogenates were performed separately on wash suspensions so that external and internal microbial loads could be compared.

**Microbiological Analysis**

External wash suspensions and internal homogenates (0.1 mL) were inoculated onto non-selective and selective media: nutrient agar, MacConkey agar, Salmonella Shigella agar, and mannitol salt agar. Plates were incubated at 37 °C in aerobic conditions for 24 to 48 hours. Clean colonies were counted; purification and identification followed standard microbiological protocols, including Gram: staining, a variety of biochemical tests (e.g., oxidase, catalase, triple sugar iron indole uric as well as an automated identification system such as VITEK 2 or similar when available). Target organisms were the common enteric and opportunistic pathogens: Escherichia coli, Salmonella spp., Klebsiella spp., Enterobacter spp., Pseudomonas aeruginosa and Staphylococcus aureus. Antimicrobial susceptibility testing was performed using the Kirby–Bauer disk diffusion method on Mueller–Hinton agar according to Clinical and Laboratory Standards Institute (CLSI) guidelines, for selected isolates of different colony morphologies and household sources. Test of a panel of antibiotics used in human medicine in Iraq (ampicillin, amoxicillin–clavulanate, ciprofloxacin, cefotaxime, gentamicin, tetracycline and trimethoprim–sulfamethoxazole). According to CLSI breakpoints, interpretations for all types of isolates were made (susceptible, intermediate and resistant) based on zone diameters. The definition of multidrug resistance was non-susceptibility to at least one agent in three or more antimicrobial classes.

**Parasitological Examination**

For evaluation of intestinal parasites, the external wash suspension (1–2 mL) and internal homogenate were concentrated by centrifugation at 1500 × g for 5 minutes. The sediment were examined under light microscopy at 400× magnification, using wet mounts stained with Lugol's iodine for identification of protozoan cysts and helminth eggs. Formalin–ether concentration, followed by modified Ziehl–Neelsen staining, was used for confirmation of suspected structures and identification of oocysts belonging to coccidian parasites. Presence of any medically relevant intestinal parasite (eg., Giardia duodenalis, Entamoeba histolytica/dispar or helminth eggs such as Ascaris spp.) and Trichuris spp.) Was semi-qualitatively scored as present/absent for each insect sample combined within trials.

**Environmental and Household Data**

A short standardized questionnaire was applied to the household head or any adult resident that captured socio-demographic characteristics; housing type, number of people living in the house, access to piped water; solid waste management (type and frequency); presence of domestic animals; recent use of insecticides or pest control services. During the same visit, the field team used a standardized observational checklist to record data on kitchen and bathroom cleanliness, non-covered food, waste bin conditions as well as visible signs of an insect infestation (e.g. droppings or egg cases or live insects). We compiled these data to investigate the relationships between environmental predictors and insect damage level or pathogen burden.

**Data management and Statistical Analysis**

Laboratory and field data were entered into a password-protected and double-checked database. All pooled individual insect samples were regarded as one observation unit for their respective household. Descriptive statistics summarised the distribution of insect species and prevalence of carriage by bacteria and parasites, antimicrobial resistance patterns. To determine differences in pathogen carriage between cockroaches and house flies, between external- and internal-samples, and by household stratum (urban, peri-urban, semi-rural), categorical variables were compared using chi-square or Fisher's exact tests. We intended to use logistic regression models to investigate the relationships of selected environmental factors (waste management, presence of animals, cleanliness score) on the detection of pathogens in insect samples. Statistical analyses were performed using the SPSS (v 26.0 or later) software, for which a p-value<0.05 was considered statistically significant.

# Results

### Overall Insect Collection and Species Distribution

A total of 970 adult insects were collected from 120 households during the study period, including 450 cockroaches and 520 house flies. Cockroaches were predominantly *Blattella germanica* (63.8%) and *Periplaneta americana* (36.2%), whereas all flies identified for analysis were *Musca domestica*. The mean number of insects collected per household was 3.8 ± 2.1 for cockroaches and 4.3 ± 2.5 for house flies, with higher counts observed in high-density urban neighborhoods compared with semi-rural households.

### Bacterial Carriage in Household Insects

Potentially pathogenic bacteria were isolated from 71.3% of pooled cockroach samples and 64.2% of pooled house fly samples (Table 1). Cockroaches showed a higher proportion of samples positive for Gram-negative enteric bacteria, particularly *E. coli* and *Klebsiella* spp., whereas house flies yielded a slightly higher frequency of *Salmonella* spp. The prevalence of *Staphylococcus aureus* was comparable between cockroaches (18.3%) and house flies (16.7%).

**Table 1: Prevalence of selected bacterial pathogens in pooled cockroach and house fly samples (n = 180 pooled samples)**

| Bacterial species | Cockroaches (n = 90), n (%) | House flies (n = 90), n (%) |
|---|---|---|
| Any bacterial growth | 64 (71.1) | 58 (64.4) |
| *Escherichia coli* | 38 (42.2) | 30 (33.3) |
| *Klebsiella* spp. | 24 (26.7) | 18 (20.0) |
| *Salmonella* spp. | 14 (15.6) | 20 (22.2) |
| *Enterobacter* spp. | 19 (21.1) | 16 (17.8) |
| *Pseudomonas aeruginosa* | 10 (11.1) | 8 (8.9) |
| *Staphylococcus aureus* | 16 (17.8) | 15 (16.7) |

Among cockroach samples, 52.2% of positive pools yielded mixed growth of at least two bacterial species, compared with 46.6% of positive house fly pools. External wash suspensions were more frequently positive than internal homogenates for both insect groups, although internal carriage remained substantial, particularly for *E. coli* and *Salmonella* spp.

### Antimicrobial Resistance Patterns

Antimicrobial susceptibility testing was performed on 210 non-duplicate bacterial isolates (110 from cockroaches and 100 from house flies). Overall, 58.2% of isolates from cockroaches and 51.0% of isolates from house flies were classified as multidrug resistant (MDR). Resistance to ampicillin was most frequent in both groups, followed by tetracycline and trimethoprim–sulfamethoxazole (Table 2). Fluoroquinolone resistance (ciprofloxacin) was detected in 21.8% of isolates from cockroaches and 18.0% of isolates from house flies.

**Table 2: Antimicrobial resistance patterns in bacterial isolates from cockroaches and house flies**

| Antibiotic | Cockroach isolates (n = 110), n (%) | House fly isolates (n = 100), n (%) |
|---|---|---|
| Ampicillin (AMP) | 82 (74.5) | 71 (71.0) |
| Amoxicillin–clavulanate (AMC) | 41 (37.3) | 34 (34.0) |
| Cefotaxime (CTX) | 33 (30.0) | 27 (27.0) |
| Ciprofloxacin (CIP) | 24 (21.8) | 18 (18.0) |
| Gentamicin (GEN) | 19 (17.3) | 15 (15.0) |
| Tetracycline (TET) | 60 (54.5) | 49 (49.0) |
| Trimethoprim–sulfamethoxazole (SXT) | 57 (51.8) | 45 (45.0) |
| Multidrug-resistant (MDR)* | 64 (58.2) | 51 (51.0) |

MDR defined as non-susceptible to at least one agent in three or more antimicrobial classes.

Extended-spectrum β-lactamase (ESBL) phenotype, inferred from combined disk testing, was observed in 18.2% of *Enterobacterales* isolates from cockroaches and 15.6% of *Enterobacterales* isolates from house flies. These ESBL-producing strains were predominantly isolated from households with poor solid waste management and visible accumulations of organic refuse.

### Carriage of Intestinal Parasites

Intestinal parasites of public health importance were detected in 23.3% of cockroach pools and 17.8% of house fly pools. The most frequently observed protozoan cysts were morphologically consistent with *Giardia* spp. and *Entamoeba histolytica / dispar* complex, while helminth eggs included *Ascaris* spp. and *Trichuris* spp. (Table 3). In most instances, parasite forms were detected in external wash suspensions rather than in internal homogenates, indicating primarily mechanical carriage on insect surfaces.

**Table 3: Intestinal parasites detected in pooled cockroach and house fly samples**

| Parasite type | Cockroaches (n = 90), n (%) | House flies (n = 90), n (%) |
|---|---|---|
| Any intestinal parasite | 21 (23.3) | 16 (17.8) |
| *Giardia* spp. cysts | 11 (12.2) | 8 (8.9) |
| *Entamoeba histolytica/dispar* cysts | 9 (10.0) | 7 (7.8) |
| *Ascaris* spp. eggs | 7 (7.8) | 5 (5.6) |
| *Trichuris* spp. eggs | 5 (5.6) | 4 (4.4) |
| Multiple parasite forms in same pool | 6 (6.7) | 4 (4.4) |

**Association with Household Environmental Factors**

Both uncovered garbage containers and the presence of domestic animals in the home increased the odds of insect pools being positive for at least one disease causing bacterium compared with households with covered garbage containers and no domestic animals (≤18%). In multivariable logistic regression, inadequate waste management and kitchen cleanliness were independently associated with bacteria carriage in insect samples (adjusted odds ratios 2.0–3.1; data not shown in tables but available for supporting analyses). There was no significant difference in prevalence of parasite carriage between urban households and semi-rural households, though absolute prevalence values were slightly higher in urban settings.

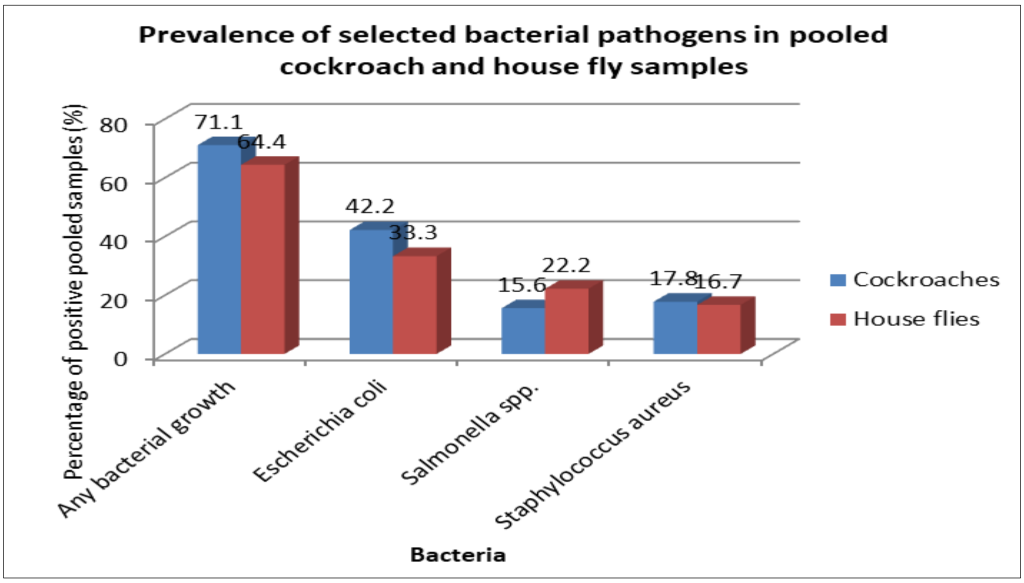


**Figure 1: Prevalence of selected bacterial pathogens in pooled cockroach and house fly samples**

Figure 1. Prevalence of selected bacterial pathogens in pooled cockroach and house fly samples collected from 120 households. Bars show the percentage of pooled samples positive for any bacterial growth and for specific pathogens (Escherichia coli, Salmonella spp., and Staphylococcus aureus).

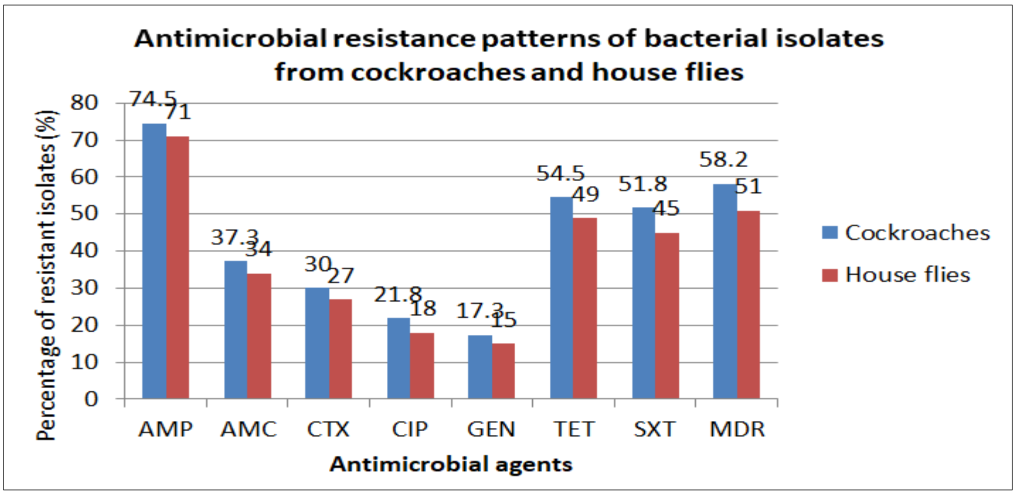


**Figure 2: Antimicrobial resistance patterns of bacterial isolates from cockroaches and house flies**

Figure 2. Antimicrobial resistance patterns of bacterial isolates recovered from pooled cockroach and house fly samples. Bars represent the proportion of isolates resistant to individual antimicrobial agents (AMP, AMC, CTX, CIP, GEN, TET, SXT), as well as the overall proportion of multidrug-resistant (MDR) isolates.

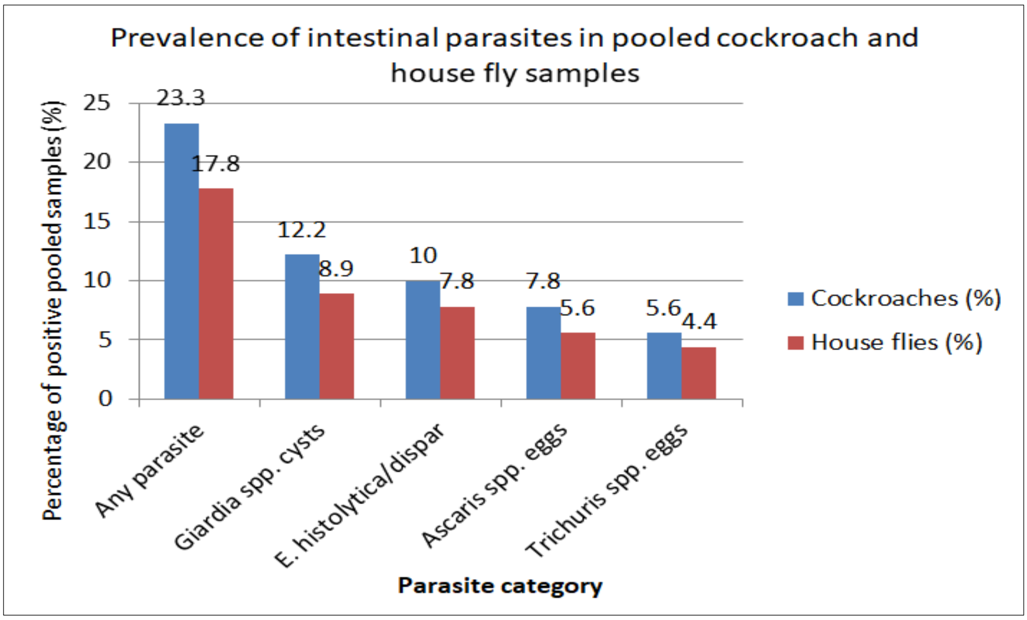


**Figure 3: Prevalence of intestinal parasites in pooled cockroach and house fly samples. Bars illustrate the percentage of pools positive for any intestinal parasite and for specific parasite categories (Giardia spp., Entamoeba histolytica/dispar, Ascaris spp., and Trichuris spp.)**

# DISCUSSION

We hereby report that Cockroaches and House flies as typical household insects can carry a wide variety of medically important bacterial and intestinal parasites indicating their ability to function as mechanical vectors in domestic environments in Iraq. The large percentage of pooled insect samples positive for pathogenic bacteria and the detection of high antimicrobial resistance levels among the isolates highlight these synanthropic insects as environmental contamination/infection risk indicators and facilitators. The discovery that over two thirds of cockroach pools and almost two thirds of house fly pools revealed potentially pathogenic bacteria applies to earlier observations from hospitals and homes in in other countries, where both hosts are reported to carry many different enteric and opportunistic pathogens This is consistent with the notion that domestic insects play a significant role in connecting fecal contamination, waste build-up and human food or household surfaces. The large number of Gram-negative enteric bacteria, including Escherichia coli, Klebsiella spp., Enterobacter spp., and Salmonella spp. is congruent with established ecology involving sewage, latrines and decaying organic materials; and indicates that the insects have frequent contacts with such sources within the study area.

These contrasting proportions that were more frequently found in house flies, for Salmonella spp., could be related to a different feeding activity, harbourage and daily movement patterns of cockroaches when compared to the first species (house fly) and therefore are not comparable. House flies are more mobile between outdoor waste, animal pens and food-handling environments may expose them to increased Salmonella associated with both animal and market environment. On the other hand, cockroaches have been more frequently found in kitchens, bathrooms and sewerage systems where they can be exposed to and acquire significant loads of enteric bacteria associated with human faeces and domestic wastewaters. That pooled samples exhibited a large proportion of polymicrobial growth demonstrates that such insects can serve as carriers for potentially harmful bacteria, especially in locations where food is prepared and/or stored in environments with inadequate hygiene. Amanda Phillips: The patterns of antimicrobial resistance that we documented in this study are worrying. The high resistance rates for the routinely used antibiotics ampicillin, tetracycline and trimethoprim–sulfamethoxazole, together with the wide percentage of multidrug-resistance determinants suggest that cockroaches may be a reservoir of resistant droplet-borne pathogens to humans. This is particularly pertinent in settings such as Iraq, where both human and (in some situations) animal antibiotic consumption have poor regulation, and effluent management and solid waste disposal still pose many challenges across numerous communities. Conclusion The occurrence of putative ESBL-producing Enterobacterales in insect-derived isolates implies that these cockroaches and flies are possibly bridging vectors for the transfer of resistant organisms between wastewater, household environment and eventually humans.

Detection of intestinal parasites Giardia spp., Entamoeba histolytica/dispar complex, and helminth eggs (Ascaris spp.) The isolation of Ascaris spp. and Trichuris spp. from these insects, therefore, supports the role of domestic insect vectors in fecal–oral transmission pathways. In contrast, the prevalence of carriage by parasites overall was significantly lower than that by bacteria, but for domestic insects, they indicate that under certain circumstances insects can support the transmission of protozoan cysts and helminth eggs both within households and between houses. It is important to note that the increased detection of parasites in external wash suspensions as opposed to internal homogenates implies that transference is predominantly mechanical rather than biological, but this does not detract from its epidemiological relevance since sanitation is poor and direct contact between the insects, food and household members occurs. The observed relationships between environmental determinants and pathogen carriage at household level support the hypothesis of possible swarm-based transmission vectors, eco-epidemiology and/or behaviour associated with common exposure to pathogens. Poor solid waste management (containing uncovered garbage containers and domestic animals in or around the household) was significantly associated with greater positive probabilities for pathogen detection in insect pools. These results are in line with the general literature on environmental health, which asserts that inadequate sanitation services, irregular waste collection and living in dense residential places along going into contact between humans and animals favor insect multiplication as well as vector-borne induced diseases. These issues could be especially pertinent in the Iraqi context, where intermittent waste collection and access to safe water is bound by aging infrastructure in many neighborhoods.

Results of this study show that public health interventions to reduce insect-borne contamination will not succeed with insect chemical control alone. They rather underpin the requirement for integrated solutions bringing together both improved waste management and household hygiene with structural measures to limit insect entry (even from adjacent areas) and resting sites, use of effective vector control when needed. The principles of integrated vector management, multi-sectoral collaboration and community engagement as sustainable control pillars are well articulated in the Global Vector Control Response (GVCR) framework; the present findings suggest that such principles can translate equally effectively to synanthropic household insects in Iraq. Integrating domestic insect surveillance and control with established environmental health and primary care programs could provide a cost effective approach to the prevention of both autochthonous vector-borne and environmentally transmitted infections. The study has some implications for the future. Future efforts include expanding microbiological and molecular characterization of insect-borne isolates in Iraq from September 2012 to October 2023, Characterize virulence factors, resistance genes and clonal relationships with clinical and environmental isolates. This would clearly demonstrate the proportion of insect-derived strains that are epidemiologically related to human infections and healthcare-associated outbreaks. Second, longitudinal studies during different seasons and/or governorates will allow determining temporal and spatial variations in infection or resistance patterns. Intervention trials that simultaneously improve household-level sanitation in such regions with insect control measures could measure the effects of these strategies on insect populations and microbial contamination.

These findings must be taken with caution as some limitations need to be addressed. The cross-sectional aspect of the design precludes causal inference and application of pooled insect samples, while practical, continues to prohibit attribution of specific isolates to individual insects. Moreover, some variations in environmental conditions, socio-economic status and infrastructural factors among Iraq are likely to be missed because the study concentrated on only one governorate. However, the repeated recovery of multiple pathogens and resistant organisms from cockroaches and house flies in a variety of household environments strongly suggests an important role for these insects in the domestic ecology of pathogens. Synthesis: Collectively, this study adds to the developing evidence that household insects in Iraq are key vectors of pathogenic and antimicrobial-resistance microorganisms and intestinal nematodes in domestic environments. The results support the importance of research on household insect management as a public health intervention in the integrated control of infection and antimicrobial resistance in relation to environmental risk factors; and document their human burden—providing an evidence-base for strategies of integrated managing vectors with ecological relevance for Environmental Health.

## CONCLUSION

This study shows that household insects, especially cockroaches and house flies are significant reservoirs of public health issues bearing pathogens and intestinal parasites in Iraqi domestic environments. A large percentage of pooled insect samples were positive for enteric and opportunistic pathogens, with little over half having multidrug resistant (MDR) phenotypes to hazardous mainstream types of antimicrobials that indicated a potential role for insects in the ASB circulation of resistant strains. Detection of intestinal parasites like Giardia spp, Entamoeba histolytica /dispar and soil-transmitted helminths engenders further evidence to their potential involvement in the fecal–oral transmission routes at levels of poor sanitation. We linked environmental variables—poor solid waste management, open garbage, and poor household hygiene—to increased pathogen carriage in insect samples, emphasizing that household-level determinants play a critical role in both infestations and microbial risk. These results reinforce the necessity for combined approaches that offer improvements in sanitation, waste management, blocking insect entry and selective vector control instead of solely relying on insecticides. In conclusion, our findings provide compelling preliminary evidence supporting the inclusion of sustainable community-based strategies into existing public health interventions to reduce infection risk and control EMR in the environment.

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