Journal of Epidemiology and Public Health (2024), 09(02): 145-155
Masters Program in Public Health, Universitas Sebelas Maret

Research
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The Prevalence and Distribution of Domiciliary Cockroaches in Rural Areas: A Cross-Sectional Study Design in Limpopo Province

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Received: 17 August 2023; Accepted: 6 November 2023; Available online: 16 April 2024

ABSTRACT

Background: Cockroach infestation raises health concerns in the communities. The study aimed to identify the type of cockroach species found in the rural parts and assess the distribution of cockroach species in the area.
Subjects and Method: A descriptive cross-sectional study was conducted in the households found in Ward 2 villages, Bolobedu and Limpopo Province in March 2021. A total of 120 households were selected using a multistage sampling strategy. Structured interviews were conducted to gather information about cockroach infestation in the households. The variables of interest in this study included the locations of cockroach sightings, pest control strategies used, and cockroach species trapped. A total of 1,186 cockroaches were trapped using a size 21×15 cm² sticky paper sheet. Data analysis was done using SPSS version 29.
Results: About 751 (64%) of cockroaches were trapped in the indoor environment and 427 (36%) in the outdoor environment. Three species of cockroaches were identified as *B. germanica, B. orientalis* and *P. americana* cockroach. Sixty-nine (66%) of the households used spray or aerosol as a control strategy to reduce the cockroach population.
Conclusion: Irrespective of the villages where the cockroaches were trapped, B. germanica was the most prevalent species across the villages. Effective control strategies are required to also reduce the likelihood of pesticide resistance as well as decrease the exposure of humans to pesticide residues.

Keywords: *Blattella germanica, Blatta orientalis, Periplaneta americana*, prevalence, distribution

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Cite this as:
Molewa ML, Barnard TG, Naicker N (2024). The prevalence and distribution of domiciliary cockroaches in rural areas: A cross-sectional study design in Limpopo Province. J Epidemiol Public Health. 09(02): 145-155. https://doi.org/10.26911/jepublichealth.2024.09.02.02.

BACKGROUND

Cockroaches are important pests that can potentially spread diseases and destroy essential products in a household. It is estimated that there are more than 3,000 species of cockroaches associated with human habitation globally. A high number of cockroach population in human dwellings

is rapidly growing every year. The main attributing factors include poor housing infrastructure, over-crowding, inadequate sanitation, poor waste management and insufficient dumpsites that encourage the breeding and spread of cockroaches (Pan and Zhang 2020; Debash et al., 2020).

A few species are associated with human habitation including the German cockroach (*Blattella germanica*), Oriental cockroach (*Blatta orientalis*), Turkestan cockroach (*Blatta lateralis*), American cockroach (*Periplaneta americana*) and Brown-banded cockroach (*Supella longipalpa*). However, *B. germanica, B. orientalis,* and *P. americana* are the most common species associated with health problems (Hughes, 1952; Shahraki et al., 2013; Prescott et al., 2002; Tatfeng et al., 2005). Atiokeng-Tatang et al., (2017) identified 6 genera of parasites prevalent on the internal and external surfaces of cockroaches. Their existence, unsanitary behavior and diet pose a threat to human health as they have been associated with pathogenic organisms responsible for illnesses that include gastrointestinal disorders (Hassan et al., 2021). The mode of disease transmission is done through mechanical transfer whereby pathogenic micro-organisms may be spread by cockroach regurgitation or faecal pellet deposition in human foodstuffs resulting in contamination which may lead to food poisoning (Hassan et al., 2021; Chaichanawongsaroj et al., 2004; Moges et al., 2016).

Despite nauseated discharges released from the mouths and glands opening from the cockroach body which gives an unpleasant odor, people are also found to be allergic to antigens and feces of cockroaches as they trigger asthmatic-related health disorders. Irrespective of the cockroach population level, smaller numbers of cockroaches can produce significant amounts of allergen. It is estimated that adult female B.germanica can produce 25,000 to 50,000 units in their lifespan (Moges et al., 2016). Even with intensive cleaning in the environment, the concentration of allergen or cockroach dust can remain for a period of more than 6 months (Gore and Schal, 2005; Tatfeng et al., 2005; Eggleston, 2003). Davies and Tatjana (1986) conducted a study in Toronto, Canada which reported that 89% of residents considered cockroaches as a health hazard. Furthermore, it was reported that the majority also considered them as a source of anxiety (Bonnefoy et al., 2008). Therefore, the study aimed to identify cockroach species found in the rural parts of Limpopo and to assess the prevalence as well as the distribution of cockroaches in the rural areas.

SUBJECTS AND METHOD

1. Study Design

A descriptive cross-sectional study was conducted in March 2021 in the rural villages in Ward 2 of Bolobedu. The area falls under the Greater Letaba Municipality in Limpopo Province which is situated in the far north parts of South Africa. Sanitary conditions in this village are almost underdeveloped. Many villagers rely on pit latrine toilets for faecal disposal and also rely on spring waters or communal taps. Due to the geographical area, the villagers lack access to waste removal and disposal services. The residents store and dispose of waste within their household vicinity.

2. Population and Sample

A probability sampling methodology using a multistage sampling design was used to sample 120 households in 6 villages namely Motsinoni, Makaba, Mohlakong, Moshakga, Ramphenyang, and Mokwasele village.

3. Study Variables

The study variable was domiciliary cockroaches trapped in different sampling villages.

4. Operational Definition of Variables

Cockroaches: are insects classified under the order Blattaria and are associated with human habitation.

5. Study Instruments

Variables were collected by questionnaire to obtain information about cockroach infestation in the households (e.g., the areas where cockroaches were spotted and the type of pest control strategies). Size 21x15cm² sticky paper sheet traps purchased commercially were used to trap the cockroaches. The sticky traps were labeled and trapping was done overnight immediately after the interviews.

No products or foodstuffs were coated on the sticky traps to attract the cockroaches. Traps were placed in any location where cockroaches were spotted for example, in the kitchen, toilets, bedroom, shelves, stoves, and tabletops. After trapping, the trapped cockroaches were counted and placed in labeled zipper bags, stored in a cooler box, and then transported to the University of Johannesburg laboratory for storage as well as for further analysis.

6. Data Analysis

The number of the counted cockroaches was captured on Microsoft Excel and then subsequently transferred to the Statistical Package for Social Sciences (SPSS), version 29 for data analysis. Data was presented using tables and bar graphs.

7. Research Ethics

Ethical clearance for the study was obtained from the University of Johannesburg: Faculty of Health Sciences Research Ethics Committee (HDC-01-105-2020). Participants gave written consent before participating in the study.

RESULTS

1. Questionnaires

Hundred and twenty (100%) participants were asked to indicate areas where cockroaches exist in their household. Seventy-three (23%) had cockroaches in the toilet area (outdoor), 65 (20%) bedroom area, 112 (35%) kitchen area, 51(16%) food storage/ containers and 11 (9%) had observed cockroaches in the water storages/containers. (Table 1).

Table 1. Areas where cockroaches were observed per village

Village	Variable	Frequency (n)	Percentage (%)
Motsinoni	Toilet (outdoor)	15	21.0
	Bedroom	15	23.0
	Kitchen	19	17.0
	Food storage /containers	10	16.0
	Water storage/ containers	1	9.0
Makaba	Toilet (outdoor)	15	21.0
	Bedroom	5	8.0
	Kitchen	20	18.0
	Food storage /containers	8	13.0
	Water storage/ containers	0	0.0
Mohlakong	Toilet (outdoor)	13	18.0
	Bedroom	14	22.0
	Kitchen	19	17.0
	Food storage /containers	19	31.0
	Water storage/ containers	2	18.0
Moshakga	Toilet (outdoor)	13	18.0
	Bedroom	13	20.0
	Kitchen	19	17.0
	Food storage /containers	15	24.0
	Water storage/ containers	3	27.0

Village	Variable	Frequency (n)	Percentage (%)
Ramphenyang	Toilet (outdoor)	10	13.0
	Bedroom	10	15.0
	Kitchen	18	16.0
	Food storage /containers	5	8.0
	Water storage/ containers	3	27.0
Mokwasele	Toilet (outdoor)	7	9.0
	Bedroom	8	12.0
	Kitchen	17	15.0
	Food storage /containers	5	8.0
	Water storage/ containers	2	18.0

Table 2 shows about 107 (89%) used pest control products in their household and 13 (11%) did not use pest control products. Participants who used pest control products were further asked a multiple-response question with a list of pest control products and were requested to select the products employed in their household. The response rate was 135 (100%). Out of 135 (100%) responses, 31 (23%) used powder products to control cockroaches in their household, 99 (73%) used spray products, 1 (1%) sticky traps, and 4 (3%) used paste products for pest control.

Table 2.Cockroach pest control products used by household per village

Village	Variable	Frequency (n)	Percentage (%)
Motsinoni	Powder	15	21.0
	Spray/aerosol	15	23.0
	Paste	19	17.0
	Traps	10	16.0
Makaba	Powder	15	21.0
	Spray/aerosol	5	8.0
	Paste	20	18.0
	Traps	8	13.0
Mohlakong	Powder	13	18.0
	Spray/aerosol	14	22.0
	Paste	19	17.0
	Traps	19	31.0
Moshakga	Powder	13	18.0
	Spray/aerosol	13	20.0
	Paste	19	17.0
	Traps	15	24.0
Ramphenyang	Powder	10	13.0
	Spray/aerosol	10	15.0
	Paste	18	16.0
	Traps	5	8.0
Mokwasele	Powder	7	9.0
	Spray/aerosol	8	12.0
	Paste	17	15.0
	Traps	5	8.0

2. Cockroach trapping

Table 3 shows a total of 1186 cockroaches were trapped overnight in 120 households that participated in the study. Seven hundred and fifty-nine (64%) cockroaches were trapped in the indoor environment and 427 (36%) were trapped in the outdoor environment. About 43(4%) of cockroaches were trapped in Motsinoni village, 269 (23%) were trapped in Makaba village, 215(18%) in Mohlakong village, 145 (12%) in Moshakga village, 244(20%) in Ramphenyang village and 275(23%) trapped in Mokwasele village.

Table 3. Distribution of indoor and outdoor trapped cockroaches per village

Village	Cockroaches trapped indoor		Cockroaches trapped outdoor	
	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)
Motsinoni	35	5.0	8	1.0
Makaba	236	31.0	33	8.0
Mohlakong	95	12.0	120	28.0
Moshakga	72	9.0	73	17.0
Ramphenyang	224	30.0	20	5.0
Mokwasele	99	13.0	176	41.0

Among the 1186 cockroaches trapped, 780 (66%) were *B. germanica*, 351 (29%) were *B. orientalis* and 55(5%) were *P. americana* (Figure 1).

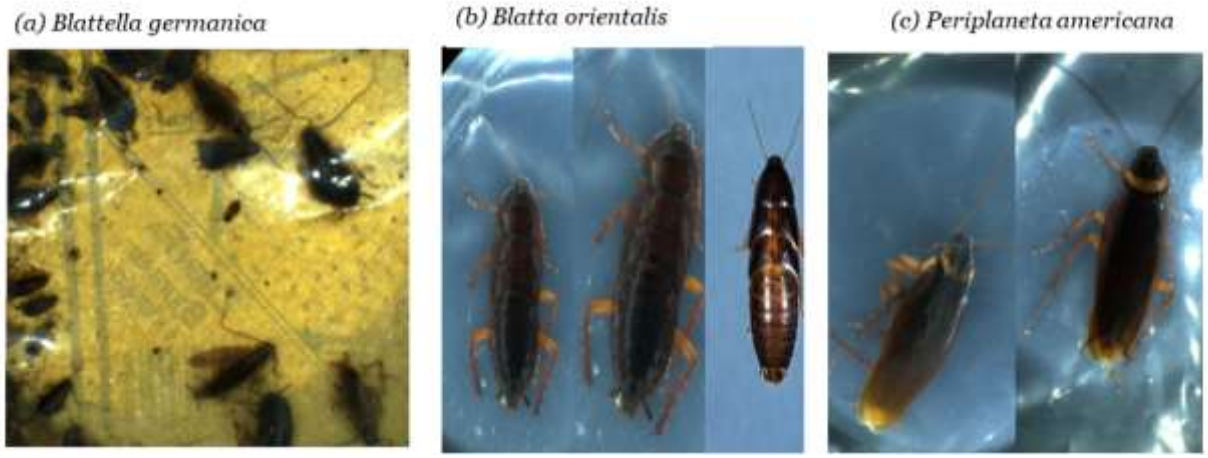

Figure 1. Three dominating cockroach species were identified in the villages

Table 4 shows the distribution of various cockroach species among the villages. The majority of *B. germanica* (58%) were captured indoors, particularly in the village of Mokwasele (31%). *B. orientalis* (84%) were predominantly found in the indoor environment of Makaba village (39%). *P. americana* (75%) were most frequently trapped outdoors in the village of Mohlakong (33%).

Table 4. Distribution and prevalence of cockroach species per village

Location	*B.germanica*		*B.orientalis*		*P.americana*	
	n	%	n	%	n	%
Indoor	451	58.0	294	84.0	14	25.0
Outdoor	329	42.0	57	16.0	41	75.0
Motsinoni	12	2.0	19	5.0	12	22.0
Makaba	111	14.0	135	39.0	18	33.0
Mohlakong	152	19.0	60	17.0	3	5.0
Moshakga	101	13.0	40	11.0	4	7.0
Ramphenyang	159	21.0	69	20.0	16	29.0
Mokwasele	245	31.0	28	8.0	2	4.0

Out of 780 *B. germanica* trapped, 51(58%) were trapped indoor and 329(42%) outdoor (Figure 2). Motsinoni village had 8(2%) households that trapped *B. germanica* in the indoor area, Makaba village households trapped 105(23%), Mohlakong village 55 (12%), Moshakga village 45(10%), Ramphenyang village 154(34%) and Mokwasele village households trapped 86 (19%) *B. germanica* in the indoor area. Out of the 329 (42%) *B.germanica* trapped outdoor, 4 (1%) *B. germanica* were trapped in the

outdoor area at Motsinoni village, 8(4%) in Makaba village, 97 (29%) in Mohlakong village, 56 (17%) in Moshakga village, 5 (1%) Ramphenyang village and Mokwasele village had 159 (48%).

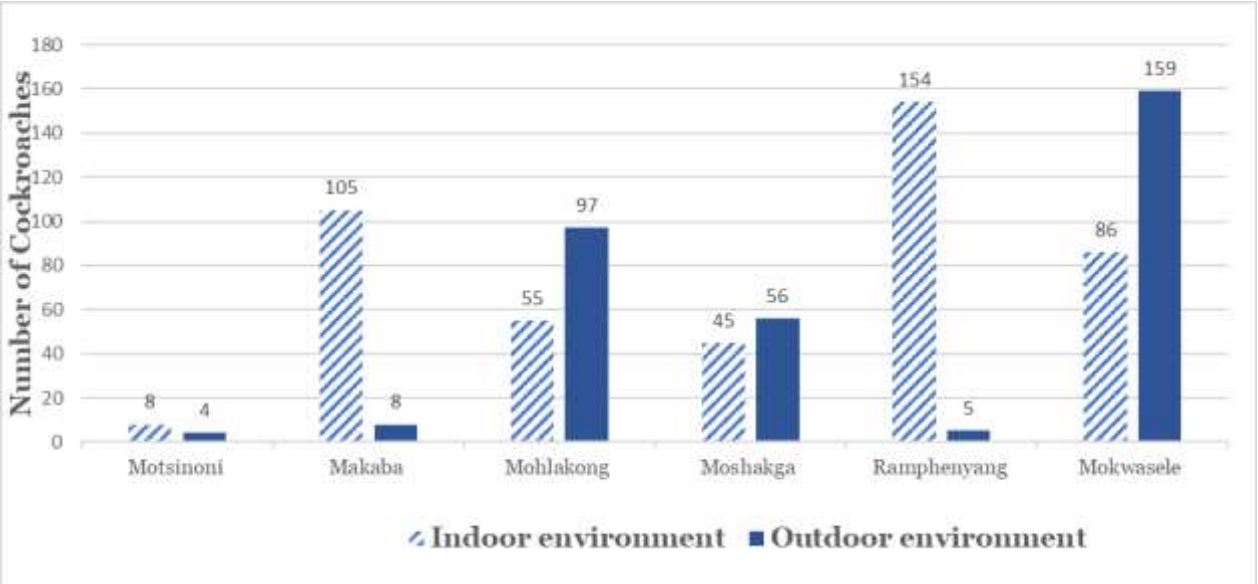

Figure 2. Distribution of *B. germanica* trapped indoor and outdoor environment of households per village

Amongst 351 (29%) *B. orientali*s trapped, 294 (84%) *B. orientalis* were trapped indoor and 57(16%) were outdoor was showed in Figure 3. Out of 294(84%) *B. orientalis* trapped indoor, 18(6%) *B. orientalis* were trapped in the indoor area at Motsinoni village, 131 (45%) in Makaba village, 39(13%) in Mohlakong village, 25(9%) in Moshakga village, 69 (23%) in Ramphenyang village and 12(4%) households trapped *B. orientalis* in the outdoor area of Mokwasele village. Among 57(16%) *B. orientalis* trapped outdoors, Motsinoni village had 1(2%) household that trapped *B. orientalis* in the outdoor area, Makaba village 4(7%), Mohlakong village 21 (37%), Moshakga village 15(26%), 0(0%) in Ramphenyang village and Mokwasele village had 16(28%) households that trapped *B. orientalis* in the outdoor area.

P. americana trapped, 14 (25%) were trapped in the indoor environment, 41 (75%) were trapped outdoor was shown in Figure 4. Motsinoni village had 9(64%) households that trapped *P. americana* in the indoor area, Makaba village 0(0%), Mohlakong village 1 (7%), Moshakga village 2 (14%), Ramphenyang village 1(7%) and Mokwasele village had 1 (7%). Out of the 41 (75%) of *P. americana* trapped outdoors, 3 (7%) cockroaches were trapped in the outdoor area at Motsinoni village, 18(44%) in Makaba village, 2 (6%) in Mohlakong village, 2 (6%) in Moshakga village, 15 (37%) in Ramphenyang village and 0 (0%) Mokwasele village.

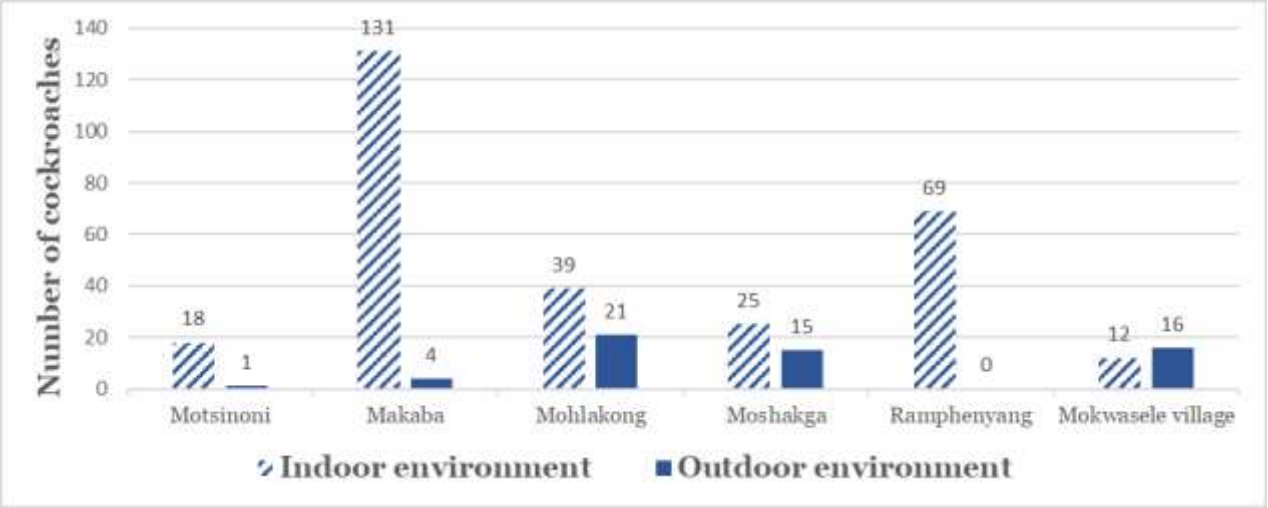

Figure 3. Distribution of *B. orientalis* trapped indoor and outdoor environment of households per village

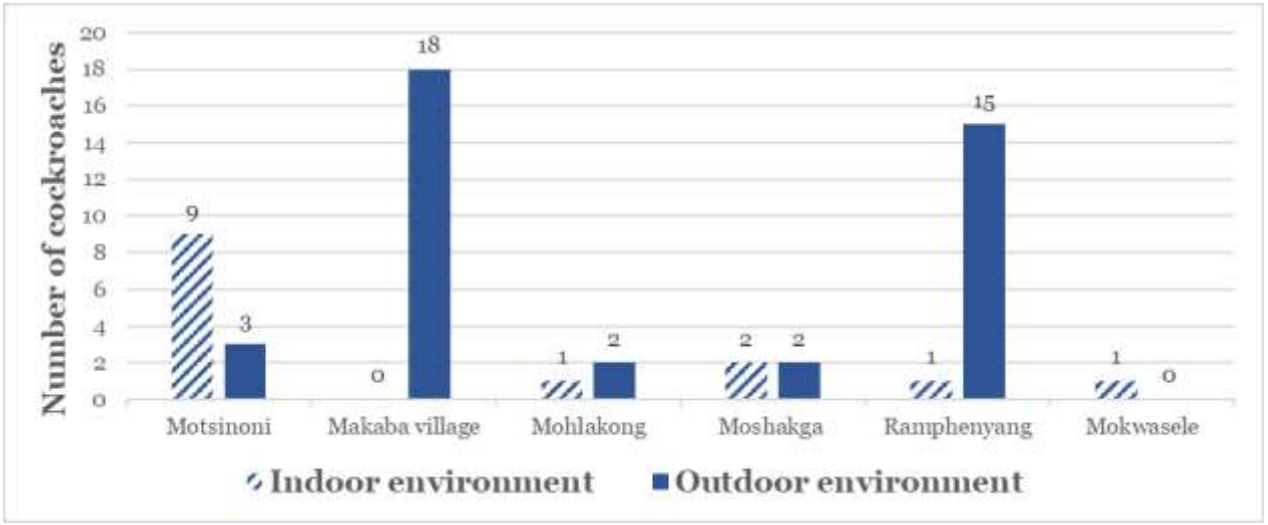

Figure 4. Distribution of *P.americana* trapped indoor and outdoor environment of households per village

DISCUSSION

Cockroaches pose a risk for humans even though their involvement in the biological transmission of diseases is still difficult to demonstrate and determine. The high prevalence and distribution of cockroaches recorded in the rural environment in this study reflect the burden of pest infestation faced by residents in the rural communities which can cause significant public health issues. Thus, affecting even the vulnerable groups such as the elderly, pregnant women, and people with compromised immune systems. Unsanitary conditions followed by the low socio-economic status of rural communities may be the attributing factor of infestation in the area.

The findings indicated that most cockroaches existed in the indoor environment as compared to the outdoor environment. The evidence is supported by the previous similar cockroach trapping surveys whereby the highest number of cockroach populations was trapped in kitchen, bedroom, food and water storage areas. Atiokeng-

Tatang et al. (2017) found cockroaches trapped in the toilet area carrying more parasites than those trapped in the kitchen area and other parts of the houses. Three dominating cockroaches included *B. germanica, B. orientalis,* and *P. americana. B. germanica* was identified as a light yellowish brown and 10–15 mm in length, the smallest domestic cockroach species as compared to other cockroaches (Shahraki et al. 2010). *B. germanica* species dwells in areas where food is prepared and stored like in kitchen appliances, trash cans, dark harbourage, such as under a stove or refrigerator, and in cracks or crevices near food and water (Bonnefoy et al., 2008). *B. Orientalis* was identified with a blackish color with sizes ranging between 20-27mm long. The species is commonly found in cool temperate regions (Hassan et al., 2021). *B. orientalis* feeds on starchy products, debris, sewage, or decomposing products (McCanless, 2007). The largest species, *P. american* was also identified in the study. Its size ranges between 35-45 mm long with colour varying from reddish to brown (Hassan et al., 2021) *P. americana* inhabits in humid places where food, water and shelter are present. It can dwell in both indoors and outdoors (Zahraei-Ramazani et al., 2018).

Shahraki et al. (2013) also conducted a study in Yasuj City in southwestern Iran. The study identified five species of cockroaches *B. germanica*, Blatta lateralis, *P. americana, Supella longipalpa*, and *B. orientalis*. Similar to this study, *B. Germanica* was the most predominant species. Hamu et al., (2014) *found B. Germanica* to be harbouring *Giardia duodenalis, Entamoeba histolytica/dispar/ moshkovski, Taenia spp, Ascaris lumbricoide, Balantidium coli, Trichuris trichiura* as well as Strongyloides (Etim et al., 2013). In other surveys, 36% of *B. germanica* samples tested positive for *Hymenolepis nana, Giardia lamblia, Cryptosporidium parvum,* and *Enterobius vermicularis* (Debash et al., 2020).

Mehainaoui et al. (2021) isolated *Citrobacter, Klebsiella, Kluyevera, Leclercia, Morganella and Serratia*, *Pseudomonas sp., Staphylococcus sp.,* and *Enterococcus sp*. Sources indicate that *B. orientalis* can spread pathogens like Salmonella, Shigella and Staphylococcus. In addition, it was reported that *B. orientalis* and *P. americana* are more likely contaminated twice than the *B. germanica* (Kopanic et al., 1994). In this study, it was noted that the prevalence of *P. americana* was few in the indoor environment and greater in the outdoor environment. Trapping in the outdoor environment was done in the toilet area and the high prevalence strengthens the evidence that suggests a high preference for sewers and warm environments by *P. americana*. The existence and preferred habitat by *P. americana* increase the likelihood of them spreading human pathogens. It was also recorded that *P. americana* infestation is mostly in the toilet area as compared to other areas in the household (Tatfeng et al., 2005). Ajang et al. (2015) isolated *Enterobius vermicularis, Entamoeba histolytica, Ballantidium coli, Ancylostoma duodenale, Strongyloides stercoralis* and *Ascaris lumbricoide* from *P.americana.* Thus, suggesting that *P. americana* species are likely to spread parasitic diseases. Some of the isolated organisms can cause enteric illnesses like salmonellosis, dysentery, cholera, campylobacteriosis, and typhoid fever (Hassan et al., 2021).

Monitoring of infestation and reducing the high number of cockroach populations can play a significant role in the reduction of the transmission of human pathogens. Some safe effective products such as essential oils

with repellent properties such as mint oil, spearmint oil, and eucalyptus oils can be used for the control of cockroaches including the use of non-toxic baits, traps, and vacuuming (Baldwin, 2018; Boné et al., 2022). In the study, the use of spray was preferred over powder, traps, and paste. However, continuous use and application of the same chemicals over a prolonged period results in the resistance of cockroaches against the chemical used (Hassan et al., 2021)Integrated pest management (IPM) system should be encouraged be adopted to ensure the achievement of long-term suppression of cockroach populations which can ultimately result in the long-term reductions in cockroach allergen concentrations as well. This will also promote a healthier and safer environment for human beings. A tailor-made IPM can include the improvement of sanitary conditions, cleanliness, hygiene, and structural settings to refute cockroaches' food, water, shelter, and movement thus preventing the chances of the spread of communicable diseases.

The number of cockroaches captured over a short period of time represents an increased risk of mechanical contamination of pathogenic micro-organisms to human health. Effective control strategies are required to reduce the likelihood of exposure to pathogens, allergens and to pesticide residues.

AUTHOR CONTRIBUTION

All authors have significantly contributed to the article cle. MLM was responsible for collecting data and writing the initial and final manuscript. TGB and NN assisted with technical aspects, reviewing, and editing the final article.

ACKNOWLEDGMENT

The authors would like to thank the data collectors from Ward 2 of Bolobedu, Greater Letaba Municipality, and the laboratory assistants from the Water and Health Research Centre at the University of Johannesburg for their assistance.

FUNDING AND SPONSORSHIP

This work was supported and funded by the Water and Health Research Centre, University of Johannesburg.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

REFERENCE

Ajang RO, Etta HE, Iboh CI, Abraham JT (2015). Public health implications of cockroaches within households in Calabar municipality, Cross River State, Nigeria. 2(2):114–119.

Atiokeng Tatang RJ, Tsila HG, Wabo Poné J (2017). Medically important parasites carried by cockroaches in Melong subdivision, Littoral, Cameroon. J. Parasitol. Res. 2017:1–8. doi: 10.1155/2017/7967325.

Baldwin P (2018). Effective management of cockroach infestation. Los Angeles: Department of Public Health Vector Management Program. 32(2):22–44.

Boné E, Roca Acevedo G, Sterkel M, Ons S, González-Audino P, Sfara V (2022). Characterization of the pyrethroid resistance mechanisms in a Blattella germanica (Dictyoptera: Blattellidae) strain from Buenos Aires (Argentina). Bull. Entom. Res. 112(1), doi: 10.1017/S000748532100050X.

Bonnefoy X, Kampen H, Sweeney K (2008). Public health significance of urban pests. WHO Reginal Office for Europe, Copenhagen.

Chaichanawongsaroj N, Vanichayatanarak K, Pipatkullachat T, Polrojpanya M, Somkiatcharoen S (2004). Isolation of gram-negative bacteria from cock-

roaches trapped from urban environment. 35(3):681–684.

Davies K, Tatjana P (1986). Survey of attitudes of apartment residents to cockroaches and cockroach control. 49(2): 85–88.

Debash H, Alemu M, Ayehu A (2020). Species composition of cockroaches, their potential as mechanical vectors of intestinal parasites and associated factors among households in Sekota Town, northeast Ethiopia; a community-based cross-sectional study. doi: 10.21203/rs.3.rs-51948/v1.

Eggleston PA (2003). Cockroach allergen abatement: The good, the bad, and the ugly. J. Allergy Clin. Immunol. 112(2): 265–267, doi:10.1067/mai.2003.1674.

Etim SEI, Okon OE, Akpan PA, Aukpong I, Oku EE, Madlul H (2013). Prevalence of cockroaches (*Periplanata americana*) in households in Calabar: Public health implications. 5:149–152.

Gore JC, Schal C (2005). Expression, production and excretion of Bla g 1, a major human allergen, in relation to food intake in the German cockroach, Blattella germanica. Med. Vet. Entomol. 19(2):127–134, doi: 10.1111/j.0269-283X.2005.00550.x.

Hamu H, Debalke S, Zemene E, Birlie B, Mekonnen Z, Yewhalaw D (2014). Isolation of intestinal parasites of public health importance from cockroaches (*blattella germanica*) in Jimma Town, southwestern Ethiopia. J. Parasitol Res. 2014:1–5, doi: 10.1155/2014/186240.

Hassan AO, Uyigue PO, Akinleye CA, Olamijuwon PB (2021). The Roles of Domiciliary Cockroach in Transmission of Enteric Disease in Humans. 3(1):246–256.

Hughes GM (1952). The co-ordination of insect movements. J Exp Biol. 29(2): 267–285, doi:10.1242/jeb.29.2.267.

Kopanic RJ, Sheldon BW, Wright CharlesG (1994). Cockroaches as vectors of salmonella: laboratory and field trials'. J Food Prot. 57(2):125–131, doi: 10.4315/0362-028X-57.2.125.

McCanless K (2007). Oriental Cockroach, Blatta orientalis Linnaeus (Insecta: Blattaria: Blattidae. 26(13).

Mehainaoui A, Menasria T, Benouagueni S, Benhadj M, Lalaoui R, Gacemi-Kirane D (2021). Rapid screening and characterization of bacteria associated with hospital cockroaches (*blattella germanica l.*) using MALDI-TOF mass spectrometry. J Appl Microbiol. 130(3): 960–970, doi:10.1111/jam.14803.

Moges F, Eshetie S, Endris M, Huruy K, Muluye D, Feleke T, Silassie F, Ayalew G, Nagappan R (2016). Cockroaches as a source of high bacterial pathogens with multidrug resistant strains in Gondar Town, Ethiopia. Biomed Res Int. 2016:1–6, doi: 10.1155/2016/2825056.

Pan XY, Zhang F (2020). Advances in biological control of the German cockroach, Blattella germanica (L.). Biol Control. 142:104104, doi: 10.1016/j.biocontrol.2019.104104.

Prescott LM, Harley JP, Klein DA (2002). Microbiology. Fifth edition. McGraw-Hill, Boston.

Shahraki GH, Noor HM, Rafinejad J, Shahar MK, Ibrahim Y Bin (2010). Efficacy of sanitation and sanitary factors against the German cockroach (*Blattella germanica*) infestation and effectiveness of educational programs on sanitation in Iran. Asian Biomed. 4(5). doi: 10.2478/abm-2010-0105.

Shahraki GH, Parhizkar S, Nejad ARS (2013). Cockroach infestation and factors affecting the estimation of cockroach population in urban communities. Int J Zool. 2013:1–6, doi: 10-.1155/2013/649089.

Tatfeng YM, Usuanlele MU, Orukpe A, Digban AK, Okodua M, Oviasogie F, Turay AA (2005). Mechanical transmission of pathogenic organisms: the role of cockroaches. J Vector Borne Dis. 42(4):129–134.

Zahraei-Ramazani AR, Saghafipour A, Vatandoost H (2018). Control of american cockroach (*Periplaneta americana*) in municipal sewage disposal system, Central Iran. J. Arthropod. Borne Dis. 172–179. doi: 10.18502/jad-.v12i2.43.