

## Environment factors affecting cockroach density: A systematic review

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### Abstract

Cockroaches are one of the insects that are vectors of disease transmission. Cockroaches are spread all over the world and are one of the most common pests on ships, airplanes and trucks especially in food storage areas. This research was conducted using a systematic review method which purposes to examine the literature that describes the factors that affect the density of cockroaches. From the results of several studies, it was found that the factors that affect the density of cockroaches are temperature, humidity, environmental sanitation and vector control efforts, both in residential areas, hospitals, storage warehouses and ship raft rooms. Temperature has a positive correlation with cockroach density. The higher the temperature of a place, the higher the density of cockroaches. Humidity has a negative correlation with cockroach density. The more humid a place is, the higher the presence of cockroaches. Environmental sanitation, including environmental cleanliness, food storage areas, no leftover food/organic materials left, basements/areas below must be kept dry, and reducing access of cockroaches to food places. Cockroach control efforts can be carried out by means of environmental management and chemical control.

**Keywords:** Cockroaches; Sanitation; Vector control; Review

### 1. Introduction

Diseases that are transmitted through vectors are still a public health problem in Indonesia, and still have the potential to cause extraordinary events. According to the Regulation of the Minister of Health of the Republic of Indonesia, vectors are defined as arthropods that can transmit, transmit and/or be a source of disease transmission to humans. One of the arthropods that are vectors of disease carriers is the cockroach <sup>[1]</sup>.

Cockroaches are one of the insects belonging to the order Orthoptera (two-winged) with the front wings covering the back wings and folding like a fan. Cockroaches consist of several genera namely *Blatella*, *Periplaneta*, *Balta*, *Supella*, and *Blaberus*. Some of the species of cockroaches are *Blatella germanica*, *Periplaneta americana*, *Periplaneta australasiae*, *Periplaneta fuliginosa*, *Blatta orientalis*, and *Supella longipalpa* <sup>[2]</sup>.

Cockroaches are one of the insects that are vectors of disease transmission. Disease transmission can arise when pathogenic microorganisms are carried by the cockroach's feet or other body parts. Then through the organs of the cockroach's body, the microorganisms as the seeds of the disease contaminate the food. In addition, cockroaches can cause allergic reactions such as dermatitis, itching, and swelling of the eyelids.

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Cockroaches are distributed all over the world and are one of the most common pests on ships, airplanes and trucks especially in food storage areas. The three most common types of cockroaches: American, Oriental and German. Cockroaches prefer dark and warm areas, crevices and various other man-made hiding places. Cockroaches are usually nocturnal, agile, and live in colonies. Cockroaches are characterized by two pairs of wings, which are flat in appearance, and are yellow-brown to dark brown in color. The length varies from 5 to 73 mm. In the tropics, cockroaches can live and breed outdoors [3].

The behavior and survival of cockroaches is strongly influenced by the cockroach's need for food, water, and safe shelter from potential predators and adverse microclimate. Cockroaches are omnivores and will consume almost any organic material, including fresh and processed foods, stored produce, and even bookbinding, pasta on stamps and wallpaper when more typical foodstuffs are not available. Cockroaches have the same general problems with water balance as other land arthropods. Their relatively small size results in a high surface area to volume ratio and a high risk of water loss through the respiratory, oral and anal routes, or the cuticle. Temperature, air flow, relative humidity, and availability of liquid water greatly affect water regulation [4].

Cockroaches live in homes, restaurants, hotels, hospitals, warehouses, offices, libraries, and many other places. They live very close to humans. The presence of cockroaches around us is very undesirable because it can cause aesthetic disturbances, fear, give a dirty impression, also act as a spread of disease, because cockroaches prefer damp, dark, dirty places. From the habit of living in dirty places, cockroaches can carry germs that stick to their bodies [2].

The manifestation of cockroaches is related to environmental sanitation. As research shown that the Relationship of TPM Sanitation to the density of cockroaches in the Mataram Class II KKP Winner Port, which states that environmental sanitation has a significant relationship to the existence of cockroaches. This study will show an overview of the factors that influence the density of cockroaches based on a systematic review of several studies that have been conducted previously [5,6].

### *Objective*

This systematic review aims to define the factors that influence the density of cockroaches, based on research that has been carried out by previous researchers. The density factor of cockroaches is perceived from several different locations, explicitly in residential areas, hospitals, storage warehouses and ship rooms.

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## **2. Methods**

### **2.1 Search strategy**

This research was driven by a systematic review research method using the PRISMA chart to describe the process of finding journals that match the research questions. The search for articles was supported using the keywords: density of cockroach, habitat of cockroach, and cockroach control. The criteria for articles to be included in this study are in English and Indonesian, published in 2017 – 2022, and available in full-text. Article searches were carried out using the ProQuest database, google scholar, and science direct.

### **2.2 Selection study**

Article searches are carried out by entering predetermined keywords into the database used. From the search results, 569 relevant articles were found with details of ProQuest as many as 170 articles, Google-Scholar as many as 278 articles, and Scencedirect as many as 121 articles. After searching for articles, duplicate checks and screening stages are carried out. The screening stage is carried out based on the title and abstract after that through the full-text screening stage. Articles that are significant to the research question will enter the synthesis stage to be compiled in a descriptive form. The stages of the journal search process up to the synthesis stage are depicted in Figure 1.

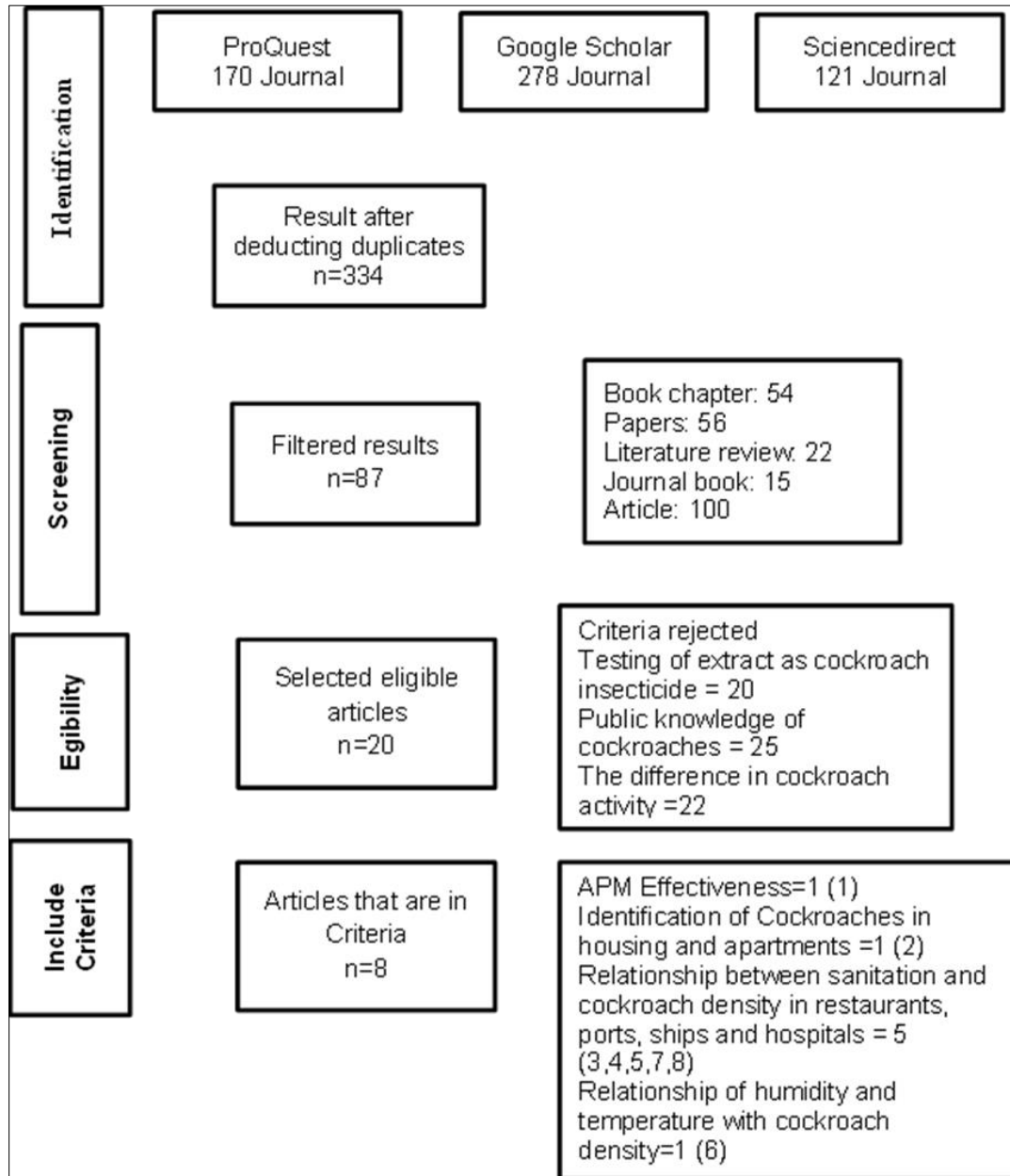


Figure 1 PRISMA Chart

### 2.3 Data Synthesis

Research results are presented descriptively to answer research questions. In this study, the PRISMA diagram or selected reporting items for systematic review is used, this diagram is used to show the overall study selection process. Articles that entered the synthesis stage were extracted to determine the year of publication, study location, source or location of the analyzed cockroach samples. Information on the factors affecting the density of cockroaches, the risk of disease transmission in humans described in the article is also recorded.

### 3. Results

Article searches are approved out by entering predetermined keywords into the database used. From the search results found 569 relevant articles. From the 569 articles, 8 articles were gained that were relevant to the research question so that they were included in the data synthesis stage.

**Table 1** Overview of Research on Factors Affecting Cockroach Density

No	Title	Author	Objective	Design	Sampling	Results
1	Quantifying the Efficacy of an Assessment-Based Pest Management (APM) Program for German Cockroach (L.) (Blattodea: Blattellidae) Control in Low-Income Public Housing Units [7]	Dini M. Miller and Eric P. Smith (2020)	To assess the long-term effectiveness of APM against the presence of German Cockroaches in low-income housing	Observational research	Number of cockroaches caught from June 2017 to September 2018 at 3 different public housing facilities located in Richmond, VA, Hopewell, VA, and Rocky Mount, NC.	In all three housing authorities, the cockroach population in the test unit was reduced by >90%. German cockroach infestations were evenly eliminated in 49 of the 65 (75%) test units during this study.
2	Isolation of Enterobacteriaceae in Cockroaches (Periplaneta americana) in Residential Areas in Cimahi City [8]	Dwi Davidson Rihibiha, Lilis Puspa Friliansari (2020)	To identify Enterobacteriaceae in the body of cockroaches.	Descriptive research	Cockroaches in Residential Areas in Cimahi Kota City	Enterobacteriaceae group of bacteria, namely Klebsiella sp. and Enterobacter sp., were isolated from the body surface of the cockroach P. americana. This shows that cockroaches that are scattered in several housing areas in Cimahi City are vectors of carriers of pathogenic bacteria that are harmful to humans.
3	A First Insight Into the Occurrence of Cockroaches in the Urban City of Thessaloniki (Greece)-Identifying Hot Spots [9]	Ioanna Dimitriadou, Georgios I. Memtsas, Fotis Xystrakis, Dimitrios Kavvadas, Theodora Papamitsou and Dimitrios N. Avtzis (2021)	Identifying places with increased cockroach presence using spatial mapping	Spatial mapping method using QGis Version 3.18.3	Data on the incidence of cockroach infestations is provided by two pest control companies active in the city of Thessaloniki. In total, 283 sites were used, corresponding to where these companies carried out chemical treatment of cockroaches in 2019-2020.	This preliminary mapping of distribution data clearly shows that areas of high cockroach density are located near Hospital facilities. In addition, areas with a high density of cockroaches are found in very densely populated and old parts of the city. In urban networks there are many parameters that contribute to the high percentage of apartments with cockroach infestations. Some of the apartments have poor sanitation and pest control practices, lack of proper apartment maintenance and natural spread of cockroaches between apartments in multi-unit dwellings

No	Title	Author	Objective	Design	Sampling	Results
4	Density of Cockroaches in Perimeter and Port Buffer Areas: Analysis of Sanitation and Physical Environment Factors <sup>[10]</sup> .	Diyana, S., Martini, M., Sutiningsih, D., & Wuryanto, M. A. (2021)	Describing cockroach density in the port area and analysing sanitation and physical environmental factors related to cockroach density	This type of quantitative research is through an analytical observational research design with a cross sectional design	The sample in this study were 51 food stalls in Tanjung Emas Harbor and all cockroaches caught in these food stalls	The types of cockroaches caught were identified according to the cockroach identification keys found in the book <i>Cockroaches: Pictorial Keys Arthropods, Reptiles, Birds and Mammals Important Public Health</i> by Harry D. Pratt, - <i>Periplaneta americana</i> - <i>Blatella germanica</i> There is a very strong relationship between poor sanitation of food stalls having a cockroach density of 3.75 (OR = 3.75) times that of good restaurant sanitation.
5	The Relationship between Sanitation Conditions and the Presence of Cockroaches on Passenger Ships at Ulee Lheue Port, Banda Aceh City <sup>[11]</sup> .	Nurbayani, N., Husna, H., Syam, B., Rosita, S., Zulyana, C., & Rafsanjani, T. M. (2021).	This study aims to determine the relationship between kitchen sanitation, food raft rooms, and warehouses with the density of cockroaches on ships in the Kendari port area.	This type of research is an observational, cross-sectional study design	37 ships taken by purposive sampling	The results showed that from 37 ships, the highest density of cockroaches met the requirements of 28 ships (75.7%), the rest did not meet the requirements of 9 ships (24.3%). The kitchen sanitation met the requirements of 28 ships (75.7%), the rest did not meet the requirements of 9 ships (24.3%), then the food raft room sanitation met the requirements of 31 ships (83.8%) and did not meet the requirements of 6 ships (16, 2%). Furthermore, warehouse sanitation meets the requirements of 23 ships (62.2%) and does not meet the requirements of 14 ships (37.8%)
6	The Relationship of Temperature, Humidity and Lighting to the Density of Cockroaches on Passenger Ships	Muhammad Firmansyah	To find out the relationship between temperature, humidity and lighting on the density level of	Analytical Survey Method	Kitchen room and food storage area on 6 passenger ships that dock at Balikpapan's Semayang port in August-September.	The results showed that the highest density of cockroaches was found in the passenger kitchen. Physical environmental factors related to the density of cockroaches on passenger ships are temperature with a

No	Title	Author	Objective	Design	Sampling	Results
	docked at Semayang Harbor, Balikpapan in 2017 <sup>[12]</sup>		cockroaches on passenger ships			significance value of 0.004 correlation coefficient 0.529, then humidity with a significance value of 0.000, a correlation coefficient of 0.808 and lighting with a significance value of 0.004 a correlation coefficient of 0.525. Physical environment temperature and lighting have a not very strong relationship while humidity has a very strong relationship.
7	Overview of the Factors Associated with Cockroach Density at the Place of Sale of Foodstuffs and Traditional Market Food in Semarang City <sup>[13]</sup> .	Cahyani, L. K., Yuliawati, S., & Martini, M. (2018).	The purpose of this study was to describe the factors associated with the density of cockroaches in grocery stores and food stores in traditional markets in Semarang City.	Observational research with cross sectional approach	The sample in this study were all cockroaches caught in 66 grocery stores and food stores in traditional markets from Semarang City	The results of this study indicate that there are 57.6% of shops with good sanitation and 42.4% of shops with poor sanitation There are 45 out of 66 shops that do not take cockroach control efforts The highest percentage of cockroach density was in wet food stores (26.9%), followed by grocery stores (25%) and dry food stores (5%) and 20% stores with high cockroach density and 80% stores with low cockroach density . Four cockroach species were found, including <i>Periplaneta americana</i> (15.1%), <i>Blattella germanica</i> (80.09%), <i>Nauphoeta cinerea</i> (4.58%), <i>Neostylopyga rhombifolia</i> (0.23%)
8	Reduction of Cockroach Density and Spreading In Benha University Hosoitals (Egypt) In The Year 2019 compare With The Year 2014 <sup>[14]</sup> .	Mohamed M. Baz; Maysa M. Hegazy (2020)	This study was conducted to determine the abundance, distribution, level of infestation, and the effect of several parameters such as humidity, and temperature on the dynamics of the	This research is an analytical survey research.	Cockroach samples were taken from different locations in three sections: internal medicine, operating room, and ophthalmology building at Benha University Hospital using sticky traps.	German and American cockroaches were found in all areas of the hospital, while brown cockroaches were found only in kitchens, outpatient clinics, and hospital medical supply warehouses. In 2014; The cockroach population density in the hospital recorded a high number of cockroaches and an infestation rate (30.9%) in the kitchen compared to other places;

No	Title	Author	Objective	Design	Sampling	Results
			cockroach population at Benha University Hospital.			<p>while in 2019; the highest number of cockroaches (the densest) and the rate of infestation (43.0%) were recorded in the outpatient polyclinic compared to other places.</p> <p>The results also showed a very significant correlation between cockroach population density and temperature (<math>R = 0.897, P = 0.006</math>); but inversely proportional to humidity (<math>R = -0.433, P = 0.332</math>) in 2014; whereas in 2019 there was an insignificant positive correlation between cockroach density and temperature and relative humidity. It is clear that the population density of cockroaches decreased in 2019 compared to 2014 (<math>F = 54.17, P &lt; 0.01</math>).</p>

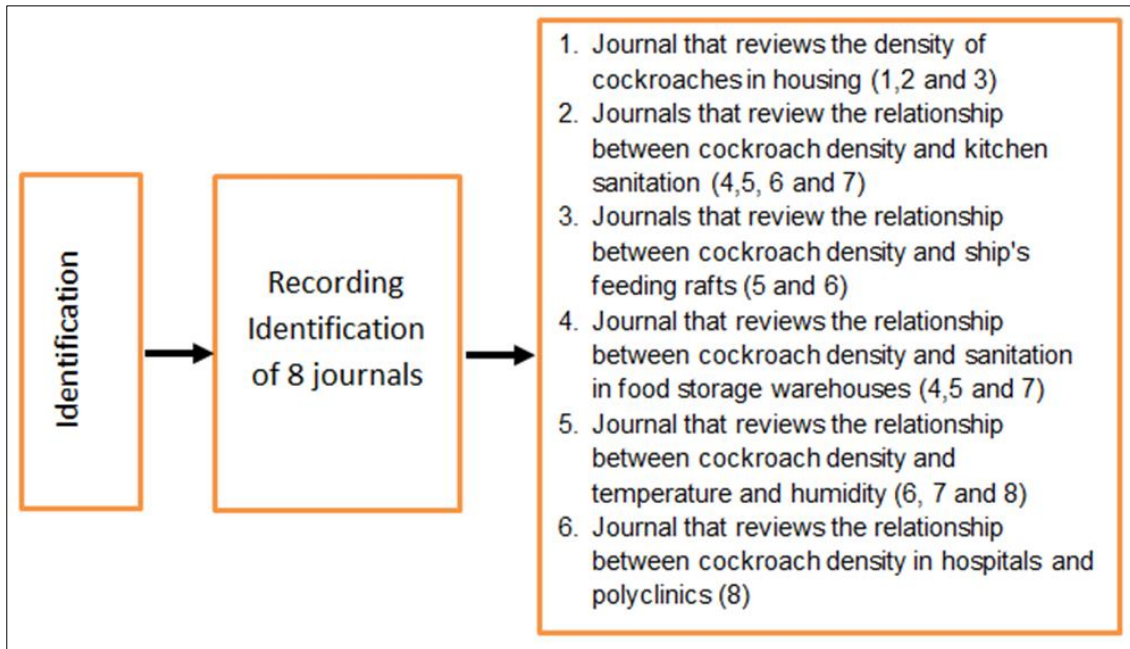


Figure 2 Study Identification Based on Articles

#### 4. Discussion

Cockroaches can be ecologically categorized as domestic, peridomestic, or wild. Domestic species live almost exclusively indoors and depend largely on humans (food, water, and shelter) for their survival. Cockroaches are rarely able to fend for themselves outdoors. This domestic species is the German cockroach. Peridomestic species are species that survive in the vicinity of human habitation. Although this species of cockroach does not need humans for its survival, it is adept at exploiting human facilities. These species are the American, Australian, brown cockroach and smoky chocolate (all *Periplaneta sp.*), the oriental cockroach, and the Florida forest cockroach. Wild species are cockroaches whose survival does not depend on humans. This species includes more than 95% of all species in the world. Only a few occur indoors as occasional and accidental invaders that don't usually survive in domestic environments [4].

The physical environment usually defines cockroach habitat preferences in and around buildings. Oriental, Turkestan, and American cockroaches, for example, require high humidity and occur in moist terrestrial, environments such as septic tanks and municipal sewer systems. Florida wood, smoky, and wood cockroaches live in a wider range of habitats associated with trees, wood and leaf piles, wall cavities, and building foundations. Brown banded cockroaches are more tolerant of drier conditions and are common in kitchens, pantries and bedrooms. German cockroaches occupy hiding places near food and water. As a result, they are found mainly in kitchens and pantry and secondly in bathrooms [4,15].

Research conducted in residential areas in Cimahi City which aims to identify *Enterobacteriaceae* in cockroaches. It found on the body surface of the *P. americana* cockroach as many as 13 isolates belonging to the *Enterobacteriaceae* group, namely *Klebsiella sp.* and *Enterobacter sp.* This shows that the cockroaches found in housing in Cimahi City are vectors of disease carriers. Unclean environmental conditions are a good place to live and breed various disease vectors. Like the *P. americana* cockroach which is often in contact with humans and is present around homes, hospitals, landfills, and other places with poor sanitation. In this study, it was not explained how much cocea density was in a residential area in Cimahi City. Researchers only identified the presence of *Enterobacteriaceae* in cockroaches in residential areas. And this of course still has an impact on humans, especially the community in the housing if the cockroach control is not carried out [8].

Research in the City of Thessaloniki, Greece on a model. Initial distribution data mapping clearly shows that areas with high density of cockroaches are located near hospital facilities. This fact concerns the large downtown area [9]. Similar studies, have shown that cockroaches are often a common pest inside hospital facilities. At Tikur Anbessa Hospital, Addis Ababa, as many as 400 cockroaches were collected from the neonatal intensive care unit. The findings suggest that pathogenic bacteria isolated from the body and intestines of cockroaches are responsible for neonatal nosocomial sepsis. Hospital internal conditions such as temperature, humidity, food, and adequate housing seem to create an ideal environment for cockroach infestations [4,8].



In addition, areas with a high density of cockroaches are found in very densely populated and old parts of the city. In the urban network there are many parameters that contribute to the high percentage of apartments with cockroach infestations. Some of these are poor sanitation and pest control practices, lack of proper apartment maintenance and the natural spread of cockroaches between apartments in multi-unit dwellings. In addition, socioeconomic status plays an important role in the treatment of cockroaches. Peers who live in urban environments and experience high levels of material difficulty show a positive correlation with increased exposure to cockroach allergens. Also, factors such as substandard housing and multi-unit buildings are considered to be the cause of cockroaches, while two large studies taking place in the United States confirmed that low family incomes and living in multifamily homes constitute a high population. Dense areas with higher occupancy rates per room were associated with increased cockroach allergens and lower concentrations of dust mites.

In the study of cockroaches are insects that belong to the free-living phylum Arthropoda. Cockroaches live in groups and prefer dark, damp places to hide. Cockroaches are active and have a habit of foraging at night (nocturnal). Cockroaches act as mechanical vectors for spreading disease agents from bacteria, viruses, protozoa, worms (helmins) and fungi, and cause allergic reactions [8,10].

The type of cockroach caught was identified according to the cockroach identification key in the book *Cockroaches: Pictorial Keys Arthropods, Reptiles, Birds and Mammals Important Public Health* by Harry D. Pratt, then calculated the cockroach density using the cockroach population index formula. Leftovers in the kitchen become a source of food for cockroaches. Based on the theory, the density of cockroaches is influenced by food availability. The types of cockroaches caught at fishing locations in food stalls in the perimeter area are: *Periplaneta americana* (81%) and *Blattella germanica* (19%). The buffer zones are *Periplaneta americana* (73%) and *Blattella germanica* (27%). The assessment of the components of sanitation facilities that do not meet the requirements for food stalls in the port area is that the doors of the food stalls are not tightly closed (98%). The assessment of the components of sanitation facilities that do not meet the requirements are cracked toilet floors (90.2%) and trash cans that do not have covers (64.7%) and wastewater treatment systems do not have fat traps (64.7%). The kitchen assessment that does not meet the requirements is a kitchen that has leftovers or leftovers (62.7%) [8,16].

A study to show the relationship between temperature, humidity and lighting factors on the density of cockroaches on passenger ships. The results showed that temperature, humidity and lighting had a correlation with the density of cockroaches on board. Temperature has a not very strong correlation, this is probably because the minimum room temperature on the ship reaches -30° C, and the maximum temperature is 30° C. While the optimal temperature for a cockroach to live is 25 - 30° C. So there are some places where cockroaches are not found. Humidity has a very strong correlation with cockroach density. This is because the humidity found on the ship ranges from 50% - 78%, this condition is a good humidity as a breeding ground for cockroaches. Lighting has a not very strong relationship. In the study, most cockroaches were found in lighting below 100 lux. The average luminance on board the vessel measured ranged from 37 lux to 75 lux. So that the presence of cockroaches is still found even though measurements are made during the day [12].

Meanwhile, in the study of Leila Kartika Cahyani et al 2018 shows that conducted at food and food stall in the Semarang City Traditional Market, 4 types of cockroaches were found, such as *Periplaneta americana* (15.10%), *Blattella germanica* (80.09%), *Nauphoeta cinerea* (4.58%), *Neostylopyga rhombifolia* (0.23%). The highest percentage of cockroach density was classified as dense in good sanitation conditions (21.1%). The highest percentage of cockroach density status was classified as dense in the group that did not control cockroaches (33.3%). the type of product sold, the highest percentage of cockroach density status is classified as solid in the type of ready-to-eat food (26.9%). The results showed that the average temperature and humidity of the place where food and food were sold in the traditional markets of Semarang City were 30.940 C and 58.34% with the density status of cockroaches classified as dense [13].

- The *Periplaneta americana* cockroach has a characteristic brown body, a yellowish pattern on its pronotum. These cockroaches are found in all types of food and food sales places, especially in storage cupboards
- Cockroach *Blattella germanica* is light brown, there are two black vertical bands on the pronotum. These cockroaches are found in all types of food and food sales places, especially in storage cupboards. According to research by Yagci et al
- The cockroach *Nauphoeta cinerea* has a light brown and gray body, there is an irregular pattern on the pronotum, the wings do not cover the whole body. These cockroaches were found in the sale of ready-to-eat food and wet foodstuffs, namely meat abattoirs.
- The *Neostylopyga rhombifolia* cockroach or *harlequin* cockroach has a black body morphology with a yellowish pattern, light brown legs and no wings. This cockroach was found in a dry food shop hiding under a food storage cupboard.

Cockroach vectors can be found on ships, especially in kitchens, warehouses and food rafts. This is because cockroaches tend to be happy with environmental conditions where there is a lot of food and which can be a place to build a nest. The impact that can be caused by the presence of nuisance vectors or animals such as cockroaches as a result of poor sanitation is the transmission of various quarantine diseases, such as bubonic plague, yellow fever, and cholera. 3 Bacteria that are often carried by cockroaches include; *Salmonella sp*, *Escherichia coli (E.coli)*, *Microbacterium leprae*, *Streptococcus*, *Shigella sp* which can cause various diseases such as diarrhea, dysentery, cholera, hepatitis A virus., food raft rooms, warehouses, signs of vector life (American cockroaches) were also found in the kitchen, warehouse and food raft rooms [17].

According to kitchen sanitation, most of them met the requirements, namely 28 ships (75.7%), the rest did not meet the requirements, namely 9 ships (24.3%), then according to the sanitation of the food raft room, most of them met the requirements, and specifically 31 ships (83.8%), the rest did not meet the requirements, namely 6 ships (16.2%). Furthermore, according to warehouse sanitation, most of them met the requirements, namely 23 ships (62.2%), the rest did not meet the requirements, namely 14 ships (37.8%) did not meet the requirements, most of the cockroach density did not meet the requirements, namely 9 ships (64.3% ) and 5 vessels (35.7%) the density of cockroaches met the requirements. Based on the research, there is a strong relationship between warehouse sanitation and the density of cockroaches on ships in the Kendari area [5,17].

This study also showed that of the 31 ships whose food raft sanitation met the requirements, there were 28 ships (90.3%) of cockroach density that met the requirements and 3 ships (9.7%) did not meet the requirements, there is a strong relationship between food raft sanitation with the density of cockroaches on ships in the Kendari port area, namely the food raft rooms that do not meet the requirements tend to be found cockroaches, while the food raft rooms that meet the requirements are mostly not found cockroaches. This study also showed that from 23 ships whose warehouse sanitation met the requirements, there were 100% cockroach density that met the requirements. Furthermore, of the 14 ships whose warehouse sanitation did not meet the requirements, most of the cockroach density did not meet the requirements, there was a strong relationship between warehouse sanitation and the density of cockroaches on ships in the Kendari Port area. Meanwhile, actions that can be taken to control vectors on ships that pose a risk of health problems are fumigation and disinfection [8,15,17].

Muhamed M. Baz, et al., to determine the abundance, distribution, level of infestation, and the effect of several parameters such as humidity, and temperature on the dynamics of the cockroach population at Benha University Hospital. From this study, it was found that the kitchen was the place with the highest cockroach density, and the outpatient polyclinic room had the highest cockroach density (2019). Three species were found, namely the German cockroach (*Blattella germanica*), *P. americana* and *P. brunnea* [14,15].

This study also analyzed the relationship between humidity and temperature on the cockroach population at Benha University Hospital. And the results were obtained in 2014, there was a significant positive correlation between temperature and cockroach density, and a negative correlation between humidity and cockroach density. This means that the higher the temperature of a room, the cockroach population will also increase, and the more humid a room is, the cockroach population will also increase. Meanwhile, in 2019, there was an insignificant positive correlation between cockroach density and temperature and humidity. Climatic factors affect the distribution of cockroaches, but temperature and relative humidity play a role in cockroach populations, so most types of cockroaches spread in the tropics and only a few in temperate climates. In this study, the temperature affects the number of cockroaches caught in the selected places, while the relative humidity is not significant [15,17].

Dini M. Miller conducted a study to determine the effectiveness of APM on the presence of cockroaches in low-income housing. Assessment-Based Pest Management (APM) is a program to reduce/eliminate the presence of German cockroaches in low-income housing. In this study, in general the implementation of the APM was successful in reducing the German cockroach population in low-income housing. APM was carried out at three locations deemed to have high cockroach density based on complaints from residents of apartment units, namely Richmond VA housing (22 units), Hopewell VA (17 units), and Rocky Mount Housing (26 units). Cockroach traps are placed at several points in each unit, namely above the kitchen sink, under the kitchen sink and behind the toilet. Places are damp places that cockroaches usually like.

Of the three housing estates, the APM program was able to reduce the infestation rate by >90%, and even eliminate German cockroach infestations in individual housing units. Rocky Mount Housing has the best results, from 26 test units, as many as 25 units of which the German cockroach population was lost. In the Hopewell housing estate, from 17 test units, 11 units, German cockroaches were also successfully eliminated. While the Richmond housing proved to be the most challenging housing to control German cockroaches, out of 22 test units, only 13 units were able to eliminate

German cockroaches. The application of this APM has succeeded in reducing or even eliminating the German cockroach population. Assessment-Based Pest Management (APM) can be used in the long term to reduce the German cockroach population in housing units <sup>[17,18]</sup>.

Previous research shows a crystal clear that the factors that influence the density of cockroaches are temperature, humidity, environmental sanitation, and vector control efforts, both in residential areas, hospitals, storage warehouses and ship raft rooms.

- Temperature has a positive correlation with cockroach density. The higher the temperature of a place, the higher the density of cockroaches.
- Humidity has a positive correlation with cockroach density. The more humid a place is, the higher the presence of cockroaches.
- Environmental sanitation, including environmental cleanliness, food storage areas, no leftover food/organic materials left, basements/underground areas must be kept dry, and reducing access of cockroaches to food places (OSM, 2014).
- Control measures taken can reduce the density of cockroaches in a place. The form of cockroach control efforts can be carried out by means of environmental management (cleanliness and hygiene), and chemical control (insecticides, baiting and traps) <sup>[17,18,19]</sup>.

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## 5. Conclusion

- Based on previous research it was found that internal hospital conditions such as temperature, humidity, adequate food seemed to create an ideal environment for cockroach infestation.
- Based on previous research, it was found that the place of selling food and food in the Traditional Market is also a favorite place for cockroaches, especially wet food and wet food. The high temperature and humidity factors where food and food are sold in traditional markets greatly affect the density status of cockroaches, which are classified as dense.
- Based on previous research, it was found that sanitation facilities that do not meet the requirements both in very dense residential areas, hospitals, residential houses, food stalls in the port area are food stall doors that are not tightly closed. The toilet floor is cracked and the trash can has no cover and the wastewater treatment system has no grease traps, unqualified kitchens with leftovers are a favorite place for cockroaches. Cockroach vectors are found on ships, especially kitchens, warehouses and rafts.
- Based on previous research, it was found that Assessment-Based Pest Management (APM) is a program to reduce/eliminate the presence of German cockroaches in low-income housing very successfully in reducing cockroach density or cockroach infestations by 90%, Assessment-Based Pest Management (APM) can be used in the long term to reduce the population of German cockroaches in residential units.

### *Recommendation*

- Good environmental management needs to be done. Cleaning food storage areas, ensuring that no food remains are left behind, closing food/food items, closing access to wet/moist areas.
- It is recommended to improve cockroach control in crowded residential areas, hospitals, clinics, food stalls, markets and ships using the Assessment-Based Pest Management (APM) method which has been proven to be effective in reducing the level of cockroach infestation.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

The authors declare no competing interests.

### *Statement of informed consent*

Informed consent was obtained from all individual participants included in the study.

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