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Review

Strongyloides Infections Among Human and Non-Human Host in Indonesia: A Systematic Review

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Abstract: *Strongyloides* have been known to infect many hosts, including humans and animals around the world. The two, *S. stercoralis* and *S. fuellborni,* were zoonotic species that cause human strongyloidiasis. The disease induces a hyper infection syndrome in an immunocompetence person, while the clinical signs of infections in animals vary from asymptomatic to sudden death in severe and fatal cases. However, integrated data on *Strongyloides* infection among human and animal hosts in Indonesia is sparse. The present study aims to provide information on the prevalence of *Strongyloides* concerning host type and geographical region in Indonesia. Literature searches were conducted to identify epidemiological data on the occurrence of *Strongyloides* in humans and animals from 1985-2022 in seven regions of Indonesia, including 1) Sumatra; 2) Java; 3) Kalimantan; 4) Bali and Nusa Tenggara; 5) Sulawesi; 6) Maluku; and 7) Papua. The data were described and mentioned as percent prevalence and confidence intervals (CIs) of 95%. A total of 46 articles confirmed the *Strongyloides* infection in Indonesia during 1985-2022. The articles consisted of nine on humans (12 data) and 37 on animals (59 data). Human strongyloidiasis could be confirmed in five regions (Bali and Nusa Tenggara, Kalimantan, Maluku, Papua, and Sulawesi). *Strongyloides* infected some animal group hosts, such as pigs, ruminants (beef cattle, swamp buffalo, sheep, and goat), rodents, non-human primates (orangutan, lutung *(Trachypithecus auratus),* and long-tailed macaque), and others (rabbit, snake, and chicken) in different regions. This study provides the prevalence data on *Strongyloides* infection in human and animal hosts. The limited data on *Strongyloides* in Indonesia indicated that the disease is still being neglected and under-reported. More epidemiological studies with the improved diagnostic method are needed to determine the societal burden of the parasites.

Keywords: *Strongyloides, Indonesia, Human strongyloidiasis, Animal strongyloidiasis*

Endonezya'da İnsan ve İnsan Dışı Konaklar Arasında Strongyloides Enfeksiyonları: Sistematik Bir Değerlendirme

Öz: *Strongyloides*'in dünya çapında insanlar ve hayvanlar da dahil birçok konağı enfekte ettiği bilinmektedir. *S. stercoralis* ve *S. fuellborni*, insan strongyloidiasis'ine neden olan zoonotik türlerdir. Hastalık, immünokompetanslı bir insanda hiper enfeksiyon sendromuna neden olurken, hayvanlardaki enfeksiyonların klinik belirtileri asemptomatikten şiddetli ve ölümcül vakalarda ani ölüme kadar değişir. Bununla birlikte, Endonezya'da insan ve hayvan konakçıları arasında *Strongyloides* enfeksiyonuna ilişkin entegre veriler nadirdir. Bu çalışma, Endonezya'da konak tipi ve coğrafi bölgeye göre *Strongyloides* prevalansı hakkında bilgi sağlamayı amaçlamaktadır. 1985-2022 yılları arasında insan ve hayvanlarda *Strongyloides* görülme sıklığına ilişkin epidemiyolojik verileri belirlemek için Endonezya'nın 1) Sumatra; 2) Java; 3) Kalimantan; 4) Bali ve Nusa Tenggara; 5) Sulawesi; 6) Maluku ve 7) Papua olmak üzere yedi bölgesinde literatür taraması yapılmıştır. Veriler, yüzde prevalans ve %95'lik güven aralıkları (CI) olarak tanımlanmış ve belirtilmiştir. 1985-2022 yılları arasında Endonezya'da toplam 46 makalede *Strongyloides* enfeksiyonu bildirilmiştir. Makalelerin 9'u insanlar (12 veri) ve 37'si hayvanlar (59 veri) üzerinedir. İnsan Strongyloidiasis'i 5 bölgede (Bali ve Nusa Tenggara, Kalimantan, Maluku, Papua ve Sulawesi) doğrulanabilmiştir. *Strongyloides*, farklı bölgelerde domuz, geviş getiren hayvanlar (sığır, bataklık mandası, koyun ve keçi), kemirgenler, insan olmayan primatlar (orangutan, lutung (*Trachypithecus auratus*) ve uzun kuyruklu makak) ve diğerleri (tavşan, yılan ve tavuk) gibi bazı hayvan grubu konakçılarını enfekte etmiştir. Bu çalışma, insan ve hayvan konakçılarında *Strongyloides* enfeksiyonuna ilişkin prevalans verilerini sunmaktadır. Endonezya'da *Strongyloides* ile ilgili verilerin sınırlı olması, hastalığın hala ihmal edildiğini ve yeterince rapor edilmediğini göstermektedir. Parazitlerin toplumsal yükünü belirlemek için gelişmiş tanı yöntemleriyle daha fazla epidemiyolojik çalışmaya ihtiyaç vardır.

Anahtar sözcükler: *Strongyloides, Endonezya, İnsan strongyloidiasisi, Hayvan strongyloidiasisi*

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Introduction

Strongyloides is a genus of gastrointestinal nematodes infecting many hosts, such as mammals, reptiles, amphibians, and birds worldwide [1]. Around fifty species have been identified, with two major species responsible for human strongyloidiasis, a zoonosis disease transmitted from companion animals such as dogs and cats, namely *S. stercoralis* and *S. fuellborni* [2]. *Strongyloides stercoralis* was first reported from the stool samples of French soldiers who have severe diarrhea during their duty in Vietnam in 1876. The disease was also known as Cochin-China diarrhea [3]. The disease was typically chronic and non-pathognomonic, such as indigestion, diarrhea, constipation, irritable bowel syndrome, urticaria, and larva currents. The infection could induce hyper infection syndrome in the immunocompetence group induced by the large numbers of larvae in organs. The clinical manifestations involving diarrhea, intestinal bleeding, alveolar hemorrhages, heart failure, jaundice, bacteremia with fatality rate near to 90% [4].

Strongyloides species that infect animals are more varied but specific to each animal group. For example, *S. stercoralis* is species that infect dogs, while cats are infected with *S. felis*, *S. tumefaciens*, *S planiceps*, and perhaps *S. stercoralis*. In farm animals, pigs enabled to be infectedwith *S. ransomi*. On the other hand, *S. papillosus* has been an infecting agent for cattle and other ruminants in many countries [5].

As a large and developing country, Indonesia has become a house of more than 270 million people with a high diversity of flora and fauna. Transmission of soil-transmitted helminth (STHs), including *Strongyloides*, is potentially found among humans and animals occurs due to minimal hygiene practice and low awareness of the transmission route of the disease. In addition, the close habitat of animal and human are increasing the potency of zoonotic disease transmission. *Strongyloides* infections in humans and animals have been previously reported, but the national distribution following region and host are sparse. This study provides information on *Strongyloides* prevalence concerning host type and geographical region in Indonesia.

Methods

Study Area

Indonesia is the largest country in Southeast Asia, located on 6°08' N-11°15'S and 95°45 W'-141°05'E. It consists of 17.504 islands in the area of 1.913.578,68 km^2 [6]. The country borders are Malaysia, Singapore, the Philippines, and the Pacific Ocean to the north, Papua New Guinea and the Pacific Ocean to the east, the Indian Ocean to the west, and the Democratic Republic of Timor-Leste and the Indian Ocean to the south. Kalimantan, Sumatera, Java, and Sulawesi are among the largest islands in the country. Furthermore, Indonesia has a large area of rainforest and the house of the highest biological diversity in the world. The geographical condition varies from west to the east, including lowland to the mountainous region. As a tropical country, Indonesia has an extended period of dry and wet seasons within a year, providing a suitable environment for parasites including the gastrointestinal parasites.

Literature Selection and Data Extraction

A literature search was conducted to identify an epidemiological field survey of the infection of *Strongyloides* among human and non-human hosts in Indonesia. We conducted a literature search on the website of Google scholar and PubMed with the date restriction of the study set from January 1, 1985, to August 1, 2022, and the search terms: *Strongyloides* Indonesia, OR Strongyloidiasis Indonesia, OR gastrointestinal nematode Indonesia, both in Bahasa Indonesia and English. The whole search output is provided in *Attachment 1* and *Attachment 2*. During the literature selection, the title and abstract were screened based on the following criteria:

1. Dealing with infection of *Strongyloides* spp. in humans and animals in Indonesia;
2. Providing the primary data based on an epidemiological study or questionnaire survey;
3. Data reported from January 1, 1985, to August 1, 2022;
4. The full text was published in Bahasa Indonesia and English in a peer-reviewed journal or indexed proceeding.

According to the geographical condition, the region is divided into: (i) Sumatera, (ii) Java, (iii) Bali and Nusa

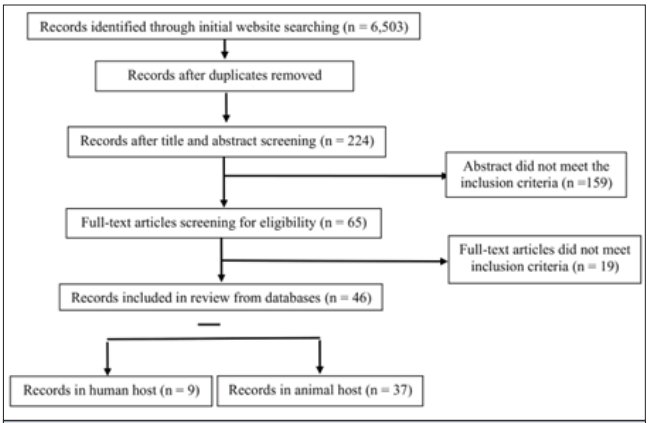

Fig 1. Flow diagram of the search strategy for strongyloidiasis in human and animal host

Table 1. *Eligible data revealed during 1985-2022*

Publication Years	Human	Animals				
		Pig	Ruminants	Rodents	Non-human Primates	Others
1985-2000	6	na	na	2	6	na
2001-2015	na	5	3	1	10	1
2016-2022	6	7	17	na	4	3
Total	**12**	**12**	**20**	**3**	**20**	**4**

na= not available

Tenggara, (iv) Kalimantan, (v) Sulawesi, (vi) Maluku, and (vii) Papua. Data added to the analysis were treated individually, even when published within one article. In addition, the data analysis was separated into humans and animals. *Figure 1* describes the flow diagram of the literature search and selection strategy.

Data Analysis

Data synthesis and calculation on prevalence of *Strongyloides* spp. in human and animals was done in the Microsoft Excel. The prevalence provided in percent and confidence intervals (95% CIs).

Results

The search initially revealed 6.503 articles, of which only 46 articles contained sufficient epidemiological data on infection of *Strongyloides* in Indonesia from 1985 to 2022 (attachments 1 and 2). The articles could be divided into nine articles (including 12 data) on humans and 37 articles (59 data) on animals *(Table 1)*. Unfortunately, the data on *Strongyloides* at the province or national level cannot be extracted for humans and animals, but the regional prevalence of *Strongyloides* is available in *Table 2*.

Nine articles (containing 12 data) confirmed *Strongyloides* in humans in five regions, including Bali and Nusa Tenggara, Maluku, Kalimantan, Sulawesi, and Papua. The highest prevalence of human strongyloidiasis was found in Papua, followed by Kalimantan and Maluku *(Table 2)*. Eleven out of 12 data on humans were obtained from a conventional coprology study, such as the Kato-Katz smear, Harada Mori coproculture, and Agar Plate Culture (APC). Only one data on humans in Mimika District, Papua, confirmed the infection agent into species level, *S. stercoralis*, by a real-time PCR technique [11].

Strongyloides spp. also infected numerous groups of animals on the farm, village, or district level *(Table 2)*. Most data on ruminants and pigs followed the standard coprology techniques for gastrointestinal nematodes, such as native, sedimentation, simple flotation and McMaster, and continued with Baermann coproculture method. The host range included Bali cattle, Madura cattle, Bligon goat, Kacang goat, swamp buffalo, crossbred sheep, and pigs. Most data on ruminants were obtained in the center of ruminant production in Java, Bali, and Nusa Tenggara region, while infection in pigs was most prevalent in Papua, Bali and Nusa Tenggara and a small part of Java where Islam is not predominantly practiced.

We identified 20 data on captive, semi-captive, and free-ranging endemic non-human primates, such as lutung *(Trachypithecus auratus)*, orangutan *(Pongo pigmaeus)*, and long-tailed macaque *(Macaca fascicularis)*. The data was collected from zoo, captivity, rehabilitation center, or national park in Java, Sumatera, Kalimantan, Bali and Nusa Tenggara. Moreover, the helminth was also found in animals that have close contact with humans, such as rodents, dogs, layer chickens, and captive phyton-snake. Since the golden standard method was unavailable for helminth identification on non-human primates, reptiles, and exotic animals, non-invasive methods such as scotch-tape perianal smear, Kato-Katz, McMaster, and sugar flotation could be chosen. On the other hand, a necropsy was feasible for rodents and chickens (domesticated fowl) following trapping in their habitat. None of the molecular epidemiology was recorded in animals in all regions, so the species of *Strongyloides* infecting each group of animals could not be determined.

Discussion

Human Strongyloidiasis

To our knowledge, the present study was the first systematic review of the epidemiology and distribution of *Strongyloides* in human and animal hosts in Indonesia. Our finding shows that the report on infection of *Strongyloides* in a human was very limited in the last three decades. Although study on human has covered at least five out of seven regions, none of the eligible studies were published for Java and Sumatera region, which has the highest human population in Indonesia. Moreover, the absence of data at the national level indicated that human strongyloidiasis is still being neglected and underreported; even disease control was prioritized in the national strategy for neglected tropical diseases control by the Ministry of Health of Indonesia in 2020-2024 [7].

Table 2. *Regional prevalence and techniques for diagnosing Strongyloides spp. infection among human and animals in Indonesia*

Region	Human (n=12)	Animals				
		Pig (n=12)	Ruminants (n=20)	Rodents (n=3)	Non-human Primates (n=20)	Others (n=4)
	% Prevalence (CI 95%)					
Bali and Nusa Tenggara	1.02 (0-2.21)	9.71 (2.98-16.44)	11.52 (1.11-21.92)	na	25.33 (3.12-47.55)	33.35 (0-85.64)
Java	na	6.1 (-)	13.47 (4.85-22.08)	53.00 (-)	71.92 (32.78-100)	15.67 (0-39.84)
Kalimantan	8.90 (0-18.30)	na	na	na	35.52 (22.36-48.69)	na
Maluku	5.59 (3.31-7.86)	na	na	48.98 (32.99-64.97)	na	na
Papua	9.42 (0-24.27)	18.25 (4.87-31.63)	65.22 (0-100)	na	na	na
Sulawesi	1.19 (-)	na	20.05 (-)	na	na	na
Sumatera	na	na	na	na	59.79 (33.68-85.89)	na
	Parasitological Techniques					
Bali and Nusa Tenggara	Kato-katz, Baermann coproculture, Koga Agar Plate, Harada Mori	Sodium Acetic Formaldehyde	Sugar Flotation	na	Formalin ethyl acetate concentration technique, Sugar Flotation	Sedimentation, Sugar Flotation
Java	na	Sugar Flotation	Sedimentation, Sugar flotation, McMaster Flotation, native	Kato-katz	Sugar Flotation	Sugar Flotation, Whitlock
Kalimantan	Kato-katz, agar plate culture	na	Na, Whitlock	na	McMaster Flotation	na
Maluku	Kato-katz	na	na	Necropsy	na	na
Papua	Direct smear, PCR	Necropsy, Sugar Flotation, McMaster Flotation	Sugar Flotation, McMaster Flotation	na	na	na
Sulawesi	Kato-katz	na	Sugar Flotation	na	na	na
Sumatera	na	na	na	na	Scotch-tape perianal smear	na

n: *number of data;* ***na:*** *not available*

In general, the prevalence of human strongyloidiasis conducted with the conventional parasitological technique was low [8]. Diagnosis of *Strongyloides* infection is challenging due to the low parasite load, irregular larval output, so the detection rate may be low, and multiple samples must be examined to achieve adequate sensitivity [2]. Results of a single stool examination using conventional techniques fail to detect larvae in up to 70% of cases [9]. The development of molecular diagnostics gave a chance to reach an accurate and timely diagnosis. In 2011, a real time-PCR was developed to diagnose the infection of *Strongyloides* spp. The 95 % detection limit, as determined by probit analysis, was one larva per PCR, equivalent to 100 larvae per 200 mg stool with 100% specificity [10]. The same technique was used in one epidemiological study on humans in Mimika Papua, which resulted in a high prevalence (32.00 %) of humans [11]. More epidemiological surveys with enhanced coprological methods from across the region and province are required to determine Indonesia's prevalence and disease burden. Estimation of prevalence at the country level has been developed by using a spatiotemporal statistic modeling approach, but it needs the large number of datasets including Gross Domestic Product (GDP), percentage of rural population, territory roughness, sanitation, annual mean temperature, and annual precipitation [8].

Another factor presumed to be linked to the prevalence of *Strongyloides* spp. is geo-climatic factors, such as temperature, humidity, rainfall, soil textures and farming ecosystem [12,13]. The combination of some climatic factors (such as temperature [10-21°C], humidity [40-75%], and annual rainfall [1 001-1 500 mm]), countries or regions with low-personal income, and availability contact to infected animals [14]. As a developing country, Indonesia shares a similar situation. Most studies on human strongyloidiasis were recorded from rural and

urban areas of Indonesia, targeting students, farmers, and housewives who have a high potential to contact the soil in their daily activities. Most face hygiene and sanitary problems due to poverty, limited access to proper public health care, and minimum intervention of health education to increase social awareness of the diseases. In addition, the low-personal income also directly affects the low-quality management of companion animals, such as the provision of caging and feeding. Through this study, we could see the zoonotic potency of *Strongyloides* spp. from possible carrier animals, such as the dog. Although only one eligible study on the dog was reported in the Java region in 2018, the disease is threatening the dog's owner due to the presence of zoonotic species on humans belonging to *S. stercoralis* [1]. As a possible transmission route is through skin penetration by the infective larvae, education on personal hygiene after contact with companion animals was crucial. More epidemiological investigation and transmission risk of *Strongyloides* spp. in dogs in another region was needed with enhanced diagnostic methodology.

Non-human Primates

The highest number of *Strongyloides* spp. infection data in animals were reported from the non-human primates' group. High prevalence of *Strongyloides* has been confirmed in foci habitat of endemic non-human primates, such as in Java, Kalimantan, Sumatera and Bali and, Nusa Tenggara. This situation must be considered a severe threat to human and animal health since the close habitat of animals to human as well as increasing number of ecotourism which involving non-human primates as the object [15]. The first molecular identification confirmed *S. fuellborni* transmission from an adult female with frequent contact with long-tailed macaque in Thailand and Lao-PDR [16]. According to the national conservation program perspective, research on *Strongyloides* in non-human primates needs to focus on early detection and developing a control strategy to avoid severe and fatal cases. A previous study reported the severe clinical symptoms of *Strongyloides* infection in 5-month-old Sumatran Orangutan, such as acute lethargy, dry and non-productive cough, pneumonia, and icterus [17]. *Strongyloides* caused histopathological changes in infected Bornean orangutans, characterized by multiple nodular elevations of the mucosa of the colon, hemorrhages in lungs, and ulcerations in the mucosa of cecum, appendix, and proximal colon [18].

- Ruminants

A total of 19 data of *Strongyloides* in ruminant was revealed through the present study. *Strongyloides* spp. was prevalent in Java, Bali and Nusa Tenggara, Sulawesi, and Papua region, which play the center of national ruminant production. The diseases may cause economic loss due to health disturbance and even mortality in livestock, including ruminants. For example, the prevalence of *Strongyloides* spp. in dairy calves (4-month-old) in Costa Rica was 4-20 % [19], and sudden death has also been reported by heavy experimental infection by 10.000 L3 on days 11-17 post-infection [20]. However, the prediction of sudden death also could be made through coproscopy if the egg count per gram of fecal samples (EPG) is more than 10.000 [5].

A young-infected goat might perform anorexia, cachexia, anemia, foaming at the mouth, and nervous system disturbance (ataxia, stupor, nystagmus), dehydration and diarrhea. In addition, some histological changes might be seen, such as liver rupture, nephrosis, pulmonary edema, interstitial pneumonia, and pneumonia. Six percents of goats died due to acute and fatal hepatic rupture. Undeveloped immunity in young calves and goats makes them susceptible to infection [21].

Infection was also detected in swamp buffalo in Java and Bali, and Nusa Tenggara region. Most of them are used for saving, working animals to plow paddy fields, and meat producers for the community [22]. However, close habitat to other farm animals, such as cattle, gave a chance for disease transmission. Therefore, further investigation needs to be conducted to provide information on cross-transmission among the livestock group in the same area.

- Pigs

The highest report on the pigs was obtained in Papua, Bali and Nusa Tenggara, and a small part of Java (Tangerang, Banten Province), where Islam is not predominantly practiced. A high prevalence of *Strongyloides* spp. in pigs was reported from high latitude in Jayawijaya, Papua, the center of the pig market, which sells both healthy and sick or dead (referred to as dead pig hereafter). The pigs are usually kept under the traditional farming system and slaughtered for consumption and cultural purposes, so the collection of helminth sample through necropsy or fecal sample collection were feasible even in the mountainous area in Papua [23].

In urban areas such as Denpasar, Bali (Bali and Nusa Tenggara region), and Tangerang, Banten (Java region), pig farming plays an essential role in economic activity. The pig population in Bali has become the second largest at the national level since Balinese Hindu people preferred to consume pig meat over cattle. Fecal collection usually obtained from slaughterhouse taken before the slaughtering process [24-26].

- Rodents

The report of *Strongyloides* spp. in rodents from Indonesia are few, but it is also likely that prevalence is high in urban

and rural areas. According to the collected data, there were two data collected from palm plantations and forests in Maluku, and one data from house rats in Surabaya (Java region) with the prevalence of both regions was 48.98% and 53.00%, respectively. The most recent study conducted in Malang City, East Java showed the lowest prevalence, but low-level of knowledge of people participating in the Knowledge, Attitude and Practice (KAP) study on strongyloidiasis are enhancing the potency of zoonotic transmission of parasite to human [27]. Eventhough all studies conducted in Indonesia used the coprological techniques with microscopic examination as the gold standart for egg determination, but those methods were insufficient to provide the data on the *Strongyloides*' species level. According to previous study, two most prevalence species found in rats were identified as *S. ratti* and *S. venezuelensis* which also become the rodent models of *Strongyloides* infection [28].

- Other Animals

Strongyloides spp. also infected exotic animals such as rabbits and phyton, as well as fowl in the region of Bali and Nusa Tenggara, and Java. More epidemiological surveys should be performed in another region since many exotic animals are kept in captivity and used as a pet animal.

Conclusion

The data on infection of *Strongyloides* in humans and animals at the national level was absent. The limited study on humans and each animal group suggest that parasite is under-reported in Indonesia. More epidemiological studies with improved diagnostic methodology are needed.

Moreover, the government at the local and national level must conduct active surveillance since mapping occurrences in humans and animals within a region will provide an integrated description of the disease as a basis for disease control at the national level. Support from private sector as well as community are needed as a key to combat *Strongyloides* infection among humans and animals in Indonesia.

Conflict of Interest

The authors declared that there is no conflict of interest

References

1. Eslahi AV, Hashemipour S, Olfatifar M, Houshmand E, Hajialilo E, Mahmoudi R, Badri M, Ketzis JK: Global prevalence and epidemiology of *Strongyloides stercoralis* in dogs: A systematic review and meta-analysis. *Parasite Vector*, 15 (1): 1-13, 2022. DOI: 10.1186/s13071-021-05135-0

2. Viney ME, Lok JB: The biology of *Strongyloides* spp. *WormBook*, 16, 1-17, 2015. DOI: 10.1895/wormbook.1.141.2

3. Grove DI: Human strongyloidiasis. *Adv Parasitol*, 38, 251-309, 1996. DOI: 10.1016/s0065-308x(08)60036-6

4. Vasquez-Rios G, Pineda-Reyes R, Pineda-Reyes J, Marin R, Ruiz EF, Terashima A: *Strongyloides stercoralis* hyperinfection syndrome: A deeper understanding of a neglected disease. *J Parasit Dis,* 43 (2): 167-175, 2019. DOI: 10.1007/s12639-019-01090-x

5. Thamsborg S, Ketzis J, Horii Y, Matthews J: *Strongyloides* spp. infections of veterinary importance. *Parasitology,* 144 (3): 274-284, 2017. DOI: 10.1017/S0031182016001116

6. Statistics Indonesia: Total Area and Number of Islands by Province, 2021. https://www.bps.go.id/indikator/indikator/view_data_pub/0000/api_pub/UFpWMmJZOVZlZTJnc1pXaHhDV1hPQT09/da_01/1Jakarta: Indonesia, 2022. *Accessed:* 20 June 2022.

7. Ministry of Health of the Republic Indonesia: Peraturan Menteri Kesehatan Republik Indonesia Nomor 21 tahun 2020 Tentang Rencana Strategis Kementerian Kesehatan tahun 2020-2024 (Regulation of the Minister of Health of the Republic of Indonesia Number 21 of Year 2020 concerning the Strategic Plan of the Ministry of Health for 2020-2024). Jakarta: Ministry of Health of the Republic of Indonesia, 2020.

8. Buonfrate D, Bisanzio D, Giorli G, Odermatt P, Fürst T, Greenaway C, French M, Reithinger R, Gobbi F, Montessor A, Bisoffi Z: The global prevalence of *Strongyloides stercoralis* infection. *Pathogens*, 9 (6):468, 2020. DOI: 10.3390/pathogens9060468

9. Ericsson CD, Steffen R, Siddiqui AA, Berk SL: Diagnosis of *Strongyloides stercoralis* infection. *Clin Infect Dis*, 33 (7): 1040-1047, 2001. DOI: 10.1086/322707

10. Kramme S, Nissen N, Soblik H, Erttmann K, Tannich E, Fleischer B, Panning M, Brattig N: Novel real-time PCR for the universal detection of *Strongyloides* species. *J Med Microbiol*, 60 (4): 454-458, 2011. DOI: 10.1099/jmm.0.025338-0

11. Kridaningsih TN, Sukmana DJ, Mufidah H, Diptyanusa A, Kusumasari RA, Burdam FH, Kenangalem E, Poespoprodjo JR, Fuad A, Mahendradhata Y, Supargiyono S, Utzinger J, Becker SL, Murhandarwati EEH: Epidemiology and risk factors of *Strongyloides stercoralis* infection in Papua, Indonesia: A molecular diagnostic study. *Acta Trop*, 209:105575, 2020. DOI: 10.1016/j.actatropica.2020.105575

12. Dey AR, Begum N, Alim MA, Malakar S, Islam MT, Alam MZ: Gastro-intestinal nematodes in goats in Bangladesh: A large-scale epidemiological study on the prevalence and risk factors. *Parasite Epidemiol Control*, 9:e00146, 2020. DOI: 10.1016/j.parepi.2020.e00146

13. Widjana DP, Sutisna P: Prevalence of soil-transmitted helminth infections in the rural population of Bali, Indonesia. *Southeast Asian J Trop Med Public Health*, 31 (3): 454-459, 2000.

14. Eslahi AV, Badri M, Nahavandi KH, Houshmand E, Dalvand S, Riahi SM, Johkool MG, Asadi N, Ahangari SAH, Taghipour A, Zibaei M, Khademvatan S: Prevalence of strongyloidiasis in the general population of the world: A systematic review and meta-analysis. *Pathog Glob Health*, 115 (1): 7-20, 2021. DOI: 10.1080/20477724.2020.1851922

15. Kurniawati DA, Suwanti LT, Lastuti NDR, Koesdarto S, Suprihati E, Pratiwi A: Zoonotic potential of gastrointestinal parasite in long-tailed macaque *Macaca fascicularis* at Baluran National Park, Situbondo, East Java, Indonesia. *Aceh J Anim Sci*, 5 (1): 47-56, 2020. DOI: 10.13170/ajas.5.1.15397

16. Thanchomnang T, Intapan P, Sanpool O, Rodpai R, Sadaow L, Phosuk I, Somboobpatarakun C, Laymanivong S, Tourtip S, Maleewong W: First molecular identification of *Strongyloides fuelleborni* in long-tailed macaques in Thailand and Lao People's Democratic Republic reveals considerable genetic diversity. *J Helminthol,* 93 (5): 608-615, 2019. DOI: 10.1017/S0022149X18000512

17. Kleinschmidt LM, Kinney ME, Hanley CS: Treatment of disseminated *Strongyloides* spp. infection in an infant Sumatran orangutan *(Pongo abelii). J Med Primatol*, 47 (3): 201-204, 2018. DOI: 10.1111/jmp.12338

18. Uemura E, Houser WD, Cupp CJ: Strongyloidiasis in an infant orangutan *(Pongo pygmaeus)* 1. *J Med Primatol*, 8 (5): 282-288, 1979. DOI: 10.1159/000460212

19. Jiménez AE, Fernandez A, Alfaro R, Dolz G, Vargas B, Epe C, Schnieder T: A cross-sectional survey of gastrointestinal parasites with dispersal stages in feces from Costa Rican dairy calves. *Vet Parasitol,* 173, 236-246, 2010. DOI: 10.1016/j.vetpar.2010.07.013

20. Tsuji N, Itabisashi T, Nakamura Y, Taira N, Kubo M, Ura S, Genno A: Sudden cardiac death in calves with experimental heavy infection of *Strongyloides papillosus*. *J Vet Med Sci*, 54 (6): 1137-1143, 1992. DOI: 10.1292/jvms.54.1137

21. Pienaar JG, Sasson PA, Du Plessis JL, Collins HM, Naude TW, Boyazoglu PA, Boomker J, Reyers F, Pienaar WL: Experimental studies with *Strongyloides papillosus* in goats. *Onderstepoort J Vet Res,* 66,191-235, 1999.

22. Nurhidayah N, Satrija F, Retnani EB: Gastrointestinal parasitic infection of swamp buffalo in Banten Province, Indonesia: Prevalence, risk factor, and its impact on production performance. *Trop Anim Sci J*, 42 (1): 6-12, 2019. DOI: 10.5398/tasj.2019.42.1.6

23. Nugroho W, Cargill CF, Putra I, Kirkwood RN, Trott DJ, Salasia SIO, Slipranata M, Reichel MP: Investigations of selected pathogens among village pigs in Central Papua, Indonesia. *Trop Anim Health Prod*, 48 (1): 29-36, 2016. DOI: 10.1007/s11250-015-0913-5

24. Akbar MW, Suratma NA, Oka IBM: Prevalensi dan intensitas infeksi cacing *Strongyloides ransomi* pada Babi yang Dipotong di Rumah Potong Hewan Pesanggaran Kota Denpasar. *Bul Vet Udayana,* 14 (3): 238-245, 2022. DOI: 10.24843/bulvet.2022.v14.i03.p07

25. Widisuputri NKA, Suwanti LT, Plumeriastuti H: A Survey for zoonotic and other gastrointestinal parasites in pig in Bali Province, Indonesia. *IJTID*, 8 (1): 54-65, 2020. DOI: 10.20473/ijtid.v8i1.10393

26. Wardhana AH, Sawitri DH, Ekawasti F, Martindah E, Apritadewi D, Shibahara T, Kusumoto M, Tokoro M, Sasai K, Matsubayashi M: Occurrence and genetic identifications of porcine *Entamoeba*, *E. suis* and *E. polecki*, at Tangerang in West Java, Indonesia. *Parasitol Res*, 119 (9): 2983-2990, 2020. DOI: 10.1007/s00436-020-06806-0

27. Kusumarini S, Danuarta MF, Karami F, Yesica R, Wisesa IBGR, Yudhana A, Nurhidayah N: Screening *Strongyloides* spp. infection from wild rodents implications for public awareness and attitudes on zoonotic diseases in Malang City, Indonesia. *JMV*, 5 (2): 196-206, 2022. DOI: 10.20473/jmv.vol5.iss2.2022.196-206

28. Viney M, Kikuchi T: *Strongyloides ratti* and *S. venezuelensis* - Rodent models of *Strongyloides* infection. *Parasitology,* 144 (3): 285-294, 2017. DOI: 10.1017/S0031182016000020

Attachment 1. *Infection of Strongyloides spp. in human host in Indonesia*

Author	N	Positive	Prevalensi	Host Group	Technique	Region
Widjana dan Sutisna [2000]	2394	39	1.63%	Human	Kato Katz	Bali and Nusa Tenggara
Onesiforus et al.[2020]	238	1	0.42%	Human	Baermann, KAP, Haradamori	Bali and Nusa Tenggara
Sedionoto et al.[2019]	213	0	0.00%	Human	Kato Katz	Kalimantan
Sedionoto et al.[2019]	213	35	16.43%	Human	Agar Plate Culture	Kalimantan
Sedionoto et al.[2021]	107	11	10.28%	Human	Kato Katz	Kalimantan
Mangali et al.[1994]	226	10	4.42%	Human	Kato Katz	Maluku
Mangali et al.[1994]	163	11	6.75%	Human	Kato Katz	Maluku
Bangs et al.[1996]	278	3	1.08%	Human	Direct smear	Papua
Bangs et al.[1996]	200	1	0.50%	Human	Direct smear	Papua
Yuwono et al.[2019]	147	6	4.08%	Human	Direct smear	Papua
Kridaningsih et al.[2020]	331	106	32.02%	Human	RT PCR	Papua
Toma et al.[1999]	589	7	1.19%	Human	Kato Katz	Sulawesi

Attachment 2. *Infection of Strongyloides spp. in animal host in Indonesia*

Author	N	Positive	Prevalensi	Host Group	Technique	Region
Akbar et al.[2022]	12	2	15.67	Pig	Flotation	Bali and Nusa Tenggara
Akbar et al.[2022]	90	8	8.89	Pig	Flotation	Bali and Nusa Tenggara
Akbar et al.[2022]	63	0	0	Pig	Flotation	Bali and Nusa Tenggara
Akbar et al.[2022]	35	0	0	Pig	Flotation	Bali and Nusa Tenggara
Antara et al.[2017]	50	1	2	Ruminants (Bali cattle)	Flotation	Bali and Nusa Tenggara
Antara et al.[2017]	50	1	2	Ruminants (Bali cattle)	Flotation	Bali and Nusa Tenggara
Apsari et al.[2022]	55	13	23.64	Ruminants (beef cattle)	Flotation	Bali and Nusa Tenggara
Awaludin et al.[2020]	175	14	8	Ruminants (sheep)	Sedimentation	Java
Baihaqi et al.[2015]	50	25	50	Ruminants (swamp buffalo)	Flotation	Bali and Nusa Tenggara
Collet et al.[1986]	22	20	90.91	Non-human primates	Scotch-tape perianal smear	Java
Collet et al.[1986]	14	13	92.86	Non-human primates	Scotch-tape perianal smear	Java
Collet et al.[1986]	21	14	66.67	Non-human primates	Scotch-tape perianal smear	Kalimantan
Collet et al.[1986]	11	4	36.36	Non-human primates	Scotch-tape perianal smear	Kalimantan
Collet et al.[1986]	13	13	100	Non-human primates	Scotch-tape perianal smear	Sumatera
Collet et al.[1986]	8	6	75	Non-human primates	Scotch-tape perianal smear	Sumatera
Dwinata et al.[2018]	100	4	4	Ruminants (Bali cattle)	Flotation	Bali and Nusa Tenggara
Ekawasti et al.[2019]	289	37	12.8	Ruminant (beef cattle)	Sugar Flotation	Java
Fadli et al.[2014]	100	4	4	Ruminants (Bali cattle)	Flotation	Bali and Nusa Tenggara
Guna et al.[2014]	20	6	30	Pig	Necropsy	Papua
Guna et al.[2014]	10	0	0	Pig	Necropsy	Papua
Hasegawa et al.[1995]	49	20	40.82	Rodents	Necropsy	Maluku
Hasegawa et al.[1995]	49	28	57.14	Rodents	Necropsy	Maluku
Hasyim et al.[2019]	150	30	20.05	Ruminants (Bali cattle)	Flotation	Sulawesi
Joesoef et al.[2018]	50	7	14	Non-human primates	FECT	Bali and Nusa Tenggara
Joesoef et al.[2018]	50	7	14	Non-human primates	FECT	Bali and Nusa Tenggara
Kurniawati et al.[2020]	100	32	32	Non-human primates	Flotation	Java
Kusuma et al.[2021]	150	42	28	Non-human primates	Whitlock	Java

Labes et al.[2010]	163	62	38.04	Non-human primates	McMaster	Kalimantan
Labes et al.[2010]	61	20	32.79	Non-human primates	McMaster	Kalimantan
Labes et al.[2010]	38	22	57.89	Non-human primates	McMaster	Kalimantan
Mul et al.[2007]	54	44	81.48	Non-human primates	Ridley Method	Sumatera
Mul et al.[2007]	32	15	46.88	Non-human primates	Ridley Method	Sumatera
Mul et al.[2007]	19	9	47.37	Non-human primates	Ridley Method	Sumatera
Murdayasa et al.[2019]	50	24	48	Non-human primates	Flotation	Bali and Nusa Tenggara
Nasution et al.[2018]	30	1	3.33	Dog	Flotation	Java
Nugroho et al.[2016]	103	16	15.7	Pig	McMaster	Papua
Nugroho et al.[2016]	92	25	27.3	Pig	Flotation	Papua
Nurcahyo and Prastowo [2013]	171	41	24	Non-human primates	McMaster	Kalimantan
Nurcahyo and Prastowo [2013]	80	11	13.75	Non-human primates	McMaster	Kalimantan
Nurcahyo and Prastowo [2013]	75	11	14.67	Non-human primates	McMaster	Kalimantan
Nurhidayah et al.[2019]	340	10	2.94	Ruminants (swamp buffalo)	McMaster	Java
Oka and Dwinata [2011]	501	37	7.4	Pig	Sodium Acetic Formaldehid	Bali and Nusa Tenggara
Prasetyo [2016]	98	52	53.00	Rodents	Kato-Katz	Java
Purwaningsih and Sumiarto [2012]	1432	90	6.28	Ruminants (beef cattle)	Native	Java
Purwaningsih et al.[2017]	32	32	100	Ruminants (Kacang goat)	Flotation	West Papua
Purwaningsih et al.[2020]	120	37	30.43	Ruminants (beef cattle)	McMaster	West Papua
Purwati et al.[2021]	35	12	34	Ruminants (Bligon goat)	Native	Java
Rahmi et al.[2010]	25	2	8	Non-human primates	Flotation	Sumatera
Ridwan et al.[2018]	263	12	4.56	Ruminants (beef cattle)	McMaster	Java
Ridwan et al.[2018]	270	19	7.04	Ruminants (beef cattle)	McMaster	Java
Sajuri et al.[2017]	100	8	8	Ruminants (Bali cattle)	Flotation	Bali and Nusa Tenggara
Sawitri et al.[2019]	109	35	32.1	Ruminants (beef cattle)	Flotation	Java
Sismami et al.[2014]	15	9	60.03	Reptile	Sedimentation	Bali and Nusa Tenggara
Suastini et al.[2021]	150	4	2.7	Ruminants (Bali cattle)	Flotation	Bali and Nusa Tenggara
Suastini et al.[2021]	150	11	7.3	Ruminants (Bali cattle)	Flotation	Bali and Nusa Tenggara
Telnoni et al.[2016]	30	2	6.67	Reptile	Flotation	Bali and Nusa Tenggara
Wardhana et al.[2020]	196	12	6.1	Pig	Flotation	Java
Widisuputri et al.[2020]	50	13	26	Pig	Flotation	Bali and Nusa Tenggara
Widisuputri et al.[2020]	50	5	10	Pig	Flotation	Bali and Nusa Tenggara