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Environmental Risk Factors and Hookworm Infection among Schoolchildren in Rural Areas of Indonesia

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ABSTRACT

Background: The prevalence of hookworm infection is a serious public health concern globally. Java Island and Kalimantan Island have differential environmental risk factors of hookworm infection, especially in rural areas of Indonesia, which have high-risk environmental factors for the prevalence of hookworm infection. This study aimed to investigate the infection rates and correlation between environmental risk factors and the prevalence of hookworm infection.
Subjects and Method: This was a cross-sectional study conducted among 226 school children from rural East Java province, Central Java Province, and East Kalimantan Province, Indonesia. A simple random sampling method was applied to select participants from each school area. This study used two diagnostic methods: Kato Katz and Koga agar plate culture/KAP culture for diagnosing hookworm infections. Environmental variables examined included soil texture, organic carbon content, clay content, soil pH, rainfall volume, number of rainy days, humidity, temperature, elevation, vegetation type, and pet infection status. Pearson's chi-square analysis was used to study the correlation between environmental factors and hookworm infection.
Results: Hookworm, Strongyloides sp, and Ascaris sp infections were found in this study; 137 (60.63%), 25 (11.1%), and 124 (9.84%), respectively. Environmental risk factors such as rainy season, quality of soil, and infection with hookworm in pets have a significant correlation ($p<0.050$) with hookworm infection among schoolchildren in a rural area in Indonesia.
Conclusion: The prevalence of hookworm infection correlates with environmental factors, and the findings in this research could contribute to decreasing the prevalence of hookworm infection, especially among schoolchildren in rural areas.

Keywords: Hookworm, *Strongyloides sp, Ascaris sp*, infections, schoolchildren

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BACKGROUND

The prevalence of hookworm infection is of serious public health concern globally. Hookworm infection is prevalent in poor rural communities in tropical and subtropical areas in many developing countries (Sedionoto et al., 2021). They are transmitted through protected contact with soil and

are endemic in tropical and temperate regions. The prevalence of hookworm infection was estimated in 2010 that 438.9 million people infected with hookworm and 100 million with strongyloides. Almost 70% of these infections occur in Asia (Bethony et al., 2006; Pullan et al., 2014; WHO, 2011). Hookworm infection is transmitted through protected contact with infected soil and is endemic in tropical and temperate regions. Humans acquire hookworm infection through direct skin contact with infective third-stage larvae where the soil was contaminated by human feces, penetrates the intact human skin and eventually reaches the small intestine (Forrer et al., 2016).

Generally, hookworm infection is found among poor people with poor environmental sanitation and where the climate is warm and humid (Hall et al., 1994; Bannon et al., 1995). Factors affecting the difference in the distribution of hookworm infection may include good hygiene practices among the population, availability of sewerage systems, and the length of the rainy season. Environmental factors have contributed to the transmission of diseases as well as the growth and development of worms (Anamnart et al., 2013; Na-Ek et al., 2016).

Environmental factors, especially the long rainy season, may affect the decrease in the prevalence of strongyloidiasis, but not for hookworm infection. The prevalence of strongyloidiasis in the south Thailand is lower than in other parts of the country. In contrast, the prevalence of hookworm infection is still high in the south. It is possible because of the failure in the control of hookworm infection due to 10 10-month-long rainy season in southern Thailand, contrasted with the 4-month-long rainy season in other parts (Anamnart et al., 2015). The study in Cambodia reported a lower prevalence of strongyloidiasis in an area with heavy rainfall than in low rainfall areas. Moreover, a high amount of soil organic carbon content affects the lower prevalence of strongyloidiasis (Khieu et al., 2014). Epidemiology study of hookworm infection and strongyloidiasis in Southern Laos showed 56.1% and 41% respectively, where has heavy rainfall and poor sanitation. In this study, Baerman and Kato-Katz techniques were used for detecting them (Vonghachack et al., 2015).

Indonesia has environmental risk factors of the prevalence of hookworm infection and strongyloidiasis, especially for school children in rural areas, which have differential characteristics from other Southeast Asia countries (Khieu et al., 2013). Rural East Java Province, Central Java Province, and East Kalimantan Province have differential environmental risk factors of hookworm infection. The study was important in exploring the association between the prevalence of hookworm infection and environmental risk factors. We performed a cross-sectional study in school children in Sumberwringin district, Bondowoso regency, East Java Province, Pakis district, Magelang Regency, Central Java Province and Muara Kaman district and Marangkayu district, East Kalimantan province to the analysis of geography, texture of the soil, humidity, hookworm, and Strongyloides in pet, vegetation, elevation, volume rain, number day and month of rain yearly, temperature and quality of soil as clay content, organic carbon of soil and pH of soil then was correlated with the prevalence of hookworm infection (Sedionoto et al., 2019). This study aimed to investigate the infection rates and correlation between environmental risk factors and the prevalence of hookworm infection.

SUBJECTS AND METHOD

1. Study Design

The study was carried out in the rural areas of East Java Province, Central Java Province, and East Kalimantan Province, especially

among schoolchildren, Indonesia. This research is schoolchild-based, and was conducted from July 2018- July 2019.

2. Population and Sample

The total number of participants is 226 schoolchildren who joined and sent stool samples. The sample population is counted. These areas were selected based on the potential risk of hookworm infection and strongyloidiasis, consisting of rural areas, poor sanitation and hygiene, agricultural activity, and surrounding forest, and have not yet data study of hookworm and S. stercoralis infection from both areas. The sample size was determined using the single population formula by Stanley Lemeshow's sampling technique. It was calculated using a prevalence rate (p) of 37% as detail in a previous study (Merisa et al., 2014), with a 95% confidence interval (z=1.96) and a 10% margin of error (d=0.1). The calculated sample size was 90 participants per province of the school area. We assumed that the final sample size would end up being reduced by around 10% due to subjects being unable to pass stool on the study date, and we aimed for a sample size of 100 schoolchildren. A simple random sampling method was used to select the population from the district of the school area. Inclusion criteria were participants who were ≥ 7 years old and studied in both school areas. We collected 226 schoolchildren participants who have completed questionnaires and stools.

3. Study Variables

Environmental data were collected consist such including vegetation, the elevation of soil, the kind of pets, the kind of soil around houses, the length of the rainy season, humidity, and temperature per year. The quality of soil, including organic carbon content, clay content, and pH, was diagnosed by the soil laboratory at Mulawarman University. Vegetation and kind of soil around houses will be collected by observation form, kind of pet will be collected by questioner and observation, and length of the rainy season, humidity and temperature per year will be collected from Central Bureau of Statistics (https://www.bps.go.id) and Central Bureau of meteorology, climatology, and Geophysical of Indonesia (https://www.bmkg.go.id).

4. Operational Definition of Variable

Soil texture: was classified based on field observations and laboratory analysis into sandy, clay, loamy, or mixed types.

Organic carbon content: was categorized into five levels based on percentage measurements analyzed in a soil laboratory.

Rainy season: was defined based on the number of days with precipitation >1 mm/ month, obtained from the Meteorology Agency (BMKG).

Hookworm infection in pets: was confirmed by laboratory stool examination.

5. Study Instruments

For collecting stool samples, the first day was requested to head of the master of school children and the parents of school children for requesting stool sample, second day in the morning would start to collect stool samples, were brought to parasitology laboratory of B2P2RV Salatiga, Ministry of Health Republic Indonesia for samples from East Java Province and Central Java Province and samples from East Kalimantan were brought to Parasitology Mulawarman University for diagnosis samples. On other days was done environmental conditions of houses surrounding the village.

Agar plate culture and Kato Katz technique. Agar plate culture will be done as described by Koga et al., 1991 (Koga et al., 1991). Briefly, a few grams of stool will be placed at the center of nutrient agar and kept at room temperature for five days. Tracks from larva crawling and larvae or adult worms will be observed. If positive, 10 ml of 10% formalin will be added to the agar surface for 5-10 minutes and transferred to a

centrifuged tube. Centrifugation at 2,500 rpm for 5 minutes, and the supernatant will be discarded. The sediment will be examined for hookworm larvae and S. stercoralis larvae or adult worm, Kato-Katz thick smear, 50 mg of stool will be placed on the slide and covered with a cellophane paper soaked in glycerin solution for 24 hours. The stool will be spread out using a rubber stick. After 30 minutes will be examined and counted for eggs (Anamnart et al., 2010; Katz et al., 1972).

6. Data Analysis

The prevalence of hookworm and Strongyloides infection was stratified according to environmental data and reported by descriptive statistics. Statistical analysis was performed by Chi-square using SPSS version 21. The correlation analysis was analyzed by Pearson Chi-square to evaluate the association of hookworm and Strongyloides infections with environmental risk factors, and the level of significance was considered as $p< 0.050$ (Daniel, 2010). Odds Ratio (OR) and 95% Confidence Intervals (CI) were not computed for environmental variables with more than two categories or continuous data, to avoid misclassification or loss of information. Therefore, association was assessed using Chi-square tests with significance level set at $p < 0.050$.

7. Research Ethics

Official permission and ethical clearance for the collection of human fecal samples were obtained from the local provincial government of East Java, Central Java, and East Kalimantan. The study protocol was approved by the Ethical Clearance Committee on human rights related to research involving human subjects, Walailak University HE: number WUEc-18-034-01.

RESULTS

1. Study Sample

A total of 226 schoolchildren participated in this study. We collected data from five schools such as three schools from East Kalimantan, one school from East Java and one school from Central Java, with detail three provinces are Central Java Provinces, East Java Provinces and East Kalimantan Province, all of areas research were conducted in rural and agriculture area with the areas have differences characteristic of environmental risk factors.

2. Parasitological Findings

Prevalence hookworm and Strongyloides infection/strongyloidiasis were diagnosed by Kato Katz technique and APC method showed of 226 tested samples from children have 137 (60.63%) cases found positive with hookworm infection and 25 (11.1%) cases found positive with Strongyloides infection and addition finding of Ascaris lumbricoides as 124 (9.84%). Detailed data on the prevalence of hookworm and Strongyloides infections are explained in Table 1. The prevalence of hookworm infection, 137 (60.63%), is higher than other infections and the Prevalence of strongyloidiasis was only found in East Kalimantan Province with 25 (11.1%) cases, and has not been found in East Java Province and Central Java Province.

Table 1. Prevalence of hookworm among schoolchildren in Indonesia (N=226)

Infections	East Java				Central Java				East Kalimantan				Overall Positive	
	Positive		Negative		Positive		Negative		Positive		Negative			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Hookworm	69	97.2	2	2.8	20	41.7	28	58.3	48	44.9	59	55.1	137	60.6
S. stercoralis	0	0.0	71	100	0	0.0	48	100	25	23.4	82	76.6	25	11.1
Ascaris sp	3	4.2	68	95.8	2	4.2	46	95.8	11	10.3	96	89.7	124	9.8

3. Characteristic Participant and Hookworm Infection

The highest prevalence of hookworm infection was found in East Java is 69 (97.2%) from total of 71 children, therefore the lowest prevalence of hookworm infection was found in Central Java province is 20 (41.7%) among 48 children, Percentage of the prevalence of hookworm infection in East Kalimantan 48 (44.9%) is higher than in Central Java.

Correlation between the prevalence of hookworm infection and the province of school children's area was shown by Pearson X^2 that hookworm infections were significantly correlated with the province ($p < 0.001$). East Java province has different characteristics from central Java and East Kalimantan Province, such as environmental risk factors, including quality of soil, kind of vegetation, number of days of rain yearly, humidity, and temperature, which are determinants of the highest percentage of hookworm infection than other provinces.

Hookworm infection in females was known to be higher than the male, with 72 (63.2%) and 65 (58.0%), respectively from 114 female participants and 112 male participants. Gender has not significantly correlated with hookworm infections ($p = 0.431$). Hookworm infection was found dominant among school children in class level 1(100%) and school children in class level 2 (88.9%). The present study showed a significant correlation between the level of study with hookworm infection is negative ($p = 0.223$).

4. Sensitivity of diagnostic method for hookworm and Strongyloides infections

By KAP culture technique showed that 33 (14.6%) of the prevalence of hookworm infection is higher than the Kato-Katz technique, and 137 (60.6%) KAP culture method is more sensitive than the Kato-Katz technique on the diagnosis of hookworm infection among schoolchildren in Indonesia.

As far as we know, the most sensitive method for S. stercoralis diagnosis is KAP culture.20 We used Kato-Katz thick smear and KAP culture on a double stool sample from school children, in a total found 14.6% infected with hookworm infection diagnosed by Kato-Katz. KAP culture has more sensitivity than Kato Katz in this research, with the founding of prevalence of hookworm infection being 60.6%. This technique can explain the detailed of growing up each step development of filariform larvae, particularly for detecting filariform larvae of hookworm.

5. Environmental Factors and Hookworm Infection

Statistical analysis of hookworm and Strongyloides infection between environmental factors such as geography, the texture of the soil, infection status of pet, humidity, vegetation, elevation, amount day of rain, the volume of rain, temperature, pH, clay content of the soil, organic carbon of soil, explained detail in Table 2. Sandy soil with 89(74.8%) hookworm infection has the highest level of the prevalence of hookworm infection than other types of soil; organic carbon content in area 1 (1.50%) with 69 (97.2%) hookworm infection is the highest level of the prevalence of hookworm infection than others cluster; clay content in Area 3 (3.0%) with 97.2% hookworm infection is the highest level of the prevalence of hookworm infection than others cluster and pH of the soil in cluster Area 5 (7.79) with hookworm infection 97.2% is the highest level of the prevalence of hookworm infection than others cluster. Texture, organic carbon content, clay content, and pH of soil have significantly correlated with hookworm infection ($p < 0.001$).

Table 2. Correlation quality of soil and hookworm infection

Quality of Soil	Status of Diagnosis Participants				p
	Positive		Negative		
	N	%	N	%	
Texture of soil					
Sandy clay	17	70.8	7	29.2	<0.001
Loamy sand	13	38.2	21	61.8	
Sand	89	74.8	30	25.2	
Clay	18	36.7	31	63.3	
Organic Carbon content (5 School children areas)					
Area 1 (1.50%)	69	97.2	2	2.8	<0.001
Area 2 (1.83%)	17	70.8	7	29.2	
Area 3 (2.77%)	20	41.7	28	58.3	
Area 4 (3.13%)	18	36.7	31	63.3	
Area 5 (7.22%)	13	38.2	21	61.8	
Clay content (5 areas)					
Area 1 (1.2%)	20	41.7	28	58.3	<0.001
Area 2 (1.9%)	13	38.2	21	61.8	
Area 3 (3.0%)	69	97.2	2	2.8	
Area 4 (34.7%)	18	36.7	31	63.3	
Area 5 (38.6%)	17	70.8	7	29.2	
pH of soil (5 areas)					
Area 1 (4.26)	17	70.8	7	29.2	<0.001
Area 2 (6.60)	20	41.7	28	58.3	
Area 3 (7.22)	18	36.7	31	63.3	
Area 4 (7.40)	13	38.2	21	61.8	
Area 5 (7.79)	69	97.2	2	2.8	
Temperature					
Area 1 (20.5°C)	20	41.7	28	58.3	<0.001
Area 2 (22.0°C)	69	97.2	2	2.8	
Area 3 (28.0°C)	13	38.2	21	61.8	
Area 4 (29.5°C)	35	47.9	38	52.1	
Humidity					
Area 1 (65%)	13	38.2	21	61.8	<0.001
Area 2 (66%)	35	47.9	38	52.1	
Area 3 (82%)	20	41.7	28	58.3	
Area 4 (90%)	69	97.2	2	2.8	
Number of days of rain yearly					
Station 1 (122 days)	69	97.2	2	2.8	<0.001
Station 2 (139 days)	20	41.7	28	58.3	
Station 3 (152 days)	35	47.9	38	52.1	
Station 4 (174 days)	13	38.2	21	61.8	
Volume of rain yearly					
Station 1 (2,937 mm)	69	97.2	2	2.8	<0.001
Station 2 (2,990 mm)	35	47.9	38	52.1	
Station 3 (3,689 mm)	20	41.7	28	58.3	
Station 4 (4,000 mm)	13	38.2	21	61.8	

6. Climatology and Hookworm Infection

Correlation climatology and hookworm infection detail was explained in Table 2. The table showed that the temperature in area 2 (22.0 °C) with hookworm infection, 97.2%, is higher than in other areas. Humidity in area 4 (90) with hookworm infection, 97.2%, is higher than in other areas. Temperature and humidity have significantly correlated with hookworm infection ($p<0.001$). Prevalence of hookworm infection stratified by several days of rain yearly. Station 1 (122 days) has the highest hookworm infection prevalence, was 97.2%. Area 1 (7 months), which has 7 months of the long

rainy season, has the highest prevalence of hookworm infection, 97.2%. Station 1 (2.937 mm) of the volume of rain yearly, hookworm infection was found 97.2% is the highest. The number of days, months, and volume of rain yearly have correlated with hookworm infection ($p < 0.001$).

7. Vegetation, Location, Pet, and Hookworm Infection

Detailed distribution and correlation of vegetation, location with hookworm infection are explained in Table 3. The table explained that the highest percentage for the prevalence of hookworm infection by stratified vegetation is palm plantation, which 55.2% hookworm infection. Prevalence of hookworm infection, as shown by geographical area, is highest in the buffer of the river (59.9%), where the location of the participant is surrounded river. The elevation where found highest prevalence of hookworm infection was found was in station 3 (50m), with a hookworm infection 69.8%. Vegetation, geographic area, and elevation are all environmental risk factors that have a significant correlation with hookworm infection ($p < 0.001$).

Table 3. Vegetation, Location, Pet, and Hookworm Infection

Environmental risk factors	Status of Diagnosis Participants				p
	Positive		Negative		
	N	%	N	%	
Vegetation					
Coffee plantation	69	97.2	2	2.8	<0.001
Vegetable plantation	20	41.7	28	58.3	
Palm and rubber plantation	48	44.9	59	55.1	
Geography of the village area					
A buffer of sea/coastal area	13	38.2	21	61.8	<0.001
A buffer of the river	17	70.8	7	29.2	
Hill	18	36.7	31	63.3	
Mountain area	89	74.8	30	25.2	
Elevation from the sea surface (m)					
Station 1 (32 m)	35	47.9	38	52.1	<0.001
Station 2 (50 m)	13	38.2	21	61.8	
Station 4 (700 m)	69	97.2	2	2.8	
Station 5 (841 m)	20	41.7	28	58.3	
Hookworm in a cat					
Infected cat with hookworm	48	44.9	59	55.1	<0.001
Non-infected cat by hookworm	89	74.8	30	25.2	
Hookworm in a dog					
Infected dog with hookworm	117	65.7	61	34.3	0.002
Non-infected dog by hookworm	20	41.7	28	58.3	

Participants were infected by hookworm with infected cat by hookworm 48 (44.9%) while they whose non-infected cat by hookworm 89 (74.8%), participants whose Participants were infected dog by hookworm 117 (65.7%), analysis pearson X^2 hookworm in human has significantly correlated with infected cat and dog by hookworm with p-value <0.001 and p=0.002 respectively. The result of statistical analysis showed that environmental factors have an association with the prevalence of hookworm infection, the environmental factors, including the geography of an area, hookworm in a dog, humidity, vegetation, and elevation. The number of days of rain yearly, several months of rain yearly, the volume of rain, and quality of soil as texture, organic carbon of soil, clay content of the soil, and pH of soil

have significance (p<0.050) with the prevalence of hookworm infection in Indonesia.

DISCUSSION

The prevalence of hookworm infection, 137 (60.63%), is higher than other infections, and the Prevalence of strongyloidiasis was only found in East Kalimantan Province with 25 (11.1%) cases, and has not been found in East Java Province and Central Java Province. The correlation of the prevalence of hookworm infection and strongyloidiasis is significant (p<0.001). A similar study in Manufahi District, Timor Leste, which is a rural area with a prevalence of hookworm infection, was 62.8% (Nery et al., 2015). Hookworm infection and strongyloidiasis are both neglected tropical diseases (Anamnart et al., 2010). In poor countries with a tropical climate, conditions favorable for transmission of these parasites have a higher prevalence of hookworm infection and strongyloidiasis (Jongwutiwes et al., 1999). Furthermore, low socioeconomic status and low hygiene living conditions of the rural population are strongly associated with hookworm infection and strongyloidiasis. In Southeast Asia, recent work in Cambodia reported a very high infection rate in Takeo Province (Khieu et al., 2014).

Hookworm infection in females was known to be higher than the males, with 72 (63.2%) and 65 (58.0%), respectively, from 114 female participants and 112 male participants. Gender has not significantly correlated with hookworm infections (p = 0.431). Hookworm infection was found dominant among school children in class level 1(100%) and school children class level 2 (88.9%). The study showed a significant correlation between the level of study with hookworm infection is negative (p= 0.223). By KAP culture technique showed that 33 (14.6%) of the prevalence of hookworm infection is higher than the Kato-Katz technique 137 (60.6%) KAP culture method has higher sensitivity than the Kato-Katz technique for the diagnosis of hookworm infection among schoolchildren in Indonesia (Anamnart et al., 2010; Steinmann et al., 2015).

Sandy soil with 89(74.8%) hookworm infection has the highest level of the prevalence of hookworm infection than other types of soil; organic carbon content in area 1 (1.50%) with 69(97.2%) hookworm infection is the highest level of the prevalence of hookworm infection than others cluster; clay content in Area 3 (3.0%) with 97.2% hookworm infection is the highest level of the prevalence of hookworm infection than others cluster and pH of the soil in cluster Area 5 (7.79) with hookworm infection 97.2% is the highest level of the prevalence of hookworm infection than others cluster. Texture, organic carbon content, clay content, and pH of soil have significantly correlated with hookworm infection (p < 0.001). The result showed that the quality of soil has contributed to high prevalences of hookworm infection (Sedionoto et al., 2021).

The temperature in area 2 (22.0°C) with hookworm infection of 97.2% is higher than in other areas. Humidity in area 4 (90) with hookworm infection, 97.2% is higher than in other areas. Temperature and humidity have significantly correlated with hookworm infection (p<0.001). The highest percentage for the prevalence of hookworm infection by stratified vegetation is palm plantation, with 55.2% hookworm infection. The prevalence of hookworm infection, as shown by geographical area, is highest in the buffer of the river (59.9%), where the location village of the participant is surrounded river. The elevation where found highest prevalence of hookworm infection was found was in station 3 (50m), with a hookworm infection 69.8%. Vegetation, geographic area, and elevation are all environmental risk

factors that have a significant correlation with hookworm infection ($p < 0.001$).

The prevalence of hookworm infection was stratified based on the number of rainy days per year. Station 1, with 122 rainy days annually, had the highest prevalence at 97.2%. Similarly, Area 1, which experiences a long rainy season of 7 months, also showed the highest prevalence of hookworm infection at 97.2%. In terms of annual rainfall volume, Station 1, with 2,937 mm of rainfall, had the highest prevalence at 97.2%. The number of rainy days, the duration of the rainy season in months, and the total annual rainfall volume were all significantly correlated with hookworm infection ($p < 0.001$).

Environmental factors of hookworm and strongyloidiasis in East Kalimantan has similar with south Thailand including long rainy season, temperature, and several geography areas, then the prevalence of hookworm infection in East Kalimantan Province (44.1%) is higher than in south Thailand but equal for Strongyloidiasis, that condition was caused other environmental risk factors like quality of soil such as organic carbon of soil, clay content and pH (Anamnart et al., 2015).

The prevalence of hookworm infection in East Kalimantan is similar to a study in southern Laos and Cambodia, where hookworm is still high, but more than the prevalence of strongyloidiasis. The study in Cambodia reported a lower prevalence of strongyloidiasis in an area with heavy rainfall than in low rainfall areas. Moreover, a high amount of soil organic carbon content affects the lower prevalence of strongyloidiasis (Khieu et al., 2014). Epidemiology study of hookworm infection and strongyloidiasis in Southern Laos showed 56.1% and 41%, respectively, where there was heavy rainfall and poor sanitation. In this study, Baerman and Kato-Katz techniques were used for detecting them (Khieu et al., 2013).

Schoolchildren were infected by hookworm with infected cat by hookworm 48 (44.9%) while they whose non-infected cat by hookworm 89 (74.8%), participants whose Participants were infected dog by hookworm 117 (65.7%), analysis pearsonX2 hookworm in human has significant correlated with infected cat and dog by hookworm with $p< 0.001$ and $p=0.002$ respectively. This research has a similar condition to the Cambodian research, where dogs in rural Cambodian villages are largely kept as guard dogs and allowed to roam freely, especially during the day. The dogs are also allowed inside the house and around rice and vegetable fields and ponds. At night, the dogs often stay in or around the house. Dogs, therefore, pose a serious zoonotic risk as they have the potential to transmit zoonotic parasites through their close association with household members as well as through heavy contamination of the environment, including soil, fresh produce, and waterways, with eggs or larvae hookworm, in our observation sew behavior of cats almost all day and night stayed around houses and rare contact with ponds and did not stay around rice and vegetable fields, the behavior of the dog is a higher potential zoonotic risk for hookworm infection than the behavior of the cat (Schär et al., 2014; Strkolcova, et al., 2017). Behavior of cat defecation makes the un-save survive of the egg or larvae of hookworm infection. Defecation of the cat does not risk of hookworm infection. Usually, the cat closed the feces after defecation with dry soil, and the cat has defecated around houses, which did not spread to other places (Sedionotoand Anamnart, 2018).

The result of statistical analysis showed that environmental factors have an association with the prevalence of hookworm infection, the environmental factors, including the geography of an area, hook-

worm in dogs, humidity, vegetation, and elevation. The number of days of rain yearly, several months of rain yearly, the volume of rain, and quality of soil as texture, organic carbon of soil, clay content of the soil, and pH of soil have significance ($p<0.050$) with the prevalence of hookworm infection in Indonesia. The transmission of hookworm infection and strongyloidiasis was caused by the tropical climate and the environmental conditions that are favorable for the survival of hookworm infection (Jongwutiwes et al., 1999).

Environmental factors of hookworm infection and strongyloidiasis among schoolchildren in Indonesia have significance with high of prevalence of hookworm infection and strongyloidiasis such as geography, vegetation, humidity, volume and amount day of rain organic carbon of soil and clay content of the soil, the environmental factors make survive of infective larvae of hookworm. Explained with Garcia (2007) that a significant increase in the prevalence of hookworm infection with environmental conditions (Garcia, 2007). Changing environmental conditions, specifically deforestation and subsequent silting of the local river, have caused periodic flooding with deposition on a layer of sandy loam topsoil and increased soil moisture (Sedionoto et al., 2021). These conditions, all of which are conducive to hookworm transmission, have allowed hookworm to reemerge as an important human pathogen in this area (Forrer et al., 2018).

The prevalence of hookworm infection among schoolchildren in Indonesia correlates with environmental factors. The result of the study analysis can make a strong contribution to preventing programs by ecological root. Preventing the program of reduced prevalence of hookworm infection by treatment of environmental risk factors is an effective program for decreasing hookworm infection among schoolchildren in Indonesia.

AUTHOR CONTRIBUTION

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCE

Anamnart W, Intapan PM, Pattanawongsa A, Chamavit P, Kaewsawat S, Maleewong W (2015). Effect of dilution of stool soluble component on growth and development of Strongyloides stercoralis. Sci Rep. 5:10749. doi:10.1038/srep10749.

Anamnart W, Pattanawongsa A, Intapan PM, Maleewong W (2010). Albendazole stimulates the excretion of Strongyloides stercoralis larvae in stool specimens and enhances sensitivity for

diagnosis of strongyloidiasis. J Clin Microbiol.48(11):4216–4220.doi: 10.11-28/JCM.00852-10.

Anamnart W, Pattanawongsa A, Intapan PM, Morakote N, Janwan P, Maleewong W (2013). Detrimental effect of water submersion of stools on development of Strongyloides stercoralis. PLoS One. 8(12):e82339.

Bannon JP, Fater M, Solit R (1995). Intestinal ileus secondary to Strongyloides stercoralis infection: case report and review. Am Surg. 61:377–380.

Bethony J, Brooker S, Albonico M, Geiger SM, Loukas A, Diemert D, Hotez PJ (2006). Soil-transmitted helminth infections: ascariasis, trichuriasis, and hookworm. Lancet. 367:1521–1532.

Daniel WW (2010). Biostatistics: A Foundation for Analysis in the Health Sciences. 10th ed. New Jersey: John Wiley and Sons.

Forrer A, Khieu V, Schar F, Vounatsau P, Chammartin F, Marti H, Muth S, et al. (2018). Strongyloides stercoralis and hookworm co-infection: spatial distribution and determinants in Preah Vihear province Cambodia. Parasit Vectors. 11(33):1–13.

Forrer A, Khieu V, Schindler C, Schar F, Marti H, Char MC, Muth S, et al. (2016). Ivermectin treatment and sanitation effectively reduce Strongyloides stercoralis infection risk in rural communities in Cambodia. PLoS Negl Trop Dis. 10(8):e0004909.

Garcia L (2007). Diagnostic Medical Parasitology. 5th ed. Washington DC: ASM Press.

Hall A, Conway DJ, Anwar KS, Rahman ML (1994). Strongyloides stercoralis in an urban slum community in Bangladesh: factors independently associated with infection. Trans R Soc Trop Med Hyg. 88(5):527–530.

Jongwutiwes S, Charoenkorn M, Sitthichareonchai P, Akaraborvorn P, Putaporntip C (1999). Increased sensitivity of routine lab detection of Strongyloides stercoralis and hookworm by agar-plate culture. Trans R Soc Trop Med Hyg. 93(4):398–400.

Katz N, Chaves A, Pellegrino J (1972). A simple device for quantitative stool thick-smear technique in schistosomiasis mansoni. Rev Inst Med Trop Sao Paulo. 14:397–400.

Khieu V, Schär F, Marti H, Bless PJ, Char MC, Muth S, Odermatt P (2014). Prevalence and risk factors of Strongyloides stercoralis in Takeo province Cambodia. Parasit Vectors. 7(221):1–5.

Khieu V, Schär F, Marti H, Sayasone S, Duong S, Muth S, Odermatt P(2013). Diagnosis treatment and risk factors of Strongyloides stercoralis in schoolchildren in Cambodia. PLoS Negl Trop Dis. 7:e2035.

Koga K, Kasuya S, Khamboonruang C, Sukhavat K, Ieda M, Takatsuka N, Kita K, et al. (1991). A modified agar plate method for detection of Strongyloides stercoralis. Am J Trop Med Hyg. 45: 518–521.

Damanik M, Soeyoko S, Sutomo AH (2014). Sanitation of house and school personal hygiene and infection of soil transmitted helminths among elementary school students. Int J Public Health Sci. 3(1):43–49. doi: 10.11591/ijphs.v3i1.46-73.

Na-Ek P, Sanpool O, Jongthawin J, Anamnart W, Intapan PM, Chamavit P, Maleewong W (2016). Restoration of hookworm egg development after prolonged storage in stool suspension. Parasitol Res. 115:2817–2828.

Nery SV, McCarthy JS, Traub R, Andrews RM, Black J, Gray D, Weking EW, et al. (2015). A cluster-randomized controll-

ed trial integrating community-based WASH and albendazole to reduce intestinal parasites in Timor-Leste. BMJ Open. 5(12):e009293.

Pullan RL, Smith JL, Jasrasaria R, Brooker SJ (2014). Global numbers of infection and disease burden of soil-transmitted helminth infections in 2010. Parasit Vectors. 7(37):1–19.

Schär F, Inpankaew T, Traub RJ, Khieu V, Dalsgaard A, Chimnoi W, Odermatt P (2014). The prevalence and diversity of intestinal parasites in humans and domestic animals in a rural Cambodian village. Parasitol Int. 63(4):597–603.

Sedionoto B, Anamnart W (2018). Prevalence of hookworm infection and strongyloidiasis in cats and potential risk factor for human disease. E3S Web Conf. 31:1–5.

Sedionoto B, Wesisombat S, Punsawad C, Anamnart W (2019). Environmental factors and prevalence of hookworm infection and strongyloidiasis in rural East Kalimantan Indonesia. E3S Web Conf. 124:04001. doi: 10.1051/e3sconf-/201912504001.

Sedionoto B, Wesisombat S, Punsawad C, Anamnart W (2021). The quality of soil and high prevalence of hookworm infection in Muara Kaman and Marangkayu districts Indonesia. Ann Trop Med Public Health. 24(1):1–10. doi:10.36295/ASRO.2021.24135.

Steinmann P, Yap P, Utzinger J, Du ZW, Jiang JY, Zhou XN (2015). Control of soil-transmitted helminthiasis in Yunnan province China: lessons from a 5-year trial. Acta Trop. 141:271–280.

Strkolcova G, Goldova M, Bockova F, Mojzisova J (2017). The roundworm Strongyloides stercoralis in children, dogs, and soil inside and outside a segregated settlement in Eastern Slovakia: frequent but hardly detectable parasite. Parasitol Res. doi: 10.1007-/s00436-016-5362-1.

Vonghachack Y, Sayasone S, Bouakhasith D, Taisayavong K, Akkavong K, Odermatt P (2015). Epidemiology of Strongyloides stercoralis on Mekong Islands in southern Laos. Acta Trop. 141: 289–294.

WHO (2011). Helminth Control in School-age Children: A Guide for Managers of Control Programs. 2nd ed. Geneva: World Health Organization.