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The Increased Risk of *Schistosomiasis* Caused by High Frequency of Rainfall and Open-Defecation Habit in Indonesia

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Abstract. *Schistosomiasis* is the third most common parasitic disease worldwide has been reported from 78 countries and endemic in 52 countries. Indonesia is one of countries which has tropical climate with high frequency of rainfall and the habit of some Indonesian people on doing open-defecation. This paper is created through the method of literature review from several sources, such as journals, websites (UNICEF, WHO, CDC, meteorology climatology and geophysics agency (BMKG) Indonesia), and other resources that associated with *Schistosoma*. The spatial analysis method used to determine the risk of ***Schistosomiasis*** in an area in topology analysis, which analyzes the relation between units of the research. Topology analysis in geospatial information system performed buffer and overlay. In Indonesia, the average rainfall during the period from 2005-2013 is 2177.24 mm/year, with an average of rainy days within a period from 2006-2013 is approximately 184 days/year. And the other risk factor, Indonesia ranked second in the number of people who practice open defecation as many as 51 million people where its 2/3 from rural areas. The risk factor that can increase the transmission of *Schistosomiasis* is open-defecation and frequency of rainfall. Indonesia is predicted to be the potential habitat of *Oncomelania* (*Schistosimiasis* vector) as the rainfall enables to provide a suitable environment to the life cycle of *Oncomelania.* And the other risk factor is open defecation behavior that affects in supporting the life cycle of *Schistosoma*.

Keywords: *schistosomiasis*, open-defecation, indonesia, rainfall, environment, health.

1. Introduction

Schistosomiasis is an acute and chronic disease caused by parasitic trematode flatworms of the genus *Schistosoma*. Infection is acquired when people come into contact with fresh water infested with the larval of the parasite [1]. *Schistosomiasis* is considered as a disease which get less attention (*neglected disease*). It may cause death if no treatment given as early as possible [2].

Schistosomiasis is the third most common parasitic disease worldwide (after malaria and intestinal helminths), has been reported from 78 countries and endemic in 52 countries, predominantly in Brazil, Africa, the Middle East, and South Asia. It affects almost 240 million people worldwide, and more than 700 million people live in the endemic areas.[1]-[3] A review of disease burden estimated that more than 200.000 deaths per year in Sub-Saharan Africa due to *Schistosomiasis*. This number of morbidity can't be underestimated.

The infection is prevalent in tropical and sub-tropical areas, commonly in poor communities without adequate sanitation. People are infected during routine agricultural, domestic occupational, and recreational activities which expose them to infested water [1]. Freshwater becomes contaminated by *Schistosoma* eggs when infected people urinate or defecate in the water [4].

Indonesia is one of countries which has tropical climate with high frequency of rainfall. This is also supported by the habit of some Indonesian people, especially in rural area, doing open-defecation. These are a risk factor of *Schistosomiasis*. *Schistosoma* eggs in the feces of patients can easily infect other people

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through the vector of *Schistosomiasis*, snails that live in the water. With the high frequency of rainfall, suitable vector habitat, and habit of open-defecating, will affect the incidence of *Schistosomiasis*.

2. Method

This paper is created through the method of literature review from several related sources, such as journals, websites (UNICEF, WHO, CDC, meteorology climatology and geophysics agency (BMKG) Indonesia), and other resources that associated with *Schistosoma*, its life cycle, and the spread of the *Schistosomiasis*. The dependent variables that are discussed in this paper is the relationship between rainfall, open defecation and vector habitat *Oncomelania* to the *Schistosomiasis* occurrence probability as the dependent variable. Confounding variables are the geographical and environmental characteristics with *Schistosomiasis*.

The spatial analysis method used to determine the risk of *Schistosomiasis* in an area in topology analysis, which analyzes the relation between units of the research. Unit analyzed the dependent variable in the form of rainfall data and areas with open-defecation cases. Topology analysis in geospatial information system performed buffer and overlay. Map of the distribution of rainfall in Indonesia overlaid with the map of distribution of the area with open-defecation cases. The statistic measurement of the data is interval which is divided into some classes. The intervals of rainfall frequency data were divided into three classes namely 60-80 mm, 81-100 mm, and 101-120 mm. While the interval of open-defecation case are divided into four classes namely 0-20%, 21-30%, 31-40%, 41-50%.

3. Results

3.1. Schistosomiasis

The agent of *Schistosomiasis* is parasitic trematodes from *Schistosomidae* family with some species that can be determined by case placed. Some areas where *Schistosomiasis* is found include Africa, South America, and Caribbean with *Schistosoma mansoni*, Middle East and part of Africa with *Schistosoma haematobium*, Cambodia and Laos with *Schistosoma mekongi*, Central and West Africa with *Schistosoma intecalatum*, and also in Indonesia, South East Asia, parts of China with *Schistosoma japonicum*. [12] By the place, this disease can be classified as NTDs (Neglected Tropical Diseases) because it occurs in tropical area commonly. [12]

Schistosoma have a long life cycle which include human as host and snail as intermediate host. The cycle is started with the eggs of *Schistosoma* in the feces or urine by infected people. Under optimal condition, the eggs hatch to be *miracidia* that can be carried by water and penetrate specific snail. In the snail body include two generations of *sporocysts* and the production of *cercariae* that will be release from snail body into water again. Water-transported *cercariae* penetrate the human's skin as host then shed their forked tail becoming *schistosimulae*. The *schistosomulae* migrate to the liver or other several tissues by the veins. Adult worms in human reside in the mesenteric *venules* in some location, which can be determined by its species, for example *S. japonica* is frequently found in the superior mesenteric veins of small intestine unlike *S. mansoni* in the large intestine. [14]

Schistosomiasis in Indonesia commonly caused by *S.japonica* that has life cycle as other *Schistosoma*. [12] Intestinal *Schistosomiasis* can result in abdominal pain, diarrhea, and blood in the stool, liver enlargement is common in advanced cases. The sign of urogenital *Schistosomiasis* is haematuria (blood in urine), bladder cancer may be possible complication in the later stage. This disease may also have other long-term irreversible consequences, including infertility. [1] Heart failure due to *Schistosomiasis* associated with pulmonary arterial hypertension (PAH). *Schistosomiasis* causes PAH in about 6.1% of those chronically infected. [3] After years of infection, not just the liver but the parasite can also damage the intestine, spleen, lungs, and bladder. [4] It also will cause liver enlargement due to accumulation of liquid in peritoneal cavity, increase the blood pressure around the abdominal, and also bile enlargement.[16] In children, *Schistosomiasis* cause anemia, stunting, and decrease the learning ability.[15] The health problems have impact to the human productivity especially in the chronic case.

3.2. Vector of Schistosomiasis

Oncomelania is intermediate vector of *Schistosoma japonicum* which has a semi-aquatic habitat or commonly called amphibian snail. The snail can live in physical condition with temperature range of 18°-32°C and optimal growing in 26°C. Snails also did not like aquatic area with fast current, typically less than 0.7 m/s. Species of *Oncomelania* can survive in marshes, irrigation systems, paddy fields, drainage canals, and ditches. [13] Snails have few natural enemies and usually attach to dense vegetation. Snails are also very tolerant to dissolved matter in water, for example chlorides, minerals, and salt. [13] The range of pH value in the water where can be found snails is 5 to 10.

The ideal environment for the survival of *Oncomelania* is in humid subtropical and monsoonal climate with annual rainfall about 1450 mm. [17] The distribution of *Oncomelania* was strongly influence by geographical and environmental characteristics. [18] The geographical and environmental characteristics include Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), elevation, slope, and distance to the nearest stream that can be the risk factor of *Shcistosomiasis*. The previous study found that in the area of endemic, the NDVI number is more than 0.446 which was defined as the survival limit for *Oncomelania*, the lowest limit of LST was defined as 22.7°C, the elevation that considered as the suitable place for breeding was lower than 2,300 m, the slope is less than 11° as survival limit of *Oncomelania*, and the distance from the infested village to the nearest stream was less that 1,000 m away. [18]

3.3. Open-Defecation

Open defecation affects in supporting the life cycle of *Schistosoma* worms. Open defecation is a behavior where people defecate in places other than the toilet, such as in landfill, forest, open water bodies, or any other place. [5] This situation supports the emergence of various kinds of diseases, such as cholera, typhoid, hepatitis, polio, diarrhea, worm infestations, and malnutrition.[6] According to the WHO, open defecation due to the lack of facilities of water to maintain environmental sanitation. This behaviors are common in the state of sub-Saharan Africa and Asia. Country with a population with the highest open defecation behavior is India, with 626 million people.[7] Meanwhile, Indonesia ranked second in the number of people who practice open defecation as many as 51 million people where its 2/3 come from rural areas. [8]

country	% open defecation	% shared or unimproved	% improved sanitation	GDP per capita
India (2011 census)	49.8			
India (JMP)	48	16	36	5,050
Southern Asia*	38	20	42	4,666
Sub-Saharan Africa*	25	45	30	3,171
Pakistan	23	29	48	4,360
Haiti	21	55	24	1,575
Low-Income Countries*	21	42	37	1,569
Ghana	19	67	14	3,638
Senegal	17	31	52	2,174
Zambia	16	41	43	2,990
Afghanistan	15	56	29	1,892
Swaziland	14	29	57	5,912
Kenya	13	57	30	2,109
Southern Asia without India*	12	31	57	-
Nicaragua	10	38	52	4,254
Democratic Republic of Congo	9	60	31	451
Republic of Congo	8	77	15	5,631
Uganda	8	58	34	1,134
Malawi	7	83	10	739
Cameroon	6	59	45	2,551
Myanmar	5	18	77	-
Bangladesh	3	40	57	2,364
Burundi	3	50	47	737
Rwanda	3	33	64	1,379
Gambia	2	38	60	1,565
Vietnam	2	23	75	4,912
China	1	34	65	10,771

Distribution of the population into each sanitaiton category (% of population) from WHO and UNICEF (2014).
India figures from Census 2011 from Government of India (2012) and relate to proportion of households not having a toilet in their house and not using a public toilet. Per Capita GDP PPP figures from World Bank (2014).

* Categories are defined by the World Bank; low-income includes countries with GNI per capita, calculated using the World Bank Atlas method, of $1,035 or less in 2012 (World Bank 2014).

Fig. 1: Open defecation in poor country, JMP data, 2012

As reported by the WHO/UNICEF Joint Monitoring Program (JMP) in 2012, Indonesia took the second rank of a country that still have open defecation behavior. This data is collected by estimating of use of sanitation facilities in rural areas in 2011. [19], [20]

Open defecation is a serious problem as it can potentially transmit a lot of pathogens to the environment. Feces (human excrement) even though in a small amount possibility contains enough pathogens that will infect someone else especially feces that secreted from the infected human. Not everyone that get infected becomes ill. Sometimes, they would be just a carrier without show any symptoms of disease. In this condition, feces from this person also contain pathogens that ready to infect more people.

Pathogens in feces can rapidly spread through various pathways and agents such as our finger that usually called fecal-oral transmission, flies as a vector, fields, fluids or water streams. Water as the one of the transmission media of pathogen is also be the media of *Schistosoma* life cycle. The risk of *Schistosomiasis* transmission will increase when people that was infected by *Schistosoma* practice an open defecation. [21], [22]

4. Rainfall

Rainfall is associated with the spread of the *Schistosoma* cysts to vector habitats. In Indonesia, the average rainfall according to BMKG during the period of 9 years from 2005 to 2013 is 2177.24 mm / year, with an average of rainy days within a period of 8 years from 2006 to 2013 is approximately 184 days / year. Areas with the highest rainfall in 2013 is a region on the island of Sumatera, Kalimantan, and Sulawesi, where the highest 5 provinces are West Sumatera (4629 mm / year), Papua (4627 mm / year), Bengkulu (4033 mm / year), Banten (3573 mm / year), West Papua (3419 mm / year) and South Sumatera (3409 mm / year). Meanwhile, Central Sulawesi as a native habitat for vectors has rainfall 2000-4000 mm / year. [9] Based on those data, most of other areas of Indonesia has similarity with the native habitat rainfall vectors, which is in the range 2000-4000 mm / year. [10] Thus, other areas of Indonesia is predicted to be the potential habitat of *Oncomelania* as rainfall in the range of humidity and temperature enables to provide a suitable environment to the life cycle of *Oncomelania.*

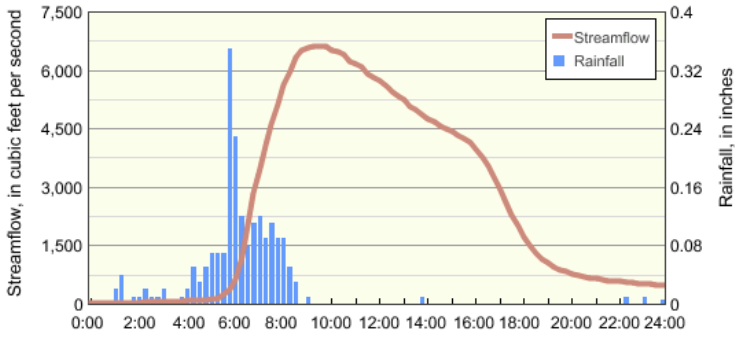

Fig. 2: Rainfall and stream flow in 2002

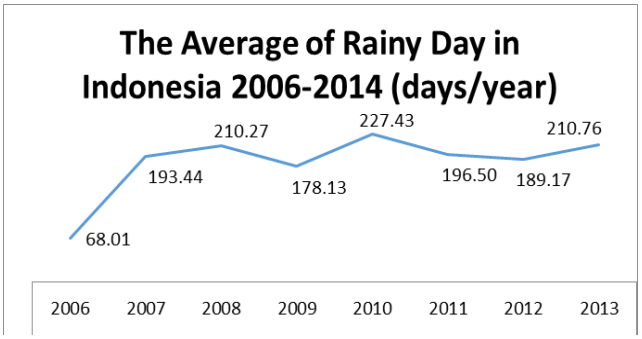

Fig. 3: The Average of Rainy Day in Indonesia 2006-2014 (days/year)

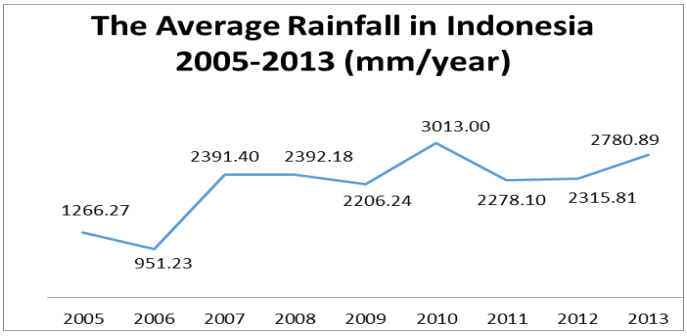

Fig. 4: The Average Rainfall in Indonesia 2005-2013 (mm/year)

The vectors can growing optimal with temperature 26^{o}C which is warm temperature after rainfall in Indonesia. [23] The *cercariae* of *Schistosoma* that release from snail body can finding the host by influence of water turbulence. [24] Runoff of rainfall can cause the stagnant stream flow as the media of transmission continuously change [25] and support the life of *cercariae*. More than that, agitation or turbulence of streamflow also the dependence factor of hatching of *Schistosoma miracidia*. Agitation accelerated egg hatching and the *miracidia* reaching peak numbers five minutes earlier. [26] The higher rainfall, the higher the turbulence in stream flow as can be seen in the table below. [25]

5. Analysis Study

This research analyzes the increasing risk of *Schistosomiasis* with two dependent variables that is the rainfall frequency and the open defecation behavior. The information of the rainfall frequency based on the data since 1990 until 2010 showed that some area in Indonesia have increased the rainfall around 40-120 mm. The other variable is open defecation case, the number of the case in Indonesia showed that some province still did the open defecation behavior.

By using spatial analysis, the distribution map of the dependent variables were overlaid to resulting the new map. Based on the overlaid mapping, the new map data were defined as the map of prediction area at risk of *Schistosomiasis.* As present below, some of the area were in dark-red color that indicates of having high risk to the *Schoistosomiasis* in Indonesia such as Central Sulawesi, West Kalimantan, and West Nusa Tenggara.

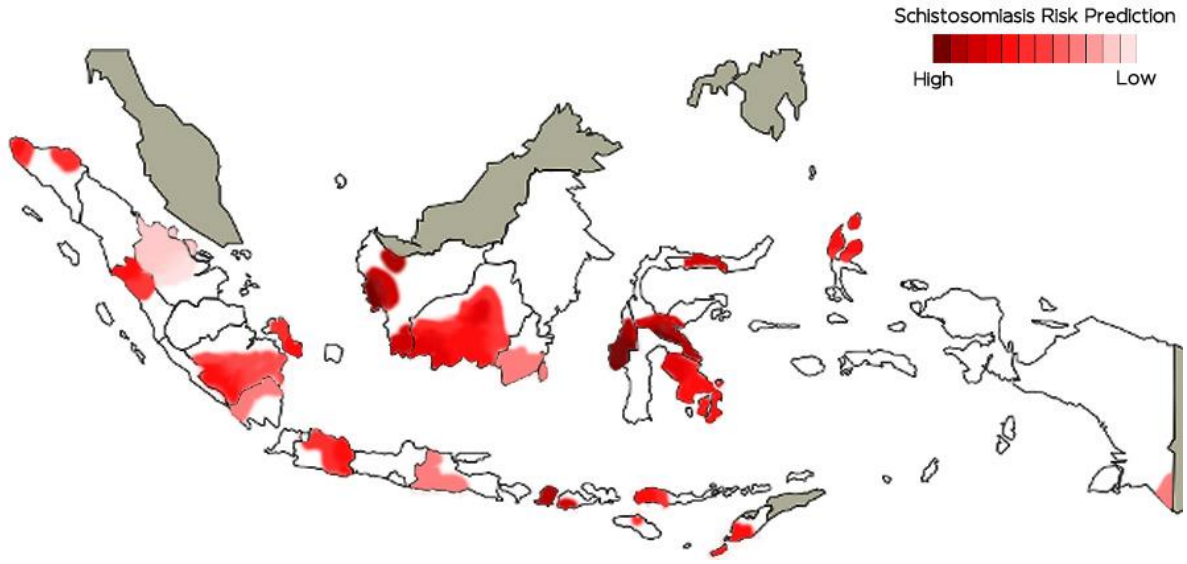

Fig. 5: The Map of Prediction Area at Risk of *Schistosomiasis* in Indonesia

6. Discussion

The average rainfall in Indonesia from 2005-2013 is 2177.27 mm/year proves that Indonesia has high frequency of rain fall. When compared with other countries such as China with the average of rainfall 645

mm/year and India with the average of rainfall 1083 mm/year. [11] Indonesia can be classified as a country with high frequency of rainfall per year. This condition will affect the suitable habitat of *Schistosomiasis* vectors. Snails as the vector that live in aquatic or semi-aquatic would have the potential to increase its population size. Some steps of *Schistosoma* life cycle need water as media and intermediate vector, from release eggs in the stool of patients to be *cercaria* which will penetrate human skin. The role of rainfall will affect the amount of water flow which is a suitable habitat of snails as the vector of *Schistosomiasis* to be their breeding places which also will increase the snail population. This condition greatly support the transmission of *Schistosomiasis*.

The other risk factor that can increase the transmission of *Schistosomiasis* is open-defecation. According to data from UNICEF Indonesia, 2014, there are 51 million Indonesian people still doing open-defecation. The unavailability of proper sanitation and some cultural habits are the reasons why the number of open-defecation still high. Doing open-defecation has the risk to increase *Schistosomiasis* because egg in the patient's stool could spread to the environment. Defecation in open place, such as river or stream as the habitat of vectors (*Oncomelania*) facilitate the process of transmission because some of *Schistosomas*'s life cycle occurred in water flow.

Using analysis spatial study in the area with high open defecation and rainfall, researchers found that some of Indonesia's regions has the increased risk of *Schistosomiasis* specifically in Central Sulawesi, West Sulawesi, South East Sulawesi, South Kalimantan, West Nusa Tenggara, and some parts of West Kalimantan. The area at risk also have suitable conditions for the vectors growing as it habitat. *Oncomelania* can survive in the condition with NDVI limit 0.446, slope is less than 11^{o}, LST above 22.7^{o}C, and the daily temperature is around $15\text{-}16^{o}$C. The area at risk have the similar characteristic of NDVI, LST, the slope, and the temperature. So that, from this research can relate the risk of *Schistosomiasis* based on the rainfall frequency and the open defection behavior in Indonesia.

7. Conclusion

In summary, *Schistosomiasis* is the disease that should be concerned more because the number of mobirdity and mortality can't be underestimated. Many factors can cause the disease, such as the vector, the habitat, and the behaviour of people. Indonesia is one of country that has high risk of *Schistosomiasis*. The eggs of *Schistosoma* found in stool of human and infected the snail as the vector. That is why Indonesian people's behaviour of open-defecation, increased the risk of transmission *Schistosomiasis*. More than that, the high frequency of rainfall in Indonesia, develop the habitat of snail which means the risk of spread also increased. We hope that this paper of review about increased *Schistosomiasis* with certain factors, such as open defecation and rainfall in Indonesia may become the literature for another research with similar topic.

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