Environmental Factors and Leprosy in Mother and Child: A Study in Endemic Areas in East Java, Indonesia

Flora Ramona Sigit Prakoeswa[1], Hardyanto Soebono[2], Dominicus Husada[3], Hari Basuki Notobroto[4], Muhammad Yulianto Listiawan[5], Anang Endaryanto[3], Cita Rosita Sigit Prakoeswa[6]

[1]Doctoral Program, Faculty of Medicine, Airlangga University, Indonesia, Department of Dermatology and Venereology, Faculty of Medicine, Universitas Muhammadiyah Surakarta, Indonesia, [2]Professor, Department of Dermatology and Venereology, Faculty of Medicine, Public Health and Nursing, Gadjah Mada University, Indonesia, [3]Associate Professor, Department of Pediatric, Faculty of Medicine, Airlangga University / Dr. Soetomo General Academic Hospital, Surabaya, Indonesia, [4]Associate Professor, Faculty of Public Health, Airlangga University, Indonesia, [5]Associate Professor, [6]Professor, Department of Dermatology and Venereology, Faculty of Medicine, Airlangga University / Dr. Soetomo General Academic Hospital, Surabaya, Indonesia

Abstract

Background: Leprosy is a chronic infection caused by *Mycobacterium leprae*. In endemic locations, children become vulnerable as a result of being continuously exposed to foci of active transmission from a very young age, especially from their mothers. This study aims to find association between environmental risk factors and leprosy in mothers and children in endemic areas.

Methods: This study is a case-control study in endemic areas in Tuban Regency, East Java Province, Indonesia. Retrieval of data was done using structured questionnaire and direct measurement. Chi-square was used to assess the association between environmental factors and leprosy in mothers and children groups.

Results: 22 pairs of cases and 57 pairs of controls were examined. It is found that access to clean water is associated with leprosy in mothers in endemic areas (p value = 0.047, OR 3.080, CI 95% 2.232-4.251). Environmental factors are not associated with pediatric leprosy in endemic areas.

Conclusion: The results of our study show that environmental factors are not associated with pediatric leprosy in endemic areas. Access to clean water is associated with leprosy in mothers in endemic areas.

Key words: *Environmental factors, Leprosy, Mother and children, Endemic*

Introduction

Leprosy is a chronic infection caused by *Mycobacterium leprae*. In 1991, the World Health Organization (WHO) has proposed the leprosy elimination program that aimed to reduce the global prevalence of leprosy to less than one case per 10,000 population by the year 2000.[1, 2] However, leprosy remains endemic in some country, with relatively high burden in children and an increase in the new cases detection rate.[3, 4] In 2019, 177,175 registered cases and 202,185 new cases of leprosy were observed globally.[3]

Three countries with the highest leprosy cases i.e. India, Brazil, and Indonesia accounted for 80% global leprosy cases.[4] In Indonesia, registered leprosy cases reached 19,938 cases in 2019, in which 17,439 were new cases; leprosy on female add up to 10,741 cases (61.59%) and 2,009 (11.52%) cases were observed amongst children.[5] Despite rarely being lethal, leprosy

Corresponding Author:
Flora Ramona Sigit Prakoeswa, MD., M.Sc.
Medical Faculty of Universitas Muhammadiyah Surakarta, Indonesia, Kampus IV UMS, Jalan Ahmad Yani Gonilan, Kartasura, Kabupaten Sukoharjo, Jawa Tengah, Indonesia (Postal Code: 57169)
Email: frsp291@ums.ac.id

cause numerous morbidity; ranging from skin and peripheral nerves manifestation to tissue damage, deformity, disability, and stigma.[6, 7]

Transmission of leprosy is accepted to be primarily person to person: the risk of developing leprosy is 5–10 times higher if one member of the family has developed the disease previously.[8] Previous studies showed that men were predominantly more affected by leprosy than women do. The significant difference could be attributed to underdiagnosis due to the sociocultural factors amongst women, such as illiteracy, limitation of mobility, and having low social status.[9] In addition, the position of women in the household increases the risk of leprosy transmission to their child.

Due to the long incubation period of this disease, leprosy is more common in adults. Nevertheless, in endemic locations, children and adolescents, theoretically considered the group most resistant to infection, become vulnerable as a result of being continuously exposed to foci of active transmission from a very young age.[10] Furthermore, it is known that new cases of leprosy in children depicts active transmission of leprosy in an area or a country.[11] Proportion of new cases of leprosy among children aged <15 years old also shows the high potential of transmission through household contacts. A study showed that cases of leprosy among children under 15 years old is a strong indicator of active leprosy source in a society.[12]

Previous studies have shown that pediatric leprosy most likely happens in an area with poor sanitation. A study in India has stated that low socioeconomic status, poor housing, and environmental factors are associated with leprosy. Bacteria can live in natural reservoirs such as land and water disposal unit, so this could contribute to the transmission of leprosy.[13] Another study has stated that social markers and environmental conditions are risk factors of *M. leprae* transmission in children and adolescents in Colombia.[14]

Finally, epidemiological studies of leprosy in children can point out the important aspects of the environment that influence the leprosy transmission in an endemic area. This is because children have lower mobility than adults.[15]

In previous studies, even though family contact increases the risk of leprosy, in a typical endemic area, the majority of new cases cannot be linked to intra-domiciliary contact with a leprosy patient.[8] This suggests the possibility that infection may result through prolonged or repeated unknown exposure to an environmental source containing viable bacilli. Evidence also suggests that the degree of vulnerability of the individual, the extent of exposure, and associated environmental factors could potentially influence the transmission. Complete understanding of ecological and environmental components may unfold the gaps in knowledge regarding the mode of transmission of leprosy.[16, 21]

Despite being one of the priority countries that are highlighted by WHO for leprosy elimination, there is a lack of studies regarding leprosy in mother and children in Indonesia, especially in endemic areas. Therefore, this study aims to analyse environmental risk factors for leprosy in mother and children in endemic areas.

Materials and Methods

Study area and population

The study was conducted from March until June 2020 in 10 sub-districts in Tuban Regency, East Java Province. Tuban Regency, a regency in northern area of East Java Province, is located 0-500 meters above sea level. This rather small regency (1.839,94 km², 3,8% of East Java) has about 1.2 million inhabitants, with paddy fields (31,6%) dominating its land. This regency is considered a leprosy pocket area, with 172 cases in 2018 of which 5.81% cases were cases among children. These 10 areas across 10 sub-districts (Bulu, Jenu, Jetak, Kerek, Palang, Soko, Sumurgung, Tambakboyo, Temandang, Tuban) are considered endemic areas of leprosy, where in the last 5 years there are always new cases every year. Study area is depicted in Figure 1.

Cases were selected from the local primary health center's registry data. The inclusion criteria for subject with leprosy was those with confirmed diagnosis of leprosy and aged between 5-18 years old for children; whilst the excluded were those with any leprosy reaction, poor general condition, and diagnosed with inflammatory or autoimmune disorder, allergy, or infection other than leprosy, and pregnancy. All of the

subjects were given informed consent. Thereafter, to confirm the diagnosis, the subjects underwent clinical examination done by a dermatologist and then acid-fast staining by trained health and laboratory professional from Dr Soetomo General Hospital and Tropical Disease Centre of Airlangga University. Controls were selected from mothers and children who visit the same primary health centers for other than skin problems and live in the same sub-districts.

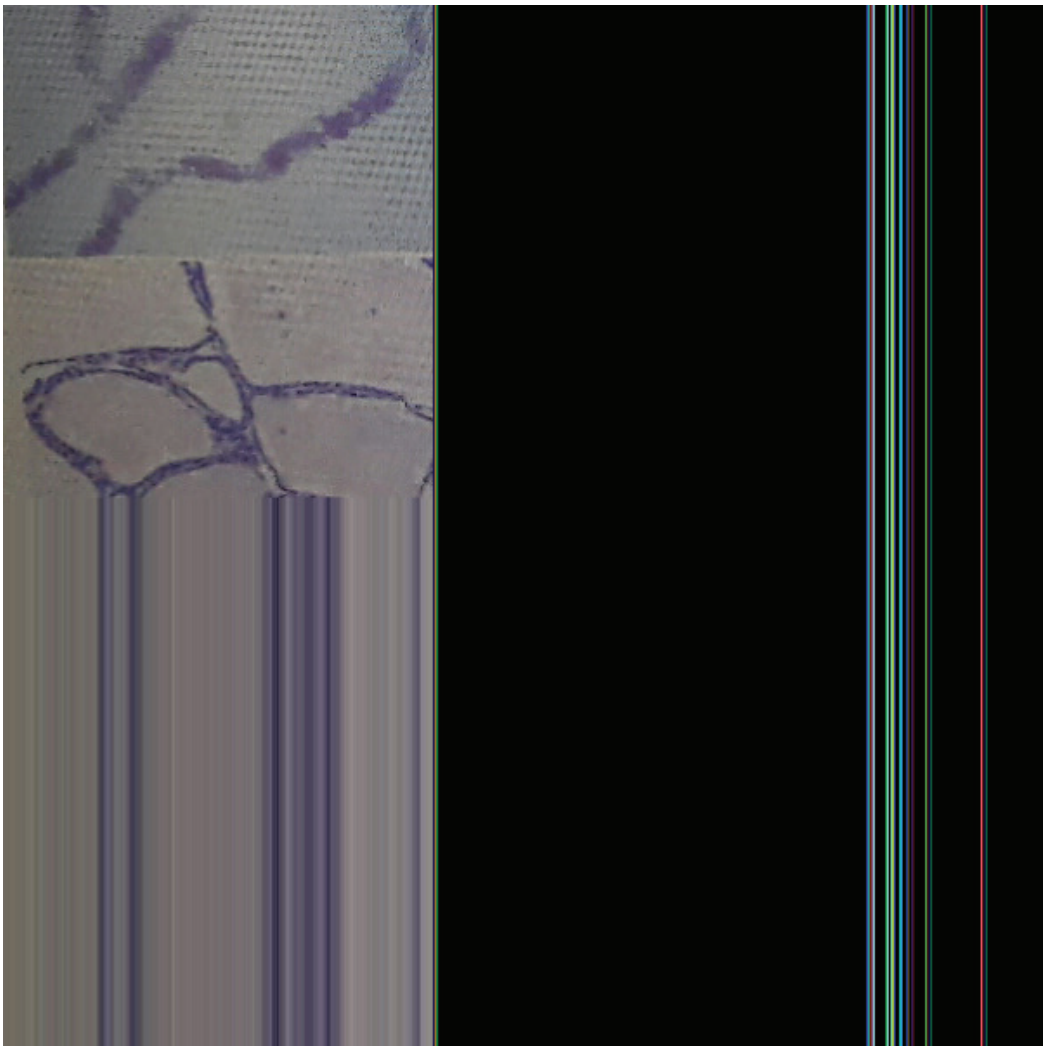

Figure 1. Study area. Ten sub-districts in which the study areas are located are colored in grey.

Data Collection

A structured questionnaire was used to collect demographic and environmental data from cases and controls (*see supplementary data*). Environmental data includes house ceiling, house windows, house walls, house flooring, lighting and house brightness, temperature, humidity, bedroom crowding, bedroom and house windows, ventilation, access to clean water, latrine availability, sewage disposal unit, trash disposal unit, and pre-tested house criteria score. Trained health professionals were responsible for interviewing cases and controls and measuring house components at the participants' houses.

Data Analysis

Data were analysed using SPSS® software (IBM Corp., Armonk, New York, USA). Variables were analysed using chi-square test to assess the association between environmental factors and leprosy in each mother and child populations.

Ethical considerations

The study protocol has been approved by the Health Research Committee of Dr Soetomo General Hospital, Surabaya (Ref. 1664/KEPK/XI/2019). Subjects were only included after written informed consent was obtained and they were reassured that non-participation would not affect their treatment.

Results and Discussion

Information was obtained from 22 pairs of cases and 57 pairs of controls in endemic areas. Within the children group, the proportion of male subjects is 48%. The mean age of all participants is 13.18 years (SD ± 4.649). The results of bivariate analyses are shown in Table 1. From bivariate analysis, it can be derived that none of the observed environmental factors are associated with pediatric leprosy in endemic areas.

Table 1. Bivariate analysis of environmental factors and pediatric leprosy in endemic areas

Variable	Diagnosis		Total	P Value	Crude OR (95%CI)
	Leprosy	Healthy			
	n (%)	n (%)	n (%)		
Having house ceiling					
No	20 (30.8%)	45 (69.2%)	65 (100%)	0.212	2.667
Yes	2 (14.3%)	12 (85.7%)	14 (100%)		(0.545 – 13.036)
House walls					
Bamboo webbing/not permanent	3 (37.5%)	5 (62.5%)	8 (100%)	0.521	1.642
Permanent walls	19 (26.8 %)	52 (73.2%)	71 (100%)		(0.357 – 7.544)
House flooring					
Soil	5 (50.0%)	5 (50.0%)	10 (100%)	0.094	3.059
Plestered/Ceramic	17 (24.6%)	52 (75.4%)	69 (100%)		(0.789 – 11.860)
Lighting					
Poor (<60 lux)	18 (31.0%)	40 (69.0%)	58 (100%)	0.294	1.912
Adequate (>= 60 lux)	4 (19.0%)	17 (81.0%)	21 (100%)		(0.563 – 6.498)
House brightness					
Dim/dark	18 (32.1%)	38 (67.9%)	56 (100%)	0.184	2.250
Brightly lit	4 (17.4%)	19 (82.6%)	23 (100%)		(0.667 – 7.586)
Temperature					
<18 oC; >30 oC	19 (26.8%)	52 (73.2%)	71 (100%)	0.521	0.609
18 oC – 30 oC	3 (37.5%)	5 (62.5%)	8 (100%)		(0.133 – 2.798)
Humidity					
>60%; <40%	21 (31.8%)	45 (68.2%)	66 (100%)	0.076	5.600
40% - 60%	1 (7.7%)	12 (92.3%)	13 (100%)		(0.683 – 45.947)
Bedroom crowding					
Crowded	14 (25.9%)	40 (74.1%)	54 (100%)	0.575	0.744
Not crowded	8 (32.0%)	17 (68.0%)	25 (100%)		(0.264 – 2.099)
Availability of bedroom windows					
No	14 (28.6%)	35 (71.4%)	49 (100%)	0.855	1.100
Yes	8 (26.7%)	22 (73.3%)	30 (100%)		(0.397 – 3.048)

Cont... **Table 1. Bivariate analysis of environmental factors and pediatric leprosy in endemic areas**

Availability of house windows					
No	13 (34.2%)	25 (65.8%)	38 (100%)	0.225	1.849
Yes	9 (22.0%)	32 (78.0%)	41 (100%)		(0.682 – 5.016)
Ventilation					
No	12 (27.3%)	32 (72.7%)	44 (100%)	0.898	0.938
Yes	10 (28.6%)	25 (71.4%)	35 (100%)		(0.349 – 2.520)
Access to clean water					
No	0 (100%)	2 (1000%)	2 (100%)	0.374	1.400
Yes	22 (28.6%)	55 (71.4%)	77 (100%)		(1.216 – 1.612)
Latrine availabity					
No	1 (14.3%)	6 (85.7%)	7 (100%)	0.402	0.405
Yes	21 (29.2%)	51 (70.8%)	72 (100%)		(0.046 – 3.570)
Sewage disposal unit					
No	5 (38.5%)	8 (61.5%)	13 (100%)	0.350	1.801
Yes	17 (25.8%)	49 (74.2%)	66 (100%)		(0.518 – 6.263)
Trash disposal unit					
No	17 (28.3%)	43 (71.7%)	60 (100%)	0.864	1.107
Yes	5 (26.3%)	14 (73.7%)	19 (100%)		(0.345 – 3.550)
House criteria					
Unhealthy (375 - 933)	13 (26.0%)	37 (74.0%)	50 (100%)	0.630	0.781
Healthy (<375)	9 (31.0%)	20 (69.0%)	29 (100%)		(0.285 – 2.142)

In the group of mothers, the mean age of all participants is 41.3 years (SD ± 7.943). The results of bivariate analyses are shown in Table 2. From bivariate analysis, it can be concluded that only access to clean water is significantly associated with leprosy in mothers in endemic areas (p value = 0.047, OR 3.080, CI 95% 2.232 – 4.251). Other factors are not are associated with leprosy in mothers in endemic areas.

Table 2. Bivariate analysis of environmental factors and leprosy in mothers in endemic areas

Variable	Diagnosis		Total	P Value	Crude OR (95%CI)
	Leprosy	Healthy			
	n (%)	n (%)	n (%)		
Having house ceiling					
No	21 (32.3%)	44 (67.7%)	65 (100%)	0.450	0.636
Yes	6 (42.9%)	8 (57.1%)	14 (100%)		(0.196 – 2.069)
House walls					
Bamboo webbing/not permanent	2 (25.0%)	6 (75.0%)	8 (100%)	0.564	0.613
Permanent walls	25 (35.2 %)	46 (64.8%)	71 (100%)		(0.116 – 3.267)
House flooring					
Soil	5 (50.0%)	5 (50.0%)	10 (100%)	0.259	2.136
Plestered/Ceramic	22 (31.9%)	47 (68.1%)	69 (100%)		(0.560 – 8.151)
Lighting					
Poor (<60 lux)	18 (31.0%)	40 (69.0%)	58 (100%)	0.328	0.600
Adequate (>= 60 lux)	9 (42.9%)	12 (57.1%)	21 (100%)		(0.215 – 1.677)

Cont... **Table 2. Bivariate analysis of environmental factors and leprosy in mothers in endemic areas**

House brightness Dim/dark Brightly lit	17 (30.4%) 10 (17.4%)	39 (69.6%) 13 (56.5%)	56 (100%) 23 (100%)	0.264	0.567 (0.208 – 1.544)
Temperature <18 oC; >30 oC 18 oC – 30 oC	25 (35.2%) 2 (25.0%)	46 (64.8%) 6 (75.0%)	71 (100%) 8 (100%)	0.564	1.630 (0.306 – 8.685)
Humidity >60%; <40% 40% - 60%	20 (30.3%) 7 (53.8%)	46 (69.7%) 6 (46.2%)	66 (100%) 13 (100%)	0.102	0.373 (0.111 – 1.250)
Bedroom crowding Crowded Not crowded	18 (33.3%) 9 (36.0%)	36 (66.7%) 16 (64.0%)	54 (100%) 25 (100%)	0.816	0.889 (0.329 – 2.401)
Availability of bedroom windows No Yes	19 (38.8%) 8 (26.7%)	30 (61.2%) 22 (73.3%)	49 (100%) 30 (100%)	0.271	1.742 (0.646 – 4.699)
Availability of house windows No Yes	15 (39.5%) 12 (29.3%)	23 (60.5%) 29 (70.7%)	38 (100%) 41 (100%)	0.339	1.576 (0.618 – 4.108)
Ventilation No Yes	19 (43.2%) 8 (22.9%)	25 (56.8%) 27 (77.1%)	44 (100%) 35 (100%)	0.058	2.565 (0.954 – 6987)
Access to clean water No Yes	2 (100%) 25 (32.5%)	0 (0%) 52 (67.5%)	2 (100%) 77 (100%)	0.047	3.080 (2.232 – 4.251)
Latrine availabity No Yes	3 (42.9%) 24 (33.3%)	4 (57.1%) 48 (66.7%)	7 (100%) 72 (100%)	0.612	1.500 (0.310 – 7.247)
Sewage disposal unit No Yes	5 (38.5%) 22 (33.3%)	8 (61.5%) 44 (66.7%)	13 (100%) 66 (100%)	0.722	1.250 (0.366 – 4.272)

Cont... **Table 2. Bivariate analysis of environmental factors and leprosy in mothers in endemic areas**

Trash disposal unit No Yes	23 (38.3%) 4 (21.1%)	37 (61.7%) 15 (78.9%)	60 (100%) 19 (100%)	0.166	2.331 (0.689 – 7.892)
House criteria Unhealthy (375 - 933) Healthy (<375)	18 (36.0%) 9 (31.0%)	32 (64.0%) 20 (69.0%)	50 (100%) 29 (100%)	0.654	1.250 (0.471 – 3.317)

In this study we analysed the association of environmental factors with leprosy in mothers and children in endemic areas in East Java, Indonesia. From our understanding, this is the first study that analyses the association of environmental factors with leprosy in mothers and children specifically in endemic areas. From bivariate analysis, it can be derived that none of the observed environmental factors are associated with an increased risk of pediatric leprosy. In the mothers population, however, access to clean water is significantly associated with leprosy in mothers in endemic areas.

This result in particular is similar to our previous study with female leprosy in a different regency with endemic and non-endemic areas.[17] The previous study concluded that there is a relationship between access to clean water and female leprosy. Matsuoka et al.[18] found that *M. leprae* DNA were detected by PCR from 21 out of 44 water sources used daily by villagers in Indonesia. The study also concluded that leprosy transmission through water contaminated by bacilli is likely to happen. Furthermore, Arraes et al.[19] stated that the finding of viable *M. leprae* in natural water sources which are associated with human contact suggests that the environment plays an important role in maintaining endemic leprosy in a region. Emerson et al.[20] also supported this statement, stating that water that is shared or reused from a source patient may become environmental reservoirs for infection, possibly by aerosolization of *M. leprae*. However, these findings need to be validated by further researches to assess viable bacteria in water samples.

The results are also in line with previous studies that stated that building or floor materials were not significantly associated with leprosy.[8, 22, 23] Furthermore, previous studies also found that sanitation (sewage system or the presence of a sanitary facility in the house) did not have association with lower incidence of leprosy.[8, 22, 24]

In this study, variable reflecting risk factors for person-to-person transmission, such as crowding, did not show a significant association with leprosy; this is probably because the study did not take detailed history of household contact with leprosy patient into account. It is accepted that household contacts with patients with leprosy are the most prone to catching the disease. A study of 12 children with leprosy in Colombia found that 9 of them had a household contact with a patient with leprosy. They reported that in a family where there are cases of undiagnosed leprosy, children are the ones most likely to get sick. Among the household contacts, the risk of developing the disease was up to nine times more, while for neighbourhood contacts the risk was four times more.[25, 26]

The present study has limitations in terms of the type of study used and the use of self-reported data, which may influence some findings. However, to ensure comparable groups and minimize possible biases, such as selection bias, participants were included from the same area.

Conclusion

In conclusion, the results of our study show that environmental factors are not associated with pediatric leprosy in endemic areas. Furthermore, access to clean water is significantly associated with leprosy in mothers in endemic areas. Further studies need to be conducted to analyse other environmental factors that are not analysed in this study.

Acknowledgements: I would like to thank to the leprosy officers, doctors, and staff of Tuban District Health Office, East Java Province.

Ethical Clearance: The study protocol has been approved by the Health Research Committee of Dr Soetomo General Hospital, Surabaya (Ref. 1664/KEPK/XI/2019).

Source of Funding: Self-funding. The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest Statement: Nil.

References

1. World Health Organization. Global Leprosy Strategy 2016–2020. Accelerating towards a leprosy-free world. Monitoring and Evaluation Guide [Internet]. World Health Organization. Regional Office for South-East Asia; 2017 [cited 2020 Nov 12]. Available from: https://apps.who.int/iris/handle/10665/254907
2. World Health Organization. Weekly Epidemiological Record, 2019, vol. 94, 13 [full issue]. Weekly Epidemiological Record = Relevé épidémiologique hebdomadaire. 2019 Mar 29;94(13):161-8.
3. World Health Organization. Weekly Epidemiological Record, 2020, vol. 95, 18 [full issue]. Weekly Epidemiological Record = Relevé épidémiologique hebdomadaire. 2020 May 1;95(18):173-84.
4. World Health Organization, Department of Control of Neglected Tropical Diseases. Integrating neglected tropical diseases into global health and development: fourth WHO report on neglected tropical diseases. 2017.
5. Ministry of Health of Republic of Indonesia (*Kementerian Kesehatan Republik Indonesia*), *Profil Kesehatan Indonesia Tahun* 2019 (Indonesia Health Profile 2019). 2019.
6. Franco-Paredes C, Rodriguez-Morales AJ. Unsolved matters in leprosy: a descriptive review and call for further research. Ann Clin Microbiol Antimicrob. 2016 May 21;15(1):33.
7. Tosepu R, Gunawan J, Effendy DS, Fadmi FR. Stigma and increase of leprosy cases in SouthEast Sulawesi Province, Indonesia. Afr Health Sci. 2018 Mar;18(1):29–31.
8. Kerr-Pontes LRS, Barreto ML, Evangelista CMN, Rodrigues LC, Heukelbach J, Feldmeier H. Socioeconomic, environmental, and behavioural risk factors for leprosy in North-east Brazil: results of a case-control study. Int J Epidemiol. 2006 Aug;35(4):994–1000.
9. Sarkar R, Pradhan S. Leprosy and women. Int J Womens Dermatol. 2016 Oct 25;2(4):117–21.
10. Santos SD, Penna GO, Costa M da CN, Natividade MS, Teixeira MG, Santos SD, et al. Leprosy in children and adolescents under 15 years old in an urban centre in Brazil. Memórias do Instituto Oswaldo Cruz. 2016 Jun;111(6):359-64.
11. Lobo C, Aithal V, Raj R. Nutritional Assessment in Patients with Leprosy. 2019;9.
12. Barreto JG, Frade MAC, Bernardes Filho F, da Silva MB, Spencer JS, Salgado CG. Leprosy in Children. Curr Infect Dis Rep. 2017 Jun;19(6):23.
13. Jariwala DA, Patel BH, Godara NR, Kantharia SL. Socio-Demographic and Environmental Correlates of Leprosy: A hospital based cases control study -. National Journal of Community Medicine. 2013;4(3):369–76.
14. Serrano-Coll H, Mora HR, Beltrán JC, Duthie MS, Cardona-Castro N. Social and environmental conditions related to Mycobacterium leprae infection in children and adolescents from three leprosy endemic regions of Colombia. BMC Infect Dis. 2019 Jun 13;19(1):520.
15. Adriaty D, SP CR, Iswahyudi, Wahyuni R, Agusni I, Izumi S. Leprosy transmission in endemic and non-endemic areas based on the profile of antibody response of PGL-1 and PCR detection of Mycobacterium leprae DNA from nasal swab among healthy children of East Java, Indonesia. Infect Dis Rep [Internet]. 2020 Jul 7 [cited 2020 Nov 12];12(Suppl 1). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7447951/
16. Joshua V, Mehendale S, Gupte MD. Bayesian model, ecological factors & transmission of leprosy in an endemic area of South India. Indian J Med Res. 2016 Jan;143(1):104–6.
17. Prakoeswa FRS, Ilhami AZ, Luthfia R, Putri AS, Soebono H, Husada D, et al. Correlation Analysis between Household Hygiene and Sanitation and Nutritional Status and Female Leprosy in Gresik Regency. Dermatol Res Pract [Internet]. 2020

Sep 30 [cited 2020 Nov 12];2020. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7545468/

18. Matsuoka M, Izumi S, Budiawan T, Nakata N, Saeki K. Mycobacterium leprae DNA in daily using water as a possible source of leprosy infection. Indian J Lepr. 1999 Mar;71(1):61–7.
19. Arraes MLB de M, de Holanda MV, Lima LNGC, Sabadia JAB, Duarte CR, Almeida RLF, et al. Natural environmental water sources in endemic regions of northeastern Brazil are potential reservoirs of viable Mycobacterium leprae. Mem Inst Oswaldo Cruz. 2017 Dec;112(12):805–11.
20. Emerson LE, Anantharam P, Yehuala FM, Bilcha KD, Tesfaye AB, Fairley JK. Poor WASH (Water, Sanitation, and Hygiene) Conditions Are Associated with Leprosy in North Gondar, Ethiopia. Int J Environ Res Public Health [Internet]. 2020 Sep [cited 2020 Nov 12];17(17). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7504265/
21. Kumar A, Girdhar A, Yadav VS, Girdhar BK. Some epidemiological observations on leprosy in India. Int J Lepr Other Mycobact Dis. 2001 Sep;69(3):234–40.
22. Pescarini JM, Strina A, Nery JS, Skalinski LM, Andrade KVF de, Penna MLF, et al. Socioeconomic risk markers of leprosy in high-burden countries: A systematic review and meta-analysis. PLoS Negl Trop Dis. 2018;12(7):e0006622.
23. Hegazy AA, Abdel-Hamid IA, Ahmed E-SF, Hammad SM, Hawas SA. Leprosy in a high-prevalence Egyptian village: epidemiology and risk factors. Int J Dermatol. 2002 Oct;41(10):681–6.
24. Murto C, Chammartin F, Schwarz K, Costa LMM da, Kaplan C, Heukelbach J. Patterns of Migration and Risks Associated with Leprosy among Migrants in Maranhão, Brazil. PLOS Neglected Tropical Diseases. 2013 Sep 5;7(9):e2422.
25. de Oliveira MBB, Diniz LM. Leprosy among children under 15 years of age: literature review. An Bras Dermatol. 2016;91(2):196–203.
26. Romero-Montoya M, Beltran-Alzate JC, Cardona-Castro N. Evaluation and Monitoring of Mycobacterium leprae Transmission in Household Contacts of Patients with Hansen's Disease in Colombia. PLOS Neglected Tropical Diseases. 2017 Jan 23;11(1):e0005325.