

## ORIGINAL ARTICLE

## ENVIRONMENTAL RISK FACTORS OF DIARRHOEA AMONG VULNERABLE POPULATION: A NARRATIVE REVIEW

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## ABSTRACT

Despite improvements in global public health, diarrhoea caused more than 1.65 million deaths in 2016, placing diarrhoea as the eighth leading cause of mortality in all ages and the fifth leading cause of death in children aged five years and below in Malaysia. The impact of frequent diarrhoeal episodes is tremendous especially for children which includes stunting and cognitive delay. There are three types of diarrhoea depending on the symptoms: acute watery diarrhoea, acute bloody diarrhoea (dysentery) and persistent diarrhoea. Diarrhoea is commonly caused by Rotavirus, Cryptosporidium, Shigella, and Enterotoxigenic Escherichia coli (ETEC). Infectious agents for diarrhoea differ by transmission route; however, the risk factors of the diarrhoeal episode are widely ranged and interconnected, which need to be identified. Modifiable risk factors such as the surrounding environment must be identified and improved to avoid diarrhoea episodes. In this review, we recognise the latrine and sanitation, waste disposal, housing condition, the existence of animals, water quality, personal hygiene, seasonality and food hygiene/safety as environmental risk factors of diarrhoea.

**Keywords:** diarrhoea, vulnerable, environmental factors, Malaysia, review

## INTRODUCTION

Diarrhoea is the passage of three or more loose or liquid stools daily. Another definition of diarrhoea includes more frequent passage than usual for the individual<sup>1</sup>. Despite improvements in global public health, diarrhoeal disease persistently ranked among the top ten causes of death in all ages, especially children under five years old<sup>2</sup>. According to Troeger (2018), there were more than 1.65 million deaths caused by diarrhoea in 2016, making diarrhoea the eighth leading cause of mortality in all ages and the fifth leading cause of death in children aged five years and below<sup>2</sup>. Another study highlighted that one in every tenth child death was due to diarrhoeal disease, making it the third leading cause of childhood mortality after pneumonia and preterm birth complications in 2017<sup>3</sup>. Interestingly, diarrhoea not only affected young children but was also the eighth leading cause of mortality among the elderly aged 70 years and older, amounting to 171.7 deaths per 100,000 population<sup>2</sup>.

With medical advancement, diarrhoeal mortality can be significantly reduced, but the frequent diarrhoeal episodes impact is tremendous, especially in children. The effect of acute diarrhoea on children's gross development was widely studied where the incidence of diarrhoea in the first six months of life is likely to cause nearly permanent stunting while the transient effect may be seen if the incidence occurs later after six months of age<sup>5,6</sup>. A recent study showed that early childhood diarrhoea was a predictor of

the intellectual function of cognitive delay during the later stage of childhood regardless of the child's stunting status<sup>7</sup>.

Diarrhoea is primarily caused by enteric infection, but risk factors vary and may be interconnected. Many studies have revealed multiple causes of acute diarrhoea, but few have focused on environmental factors, which are essential to the population, particularly those who live in poverty or in remote areas far from public facilities. Environmental risk factors are all the physical, chemical, and biological factors external to an individual, and all related behaviours, excluding non-modifiable natural environments<sup>8</sup>. The United States of America National Center for Environmental Health includes air quality, climate, food safety, safe water, sanitation, environmental chemicals and many more for their environmental health topics<sup>9</sup>.

## METHODOLOGY

This is a narrative review that only includes clinical, observational studies or any article reviews carried out over the past years globally. This review only accept any articles on diarrhoeal prevalence or incidence with its environmental risk factors. This review aims to identify various environmental factors that may cause diarrhoea from available resources.

**RESULTS**

**Pathogenesis**

Diarrhoea is a general symptom of the gastrointestinal system with broad aetiology. Usually, it is a symptom of an infection in the gastrointestinal system, which can be caused by either bacteria, viral, or parasitic organisms. Most of the time, infection is spread through faecal-oral methods through contaminated food or drinking-water or from person to person<sup>1</sup>. The World Health Organisation (WHO) categorised diarrhoea into three clinical types which are 1) acute watery diarrhoea which lasted for several hours or days, 2) acute bloody diarrhoea (dysentery) and 3) persistent diarrhoea which lasted for 14 days or longer<sup>1</sup>.

Diarrhoea is the derangement of water's expected net absorptive status and electrolyte absorption to secretion. In osmotic diarrhoea, stool output is comparable to the intake of the unabsorbable substrate and is usually not heavy; diarrheal stools will improve with the discontinuation of the offending agents<sup>10</sup>. While in secretory diarrhoea, a bacterial infection of the intestinal tract is the most common cause of acute-onset secretory diarrhoea. After bacterial colonisation, enteric pathogens may hold to or occupy the epithelium,

producing enterotoxins or cytotoxins. The colonisation may also trigger the release of cytokines attracting inflammatory cells, by inducing the release of agents such as prostaglandins or platelet-activating factors which lead to a state of active secretion<sup>10</sup>.

**Aetiology**

Bacteria and viruses primarily cause the diarrhoeal disease. Rotavirus is the commonest causative agent of diarrhoea in children less than five years old worldwide accounting for 27% of a child death in diarrhoeal cases. Other viruses including adenovirus and norovirus, accounted for 11% and 2% of child death of total cases respectively<sup>2,3</sup>. Bacterial causes include Shigella, accounted for 13% of a child's death of total cases and is the most typical cause of diarrhoea in older age. Other bacteria include cholera, campylobacter, enterotoxigenic E.coli (ETEC), non-typhoidal Salmonella, and Clostridium difficile<sup>2,3,11,12</sup>. Common parasitic infestation includes amoebiasis and cryptosporidium<sup>3</sup>. Neglected tropical disease such as Soil Transmitted Helminth also may cause diarrhoea with abdominal pain in a heavy infection<sup>12</sup>. Table 1 shows the common aetiology of diarrhoeal cases.

**Table 1: Common aetiology of diarrhoeal cases**

Viral	Bacteria	Parasites
Rotavirus	1. Invasive bacteria	Giardia species
Adenovirus	a. Escherichia coli (enteroinvasive, enterohemorrhagic)	Cryptosporidium species
Calicivirus	b. Shigella species	Entamoeba organism
Astrovirus	c. Salmonella species	
Norovirus	d. Campylobacter species	
	e. Yersinia species	
	f. Aeromonas species	
	g. Plesiomonas species	
	2. Enterotoxigenic bacteria	
	a. E. coli	
	b. Klebsiella	
	c. Clostridium perfringens	
	d. Cholera species	
	e. Vibrio species	
	3. Toxic bacteria	
	a. Clostridium difficile	

## FACTORS ASSOCIATED WITH DIARRHOEA

### Sociodemographic factors

#### **Age**

The risk of developing diarrhoea varied among studies done. A study was done at the global level by WHO revealed that the majority of cases occurred in the age group five years old and below accounted for 39% of all cases<sup>13</sup>. A similar observation was seen in France and Trinidad and Tobago showing that the incidence of diarrhoea peaked in the age group 5 years old and below amounting to 0.74 cases/person-year and 1.3 episodes/year respectively<sup>14,15</sup>. For Guyana and Jamaica, the highest prevalence of diarrhoea can be seen among age 1-4 years old, accounting for 12.7% and 14.6% respectively. However, a rather unusual finding in a local national level study showed that the highest incidence of acute diarrhoea was seen in the age group 20-29 years old, followed by teenagers 10-19 years old. This can be contributed by the lifestyle of younger generations who love meeting with friends and eating outside<sup>16</sup>.

#### **Gender**

A study in Nigeria revealed that male children were more likely to contract diarrhoea compared to female children for two years old and below, while a study in Miyagi, Japan showed the prevalence in males (11.0%) was predominantly higher compared to females (3.1%) in younger age group less than 15 years old<sup>17,18</sup>. A different observation was seen in the older age group showing that the prevalence of diarrhoea among females was higher in middle age<sup>18</sup>. A similar finding can be seen in a study in France where the incidence of diarrhoea in the age group 30-64 years old was higher among females (0.32 cases/person-year) compared to males (0.16 cases/person-year)<sup>15</sup>. Meanwhile, a Malaysian study showed no difference between males and females in the incidence of diarrhoea<sup>16</sup>.

#### **Ethnicity**

A study in Malaysia, a multiracial country, revealed that the native population in Sabah and

Sarawak have the highest risk of contracting diarrhoea, followed by Malay and Chinese<sup>16</sup>. This finding is similar to other studies focusing on the incidence of diarrhoea in children under five years of age which found Sabah and Sarawak natives have a higher risk of getting diarrhoea, followed by Indian and Chinese<sup>19</sup>.

#### **Location**

Residential places also play an essential role in determining the prevalence of diarrhoea. Multiple studies showed that those living in rural areas were more likely to develop diarrhoea than those living in urban areas<sup>19,20</sup>. In a study in Indonesia, living in urban slum areas had a higher prevalence of diarrhoea compared to the peri-urban developed region where the sanitary facility, waste disposal and environmental cleanliness is poorer compared to well-developed area<sup>21</sup>.

#### **Household income**

A household with more severe poverty was more likely to have a higher prevalence of diarrhoea as shown in a study from Indonesia<sup>21</sup>. This was supported by another study done in Malaysia where the poorest household was the most vulnerable to diarrhoea compared to other household income groups<sup>19</sup>. This can be explained by improper sanitary facilities, unsanitary waste disposal and poor child hygiene from more impoverished households than their counterparts<sup>19</sup>.

#### **Environment factors**

In this review, we found 23 articles relating environmental factors to diarrhoea cases. We can divide environmental factors into six factors which are water quality, sanitation, personal hygiene, food safety, living condition and seasonal factor. Among these six factors, only one is unmodifiable: seasonal factor, which includes temperature, rainy season and school holidays. Table 2 below shows the summary of environmental risk factors in this review.

Table 2a: Summary of review for environmental factors according to specific factors

Bil	Author, Year	Country	Population	Water Quality	Sanitation	Personal Hygiene	Food Safety	Living Condition	Seasonal factor
1	Troeger et al. 2018	Global		/	/				
2	Azry et al. 2018	Malaysia	5 years and below	/					
3	Choy et al. 2014	Malaysia (OA)	Indigenous age 1 month - 84 years		/	/	/		
4	Nasr et al. 2020	Malaysia (OA)	indigenous schoolchildren 8 - 12 years old	/	/	/	/	/	
5	Nwaoha et al. 2017	Nigeria	5 years and below	/	/	/	/		
6	Voth-Gaedder et al. 2020	South Africa	All ages	/	/				
7	Wasihun et al. 2018	Northern Ethiopia	Rural area, low socioeconomic status 5 years and below	/	/	/			
8	Workie et al. 2019	Northeast Ethiopia	5 years and below	/	/	/		/	
9	Sharizman et al. 2020	Sabah, Malaysia	5 years and below		/				/
10	Penakalapati et al. 2017	Global						/	
11	Headey et al. 2017	Ethiopia, Bangladesh, and Vietnam	Rural areas 6-23.9 months of age					/	

Table 2b: Summary of review for environmental factors according to specific factors

Bil	Author, Year	Country	Population	Water Quality	Sanitation	Personal Hygiene	Food Safety	Living Condition	Seasonal factor
12	Bukenya & Nwokolo 1991	Papua New Guinea	5 years and below		/			/	
13	Bahartha & Alezzi 2015	Yemen	5 years and below					/	
14	Shahrul Anuar et al. 2012	Malaysia (OA)	Indigenous population All ages		/		/	/	
15	Hussein 2017	Northern Nigeria	Areas of conflict 5 years and below	/				/	
16	Cohen & Colford 2017	Low- and Middle-Income Countries	Systematic review	/					
17	Käferstein 2003	Narrative review					/		
18	Takanashi et al. 2009	Vietnam	Sub-urban community 6 months-5 years				/		
19	Al-Delaimy et al. 2014	Malaysia (OA)	Indigenous 7-12 years old	/	/	/	/		
20	Chao et al. 2019	Africa South Asia	Under 5 years						/
21	JV et al. 1991	Northeast Thailand	Under 2 years						/
22	Musengimana et al. 2016	Cape town, South Africa	Under 5 years						/
23	Aik et al. 2020	Singapore	Singapore general population						/

## DISCUSSION

This review aims to provide an overview of various environmental factors that may cause diarrhoea. Diarrhoeal research mainly focuses on children especially aged five years and below as diarrhoea is a leading cause of mortality. The vulnerable population in this review include small children, lower socioeconomic status, indigenous people, and those who live in rural and remote areas with limited public facilities.

### Water quality

Water quality is the most frequent factor mentioned in this review where 10 out of 23 articles cited water quality as a factor of diarrhoea, including the source of drinking water and treatment of the water before consumption. Contaminated water is linked to an increased risk of diarrhoea which may lead to death due to dehydration as well as malnutrition in children<sup>34</sup>. Generally, there are two types of water sources, namely unimproved and improved drinking water sources<sup>35</sup>. Unimproved drinking water sources include any surface water and unprotected dug well or spring and cart with small tank; improved drinking water sources were piped household water connection and protected drilled wells or tube wells, and public taps or standpipe<sup>35</sup>. Unimproved source of drinking water are highly associated with diarrhoeal episodes especially among children aged five years and below<sup>2,16,19,26,35,47,48</sup>. Improved drinking water sources are proven as protective factors against diarrhoea. A study done in Papua New Guinea showed that the presence of a standpipe in the residential compound reduced diarrhoea morbidity to more than half<sup>31</sup>. Another study in Northern Ethiopia and Northern Nigeria revealed that the usage of unimproved water and the type of drinking water source become predictors of diarrhoea<sup>27,36</sup>.

An improved water source is not enough to protect the population from pathogens exist in the water source. In this review, we identify four articles that showed a significant association of adequate water treatment before consumption may protect against diarrhoea<sup>18,22,23,36</sup>. Simple in-house water treatment such as boiling water is highly protective and effective in preventing non-specific cases of diarrhoea as most pathogens may be killed by boiling such as *Vibrio cholera* and across specific protozoa<sup>37</sup>. A study done among Orang Asli revealed that the prevalence of Giardia infection was higher in those who did not boil water before consumption<sup>24</sup>. Storage method and cleaning frequency of the water storage space were also significant risks of diarrhoea<sup>17</sup>.

### Sanitation and latrine

Unsafe sanitation is the third leading risk factor for diarrhoeal episodes globally<sup>2</sup>. The Centers for Disease Control and Prevention USA defined sanitation as having facilities for safe human waste disposal and the ability to maintain hygienic conditions<sup>2</sup>. Seven studies highlighted usage of an unimproved toilet as an environmental risk factor for diarrhoeal episode<sup>2,16,19,22-24,32</sup>. A study targeting Sabah's under-five children showed that unsanitary latrines become predictors of diarrhoeal cases under five years of age<sup>19</sup>. Shared latrine posed a risk factor where a study in Nigeria and the Eastern Cape revealed that shared latrines especially by five people or more increased the prevalence of diarrhoea<sup>17,23</sup>. A Malaysian study showed that the prevalence of Giardia infection and Soil-Transmitted Helminth (STH) was higher in a household with no toilet in the house compared to those with a functioning in-house toilet, and also in an unimproved toilet in the house<sup>24,25</sup>.

### Waste management

According to the World Bank, waste was defined as any unwanted material intentionally thrown away for disposal<sup>26</sup>. Generally, the higher socioeconomic area will generate more solid waste than poverty, but with improper solid waste management, even a little solid waste will contribute mainly to diarrhoea, especially in low-income countries and poverty areas<sup>26</sup>. A study in northern Ethiopia showed that improper solid waste management contributes to predictors of diarrhoeal cases<sup>20,27</sup>. Two studies done in Sabah, Malaysia determining the risk of diarrhoea for children under five years of age showed that no garbage collection and open garbage in the surrounding house become predictors for diarrhoeal cases<sup>19,28</sup>.

### Personal hygiene

#### *Washing hands, wear shoes, washing clothes*

Hygiene is a practice that helps to maintain health and prevent the spread of diseases<sup>46</sup>. Hygiene practices by the primary caregivers include hand washing regularly, washing hands with soap, regular bathing, bathing with soap, and cleaning a child, cleaning the house and children's play area, adequate disposal of child's waste, use of sanitary facilities, and safe water source, consume safe water and laundering of clothes<sup>40,47</sup>. A study done among Orang Asli for the prevalence of Giardia showed that not wearing shoes when outside and not washing hands before eating and after playing with animals were significant risk factors of Giardia infection<sup>24</sup>.



## Food safety

### Food storage

Storage area for high-risk food such as meat and fish is essential to ensure freshness and avoid contamination and spoilage. Food storage includes preparing cooked food several hours before consumption, insufficient storage temperature, insufficient cooking or reheating food<sup>38</sup>. A study was done in Indonesia in which food hygiene indicators, including owning a refrigerator, is a significant predictor of diarrhoea<sup>21</sup>.

### Food Cleanliness/hygiene

Food hygiene behaviour includes washing hands before preparing food (with or without soap), washing cooking utensils (with or without soap), separating utensils for raw and cooked food, preparing food on the table or floor; raw fruits and vegetables must be washed before consumption, and to cook food thoroughly<sup>39,40</sup>. Studies involving Orang Asli children showed that not washing fruits before eating was a risk factor for Soil-Transmitted Helminth (STH) and those not washing vegetables before consumption was a significant risk factor for contracting intestinal polyparasitism<sup>25,41</sup>.

### Living condition

A crowded house is one of the factors causing diarrhoea. Crowded houses result in many people sharing sanitation, which worsens by improper sanitation, and poor waste disposal management increases the risk of diarrhoea<sup>22,24</sup>. In a study in Yemen, a packed house contributes two times higher risk of contracting diarrhoea<sup>32</sup>. Local research involving three ethnic groups of Orang Asli revealed that the Orang Asli group who lived in a traditional bamboo house lacking basic amenities were at a higher risk of contracting *Entamoeba histolytica*, *dispar* and *moshkovskij*<sup>33</sup>.

Some pathogens associated with diarrhoea may arise from contact with animal faeces. A systematic review suggests that any contact with animals and animal faeces increased the risk of soil-transmitted disease and trachoma, which increased the incidence of diarrhoea<sup>29</sup>. Another multi-country observational study revealed a positive association between animal faeces and diarrhoeal symptoms in Bangladesh<sup>30</sup>. Another study done in the urban area of Papua New Guinea showed that the presence of pigs in the residential premises increased diarrhoea morbidity by 69%<sup>31</sup>.

### Weather and seasonality

Climate and seasonality may increase or decrease the incidence of diarrhoea and impact vulnerable

populations. Different pathogens will peak with specific temperatures and rain or with general seasons throughout the year<sup>42</sup>. Interestingly, a study in northern Thailand found the relative incidence of diarrhoea reduced with age during winter which increased with age during the hot and early rainy season<sup>43</sup>. While another study in Cape Town revealed that a five °C increase in minimum and maximum temperature led to a 15% and 6% increase in diarrhoea cases<sup>44</sup>. For the humidity factor, a study reported every 10% increase in relative humidity would cause an increase in the number of diarrhoeal cases one week later<sup>45</sup>. Interestingly, public holidays were associated with an increase in diarrhoea reports a week after a decrease in the same week of public holidays<sup>45</sup>.

## CONCLUSION

Diarrhoea is still one of the leading causes of morbidity among the general population, especially in children where it affects cognitive function and causes stunting. Diarrhoea is usually a manifestation of an infection of the gastrointestinal system. Infectious agents for diarrhoea differ by transmission route; however, the risk factors of diarrhoeal episodes are widely ranged and interconnected, which need to be identified. Modifiable risk factors such as the surrounding environment can be improved to avoid diarrhoeal episodes. In this review, we recognise the latrine and sanitation, waste disposal, housing condition, existence of animals, water quality, personal hygiene, seasonality and food hygiene/safety as environmental risk factors of diarrhoea. Special efforts can be diverted to the vulnerable population such as Orang Asli who live in remote areas away from public facilities to improve their environmental health risk factors. Future research should focus on Orang Asli on diarrhoea prevalence and their environmental risk factors that can be improved.

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### Competing Interest

The authors declare no competing of interest.

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