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Microbial Contamination of Groundwater in Rural Area of Sittwe District, Rakhine State, Myanmar

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Abstract

Rakhine state has high rates of open defecation compared to other parts of Myanmar. In the rural area of the Sittwe district, pit latrines were constructed near water sources such as boreholes, wells, lakes, creeks, and rivers. The discharge of chemical and microbial contaminants from pit latrines to groundwater may have a negative impact on human health and drainage and solid waste disposal are major challenges in both urban and rural areas. Open defecation, lack of waste management disposal, and construction of pit latrines near water sources lead to fecal contamination or pollution of the groundwater table. Groundwater samples in rural areas of Sittwe district, Rakhine State, Myanmar were characterized microbiological properties of groundwater. For microbiological analysis, water samples were analyzed for qualitative analysis of total coliform and quantitative analysis of fecal coliform (*Escherichia coli*; *E. coli.*) by membrane filtration technique (MFT) to determine the safety aspect of the utilization of groundwater as a source of drinking purpose. Almost all the indicator organisms' counts in collected samples were above WHO guidelines for drinking water quality and Myanmar national drinking water quality standard (MNDWQS). The presence of fecal coliform bacteria indicates that the water is contaminated with fecal waste from human or warm-blooded animals and the presence of total coliform indicates that the groundwater is contaminated with both fecal waste and other coliform species from the environment. Safe drinking water, adequate sanitation, and hygiene are crucial to prevent microbiological contamination of drinking water which can produce diseases such as diarrhea. Reduction of open defecation, construction of systematic latrines, proper waste disposal, and management can protect the groundwater pollution and increase the quality of drinking water.

Keywords : Groundwater Pollution; *Escherichia coli*; Drinking Water; Risk Assessment

Introduction

According to a WHO report, more than two billion people are living with water stress. Around two billion people worldwide are drinking water sources polluted with fecal matter. Microbial contamination of drinking water as a result of contamination with feces poses the greatest risk to drinking water safety [1]. *Escherichia coli* (*E. coli.*) are commonly found in the large intestine of humans and warm-blooded animals [2]. Most strains of *E. coli.* are harmless and can cause severe foodborne illness due to the production of Shiga toxin produced by *E. coli.* (STEC). Human transmission of *E. coli.* O157:H7 occurs by contaminated foods, water, and direct contact with the infected person or animal [3]. Abdominal cramps and diarrhea are the symptoms of the diseases caused by STEC that may in some cases progress to bloody diarrhea (hemorrhagic colitis). It may also cause fever and vomiting [4].

Diarrhea, cholera, dysentery, typhoid, and polio can be transmitted through microbiologically contaminated drinking water and are estimated to cause 485,000 diarrheal deaths each year [1]. Diarrheal disease is the second leading cause of death in children under five years old, and around 525,000 children are killed by diarrheal diseases every year. Safe drinking water, appropriate hygiene, and sanitation can significantly reduce the incidence of diarrheal disease. Globally, there are approximately 1.7 billion cases of childhood diarrheal disease every year [5]. In 2020, over 1.7 billion people still do not have basic sanitation services, such as private toilets or latrines. The remaining 494 million are still flushing in open areas such as street gutters or surface water bodies [6]. In 2020, WHO estimated that 74% of the world's population, 5.8 billion people, would use a safe and reliable water supply free from contamination. However, diarrhea remains a major killer but is largely preventable. Each year, 297,000 children aged less than five years could be prevented from dying through improved water, sanitation, and hygiene [1]. The first large-scale review of the safety of drinking water through fecal contamination testing will be carried out in the 2019 intercensal survey. Rakhine and Ayeyarwady are particularly vulnerable and in need of help due to their high dependency on surface water, as well as the impact of climate change [7]. Almost 18% of deaths among children under five in Myanmar are due to diarrhea each year [8].

Since the turn of the 20th century, when there was a long period of stagnant development in Rakhine state, it has been plagued by communal problems which have left its inhabitants desperately short of basic needs. This regrettable situation was compounded from 2012 to 2014 when violent communal riots between members of the Muslim and Rakhine communities erupted in various parts of the state [9]. The tensions that flared in June and October of 2012 resulted in widespread displacement and camp settlement; the loss of housing, and psycho-social trauma that impacted both community and family-level traditional support mechanisms as well as individual mental health [10]. In Rakhine State, the coverage for water and sanitation facilities stands at 75 percent and 58 percent respectively, while 99 percent of the camps are administered by WASH focal agencies [11].

Sittwe is one of the 17 townships of the Rakhine state, which is the most western of Myanmar's States and Regions. It is the second most populous state with around 3.2 million [12]. According to the Myanmar Census, there are approximately 83% of the rural population and 17% of the urban population in Rakhine State [13]. World Bank stated that Rakhine State has the highest level of poverty in all States and Regions [9]. The main challenges faced by the state of Rakhine in its social development are poor infrastructure, particularly road infrastructure, insufficient connectivity with other parts of Myanmar, energy shortages, and lack of communication facilities [12].

Rakhine state is high levels of open defecation due to a combination of factors. Households have very limited spare funds for the construction of latrines in households. Furthermore, low-lying paddy fields divided by a maze of streams and channels make up a large part of the populated area. This leads to a great many opportunities for open defecation without consequence on bodies of water [14]. The use of unprotected groundwater aquifers, which do not contain any water purification or disinfection measures for drinking purposes, is a major public health concern [15]. A variety of pathogenic microbes, such as bacteria and viruses, may be present in solid waste contamination with human and liquid excreta, which is usually disposed of in landfills, open dumping sites, and near unlined disposal sites. In the groundwater aquifer, harmful chemicals, nutrients, and pathogenic bacteria are being released as well as polluting an ecosystem of water [16]. Discharges from sewage works and runoff from informal settlements are major factors affecting the microbiological quality of groundwater [17]. In low-income countries, contamination of drinking water is a significant burden on their health caused by waterborne diseases such as diarrhea. The presence of fecal indicator bacteria, Escherichia coli, or thermotolerant coliform, is recommended for the WHO to assess fecal contamination [18].

In the area of Rakhine State, drainage, and solid waste disposal are major challenges in both urban and rural areas [19]. A high risk for diarrheal and other infectious disease outbreaks due to insufficient WASH facilities, which are exacerbated by rains and waterlogging. According to WHO reports, Rakhine state has regularly reported cases of severe acute watery diarrhea for the past 5 years [20]. In Rakhine state, five severe cases of diarrhea were reported; 3,345 mild cases and 795 cases in 2014, by the Inter-Cluster Coordination Group for Humanitarian Country Teams [12]. Since 25 April 2021 at Sittwe and Pauktaw camps for internally displaced persons, there has been an increase in cases of acute vomital diarrhea as reported by the early warning alert and response system. More than 2,000 cases have been reported [21]. UNOCHA reported an acute watery diarrhea outbreak in Rakhine State, acute watery diarrhea has been outbroken in conflict areas and IDP camps across Kyauktaw, Pauktaw, and Sittwe Townships. A total of 686 cases have been detected across these three townships, of which 385 cases were in Sittwe camps and most of the reported cases are among children under five years [22].

The purpose of this study was to determine the microbiological properties of groundwater from rural areas of Sittwe district, Rakhine State, Myanmar, and to determine the safety aspects of utilization of groundwater as a source of drinking purpose.

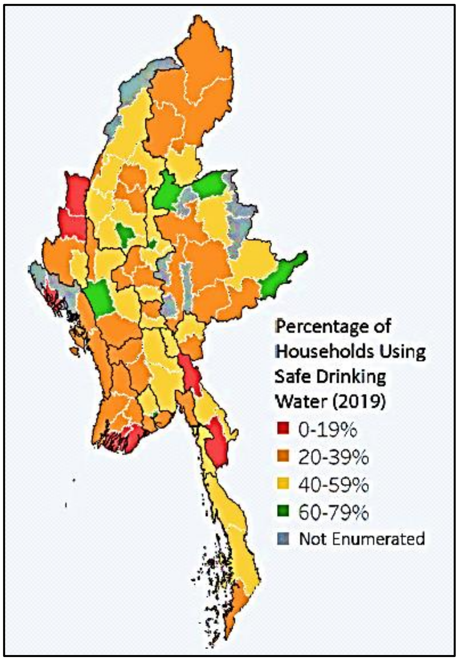

Figure 1 Percentage of Household using Safe Drinking in Myanmar [7]

Materials and Methods

1. Study Area and Collection

Two hundred and three samples of groundwater samples were collected using polyethylene terephthalate (PET) bottles from tube wells located in Ma Gyi Myaing (MGM), Ywar Gyi South (YGS), Ywar Gyi North (YGN), Aung Mingalar (AMGL), Nga Pon Gyi (NPG) and Aung Taing (AT) villages, Sittwe district, Rakhine State, Myanmar. Collected groundwater samples were transported in a cool box to the laboratory and groundwater samples were analyzed within 24 hours.

2. Laboratory Analysis

Total coliform and fecal coliform (*E. coli.*) were determined by Palintest PTW10005 Potates+ Repaid Respond Water Quality Laboratory instrument (Membrane Filtration Technique; MFT) and was approved by USEPA for measuring coliforms. The water sample was filtered through the membrane filter (0.45 µm, 47 mm) using a vacuum to pull the water through a membrane. The membrane filter was placed onto an absorbent pad rich with lauryl sulfate nutrient broth in a petri dish and incubated at 37°C; total coliform (qualitative) and 44°C; fecal coliform (*E. coli.*) for 24 hours. Yellow colonies were enumerated. The measurement was conducted in duplicate and reported the average number. The interpreted results were compared with the WHO Guidelines for Drinking Water Quality [5] and Myanmar National Drinking Water Quality Standard (MNDWQS) [23].

Figure 2 Map of Sittwe District, Rakhine State, Myanmar [24]

Table 1 Composition of Membrane Lauryl Sulfate Broth

Nutrients	Composition (g/L)
Peptic Digest of Animal Tissue	39
Yeast Extract	6
Lactose	30
Sodium Lauryl Sulfate	1
Phenol Red	0.2

*Final pH: 7.4±0.2 at 25°C

Table 2 WHO and Myanmar National Drinking Water Quality Standard

Standard	Total Coliform	*E. coli.*
WHO	Absent	Absent
Myanmar	Absent or 0 MPN/100ml	Absent or 0 MPN/100ml
Emergency Situation*	10 MPN/100ml	3 MPN/100ml

*MNDWQS

Results and Discussion

Large numbers of people use pit latrines, which must be filled rapidly every 3 months without sewage and proper waste disposal in Rakhine state. The relocation of latrines to a number of sites is not feasible due to space constraints, expensive transport costs, and complex logistical arrangements. Around 35% of the population are practicing open defecation in 2012. Rakhine State has high rates of open defecation compared to other parts of Myanmar [19]. According to the survey conducted on 203 households located in the rural area of Sittwe district, the depths of the tube wells were a minimum of 25 ft. to a maximum depth of 40 ft., and pit latrines were constructed near the water sources such as boreholes, wells, lakes, creeks, and river. In low-income countries, pit latrines are one the most common systems for the disposal of human excreta, and the discharge of chemical and microbial contaminants from pit latrines to groundwater may have a negative impact on human health [25]. The distances of boreholes were minutest 5 ft. to a maximum of 100 ft. from latrines. Open defecation, lack of waste management disposal, and construction of pit latrines near water sources lead to fecal contamination or pollution of the groundwater table.

Overall, 44% of collected groundwater samples (90 of 203) were negative and 56% of groundwater samples (113 of 203) were positive for total coliform and *E. coli.* Aung Taing village was found the highest microbial contamination (85%), Ma Gyi Myaing was ranked as the second contaminated area (70%), Nga Pon Gyi, Ywar Gyi South, Ywar Gyi North were third contaminated areas, 66%, 53%, and 40%, respectively. Aung Mingalar was the lowest contaminated area (7%) in Sittwe compared to others and the results were shown in Table 3. The distribution of *E. coli.* concentrations in groundwater samples, according to WHO risk categories [26], were shown in Table 4 and Fig. 3. Of the total number of groundwater samples (203) in MGM (n=30), YGS (n=30), YGN (n=30), AMGL (n=30), NPG (n=44) and AT (n=39); 30%, 47%, 60%, 93%, 34%, and 15% were in compliance with WHO standard (<1 cfu/100ml), 13% 23%, 6%, 7%, 27% and 36% were in low risk level (1-10 cfu/100ml), 47% 13%, 6%, 0%, 32% and 23% were in intermediate level (11-100 cfu/100ml) and 10%, 17% 28%, 0% and 7% were in high-risk level (101-1000 cfu/100ml), respectively. Overall microbiology quality of groundwater samples in the rural area of Sittwe (n=203) were 44% (n=90) in compliance, 20% (n=41) at the low-risk level, 22% (n=43) in the intermediate level, 26% (n=10) in high-risk level, respectively.

Table 3 Total coliform and *E. coli.* contamination of groundwater in rural area of Sittwe

Village	Number of Sample (n)	Total Coliform		*E. coli.*	
		Negative (n, %)	Positive (n, %)	Negative (n, %)	Positive (n, %)
MGM	30	9 (30)	21 (70)	9 (30)	21 (70)
YGS	30	14 (47)	16 (53)	14 (47)	16 (53)
YGN	30	18 (60)	12 (40)	18 (60)	12 (40)
AMGL	30	28 (93)	2 (7)	28 (93)	2 (7)
NPG	44	15 (34)	29 (66)	15 (34)	29 (66)
AT	39	6 (15)	33 (85)	6 (15)	33 (85)
Overall	203	90 (44)	113 (56)	90 (44)	113 (56)

Table 4 Water quality results of groundwater based on WHO classification of health-risk

	Number of *E. coli.* (CFU/100 ml)				
	<1 (Compliance)	1-10 (Low Risk)	11-100 (Intermediate)	101-1000 (High-Risk)	>1000 (Very High-Risk)
	n (%)	n (%)	n (%)	n (%)	n (%)
MGM	9 (30)	4 (13)	14 (47)	3 (10)	0 (0)
YGS	14 (47)	7 (23)	4 (13)	5 (17)	0 (0)
YGN	18 (60)	2 (6)	2 (6)	8 (28)	0 (0)
AMGL	28 (93)	2 (7)	0 (0)	0 (0)	0 (0)
NPG	15 (34)	12 (27)	14 (32)	3 (7)	0 (0)
AT	6 (15)	14 (36)	9 (23)	10 (26)	0 (0)
Overall	90 (44)	41 (20)	43 (22)	29 (14)	0 (0)

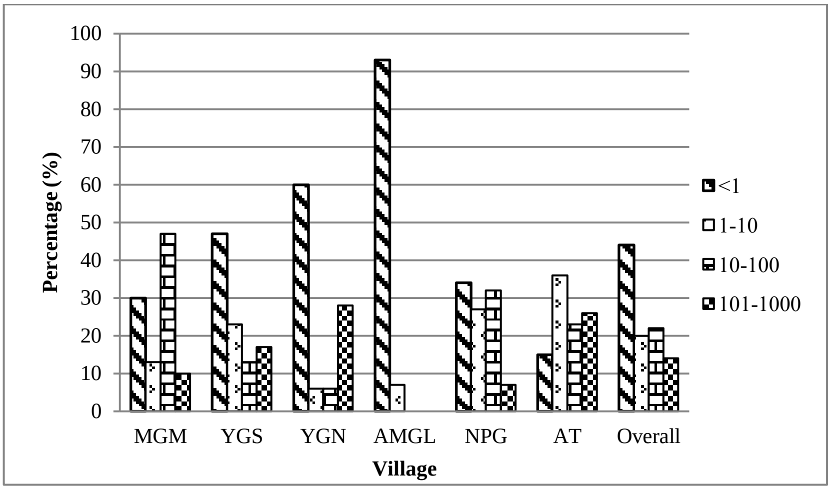

Figure 3 Water quality graph of groundwater samples based on WHO health-risk classification

Pit latrines in Sittwe are typically built near tube wells or boreholes for reasons of space, hygiene, and convenience. Pit latrines are a major source of groundwater contamination due to their widespread use in rural and suburban regions. When the safe distance between a water point and a pit latrine is not sufficiently maintained, groundwater sources are frequently affected. In many underdeveloped nations, including Myanmar, inadequate sanitation systems promote microbial contamination and water-borne diseases [27-28]. Pit latrines exacerbated microbial contamination of adjacent shallow tube well water where hydrogeological conditions (i.e. thickness and hydraulic properties such as hydraulic conductivity of surface clay aquitard, depth of groundwater table, and groundwater flow direction) played a significant role in bacterial transport [29]. Fecal waste contains a variety of pathogens, including viruses, bacteria, protozoa, and helminths (parasitic worms). This waste eventually percolates to the groundwater table. Pit latrines, it is often assumed, should not be utilized in locations where groundwater is used for residential water consumption. The groundwater protocol in Southeast Asia does not prohibit pit latrines in such places, but it does advise prudence and suggests that pit latrines be positioned at least 75 meters from water sources [30]

The results of the water quality analysis showed that groundwater from the rural area of Sittwe has risks associated with pathogenic infections due to microbial contamination of groundwater. The bacteria contaminate the water and can cause illnesses and illness among the local people In comparison to others, *E. coli.* had higher ingested dosages, infection risks, and illness per year. This implies a significant prevalence of E. coli-related illnesses in the studied area [31]. It is crucial to highlight that during the research period; a lot of observations were taken about the environmental conditions in the district, which provides insight into the pollution of the water sources. First, we discovered that their groundwater sources shared similar characteristics, namely the lack of effective physical barriers such as concrete seals, well linings, hygienic covers, and secured aseptic lids, among others, capable of avoiding terrestrial runoff containing anthropogenic and animal waste, which will undoubtedly pollute the sources. This could be related to the current study's discovery of E. coli counts in groundwater sources. Building strategically planned pit latrines is an important step in preventing microbial contamination of groundwater, which serves as a primary supply of drinking water for many communities. These pit latrines are designed to hold and decompose human waste properly, reducing the possibility of harmful germs penetrating the surrounding soil and seeping into groundwater. These systems contribute to the overall well-being of communities by decreasing the transmission of waterborne diseases by adhering to correct construction and maintenance regulations. Implementing such measures is critical to guaranteeing access to safe and clean drinking water, particularly in locations where sanitation infrastructure is inadequate or non-existent.

Second, a domestic water treatment system developed to address E. coli contamination in groundwater sources is an important lifeline for safe and clean drinking water. Typically, these systems use a combination of filtration and disinfection approaches. Water is first filtered to eliminate suspended particles and silt. The bacteria are then successfully killed or inactivated using ultraviolet (UV) or chlorine-based disinfection procedures. These systems ensure that residents in areas with contaminated groundwater have access to a consistent source of drinkable water, protecting public health and reducing waterborne infections. Finally, raising water and sanitation (WASH) knowledge is critical for reducing waterborne infections. Communities can dramatically lower the risk of diseases like cholera and dysentery by instructing safe water practices and good sanitation. Individuals can be empowered to make informed decisions that protect their health and the well-being of their families by learning about the importance of clean water sources, good hygiene, and waste disposal. Such public awareness initiatives are critical in guaranteeing access to clean, safe water and improved sanitation, eventually protecting public health and fostering a higher quality of life for all.

Conclusion

Over 50 percent of collected groundwater samples were contaminated with total coliform, and fecal coliform (*E. coli.*) and exceeded WHO guidelines for drinking-water standards and Myanmar's national drinking-water standards. Overall, the groundwater in the village is not suitable for human consumption without prior treatment such as chlorination. Diarrhea is still outbreak in Rakhine State and the diarrhea outbreak has only affected children under the age of 5, with the fatalities being toddlers. The quality of water and sanitation facilities has been found to be unsatisfactory in a large number of cases of diarrhea. To prevent the outbreak of diarrhea and to increase water and sanitation facilities, government, non-government, and community organizations should support the WASH campaign, environmental awareness sessions, and first-aid training. In recent years, most of the organizations supported in construction of pit latrines to reduce the open defecation system, while this provides a desirable alternative to open defecation, widespread use of unlined pit latrines may result in hazardous side-effects. Therefore, government and non-government organizations should develop the design of pit latrines, septic tank systems, and sewage management systems. In addition, the rural area of the Sittwe is far from the mainland, and difficult to access high technology for the treatment of the drinking water system. Despite this constraint, addressing the issue requires a comprehensive approach that combines preventive measures, various water treatment techniques (such as boiling, chlorination, SODIS, filtration, UV treatment, and biological treatment), and community education on hygiene practices. Given the limited access to high-tech solutions, reliance on simpler, cost-effective methods such as boiling and community-based interventions becomes essential. Community involvement, ongoing education, and regular water quality monitoring remain critical for achieving and sustaining success in mitigating E. coli contamination in the region. Physical, chemical, and microbiological qualities of water should be carried out on all the water sources in the State at least two times per year to monitor the contaminants.

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