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A Preliminary Study of the Quality of Seawater at Rasfannu Beach of Male' City

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Abstract: The coastal waters of Malé, Maldives, suffer from pollution due to sewage and untreated waste effluent discharge. Unlike other islands, Malé lacks natural beaches, leading to the creation of two artificial beaches. These beaches are overcrowded, and concerns about water quality persist due to poor water circulation and nearby sewage pipes. This study aims to assess the water quality of Rasfannu, a recently created artificial beach. Water samples were collected weekly over four weeks and analyzed for physicochemical parameters (pH, turbidity, conductivity, nitrate, nitrite, nitrogen ammonia) and bacteriological parameters (*E. coli, fecal coliform, total coliform*). The membrane filtration method was used for bacterial analysis, while absorption spectroscopy was used for measuring nitrate, nitrite, and nitrogen ammonia. The pH and conductivity were measured using the Mettler Toledo pH meter. The results were compared with guidelines from the World Health Organization (WHO), United States Environmental Protection Agency (USEPA), recreational water guidelines from Canada, California, and the European Union (EU). The hypothesis was that the water at Rasfannu beach is contaminated and unsafe for recreational purposes. However, the results indicated that all parameters fell within acceptable ranges as per these guidelines, and the water quality index calculated following the National Sanitation Foundation (NSF) rated the water quality as good. Thus, Rasfannu beach is deemed safe for recreational use.

Keywords: seawater quality; Rasfannu Beach; physicochemical parameters; bacteriological parameters; recreational water

1. INTRODUCTION

Beaches are vital for human recreation and serve as habitats for marine organisms, but they face threats from domestic wastewater, sea traffic, industrial wastewater, accidental spills, and climate change [1]. Recently, the contamination of seawater by wastewater has become a significant issue for both human users and marine life [2]. Untreated sewage release introduces high concentrations of suspended solids and nutrients, along with human and

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animal organic waste, altering the physicochemical properties of coastal waters and increasing microbial loads [3-6]. This contamination poses health risks to recreational users, with millions seeking medical help annually due to gastrointestinal diseases from polluted coastal waters [7].

Pathogens and opportunistic pathogens such as Aeromonas, Pseudomonas, Vibrio, and yeasts indicate seawater contamination from sewage. Pathogens enter water through point sources like sewage outfalls and non-point sources like storm runoff, sand resuspension, animal fecal inputs, and human shedding [8-9]. Waterborne pathogens often occur at low concentrations, making detection challenging due to their nutritional needs and environmental susceptibility [10]. Fecal Indicator Bacteria (FIB), such as *Escherichia coli, enterococci, and clostridia*, are more abundant and easier to measure, indicating the potential presence of pathogens [11]. Among FIB, fecal coliforms are commonly used to assess recreational water quality globally [12].

Malé, the capital of the Maldives, is overcrowded and lacks natural beaches, leading to the construction of two artificial beaches and a swimming area. The coastal water quality of these beaches is compromised by sewage effluent and chemical waste disposal [13]. The pollution load likely exceeds the coastal waters' capacity to dilute contaminants. Although no previous research has been conducted, these beaches have been closed down due to high sewage contamination [14-15].

This study aims to assess the contamination level of recreational waters of Rasfannu beach of Male′ to ensure public safety. The results will help in ensuring the quality of seawater at Rasfannu, promoting the wellbeing of its users.

2. METHODS

In this study, sea water samples were collected from Rasfannu every Thursday for four weeks from a depth of one foot. Six locations were selected: three from the beach area and three from the ocean opposite the artificial beach area separated by where sewage effluent chemicals are discharged. Samples were taken twice daily, in the morning and evening. Sterile bags were used for collecting samples for microbial parameters, and plastic bottles from the Male' Water and Sewerage Company (MWSC) laboratory were used for other parameters. MWSC is an external ISO 17025 certified state of the art laboratory. MWSC is an external ISO 17025 certified state-of-the-art laboratory. Samples were transported to the MWSC laboratory in ice boxes, and the temperature was maintained at 4°C during transportation to ensure sample integrity.

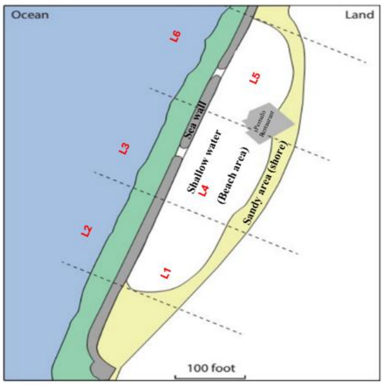

Figure 1. The Sampling Site (L1, L2, L3, L4, L5 & L6 shows the six locations from which samples were taken)

All samples were analyzed using standard methods, including the Nessler Method for ammonia, the Cadmium Reduction Method for nitrate, and the Diazotization Method for nitrite, all conducted via absorption spectroscopy. Indicator bacteria, such as *total coliform (TC), fecal coliform (FC)*, and *Escherichia coli (E. coli),* were analyzed using the membrane filtration method. Conductivity and pH were measured using the necessary instruments. Rainfall was observed during the first two weeks, with the most precipitation occurring in week two.

For bacteriological analysis, m-ColiBlue24 Broth PourRite Ampules media from Hach Company was used to analyze samples for *E. coli*, *total coliforms*, and *fecal coliforms* using membrane filtration method [16]. This method is approved by USEPA for testing coliforms and *E. coli*.

Physicochemical analysis included pH, conductivity, turbidity, nitrogen, ammonia, nitrite, and nitrate. pH was measured using a Mettler Toledo pH meter, employing electrometry methods to evaluate the electrical properties of the solution. Electrical conductivity, indicating the presence of salts, was measured using a METTLER TOLEDO meter. For simplicity, MWSC used electrical conductivity values to estimate TDS, correlating conductivity with TDS through an experimentally determined factor.

Ammonia concentrations were measured using the Nessler method [17], which forms a yellow color proportional to ammonia concentration. Measurements were taken at absorption DR6000 spectrophotometer set at 425nm.

Nitrite and nitrate levels were analyzed using USEPA-approved methods [18] the diazotization method for nitrite and the cadmium reduction method for nitrate. Samples reacted with sulfanilic acid to form a diazonium salt, which coupled with chromotropic acid to produce a pink complex. The measurement wavelength used for the DR6000 spectrophotometer was 507 nm.

For nitrate analysis, Cadmium metal reduced nitrates to nitrite, which then reacted with sulfanilic acid to form a diazonium salt, coupling with gentisic acid to form an amber solution. Test results were measured using absorption spectrometer set at 400 nm.

3. RESULTS AND DISCUSSION

3.1 Bacteriological Analysis

Table 1. Minimum, Maximum, Average and Geometric Mean value for *E-Coli*, *Fecal Coliform* and *Total Coliform*

Location	*E. Coli* (cfu/100 ml)				*Fecal Coliform* (cfu/100 ml)				*Total Coliform* (cfu/100 ml)			
	Min	Max	Avg	GM	Min	Max	Avg	GM	Min	Max	Avg	GM
L-1	10	290	129.3	76.62	34	193	97.5	80.59	83	1550	567.5	339.79
L-2	6	152	71.9	46.27	31	188	81.4	64.87	63	930	283.8	156.42
L-3	11	278	112.1	72.75	46	183	110.9	102.55	102	810	346.3	259.01
L-4	3	600	166.6	41.83	12	1440	329.3	73.79	68	2730	664.7	186.04
L-5	2	270	91.4	35.84	18	88	52.8	46.88	43	1210	378.9	190.88
L-6	4	150	64.6	37.1	34	470	132.5	63	36	320	170.4	139.26
Overall	2	600	106	51.73	12	1440	134.1	71.95	36	2730	401.9	211.9

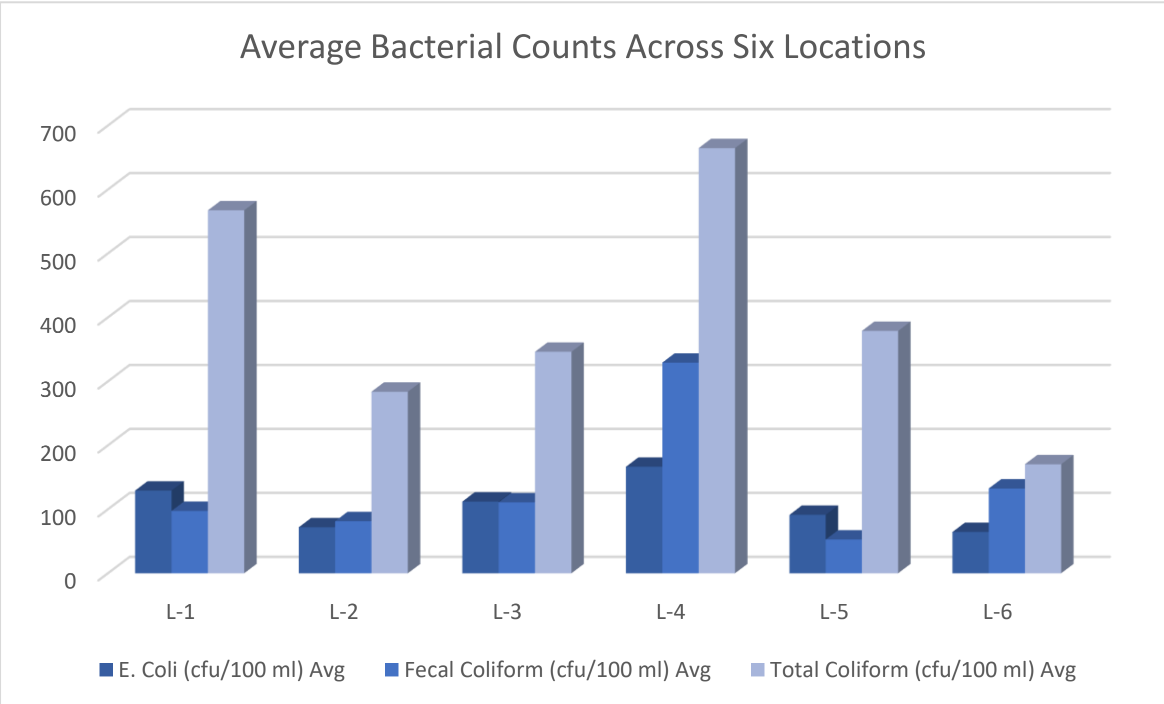

Figure 2. Average *E.coli, Fecal Coliform and Total Coliform levels across 6 locations*.

Table 1 shows the minimum, maximum, average, and geometric mean values of *E-Coli* for all six locations. The minimum value observed was 2 cfu/100 ml, and the maximum was 600 cfu/100 ml. The average value was 106 cfu/100 ml, and the geometric mean value was 51.73 cfu/100 ml. These values do not exceed the USEPA recommended [18] geometric mean value of 126 cfu/100 ml. The highest value observed was from location 4, located outside the sea wall (from the ocean). Both inside the beach and outside the sea wall, the highest values were obtained in week 2, attributed to rainfall on the sampling day as observed from the meteorological data and the site (Table 6). Rain releases pathogens trapped on the beach into the water. In areas like Rasfannu, which represents a coastal embayment, the dilution is assumed to be low [19]. The gradual increase in *E-Coli* over the next two weeks could be due to the increase in bathers, as there was limited precipitation during those weeks.

The minimum value detected for *total coliforms* was 36 cfu/100 ml, and the maximum value was 2730 cfu/100 ml. The average was 402 cfu/100 ml, and the geometric mean value was 211.90 cfu/100 ml. According to the California guideline [20] for recreational water, the amount of total coliform in seawater should be less than 1000 cfu/100 ml for an average value over 30 days of sampling. For a single sample, the value should be less than 10,000 cfu/100 ml. The results are within the acceptable range, agreeing with the guidelines. Total coliform levels remained almost the same throughout the weeks, except for week 2, when both outside the sea wall and inside the beach had higher values compared to other weeks, with the highest values outside the beach. This can be explained by rainfall and overflow of sewage will contribute to faecal coliform load in addition to the total coliform [19].

The minimum value detected was 12 cfu/100 ml, and the maximum value was 1440 cfu/100 ml. The average was 134.07 cfu/100 ml, and the geometric mean value was 71.95 cfu/100 ml. According to the California guideline for recreational water, the amount of fecal coliform in seawater should be 200 cfu/100 ml for an average over 30 days of sampling. For a single sample, the value should be less than 400 cfu/100 ml. The results obtained are within the acceptable range for the California guideline for recreational water [20]. Fecal coliform levels showed high levels at location 4 in week 2, similar to other indicator bacteria, due to rainfall on that date.

3.2 Physicochemical Parameters

Table 2. Minimum, Maximum, and Average Values for pH, Turbidity, Salinity and Conductivity

Location	pH			Conductivity (µS/m)			Turbidity (NTU)			Salinity (ppt)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
L-1	8.02	8.22	8.12	50100	54900	52930	0.86	3.27	1.84	32.8	36.4	34.9
L-2	8.02	8.19	8.12	50000	55200	52830	0.84	4.03	1.75	32.7	36.6	34.82
L-3	8.08	8.21	8.15	50700	54800	52830	0.33	1.99	1.24	33.3	36.3	34.84
L-4	8.06	8.22	8.15	51500	54900	52870	0.14	0.71	0.33	33.8	36.4	34.86
L-5	8.05	8.19	8.13	51600	55100	52990	0.18	0.35	0.26	33.9	36.5	34.95
L-6	8.03	8.13	8.13	51200	54900	52790	0.17	0.67	0.34	33.6	36.4	34.79
Overall	8.02	8.22	8.13	50000	55200	52873	0.14	4.03	0.95	32.7	36.6	34.65

Table 3. Minimum, Maximum, and Average Values for Nitrate, Nitrite, and Ammonia

Location	Nitrate (mg/L)			Nitrite (mg/L)			Ammonia (mg/L)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
L-1	2.3	4	3.14	0.006	0.023	0.0138	0	0.07	0.031
L-2	2.3	4.9	3.3	0.008	0.027	0.0158	0	0.18	0.077
L-3	1.8	3.7	2.87	0.002	0.016	0.0094	0	0.28	0.096
L-4	2.5	3.7	3.04	0.008	0.019	0.0123	0	0.29	0.077
L-5	2.1	4.4	3.05	0.003	0.024	0.0104	0	0.21	0.066
L-6	2.2	4.7	3.32	0.005	0.018	0.0108	0	0.23	0.064
Overall	1.8	4.9	3.12	0.002	0.027	0.012	0	0.29	0.069

Table 2 summarizes the physical characteristics of seawater samples from all stations. pH values ranged from 8.02 to 8.22, with an average of 8.13. These values fall within the WHO guidelines, which recommend a pH range of 6.5 to 9.5 for recreational waters. The Canadian recreational water guideline states a desirable pH range of 5 to 9 for primary contact recreational water bodies. For saltwater beaches, a pH around 8 is expected.

Turbidity ranged from 0.14 to 4.03 NTU, with an average of 0.95 NTU. The WHO guideline recommends turbidity should be less than or equal to 5 NTU, so the values are within range.

The minimum salinity observed was 32.7 ppt, and the maximum was 36.6 ppt (Table 2). The overall average was 34.65 ppt. The average salinity of saltwater around the world is 35 ppt, with a range of 34 to 36 ppt.

Conductivity ranged between 50,000 and 55,200 μS/m (Table 2), with an average value of 52,873.33 μS/m. The higher conductivity is due to the high amount of dissolved solid ions present.

Nitrate, nitrite and ammonia are important parameters for measuring pollution. Table 3 shows the highest nitrate value observed was 4.9 mg/l, and the lowest was 1.8 mg/l. The average nitrate value was 3.12 mg/l. The WHO recommended value for nitrate is 50 mg/l for drinking water, but no specific guideline exists for recreational seawater samples [19]. The water quality index for nitrate was 85.5, classified as good according to the NSF water quality index. Nitrate levels can be influenced by untreated sewerage and domestic waste is a source of nitrates, nitrites and ammonia released into the ocean, stimulating growth in hydrophytes and phytoplankton, leading to eutrophication.

Nitrite levels ranged from 0.002 mg/l to 0.027 mg/l (Table 3), with an average of 0.01 mg/l. WHO recommends a maximum nitrite value of 3 mg/l for drinking water. The values found in the beach were within standard limits [19].

Ammonia levels ranged from 0 to 0.29 mg/l, with an average of 0.07 mg/l (Table 3). WHO recommends 1.5 mg/l for drinking water, which can be used as a reference for recreational seawater samples [19]. All samples were below this recommended value and this indicates there is no recent pollution from sewerage sources.

3.3 National Sanitation Foundation (NSF) Water Quality Index

Table 4. Guidelines and Recommended Values for Recreational Water

Parameter	WHO Guidelines	USEPA Guidelines	California Guidelines
E-Coli (cfu/100 ml)	-	Geometric Mean ≤ 126	-
Total Coliform (cfu/100 ml)	-	-	Single Sample ≤ 10,000
Fecal Coliform (cfu/100 ml)	-	-	Average ≤ 200, Single ≤ 400
pH	6.5 - 9.5	6.5 - 9.5	5 - 9
Turbidity (NTU)	≤ 5	≤ 5	≤ 5
Nitrate (mg/L)	50 (for drinking water)	-	-
Nitrite (mg/L)	3 (for drinking water)	-	-
Ammonia (mg/L)	1.5 (for drinking water)	-	-

Table 5. Water Quality Index (WQI) for Rasfannu

Parameter	**Value**	**Classification**
WQI	71	Good

Table 5 presents the water quality index (WQI) for Rasfannu. The overall WQI value was 71, falling in the range of good quality according to NSF grading (Table 4). This indicates that the water quality is suitable for recreational use, though some pollutants may be present at low to moderate levels. A WQI score of this range suggests that while the water is generally safe, there is a need for ongoing monitoring to prevent any potential degradation in quality.

In comparison, studies from Sri Lanka reveal a more concerning scenario. For example, the water quality index of Beira Lake shows significantly higher levels of pollution, with surface and deep water WQI values of 233.635 and 312.256, respectively, classifying it as severely polluted and unfit for any usage, including drinking and irrigation [21]. This highlights that while Rasfannu enjoys relatively good water quality, areas in Sri Lanka face more serious environmental challenges, underscoring the importance of proactive measures to maintain water quality in Rasfannu.

Table 6. Meteorological data of Male' area by National meteorological center of Maldives

Date	Average Wing (mph)	Rainfall (mm)	Tide	
			Maximum	Minimum
			Time cm	Time cm
21/08/2019	WSW-08	0.4	03:55 - 60.05	09:44 - 12.9
			15:44 - 67.1	22:10 - 0.0
28/08/2019	WSW-09	73.2	12:09 73.1	04:59 -0.9
			23:37 - 52.0	18:23-21.8
04/09/2019	SSE-07	0	03:58-70.7	09:43 - 13.2
			15:40-67.5	22:07--9.4
11/09/2019	WSW-07	0	-	05:24 - 6.1
			12:03 - 64.5	18:28 12.5

4. CONCLUSION

This study provides a preliminary assessment of the seawater quality at Rasfannu Beach, identifying wastewater discharge and beach users as primary contamination sources. Although the results indicate that microbial and physicochemical parameters generally meet acceptable recreational standards, there is an increasing concern about potential health impacts due to elevated pollution levels and the continuous recirculation of contaminated water. *E-Coli* concentrations at the beach are notably higher than in surrounding areas, suggesting significant pollution from beach activities. Despite these findings, the water quality index rates the beach as safe for recreational use, but ongoing monitoring and maintenance are essential. The study's limitations, including restricted access to previous research, time constraints, and resource limitations, impacted the breadth of bacteriological and physicochemical analyses. Future research should address these gaps by including additional parameters like temperature and enterococci bacteria. Enhanced wastewater treatment, continuous seasonal water quality monitoring, and ecological assessments of local marine ecosystems are recommended to manage pollution effectively. Regular reviews of sewage discharge practices and comprehensive water quality measurements using NSF parameters will help in developing accurate water quality indices and informing sustainable beach management policies.

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Conflicts of Interests: The authors declare no conflicts of interest related to this study. There are no financial or personal relationships with other people or organizations that could inappropriately influence or bias the content of the manuscript.

Data Availability Statement: The data supporting the findings of this study are available upon request from the corresponding author.

Author Contributions: Saeed Ibrahim conducted the study, including data collection and analysis. Aishath Shaira provided supervision and guidance throughout the study. Fathika Adnan was responsible for editing, formatting, and finalizing the manuscript. All authors reviewed and approved the final version of the manuscript.

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