

End-phase Rehabilitation Assessment of Boracay Island Using Microbial Parameters as Indicator of Water Quality

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Abstract. The tourism-dependent Boracay island continued to accommodate tourists reaching a peak of >2 million in 2017 after nearly breaching through the island's ecological threshold in 2012. Anthropogenic pressures resulting in poor water quality and disturbance of wetlands forced the authorities to close the island and undergo rehabilitation from April 2018 to December 2019. Inland and offshore water quality were assessed during the final phase of rehabilitation, although the sewerage system at this time was not yet completed. Microbial parameters from water samples collected offshore, nearshore, and inland were analyzed for total coliform (TC), *Escherichia coli* and *Enterococcus spp.* using the IDEXXTM Colilert-18TM and EnterolertTM systems. The end-of-pipe drainage at the Dead Forest Drainage (DFD) yielded the highest concentration in microbial parameters recorded at >100,000 MPN/100 mL. Microbial loads were higher in the lagoons, wetlands, and the well used for drinking. In most inland sites, the permissible microbial concentrations were exceeded based on the Philippines' Department of Environment and Natural Resources Administrative Order 2021-19. Despite the distance from the shore, TC, *E. coli* and *Enterococcus spp.* were detected even 3 km offshore with values ranging from 20 to 56,775 MPN/100mL, 20 to 11,199 MPN/100mL and 10 to 892 MPN/100mL respectively.

Keywords: coliforms, wastewater, water quality, carrying capacity, anthropogenic disturbance

1. Introduction

Known for its paradise-like beaches, vibrant nightlife and breathtaking sunsets, Boracay Island has attracted millions of tourists every year since 2012. With this rate of occupation, implementation of sustainable development is a challenge and environmental violations prevailed resulting in encroachment of wetlands and water pollution. Exceeding the island's capacity in terms of population, infrastructure and wastes generated, environmental degradation arises forcing the authorities to temporarily close the island in April 2018 to give way for a 3-phase rehabilitation — targeting to complete major road networks in the 1st phase (October 2018),

public works in 2nd phase (April 2019) and sewerage systems in 3rd phase (December 2019).

As a tourism hotspot where various recreational water contact activities were common, it is essential to monitor the quality of inland, nearshore and offshore water particularly its bacteriological characteristics. During the final phase of Boracay rehabilitation in December 2019, this study assessed the water quality by enumerating the total coliform (TC), *Escherichia coli* and *Enterococcus spp.* counts in water samples collected from inland lagoons, wetlands, and groundwater, nearshore and few kilometers offshore to determine the extent of concentrations. Total coliforms along with fecal coliforms, are used as indicator organisms for the contamination of water by fecal matter both in Philippine fresh and marine waters (DAO 2016-08).

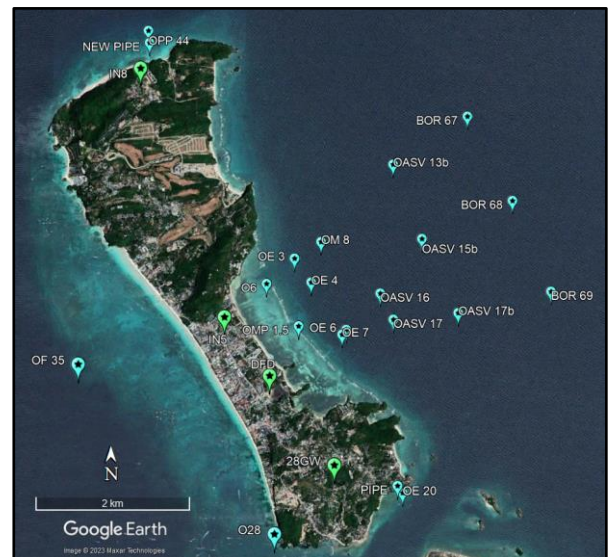


Figure 1. Inland (green) and marine (blue) sites covered during December 2019 water sampling for microbiological analysis using IDEXXTM Colilert-18TM and EnterolertTM.

1. Methods

2.1. Study Site

The 10.32 km² world-famous island of Boracay is located 315 km South of Manila. The island originally has 12 wetlands but only 9 were found and recovered. It has a carrying-capacity of 54,945 people at a time which includes 19,215 tourists and 35,730 residents. Last year 2022, the island welcomed a total of 1,759,592 tourists where 172,852 was recorded in December.

Initially, specific sampling points were determined based on the established inland sampling sites of Mines and Geo-sciences Bureau (MGB) then expanded offshore based on field observations where seepage was present and through tracing pipes on satellite images.

2.2. Sampling Method

Sterilized metal sampling cup was used to collect surface water samples from inland and marine sites in Boracay Island, Malay, Aklan. To avoid cross-contamination, duplicate samples were then stored in a clean re-sealable plastic bag and transported in a cooler with ice. For quality control, trip blanks were prepared, transported, and analyzed along with the samples.

2.3. Laboratory Analysis

Within 24 hours from sampling, room temperature samples were analyzed using IDEXX™ Colilert-18™ for total coliforms and *Escherichia coli* and Enterolert™ system for *Enterococcus spp.*

The IDEXX Colilert-18® and Enterolert® system employs a Defined Substrate Technology (DST) wherein the culture media, indicator, and inhibitors are mixed in one reagent system to be reconstituted once the sample is added thereby eliminating the need for media preparation. About 100 mL of sample or a suitable sample dilution (ten-fold as in the case of seawater samples) is inoculated, mixed with reagent then transferred to a sterile QuantiTray™ 2000. The samples are then incubated at 41 ± 0.5°C for 24 ± 2 hours for Enterococci and 35 ± 0.5 °C from 18 to not more than 22 hours for total coliforms and *E. coli*.

2. Results and Discussion

Inland sites showed generally higher counts of total coliform compared to the marine sites. Highest enumeration recorded inland is at an end-of-pipe drainage in the Dead Forest lagoon (DFD) soaring up to >241,960 MPN/ 100 mL. Freshwater sample from a deep well (28GW) was also found to be contaminated with total coliform counts of 29,435 MPN/ 100mL. On the other hand, a newly installed pipe at the North part of the island showed the highest concentration of 56,775 MPN/ 100 mL total coliforms in marine water.

Based on the DENR Administrative Order (DAO 2016-08 and DAO 2021-19) and Environmental Management Bureau (2014), effluents draining to the waters around Boracay Island should have a maximum allowable limit of 1,000 MPN/100mL (Class SB) for total coliform. This suggests that the total coliform count of 4 inland sites (IN8, IN5, DFD, 28GW) and 7 offshore sites (OASV

13b, BOR 67, BOR 68, OASV 15b, OASV 16, OE3, NEW PIPE) exceeded the standard limit during the time of sample collection.

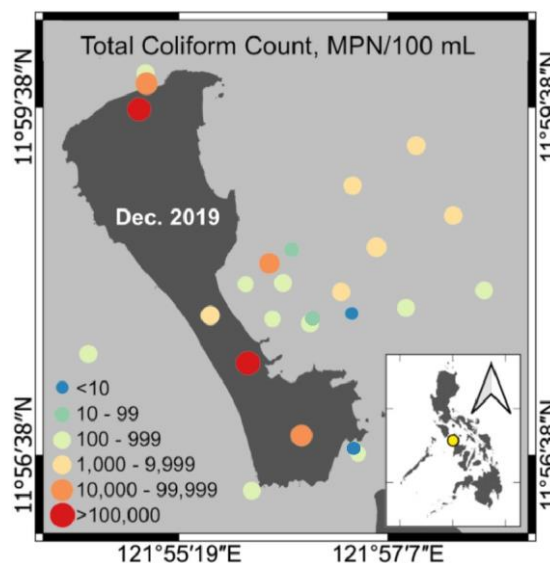


Figure 2. Density plot showing elevated levels of Total Coliforms inland.

Similarly, *Escherichia coli* counts were higher inland versus marine sites with the most number of >241,960 MPN/ 100 mL recorded at DFD followed by a wetland with stagnant water surrounded by residential houses in Barangay Yapak (IN8) 4480 MPN/ 100 mL. In marine sites, the New Pipe site yielded the highest count of 11,199 MPN/ 100 mL.

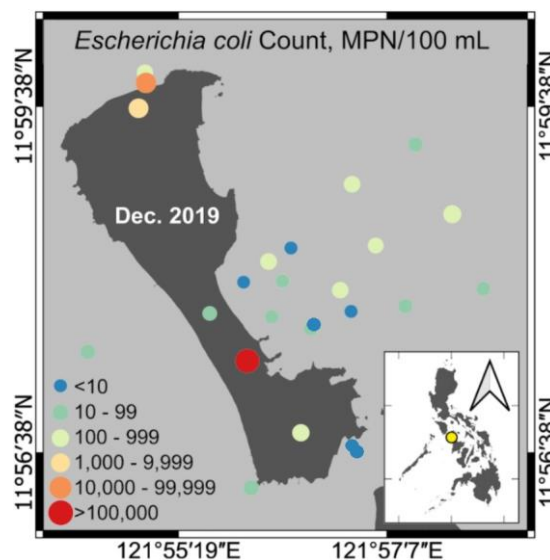


Figure 3. Density plot showing elevated levels of *Escherichia coli* inland.

As per the same DENR administrative order previously mentioned, only 100 MPN/ 100 mL is the maximum allowable limit for fecal coliform suggesting 3 inland sites (IN8, DFD, 28GW) and 7 offshore sites (OASV 13b, BOR 68, OASV 15b, OASV 16, OE 3, OPP 44, NEW PIPE) exceeded the standard threshold. *E. coli* does not survive long enough in marine waters, hence its detection indicates the supply of untreated wastewaters.

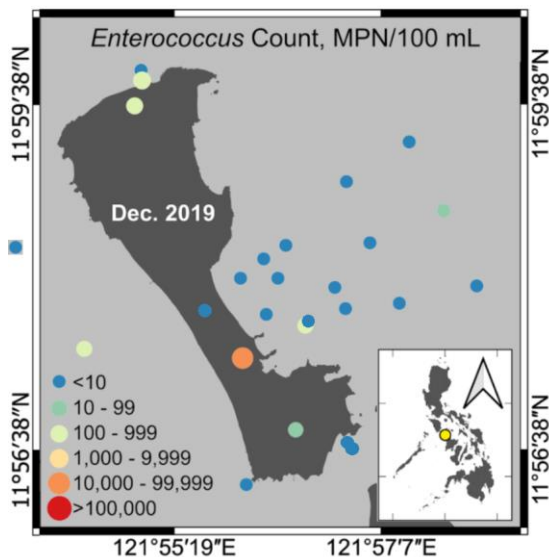


Figure 4. Density plot showing elevated levels of *Enterococcus spp. inland*.

High counts of *Enterococcus spp.* were observed in all inland sites highest in DFD (23,459 MPN/ 100 mL). The ASEAN Marine Water Quality Criteria allows up to a maximum of 35 MPN/100mL *Enterococci* for human health protection, which is applicable to offshore waters in consideration to the health of beach-goers, recreational divers, etc.

3. Conclusion

Boracay continues to be a significant tourist destination in the Philippines. With increasing flux of tourists, contamination of inland and offshore bodies of water has become evident. In sites where human disturbance is concentrated, microbial counts exceed standard thresholds. Highest microbial counts were recorded in DFD where a pipe is directly discharging wastewater into the lagoon. At a distance of at least 3km from the shore, microbial detection was still observed suggestive of extensive fecal contamination.

4. Recommendation

As a world-renowned tourist destination, regular monitoring of water quality is recommended to ensure that the waters are suitable for recreational activities. Identifying and coordinating with the remaining households and commercial establishments not yet connected to sewer systems is critical to control and treat all wastewater. Proper treatment before releasing the wastewater to the sea is essential. For sewer lines presently connected, a thorough review of the system would be beneficial to assess effectiveness of the island's water treatment capability and capacity. During peak tourist seasons, increased capacity of treatment is recommended.

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