An assessment of faecal and supplemental indicator bacteria-based water quality of Kavaratti island, Lakshadweep archipelago, Arabian Sea, India

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Surface water quality deterioration around the Kavaratti island was studied through the determination of the traditional indicators of faecal pollution, total coliforms (TC), faecal coliforms (FC) and *Faecal streptococci* (FS) along with supplemental indicator bacteria, *Vibrio cholerae* (VC), *Vibrio parahaemolyticus* (VP), *Escherichia coli* (EC) and *Shigella* species (SH). Cluster analyses were performed to differentiate the bacterial loading of different area. Helipad region indicates a separate cluster with the abundance of all bacteria (TC of 740CFU/mL, FC of 290CFU/mL, EC of 120CFU/mL, SH of 160CFU/mL, VC of 650CFU/mL, VP of 190CFU/mL and FS of 120CFU/mL). Significant positive relationship was observed between total nitrogen and indicator bacteria ($R^2 > 0.844$).

[Keywords: Pollution, Bacterial population, Cluster analysis, Coral bleaching, Kavaratti island]

Introduction

Lakshadweep islands (36 islands, 10 inhabited, tiniest Union territory of India) situated off the Kerala coast are made up of coral reefs of Holocene age$^{1,2}$ and lies between 8° and 12° 30’ N latitude and 71° and 74° E longitude. Kavaratti is the administrative centre of the Lakshadweep group of islands, has a land use area of 3.63 sq. km. Coral reef ecosystems world-wide have been subject to unprecedented degradation over the past few decades. Although eutrophication is not directly involved in coral degradation, it could cause secondary adverse affects such as increase in bacterial and viral load, lowering of coral resistance and greater susceptibility to diseases. Alternatively, certain bacteria are coral pathogens, which infect zoanthellae$^3$, the symbiotic dinoflagellates essential for coral growth and reproduction$^4$ and thus attributed to disease outbreaks$^{5,6,7}$ and coral bleaching$^{8,9}$. The decline of coral reefs is fatal, because coral reefs maintain high levels of biodiversity, provide habitats for coastal fishes$^{10}$, may contain potential pharmacological compounds, and protect shorelines from erosion$^{11}$. Information on the microbial load in any given ecosystem is mandatory as it provide clear information on the quality of water as they disclose the immediate or near antecedents with reasonable ease$^{12}$, and with greater reliability.

Pollution of Kavaratti island is mainly of microbial, as the industrial development were comparatively low in this region and the island has little or no suitable sewage treatment for a coral reef area. Most of the resident population of around 10,000 people disposes of their sewage directly into pits in the ground or into surface drainage, which soaks directly through the porous sand and limestone into the sea. Sewage effluents contain a wide range of pathogenic organisms that might pose a health hazard to human population when they make their way to recreational waters$^{13}$. Moreover, pollution by sewage effluents containing human pathogens may result in the prohibition of sale of shellfish causing economic loss$^{14}$.

Apart from the two previous studies$^{15,16}$ which features the chemical characteristics of the waters, no systematic studies have been carried out on the microbial pollution of this coastal island during the last decade. Presence of faecal pollution indicator bacteria (TC, FC and FS) and supplemental indicator bacteria (*Vibrio cholerae, Vibrio parahaemolyticus, Escherichia coli* and *Shigella spp*) used in this study can forecast the possible presence of disease causing organisms$^{17,18}$. It was also reported that few *Vibrio spp* can cause coral diseases$^{8,9}$. Present study consists the pollution status of the Kavaratti island with special reference to the indicator bacteria, together with nutrients (total nitrogen and phosphorus).
Materials and Methods.

**Sampling and analysis**

Three stations (Fig. 1 & Table 1) were selected in Kavaratti island viz. Lagoon, Lighthouse and Helipad and in each station except for Lagoon, 5 sampling points (nearshore, 1 km, 3 km, 5 km and 10 km) were fixed in relation to the horizontal proximity from the shore region. 3 locations were fixed in the lagoon viz. near shore, centre (0.4 km from shore) and reef (0.8 km from shore) for monitoring. Surface water

Fig. 1—Map showing the sampling sites in Kavaratti island
samples were collected during November 2009, using Niskin water sampler and aseptically transferred into sterilized glass bottles and 0.5 L plastic bottles for microbiological analysis and nutrient analysis respectively. Triplicate sampling and analysis were performed for each station.

Standard procedures adopted for all parameters, bacterial as well as total nitrogen (TN) and total phosphorous (TP). TN was determined by heterogeneous reduction method and TP by ascorbic acid method. Seven different enteric bacterial groups were selected for the study which includes total coliforms (TC), faecal coliforms (FC), *Faecal streptococci* (FS), *Escherichia coli* (EC), *Vibrio cholerae* (VC), *Vibrio parahaemolyticus* (VP) and *Shigella spp* (SH). The Readymade media (Himedia) used for the isolation of indicator organisms were MacConkey agar (M081) for total coliforms, Membrane filter coliform agar (M1122) for faecal coliforms, M-enterococcus agar (M081) for *Faecal streptococci*, M7HrFC agar (M635) for *Escherichia coli*, Thiosulphate Citrate Bile Sucrose agar (M189) for *Vibrio cholerae* and *Vibrio parahaemolyticus* and *Shigella spp.* by Xylose Lysine Deoxycholate agar (M031). Spread plate technique was adopted for all the indicator bacteria except *E. coli*. Various aliquots ranging from 0.2 to 1.0 mL were plated in duplicate, in order not to miss the lower limits, and the results were reported in Colony Forming Units (CFU/mL). Isolation of *E. coli* was carried out using the membrane filtration method (MF): this is based on the filtering, under negative pressure, of the water sample through a cellulose acetate membrane with a porosity of 0.45 µm and connecting the inox steel filtration unit to an aspiring pump. The counts were made after 48 to 72 hrs.

### Results and Discussion

In the present study, a total of 78 water samples were collected and analyzed for different indicator as well as supplementary indicator bacteria. Data of the bacteriological analysis were graphically represented and are shown in Fig. 2. Generally microbial parameters in the surface water followed a decreasing trend in values from the onshore to offshore, as might be expected. Except VC, none of the indicator bacteria were made their presence towards offshore. TC showed their maximum abundance towards nearshore region and VC towards offshore and which should

<table>
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<tr>
<th>Station name</th>
<th>Latitude</th>
<th>Longitude</th>
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<tbody>
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<td>72°38’21”E</td>
</tr>
<tr>
<td>Lagoon Centre</td>
<td>10°34’21”N</td>
<td>72°38’09”E</td>
</tr>
<tr>
<td>Lagoon Reef</td>
<td>10°34’22”N</td>
<td>71°37’57”E</td>
</tr>
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<td>Lighthouse Nearshore</td>
<td>10°33’34”N</td>
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</tr>
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<td>72°39’25”E</td>
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<td>Lighthouse 3 km</td>
<td>10°33’34”N</td>
<td>72°40’32”E</td>
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</tr>
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<td>Helipad 1 km</td>
<td>10°32’29”N</td>
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<td>72°40’05”E</td>
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<tr>
<td>Helipad 10 km</td>
<td>10°32’29”N</td>
<td>72°42’50”E</td>
</tr>
</tbody>
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Table 1—Geographical coordinates of the sampling sites

Fig. 2—Distribution status of faecal and supplemental indicator bacteria (TC- Total coliforms, FS- *Faecal streptococci*, FC- *Faecal coliforms*, EC- *Escherichia coli*, SH- *Shigella spp*, VC- *Vibrio cholerae* and VP- *Vibrio parahaemolyticus*) in Kavaratti island
be obvious in their mean values. The mean values reported for TC and VP were respectively of 93CFU/mL and 124CFU/mL.

Cluster analysis was applied to find out the similarity groups between the sampling points, grouping all the 13 sampling points into three statistically meaningful clusters (Fig. 3). The highest values for all indicator bacteria were found at Helipad nearshore (TC of 740CFU/mL, FC of 290CFU/mL, EC of 120CFU/mL, SH of 160CFU/mL, VC of 650CFU/mL, VP of 190CFU/mL and FS of 120CFU/mL) and is found to be highly polluted, forming the first cluster, which is explained by the fact that inputs of organic substances caused an increase in the growing rates and density of the heterotrophic bacterial community. TN and TP (Fig. 4) also reported their mean high concentration in Helipad near shore region, respectively of 39.54 µmol/l and 2.87 µmol/l. Increase in total phosphorous content is evident from the presence of seagrass. Large numbers of coral colonies, particularly Acropora was also observed to be bleached indicating impact of certain stress in the area. FC/FS ratio also suggests that the pollution in helipad may be principally of human faecal sources rather than animals as the ratio produced was excess of 2. In general, owing to large outfalls of sewage and dumping wastes supports high microbial activity, and abundance of both faecal as well as supplementary indicator bacteria in Helipad transect.

Cluster 2 includes Lagoon nearshore and Helipad 3 km and suggested to be moderately polluted sites. Though the area observed to have lower nutrient concentration, the microbial population showed a moderately high count. It was stated that when substrates become depleted, the large microbial cells divided repeated to produce a number of small cells that have very low metabolic rate. Rest of the sampling points from Helipad, Lagoon and Light house together form the cluster 3 that these possess totally low pollution. The area also observed with live corals. Lower incidence of indicator bacterial population in Lagoon reef may be explained by the removal of bacterial biomass by benthic filter feeding organisms associated with reefs. Nutrient concentration also found to be very low. It was also reported that Lakshadweep waters have been generally of oligotrophic in nature. However, areas that are oligotrophic at certain times can be eutrophic at other times. Reported low nutrient concentration may be due to increase uptake by phytoplankton or less inflow from terrestrial source. The low nutrient concentrations in the Lagoon could be attributed to their utilization by macrophytes, particularly seagrasses and seaweeds, and low retention by loose and unstable sediments.

Regression analysis was performed to analyze the relationship between indicator bacteria with total nitrogen and total phosphorous. All indicator bacteria showed significant positive correlation (R² > 0.844) with total nitrogen (Fig. 5A &B), while no significant correlation were observed with total phosphorous, indicating total nitrogen is the major factor influencing the indicator bacterial population. Higher nutrient concentration and also observed coral bleaching in helipad suggests that higher nutrient concentration may favour the proliferation of indicator bacteria, more the incidence of indicator bacteria the more the chance for the presence of pathogenic
bacteria causing the water quality deterioration. Alternatively few were coral pathogens, cause coral diseases and coral bleaching. It was already reported that the large-scale natural death and the bleaching phenomenon of the corals all over the tropics have been related to global warming causing a rise in seawater temperature by 1-2°C during the summer. On the other hand, associations found with *Vibrio* spp to temperature were also reported. We also observed a similar phenomenon in our hotspot monitoring studies in Kavaratti island during 2005-09 (Fig. 6), suggests that higher temperature and nutrient condition may favour the growth of *Vibrio* spp; unfortunately few may be coral pathogens causing coral bleaching. *Vibrio* spp were also isolated from coral mucus at a relative higher abundance. Coral mucus also plays an important part in coral disease which has been responsible for significant coral mortality. Coral mucus may function both as a protective physicochemical barrier and as a growth medium for bacteria, including potential pathogens. Even the most fundamental measure, the rate of mucus production, is extremely difficult to assess and is poorly defined in the literature. We assume that mucus production may be comparatively high during stressful condition. It was suggested that the organic content of coral mucus collected during stressful condition was much higher (76 to 82% ash free dry weight, AFDW) than mucus collected *in situ* (9 to 60% AFDW). In general the stressful condition created by the nutrient loading and increased mucous production and also the increased temperature condition may favor the growth potential of *Vibrio* spp and indicator bacteria with coral pathogen cause coral bleaching. Simultaneous presence of increases indicator and supplementary indicator bacteria especially in helipad suggests that higher incidence of indicator bacteria can forecast coral bleaching.

**Conclusion**

Study reveal that the coastal water of Kavaratti island receives hefty quantity of sewages which enhance the microbial load especially at near shore water. Helipad region found to be the most polluted site characterized by high nutrient concentration and abundance of indicator bacteria. The occurrence of *Vibrio cholerae* and *parahaemolyticus*, *E. coli*, *Shigella* spp. and *Faecal streptococci* in marine ecosystem is alarming, even though their count in low, to the people residing along the coast and their count exceeds form the legal limit. Disposal of sewages further may impact the potential socio-economic benefits of recreational and tourism based activities due to the permanent loss of water transparency and also the attractiveness of living reefs. Development of a new waste treatment strategy for proper treatment of sewages and sanitary requirements is an essential component for all coral islands which would reduce the pollution load, until and otherwise raw sewage may soaks directly through the porous sand and limestone into the sea making high risk for living corals and human health.
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References


