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COASTAL WATER POLLUTION: A CASE STUDY OF FOUR COASTAL TOWNS IN ONDO STATE, NIGERIA

OLAWUSI-PETERS, O.O.,[1] IGEJONGBO, F.T.,[1] ADEGUNLOYE, D.V.[2] AND *IGBASAN, V.T.[1]
[1]Department of Fisheries and Aquaculture Technology, Federal University of Technology, Akure, Nigeria
[2]Department of Microbiology, Federal University of Technology, Akure, Nigeria
*Corresponding author: vikidemehin@gmail.com

Abstract
Globally, coastal areas are under stress due to increasing human population, industrial activities and indiscriminate discharge of untreated wastes. Some of these wastes are toxic and persist and could consequently compromise the integrity of the aquatic ecosystem. However, this study was carried out to evaluate the effects of water pollution in four coastal towns located in Ilaje Local Government, Ondo State, Nigeria. The study areas are Obi, Idi-Egbin, Okesiri and Araromi waters with three sampling points per location. Water samples were collected in triplicate for physical, chemical and microbial analysis. At $p<0.05$, the total mean concentration of pH, Temperature, Dissolved Oxygen, Salinity, Turbidity, Colour, Total Dissolved Solid, Conductivity, Nitrate, Nitrite, Phosphate, Sulphate, Chloride, Total Hardness, Calcium, Magnesium and Chemical Oxygen Demand showed a significant variation at Obi, Idi-Egbin, Okesiri and Araromi but no significant variation was recorded in Biological Oxygen Demand, Ammonia, Total Suspended Solid, Bicarbonate and Carbonate among the sampling locations. The mean of total microbial load in water samples were reported as; Obi ($50.72 \pm 21.83 \times 10^3$ cfu/g), Idi-Egbin ($61.72 \pm 29.02 \times 10^3$ cfu/g), Okesiri ($62.68 \pm 28.90 \times 10^3$ cfu/g) and Araromi ($64.01 \pm 17.87 \times 10^3$ cfu/g). Ten bacteria species were identified, as well as their occurrences. They comprise both Gram positive and Gram-negative bacteria. The present study therefore reveals the dangers associated with the health status of the Coastal water of Ondo State which may further deteriorate and become detrimental to the health of inhabitants of these coastal communities.

Key Words: *Health status, Microbial analysis, Toxic, Untreated wastes, Aquatic ecosystem, Discharge*

Introduction

Coastal areas around the world have been contaminated by various types of human wastes with high concentrations of nutrients, organic pollutants, trace metals and radionuclides (Olawusi-Peters *et al.*, 2017). Some of these wastes are highly toxic and persistent, allowing them to bioaccumulate (Ajibare, 2014). The environmental status of coastal areas worldwide is under pressure from industry, trade and population growth, and the transboundary transport of these pollutants is of great concern (Fang *et al*., 2005).

In developing countries, infrastructures in coastal areas often does not meet the needs of the population and causes environmental degradation through the direct discharge of uncontrolled and untreated waste (Dhage *et al*., 2006). Household solid waste, trash, garbage and sewage are generated daily by the inhabitants of all societies. To dispose of these substances, humans unintentionally pollute the environment (Adeniji *et al*., 2007; Adebowale *et al*., 2008). Good quality source water depends on the physical, chemical and biological parameters of the water (Lawson, 2011: Rafiullah *et al*., 2012) and any sources of contaminants, and monitoring these parameters is important for evaluation (Lawson, 2011).

The coastal area of Ondo State, Nigeria, is one of the coastal areas that require regulation and monitoring. Global dumping of human waste occurs in coastal areas due to the belief that the ocean has a greater capacity to assimilate waste (Fang *et al.*, 2006). Unfortunately, estuaries or coastal waters cannot absorb pollutants indefinitely. As a result, coastal environmental monitoring and control is largely justified in developed countries, but largely ignored in emerging and developing countries. Hence, global environmental issues now require strict regulation and proper management of all pollutants emitted from coastal areas, especially in developing countries. Therefore, this study aims to assess the pollution and its resultant effects on Ilaje coastal waters, Ondo State.

Materials and Methods

Study Area

The study areas (Obi, Idi-Egbin, Okesiri and Araromi) are located in Ilaje Local Government Area, the coastal region of Ondo State (Lat. 5° 50′ N – 6° 09′ N and Long. 4° 45′ E – 5° 05′ E), which has over 50 settlements scattered around the river tributaries that empty into the coast (Figure 1). The area also falls within the oil prospecting states in Nigeria called Niger Delta region. It consists of rivers and streams which traverse different settlements and discharge into the coastal ocean (Bright of Benin, Atlantic Ocean) (Ajibare, 2014). The area is blessed with many Rivers, lagoons, tributaries lakes and a very long coastline, of about 180km extending from the boundaries of Delta State to the boundaries of Ogun State with Ondo State. Thereby making Ondo State as the coastal state with the longest coastline (Olusola and Festus, 2015).

In the study area, the waters are linked together (from Obi to Araromi), with a flow across each other. The inhabitants are predominantly fishermen, while some others engage in water transportation and trading of fishery products. Most of the houses and processing huts are built on water or swamps. Hence, all forms of activities such as bathing, sewage discharge, waste water disposal, refuse dump, etc., are carried out in the water. The area is affected by the dry and rainy seasons.

During the dry season (December – April), water levels fall and during the rainy season, the water level rises gradually reaching a peak of up to 9m or more (around August to September) causing floods (Ajibare, 2014). Okesiri and Idi-Egbin constitute some of the Estuaries at the coastline of Ilaje. The high tides carry saline marine waters into the rivers, creeks, canals, lakes and undulating lowlands via the Estuaries, while low tides reverse the flows. These scenario influences physico-chemical parameters and in particular, salinity of the areas. From preliminary site study, all municipal and domestic wastes in the study areas are directly discharged into the coast, untreated. There is no existence of any waste treatment plant in the area. Heavy transportation of goods and people in the area and fishing activities are by motorboats. The fueling stations in the area are notable sources of pollution.

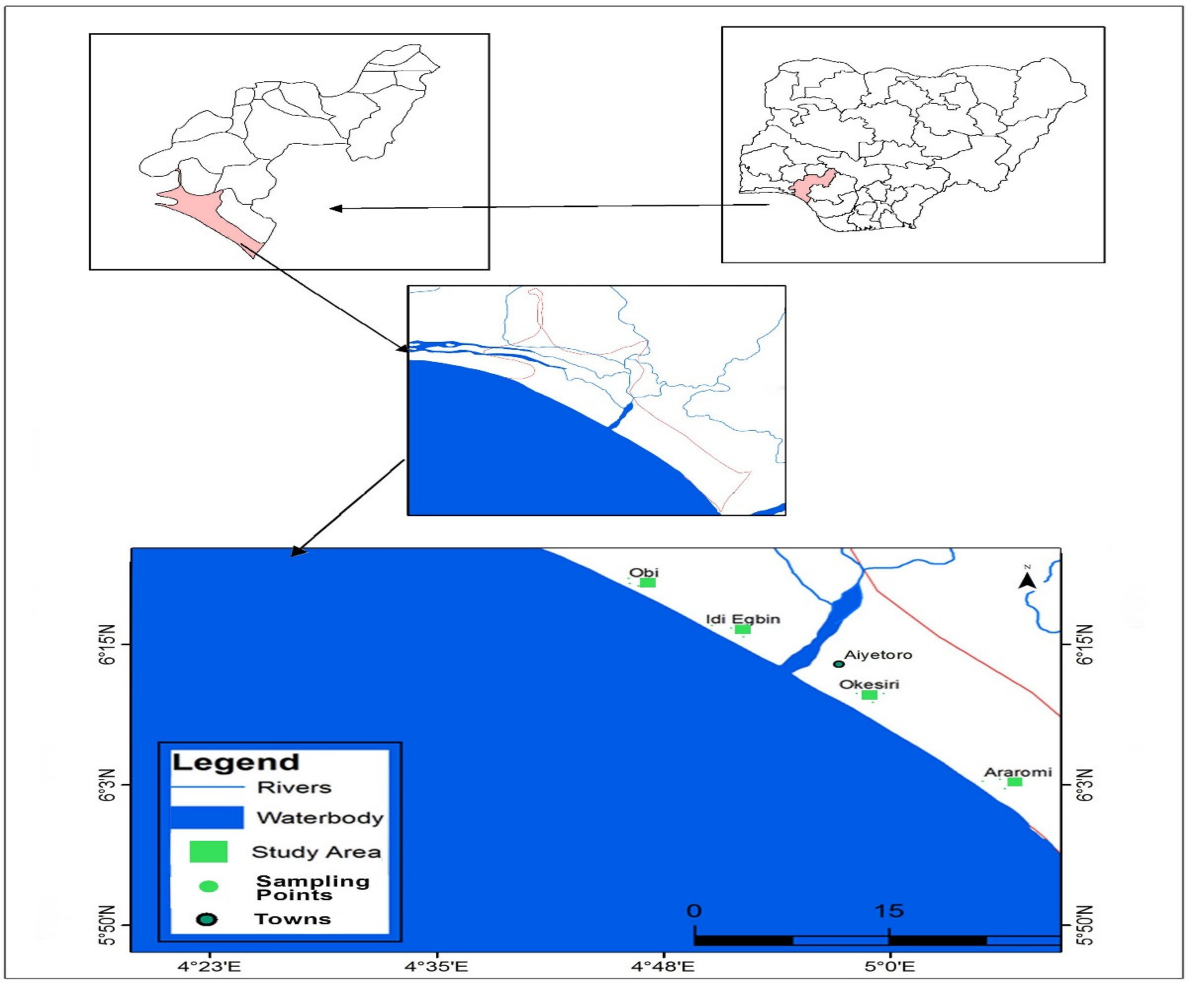

Fig. 1: Map of Ilaje community showing the sampling sites

Collection of Water Samples

Three (3) sampling points in each area were selected for evaluation. The choice of sampling points was based on the observed anthropogenic activities in the area that have the potential of impacting the zone negatively, such as public toilet locations, landing sites, washing and bathing spots, fish and shellfish carcasses, dump sites, etc. Sampling was done through collection of water from 10- 16cm depth by discrete grab method in a speedboat with engine switched off. Samples were collected in plastic water samplers. Sample bottles were rinsed with the sample water before taking the samples.

Determination of Physico-chemical Parameters of Water

The physicochemical parameters such as odour, colour, pH, conductivity, salinity, turbidity, temperature and dissolved oxygen was determined insitu by a multi parameter water quality test meter. Nitrate, nitrite, orto-phosphate, sulfate, chloride, total hardness, calcium and magnesium were analyzed in the laboratory according to the APHA (1995) standard methods for the examination of water and wastewater.

Determination of Microbial Load in Water Samples

Sample Preparation/Isolation of Samples

Six fold serial dilution of the water samples were prepared. An aliquot of 0.1 ml of 103 diluent was then aseptically transferred into Petri dish and 14ml of molten NA, EMB, SSA, MAC, and MSA was introduced. The plates was gently swirled and allowed to solidify at room temperature. The plates were prepared in duplicates and incubated at 37^{o}C for 24 hours. Discrete colonies were observed, counted, recorded as colony forming unit per gram (cfu/g) the samples were plated using pour plating method (Maturin and Peeler, 2001). Distinct colonies were picked and streaked severally on appropriate agar media until pure cultures were obtained.

Identification of Bacteria Isolates by Cultural and Biochemical Tests

The identities of all the bacterial isolates were determined using standard methods as reported by Cheesbrough (2006). The bacterial isolates were tentatively identified by means of morphological characteristics, cellular and biochemical tests. Morphological characteristics were observed for each bacterial colony after 24 hours of growth. The appearance of the colony of each isolate on the media was studied and the characteristics observed include; cell shape, elevation, edge, optical characteristics, consistency colony, surface and pigmentation. Biochemical tests carried out include; catalase, citrate, indole, methyl red, oxidase, coagulase, motility, spore staining and sugar fermentation.

Results

Physicochemical Parameters of Water

The results of water analyses of Ilaje water at different locations were presented in Table 1. The total mean concentration of pH, Temperature, Dissolved Oxygen, Salinity, Turbidity, Colour, Total Dissolved Solid, Conductivity, Nitrate, Nitrite, Phosphate, Sulphate, Chloride, Total Hardness, Calcium, Magnesium and Chemical Oxygen Demand showed a significant variation at Obi, Idi-Egbin, Okesiri and Araromi but no significant variation was recorded in Biological Oxygen Demand, Ammonia, Total Suspended Solid, Bicarbonate and Carbonate among the sampling locations.

Table 1: Physico-Chemical Parameters of the Studied Area

Parameters	Obi	Idi-Egbin	Okesiri	Araromi
pH	7.59±0.19^{a}	7.71±0.28^{a}	7.72±0.20^{a}	8.10±0.28^{b}
Temperature	28.47±0.60^{a}	27.97±1.01^{b}	28.10±0.74^{ab}	28.43±0.35^{ab}
DO	6.98±0.24^{a}	6.35±0.76^{b}	6.97±0.50^{a}	6.92±0.50^{a}
Salinity	1739.54±327.38^{a}	2121.35±460.14^{b}	1898.48±449.84^{a}	2465.32±586.28^{b}
Turbidity	12.45±1.59^{a}	10.27±2.28^{b}	11.49±2.11^{a}	11.42±2.63^{a}
Colour	5.83±6.35^{ab}	6.33±2.65^{ab}	4.67±3.81^{b}	6.93±2.22^{a}
TDS	1581.91±306.89^{a}	2089.60±439.73^{b}	2379.52±975.09^{bc}	2511.82±903.54^{c}
Conductivity	4043.29±919.45^{a}	5489.57±1641.61^{b}	6129.61±2354.01^{bc}	6795.96±2731.03^{c}
Nitrate	104.27±37.27^{a}	118.36±64.82^{a}	104.74±47.36^{a}	108.85±49.24^{a}
Nitrite	198.23±37.91^{a}	127.75±20.47^{b}	199.66±35.33^{a}	418.67±9.91^{c}
Phosphate	23.80±16.52^{a}	22.03±15.42^{a}	48.54±21.15^{b}	31.45±5.66^{c}
Sulphate	9.27±5.111^{a}	13.53±9.98^{ab}	15.11±11.47^{b}	12.82±8.14^{ab}
Chloride	1211.31±279.28^{a}	1451.96±334.63^{b}	1724.56±368.46^{c}	2043.80±464.50^{d}
Hardness	5777.89±543.21^{a}	6704.23±684.62^{b}	7396.71±593.59^{c}	8219.70±312.12^{d}
Calcium	158.59±33.25^{a}	186.19±33.25^{b}	180.50±44.70^{b}	192.11±44.07^{b}
Magnesium	26.11±16.40^{a}	31.68±11.94^{ab}	32.60±10.57^{ab}	41.45±36.99^{b}
COD	253.76±77.86^{a}	308.92±137.08^{ab}	341.86±122.99^{bc}	401.25±151.17^{c}
BOD	1.95±0.35^{a}	2.06±0.24^{a}	2.08±0.29^{a}	2.07±0.32^{a}
Ammonia	8.59±3.43^{a}	8.11±3.89^{a}	8.83±2.89^{a}	8.77±3.37^{a}
TSS	10.36±1.56^{a}	9.68±0.86^{a}	9.74±1.55^{a}	9.88±1.62^{a}
Bicarbonate	1.01±0.70^{a}	1.00±0.69^{a}	1.03±0.76^{a}	1.00±0.82^{a}
Carbonate	1.10±0.99^{a}	0.98±0.92^{a}	1.19±1.10^{a}	1.23±1.08^{a}

*Mean with the same superscript along the rows are not significantly different at p>0.05
TDS = Total Dissolved Solid, COD = Chemical Oxygen Demand, BOD = Biological Oxygen Demand, TSS = Total Suspended Solid

Microbial Load in Water

The total bacterial loads obtained from water samples were counted and the mean count from water samples from four different locations within Ilaje coastal waters are shown in Table 2. The highest bacterial count of (76.00±16.69) x10^3 cfu/g was recorded in Idi-Egbin (location A) while in Obi (location A) had the least bacterial count of (48.83±20.19) x10^3 cfu/g. This could be as a result of high contamination from the jetty areas. No significant differences were observed in the bacterial count in all the sampling locations.

Table 2: Total Microbial load (x10^3 cfu/g) in water column

	A	B	C	Total mean concentration
Obi	48.83±20.19^{a}	54.17±20.23^{a}	49.17±25.07^{a}	50.72±21.83^{a}
Idi-Egbin	76.00±16.69^{a}	48.79±37.87^{a}	60.37±32.51^{a}	61.72±29.02^{a}
Okesiri	62.35±34.96^{a}	58.03±30.43^{a}	67.67±21.30^{a}	62.68±28.90^{a}
Araromi	71.83±10.57^{a}	70.67±16.99^{a}	49.52±26.05^{a}	64.01±17.87^{a}

*Mean with the same superscript along the rows are not significantly different at p>0.05
NB: *Total mean concentration with the same superscript along the column is not significantly different at p>0.05
A = Jetty areas, B = Fueling station, C = Landing site and wastes discharge areas

Occurrence of Microbial Isolates in Water Samples

Ten bacteria species were identified and their occurrences were presented in Table 3. This comprises both Gram positive and Gram-negative bacteria. The result established that *Aeromonas hydrophila* and *Micrococcus spp* were the most predominant bacteria.

Table 3: Occurrence of Microbial Isolates in Water Samples

Bacterial Isolates	Obi	Idi-Egbin	Okesiri	Araromi
Staphylococcus aureus	+	+	+	-
Klebsiella spp	-	+	-	-
E. coli	-	+	+	-
Salmonella spp	-	+	-	+
Aeromonas hydrophila	+	+	+	+
Micrococcus spp	+	+	+	+
Bacillus cereus	-	+	+	-
Enterobacter aerogenes	-	+	+	_
Pseudomonas aeruginosa	-	+	+	+
Staph. epidermidis	+	+	-	+

Keys: + = Positive = Negative

Source of Pollution Identification Using Principal Component Analysis (PCA)

The results obtained from the KMO and Bartlett's sphericity test (Table 4) were 0.591 and 2079.549 (df = 253, p<0.001), respectively, implying that PCA would be effective in reducing dimensionality. The first eight factors with eigenvalue greater than 1 were extracted and explained 72.48% of the total variance.

Table 5 shows the principal components (PCs), their eigenvalues and the percentage of variance of each PC. Table 6 shows the first-eight principal components account for 72.48% of the variation in water quality. PC1 explains 17.45% of the variance and consist of strong loading of Chloride and Calcium. This represent the contribution of dissolved ions through industrial and municipal outlets. PC2 explains 15.00% of the variance. They are mainly contributed by Microbial load, Bicarbonate and Carbonate. This could represents soil leaching processes and domestic waste discharged to the coastal area. PC3 explains 9.50% of the variance and consist of strong loading of salinity. These PCs represents contribution of dissolved ions in the water quality. PC4 explains 8.33% of the variance and consist of strong loading of Temperature and Dissolved oxygen. This PC can be interpreted as representing the domestic wastewater discharge activities. PC 5 explains 7.21% of the variance and consist of strong loading of nitrate and sulphate. These PCs represents contribution of industrial activities and run off from agricultural land to the water quality. PC6 explains 5.56% of the variance and this is mainly participated by Biological Oxygen Demand. This PC can be interpreted as representing the domestic wastewater discharge activities. PC7 explains 4.82% of the variance and consist of strong loading of colour and Chemical Oxygen Demand. This PC can be interpreted as representing influences domestic waste discharge and dissolved organic matters. PC8 explains 4.60% of the variance and consist of strong loading of Turbidity. This PC can be interpreted from influences from non- point source of pollution such as run off/erosion of soil particles.

Table 4: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.591
Bartlett's Test of Sphericity	Approx. Chi-Square	2079.549
	Df	253
	Sig.	0.000

Table 5: Total variance explained in Initial Eigenvalues of the physicochemical parameters in water column of sampling Locations

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	4.01	17.45	17.45
2	3.45	15.00	32.45
3	2.19	9.50	41.95
4	1.92	8.33	50.29
5	1.66	7.21	57.50
6	1.28	5.56	63.05
7	1.11	4.82	67.88
8	1.06	4.60	72.48
9	0.95	4.15	76.63
10	0.72	3.14	79.77
11	0.70	3.04	82.81
12	0.66	2.87	85.68
13	0.53	2.32	88.00
14	0.48	2.08	90.08
15	0.45	1.95	92.02
16	0.43	1.86	93.88
17	0.38	1.65	95.54
18	0.31	1.35	96.89
19	0.21	0.93	97.81
20	0.18	0.79	98.60
21	0.17	0.72	99.32
22	0.13	0.58	99.90
23	0.02	0.10	100.00

Table 6: Total variance explained in extracted component of the physicochemical parameters in water columns of the sampling locations

Component	Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
PC1	4.01	17.45	17.45
PC2	3.45	15.00	32.45
PC3	2.19	9.50	41.95
PC4	1.92	8.33	50.29
PC5	1.66	7.21	57.50
PC6	1.28	5.56	63.05
PC7	1.11	4.82	67.88
PC8	1.06	4.60	72.48

Discussion

The values recorded for temperature and Dissolved Oxygen were normal and this implies that, despite the influence of domestic wastes on water quality, fish can still grow and survive. At high temperature, the solubility of oxygen decreases. Temperature can affect physical, chemical and biological activities in water. When the water temperature is high, there is an increase in the rate of chemical processes and solubility of oxygen. The fluctuation in water temperature depends on season, geographic location, sampling time and temperature of effluents/wastes entering the water (Ahipathi, 2006). The Biological oxygen demand level recorded was low. This implied that the load of domestic wastes entering this coastal waters is not sufficient to flourish the growth of decomposer and this could be as a result of the large water body. Prandi-Rosa and Farache Filho (2008) and Sadhuram *et al*. (2005) reported that, for a water body to be considered polluted, the Biological Oxygen Demand must be above 10mg/l and in this study, the mean value was 2.08±0.29mg/l and this means, Ilaje coastal water is considerable clean because the value was below 4 or 5 mg/l.

Hardness of water is an important consideration in determining the suitability of water for domestic and industrial uses. Water hardness is a result of concentrations of calcium and magnesium and carbonate, bicarbonate, chloride and sulphate in water. In this study, total hardness range was above the desirable range of 75-150mg/l as recommended by Bhatnagar and Devi (2013). From the results, the value of Calcium was high compared to the standard range. This high values of calcium implies higher impurity of the water. Magnesium was within the range of 29.10mg/l to 121.87mg/l reported by Akhigbe *et al.* (2018) at Trans-Amadi Industrial Layout, Port-Harcourt. This study further showed that, high hardness recorded could be as a result of soil leaching and domestic waste discharged into the coastal area. The mean range of Bicarbonate and Carbonate in were within the mean range 25.6 mg/l to 36 mg/l and 3.6 mg/l to 11 mg/l respectively while Sulphate level was below the mean value of 106.6 mg/l to 417 mg/l as reported by Akhigbe *et al.* (2018). Concentrations of carbonates and bicarbonates in water give pH rating of the water.

The total dissolved solid measures the amount of dissolved substances from anthropogenic sources in the water body. The presence of such solutes alters the physical and chemical properties of water. Elevated levels of total dissolved solid in this study could be attributed to influx from household and industrial wastes. Turbidity was relatively stable across sampling locations and this could be as a result of influence of run off from domestic wastes or soil particles. Abdus-Salam *et al*., (2010) reported that turbidity in natural water seldom exceeds 20,000mg/l and even muddy waters usually have less than 2000mg/l. The turbidity range (10.27±2.28 - 12.45±1.59NTU) was within the range of 2NTU to 47NTU as reported by Asonye *et al*. (2007) for the turbidity of Nigerian water bodies.

Phosphate is rarely found in high concentrations in waters as it is actively taken up by plants. High concentrations of phosphates can indicate the presence of pollution and are largely responsible for eutrophic conditions (WHO, 1993). The anthropogenic additions of phosphorus to the water bodies have a considerable effect on the quality of the water. Such phosphate is derived mainly from domestic sewage and the runoff from agricultural areas. The phosphate value found in this study ranged from 22.03±15.42 to 48.54±21.15mg/l. The values were above the desirable range of 0.01-3mg/l as recommended by Bhatnagar and Devi (2013).

In the study, the occurrence of *E. coli* was low and this could be as result of the high salinity recorded during this study. Physical and chemical qualities of aquatic environment influence the growth of *E. coli* (Nursyirwani and Moestomo, 2002). *E. coli* is not an inhabitant of marine environment. The existence of *E. coli* in marine environment is opportunistic, where they will develop in advantageous environmental condition, and available nutrient for the growth.

Environmental bacteria such as *Pseudomonas* and *Aeromonas*, were also identified during the study. Species of the genus *Aeromonas* are widely isolated from aquatic environments and frequently reported to cause waterborne and seafood infections (gastroenteritis and septicemia) (Chopra and Houston 1999; Joseph *et al.*, 2013; Hamid *et al.,* 2016). *Pseudomonas* spp. are another ubiquitous micro-organism also reported by Maravić *et al.* (2018) and Goh *et al.* (2019) in marine shellfish and recreational waters.

Conclusion

The natural characteristics of the coastal ecosystem are changing due to the rise in the indiscriminate discharge of waste in the coastal water bodies. Different kinds of untreated wastes from agriculture, households as well as other aquatic organisms disposed into water release large amounts of pathogens into water bodies, posing potential health risks for those who consume them. It can be concluded that the study areas are characterized by high rate of pollution from anthropogenic activities fueled by situation of houses and settlements directly on water. This situation is worrisome because it depletes coastal resources, threatens human health and causes economic damage. Sanitation requirements therefore must be established to provide coastal areas with the care and treatment needed to reduce pollution load and protect their livelihoods.

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