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A comparative study of physicochemical and biological water quality parameters of Iligan Bay, Philippines

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Abstract

Changes in the physico-chemical characteristics provide significant information on status and health of aquatic ecosystem particularly marine life. This study was conducted to analyze the physico-chemical and biological water quality parameters of the selected three coastal waters of Iligan Bay, Philippines which has been a major fishing ground for its rich fishery resources. A total of 11 physico-chemical and 3 biological parameters were observed. Principal component analysis showed four major PCs which accounted for 88.3% variance of the original data structure. The first PC explained 38.191% of the total variance and was best represented by nitrate, phosphate and conductivity. The second PC was dominated by Dissolved Oxygen (DO) and Total Dissolved Solids (TDS), accounting for 26.062% of the total variance. The third PC explained 13.787% of the total variance and loaded heavily on transparency and substrate type. The fourth PC accounted for 10.212% of the total variance which is dominated by hetero plate count, total coliform and *E. coli*. Results showed that selected sites in Iligan Bay generally, did not comply with the limits of quality set by the DENR especially for surface water temperature and pH. Moreover, results for bacteriological analysis implied that the three sites examined exhibited relatively poor water quality during the study period. In this respect, poor water quality is attributed to anthropogenic activities in the area.

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Introduction

Coastal water environment has served as the ultimate destination of virtually all terrestrial runoffs and a recipient for various kinds of anthropogenic wastes. Population growth resulting to acceleration of domestic, municipal, industrial, agricultural and recreational activity were the primary causes of these pollution in the marine realm. These activities have, in many cases, severely affects the local biota and the shallow near shore marine environment are particularly subject to frequent and extensive industrial and municipal pollution (Kravchuk, 2006). In a study by Al-Zamel (2008), habitat loss and degradation as well as man-made pollution were to blame for the steep decline in the quality of marine waters. Herewith, there is a need to assess the status and health of water resources. Noteworthy, assessment of water quality can be defined as the analysis of physical, chemical and biological characteristics of water that influence species composition, diversity, stability, production and physiological conditions of indigenous populations of a water body (Boyd, 1982 as cited by Ogidiaka *et al.*,2012). Duran (2006) from University of Pamukkale stated that one of the best approaches of biological monitoring studies for indicating water quality are the combinations of chemical and biological methods constitution.

In addition, bacterial indicators have been utilized worldwide to show if a water body is contaminated by fecal contamination. The occurrence of fecal coliform in aquatic environments signifies water contamination via fecal matter. Some of these indicators, i.e. fecal coliforms, *E. coli* and *Enterococcus* spp., are used to monitor the fecal contamination of seawater bodies worldwide (Feng *et al.*, 2002). Exceeding contents of indicator bacteria in seawater have been related to increased risk of pathogenic microorganism-induced sickness to humans (Donovan *et al.*, 2008). Many researches such as Shuval (2003), Colford *et al.* (2007) and Fleisher *et al.* (2010) have documented an elevated risk of contracting gastrointestinal diseases, skin infections as well as acute respiratory infections after exposure with recreational waters and seawater body with increased concentrations of indicator bacteria. Hence, their presence suggests that a potential health risk exists for individuals utilizing the water (USEPA, 2001).

Moreover, with the growth of human population and industrialization, marine water has received large amounts of pollution from recreation and discharge of polluted effluents. In Iligan City, there have been previous studies on monitoring and assessment of the microbial quality of the stressed coastal zone of Iligan Bay. According to Apuan *et al.* (2014), the seawater of Barangay Dalipuga and Kiwalan have been contaminated by microbiological organisms of fecal origin viz. *Enterobacter, Citrobacter, Kleibsiella, Salmonella* and *E. coli*, and therefore not safe for recreational and fishing activities.

Hence, there is an urgent need to determine and monitor the physico-chemical and biological profile of Iligan Bay since it has been a major fishing ground for its rich fishery resources such as fish, algae and mollusks which is their source of livelihood for many people in the area. Severe alterations of the physico-chemical conditions of the Bay can easily affect the marine life and this ecosystem has become the privileged receptacle of pollution because of the anthropogenic development resulting to waste effluents in many points. A description of such factors will be very relevant towards effective monitoring and manipulation of Iligan Bay to maintain its dynamic equilibrium, which is a very important in maximizing productivity.

This study aims to (1) assess the physico-chemical and biological properties along the shores of Barangay Kiwalan, Sta. Felomina and Saray using the physico-chemical parameters such as surface water temperature, pH, Total Suspended Solids (TSS), Total Dissolved Solids, salinity, conductivity, transparency, Dissolve Oxygen (DO), substrate type, nitrate, phosphate, (2) determine total coliform levels and heterotrophic plate count using Most Probable Number (MPN) Technique for Multiple Tube

Fermentation and to detect and isolate E. coli strains (3) compare the dataobtained with standard values recommended by DENR and (4) determine the relationship between physico-chemical and biological conditions of the surface waters using Principal Component Analysis coupled with Pearson's Correlation.

Materials and methods

Study Area

Iligan Bay is located in Mindanao (Fig. 1), with a latitude of N 80 25' 0 and a longitude of E 1240 4' 60. It has an estimated coastline of 170 km with surface area of about 2,390 km^3. Along its coast are the provinces of Misamis Occidental, Misamis Oriental, Zamboangadel Sur, and Lanao del Norte. It connects with Panguil Bay on the south western part and opens to Bohol Sea in the north.

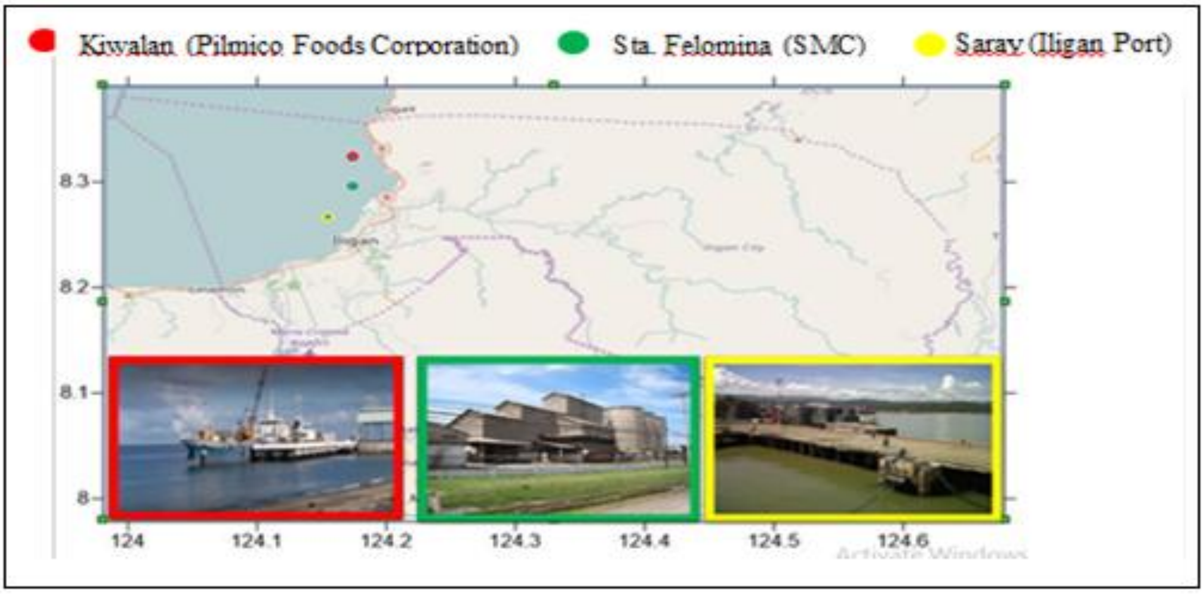

Fig. 1. Map of the area showing the sampling sites along Iligan Bay.

The climatic condition in Iligan Bay is governed by 3 main air currents, namely the prevailing winds (Trade wind) during March to May, the Southwest monsoon (Habagat) in June to October, and the Northeast monsoon (Amihan) in November to February.

Three sampling stations were established near the coastline on the water depth ranging 10-15 meters using the Global Positioning System (GPS).

Station 1 was situated in front of PILMICO FOODS CORPORATION at Kiwalan, Iligan City. It is bounded by Iligan Bay on the north, Municipality of Dalipuga on the east and Barangay Acmac on the west.

It is primarily engaged in the manufacture of wheat flour and related products such as feeds and feed ingredients, yeast, powdered sugar and baking powder.

Station 2 was situated in front of SAN MIGUEL CORPORATION – ILIGAN COCONUT OIL, (formerly ILICOCO)which is located in Barangay Sta. Felomina and is 7.8 kilometers from the city proper. It is bounded by Iligan Bay on the north, Municipality of Acmac on the east and Barangay Hinaplanon on the west. It is one of the two copra solvent extraction plants in the city and was established in 1975.

Station 3 was situated in front of port which is in Barangay Saray and is near the city proper. The port is also located near the wet market.

All three sampling stations were considered highly impacted and disturbed areas. Table 1 shows the coordinates of each sampling stations established within Southern portion of Iligan Bay.

Physico-chemical Water Quality Parameters

Nine cleaned polypropylene bottles for physico-chemical analysis plus another 3 pre-autoclaved and sterilized 250 ml bottles for microbial analysis were prepared in the laboratory and brought to the field. A total of 12 samples were obtained at the study area, 4 samples from each station which later divided into two groups, the first group of bottles was for microbial analysis while the second was for physico-chemical analysis. Surface water (~20 cm deep), was obtained manually and immediately secured in an ice bucket for delivery to the laboratory within 4 hours.

The physical and the chemical parameters of the coastal waters were measured such as; temperature, pH, dissolved oxygen (DO), conductivity, total dissolved solids (TDS), salinity, total suspended solids (TSS), transparency. The determination of these parameters was done once a month from February 2017 to April 2017 with three replicates. The total average was calculated.

Phosphates were determined by colorimetric method. To 2 ml aliquot of the water sample in a 25 ml volumetric flask was added one drop of phenolphthalein indicator followed by 2 ml of ammonium molybdate and then 1 ml of freshly diluted stannous chloride solution. These were made up to 25 ml volume with distilled water and mixed thoroughly. After 5 - 6 minutes and before 20 minutes, the colour intensity (absorbance) was measured at a wavelength of 660 nm in a Spectrophotometer.

Nitrates were determined by modified Kjeldahl method (Bremner and Mulvaney, 1982). 50 ml of water sample and 4 ml of salicylic acid/sulphuric acid were added in the digestion flask and swirled thoroughly to achieve homogenous mixture. 0.5 g of sodium thiosulphate was added and the mixture was heated cautiously until frothing has ceased. 1.1 g of potassium sulphate catalyst mixture was added and heated until the digestion mixture became clear. The mixture was boiled for up to 2 hours. It was ensured the temperature did not exceed 400˚C. The digested mixture was allowed to cool and 20 ml distilled water was added slowly while shaking. 10 ml of boric acid was added, diluted with 20 ml distilled water and the flask was placed under the condenser of the distillation apparatus. 20 ml of sodium hydroxide was added through the funnel of the apparatus. About 50 ml of condensate was distilled and a few drops of Boric acid indicator added. This was titrated with 0.01 mol/L sulphuric acid to a violet end point. The titre values were recorded and used to calculate nitrate content.

Biological Water Quality Parameters

A volume of 100 milliliter (ml) of seawater sample was aseptically collected into a sterile, 250- ml glass bottle. One sample from each site was collected. Samples were kept on ice and were transported immediately to the Iligan Waterworks laboratory. The water samples were processed immediately upon stabilization of the temperature. The Most Probable Number (MPN) Technique for Multiple- Tube Fermentation and Spead Plate method for isolation were used for the analysis.

A set-up of double strength lactose broth (DSLB) tubes and 6 single strength lactose broth (SSLB) tubes were prepared. The bottle of water sample was shaken twenty-five times. The 3 DSLB tubes were mixed with 10 ml of the water sample. The 6 SSLB tubes were equally divided into two sets and were dispensed with 1.0 ml and 0.1 ml of the water respectively. Each tube was labeled according to the amount of water that was to be dispensed into it. The tubes were incubated at room temperature for 24 hours and were examined for at least 10% gas formations which were recorded as positive.

Positive lactose broth cultures were selected from the presumptive test and were spread-plated onto a plate of Levine EMB agar medium that would preferably produce good isolation of colonies. The EMB plates were incubated for 24 hours at room temperature. Positive tests gave isolates with a metallic green sheen. These were presumptively identified as E. coli isolates. Other isolates exhibiting purple, blue-black to dark brown colors of different texture were other member of Enterobacteriaceae.

An agar slant was inoculated by randomly picking an isolate with a metallic green sheen. Wet mount and Gram staining was conducted on the 24-hour old cultures in order to verify further if the isolates were E. coli.

Determination of Heterotrophic Plate Counts (HPC) using Serial Dilution and Spread Plate Method of Isolation

Sterile blue tips and 9.9 ml distilled water diluents were prepared. Aseptic techniques were strictly followed in conducting serial dilution. Using a micropipette, 0.1 ml was aseptically transferred from the sample water bottle into the diluent (10 -2). This was then slightly mixed, and from this first dilution, another 0.1 ml was pipetted out into another tube with diluent (10-4). After slight mixing, another 0.1 ml was pipetted out and diluted into the final diluent 10-6.

Using a micropipette, 0.1 ml was collected from the water sample bottle and introduced into the nutrient agar plate. The same amount was pipetted from prepared dilutions of 10-2, 10-4, and 10-6 and dispensed into the nutrient (NA) plates. The same process was done for each respective duplicate of each dilution. These were incubated for 24 and 48 hours at room temperature.

After 24 and 48 hours of incubation, colony counts were conducted. After 48 hours of incubation, characterization of the different bacterial colonies was done and was assigned with bacterial species number for identification purposes.

To determine the heterotrophic plate count (cfu/ml), the average number of colonies (if counting duplicate plates of the same dilution) per plate was multiplied by the reciprocal of the respective dilution of the water sample.

Statistical analysis

The structure of the water quality indicator was explored using multivariate analysis. Data on the 14 variables were pooled and subjected to Principal Component Analysis (PCA) to sort variables and identify the most important that best describe the character of seawater quality. Coupled with Pearson's product moment correlation analysis, allows resolving this complex data matrix. These multivariate approaches help to identify possible factors/sources that influence the water systems and offers a valuable tool for reliable management of water resources, as well as a rapid solution on pollution problems (Morales *et al.,* 1999). Significant component factor was identified based on eigenvalue. Any principal component (PC) with eigenvalue >1.0 was considered significant. Multivariate analysis was implemented using SPSS software version 24.

Results and discussion

Physico-chemical Water Quality Parameter

Temperature

The results of the study on physico-chemical during the period of study are presented in Table 2. The values were compared with the standard values set by Department of Environment and Natural Resources (DENR).

Table 1. Coordinates of the different sampling sites established in Iligan Bay.

Site	Designated name	Coordinates
1	Pilmico Foods Corporation	N 8º 28' 24.5 E 124º 25' 80.4
2	San Miguel Corporation	N 8º 27' 57.5 E 124º 25' 89.2
3	Iligan Port	N 8º 14' 8.2 E 124º 24' 8.6

The present investigation observed that the surface water temperature did not fell within the acceptable range (26 °C- 30 °C) as recommended by the DENR in coastal waters (DAO 34, 2016). Water temperature in each coast range from 24 °C to 26 °C. In March sampling period, the temperature in sampling sites slightly increased varying from 25.5 °C to 26.6 °C and Barangay Kiwalan has the highest temperature.

Table 2. Comparison of physico-chemical parameters of three coastal waters in different sampling period.

Site	Temp.	DO (mg/L)	pH	Salinity (ppm)	Conductivity	TSS (g/ml)	TDS (ppm)	Transparency (m)	Hetero Plate Count	Total Coliform (MPN/100mL)	Coliform Fecal E.Coli (MPN/100mL	Nitrate (mg/L)	Phosphate (mg/L)	Substrate Type
February														
Kiwalan	26.0	5.67	10.8	31	363	0.029	924	5	98	>16	>16	3.7	0.01	Sandy-rubble
Sta. Fe	24.8	6.0	10.6	33	381	0.039	962	5	56	9.2	9.2	3.7	0.02	Sandy
Saray	24.7	5.72	10.3	35	362	0.065	855	4.5	79	>16	>16	4.5	0.09	Sandy
March														
Kiwalan	26.6	5.45	10.8	31	282	0.057	724	7	92	>16	9.2	3.2	0.08	Sandy-rubble
Sta. Fe	26.2	5.90	11.0	31	302	0.046	827	5	89	>16	9.2	2.4	0.05	Sandy
Saray	25.5	5.32	10.7	21	258	0.083	643	4	177	>16	>16	2.9	0.04	Sandy
April														
Kiwalan	29.1	6.86	11.1	32	282	0.064	820	5	77	>16	9.2	0.1	-0.09	Sandy-rubble
Sta. Fe	28.8	7.32	11.2	31	281	0.035	831	5	113	>16	16	0.4	-0.09	Sandy
Saray	29.1	6.38	11.1	21	198	0.070	798	4	82	16	9.2	0.2	-0.09	Sandy
DENR STANDARD	26-30	5	7.8-8.5	-	-	7^{-5} to 9^{-5}	1000	-	-	70	-	10	0.20	-

The water temperature in the month of April drastically increased ranging from 28.1 °C to 29.1 °C and Barangay Kiwalan and Saray have the same temperature with the highest value recorded.

February period has the lowest temperature recorded which implies continues rainfall the night before sampling. Among the areas, Saray site has the lowest temperature due to the freshwater runoff over the area or else due to rainfall. Temperature plays an important factor in controlling the functioning of aquatic ecosystem which also influences biological and chemical characteristics of aquatic environment (Singh and Mathura, 2005; Basualto, 2006; and Dallas, 2008). Moreover, the presence of household wastes and constructions causes such changes in temperature (Levén, 2007; Guiemaraes *et al.*, 2009 and Jouhara, 2017).

Table 3. Pearson correlation matrix between the physicochemical and biological parameters.

	Temp	DO	pH	Sal	Cond	TSS	TDS	Trans	HPC	total col.	E coli	Nitrate	Phosp	subs
Temp	1													
DO	.778*	1												
pH	.887	.692*	1											
Sal	-.287	.136	-.304	1										
Cond	-.712*	-.255	-.641	.782*	1									
TSS	.059	-.270	-.166	-.583	-.573	1								
TDS	-.163	.263	-.132	.628	.699*	-.751*	1							
Trans	-.029	-.133	.036	.487	.187	-.349	-.015	1						
HPC	-.057	-.259	.050	-.609	-.378	.409	-.747*	-.276	1					
Total col.	.409	.039	.319	-.257	-.511	.317	-.554	-.024	.437	1				
E coli	-.268	-.087	-.311	-.010	.243	-.064	-.071	-.344	.578	.316	1			
Nitrate	-.960	-.798*	-.898	.384	.751*	-.134	.199	.195	-.017	-.301	.298	1		
Phosp	-.879	-.858	-.790*	.283	.501	.076	-.113	.320	.084	-.091	.132	.904	1	
subs type	.200	-.085	.145	.265	.102	-.176	.017	.614	-.151	.250	-.158	.010	-.023	1

*Correlation is significant at the 0.05 level (2-tailed).

Dissolved Oxygen

The DO levels in three coastal areas listed in the table where Sta. Felomina obtained the highest DO value (6.0 mg/l) among the three sites conducted in February whereas Kiwalan has the least DO value (5.67 mg/l). In March, the highest DO level was still obtained in Sta. Felomina (5.90 mg/l) while Saray has the lowest value recorded (5.32 mg/l) among the three sites. In April period, DO levels slightly increased with the following sites: Sta. Felomina (7.32 mg/l), Kiwalan (6.86 mg/l), Saray (6.38 mg/l).

Table 4. Eigenvalue and variance per principal component (PC).

Component			
	Total	% of Variance	Cumulative %
PC1	5.347	38.191	38.191
PC2	3.649	26.062	64.253
PC3	1.930	13.787	78.039
PC4	1.430	10.212	88.251
PC5	.630	4.502	92.753
PC6	.516	3.685	96.438
PC7	.361	2.576	99.014
PC8	.138	.986	100.000
PC9	8.032E-16	5.737E-15	100.000
PC10	4.340E-16	3.100E-15	100.000
PC11	8.931E-17	6.380E-16	100.000
PC12	-8.071E-17	-5.765E-16	100.000
PC13	-3.867E-16	-2.762E-15	100.000
PC14	-5.121E-16	-3.658E-15	100.000

PC= Principal component; Bold numbers indicate the most important factor capturing the character of seawater quality. PC1 is related mostly with nutrients. PC2 represent organic pollution (DO and TDS) PC3 is the physical characteristics (transparency and substrate type). PC4 represent the biological characteristics.

Dissolved oxygen is a very important water quality parameter required to assess the effect of discharged wastewater on the receiving environment. DO is affected largely by waste influx which causes depletion of DO in the process of organic degradation (Babu, 2006). The DO value was high at Sta. Felomina in all sampling period indicating that this area was well oxygenated compared to the other two sites. According to Singh *et al.* (2012), the high values of DO are due to the time of the day where the samplings were conducted. Samplings were done in between 9:00 a.m. to 11:00 a.m and at that time photosynthetic rates of sea algae are maximum. The DO value was lower at Saray site in month of April due to influx of flood water from river and a commercial seaport where it provides transport ferry services in Iligan Bay with the used of ferry boats (http://wikimapia.org/ILIGAN-PORT-EXPANSION). This water has accidental spillage of oil and fuel by boats, which will affect the growth of aquatic plants, thus affecting the photosynthetic rate resulting in low DO (Pizzato *et al.*, 2003 and Raouf *et al.*, 2012). Low ranges of DO indicates the presence of biological stressors such as high nutrient levels, anthropogenic impacts, release of domestic and industrial effluents (Wang *et al.*, 2007 and Glover *et al.*, 2008).

pHs

The pH value of the three sites ranges from (10.3 to 10.8) in the month of February where Kiwalan site has the highest pH level reading (10.8). In March, the pH level ranges from 10.7 to 11.0. In the month of April, the pH level rises ranging from 11.1 to 11.2. February period has the lowest pH level readings (10.3 to 10.8). Among the three coastal sites, Sta. Fe has the highest pH value readings within three sampling periods (10.6 to 11.2) while Saray has the lowest pH level readings ranging from (10.3 to 11.1).

The results of pH level studied within three sampling period obtained pH levels 10.3 to 11.2. These values are not within the standard range (7.5-8.5) set by the DENR (DAO 34, 2016). They could be due to higher biological activity (Balasubramanian and Kannan, 2005; Sridhar *et al.*, 2006) such as photosynthetic activity and microbial respiration (Tucker *et al.*, 2008 and Yap *et al.* 2009) and to some alkaline discharge from the industrial area or due to rainwater-runoff such as fertilizers and detergents from upper portion of the inland water bodies that is rich in soluble alkaline matters (Upadhyay, 1988;Rajasegar, 2003; Singh *et al*., 2012). Also effluent from the copra extraction plant could be the reason for the recorded alkaline condition of the coastal water.

Salinity

The overall salinity values of the three sites conducted were between 21-35 ppm. During February, values were between 31-35 ppm and Saray site has the highest salinity level. Salinity values during March period decreased with the following site: Kiwalan (31 ppm), Sta. Felomina (31 ppm) and Saray (21 ppm). In April, salinity values range from 21-32 ppm and Saray has the lowest value. The lowest value of salinity in Saray between sampling months indicates that the area received major influence from drainages and river. The salinity at any point is dependent on the state the tide (high or low; spring or neap), time of the year, rainfall extent of fresh water inflow (Mclusky, 1971; Desousa, 1977). Several authors, Gibson, 1982; Balasubramanian and Kannan, 2005; Sridhar *et al.*, 2006; Yap *et al.* 2009 stated that salinity is an ecological factor of considerable importance which act as limiting factor for the distribution of living organisms e.g. its variation caused by dilution and evaporation is most likely to influence the fauna in the coastal ecosystem. High salinity means higher NaCl, $MgCl_2$ and other inorganic compounds. Generally, salinity increases along a coastal water as it gets closer to the river mouth, where tidal influences are strongest (Pizzato *et al*., 2003). Reduce normal salinity levels within the coastal waters are also caused by storm water which can add freshwater to it. Salinity affects the degree of mixing of water. Amarathunga *et al.,* (2010) states that as saltwater is heavier, it sinks to the bottom making it more saline than surface water hence it will affect aquatic species that live at the bottom of the aquatic zone.

Table 5. Principal component matrix.

Parameters	PC1	PC2	PC3	PC4
Temperature	-.920	.338	.129	.071
DO level	-.627	.625	-.278	.200
Ph	-.854	.356	.130	.090
Salinity	.594	.622	.152	.235
Conductivity	.887	.335	-.143	.222
TSS	-.308	-.728	.053	-.386
TDS	.425	.780	-.367	.059
Transparency	.257	.327	.825	-.003
hetero plate count	-.251	-.797	-.028	.379
total coliform	-.467	-.383	.382	.501
E coli	.178	-.402	-.341	.810
Nitrate	.956	-.270	.050	.042
Phosphate	.818	-.433	.268	-.089
substrate type	.022	.265	.788	.244
Eigen Values	5.347	3.649	1.930	1.430
Total Variance (%)	38.191	26.062	13.787	10.212
The Percentage of cumulative variance (%)	38.191	64.253	78.039	88.251

PC= Principal component; Bold numbers indicate positive correlation; Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization.

Conductivity

Conductivity levels in three sampling sites ranges from 362 to 381 in the month of February. In March, it slightly decreased ranging from 258 to 302 whereas in the month of April, the conductivity readings range from 198 to 282. Among the sampling period, the highest obtained value was in Sta. Felomina in the month of February while Saray site has the lowest recorded value in the month of April. The value of conductivity depends on salinity and is affected by the presence of dissolved solids (Pezard, 1990; Singh *et al.*, 2012; Levlin *et al.,* 2008; Dixit, 2013). As the level of total dissolved solids (TDS) raises, the conductivity also increases. Salinity value is minimum in the month of March and April, so conductivity is also less.

Total Dissolved Solids

Total dissolved solids are a measure of the total ions in a solution with a standard value of 1000 ppm. Dissolved solid concentrations in natural waters are the result of weathering and dissolution of minerals from local soil and bedrock (Freeze and Cherry, 1979). The minimum reading of TDS obtained from the sites studied was 643 ppm recorded at Saray site on the month of March and the highest was 962 ppm at Sta. Felomina on February. The TDS is lower than the standard might be due to some organic and inorganic matters that were suspended in sediments of the coast from anthropogenic factors of human activities (Amparado, 2014).

Turbidity

Turbidity is the amount of particulate matter that is suspended in water which measures the relative clarity of water. Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and microscopic organisms (Lawler 2004). Those sampling sites with high turbidity are places with plenty of organic and inorganic wastes flowing into the coastal water from the residential areas especially at Saray where there is a wet market nearby which could be the cause of the high turbidity (4 m to 4.5 m) and total suspended solids (0.065 g/ml to 0.083 g/ml). Similar study of Hettige *et al.*, 2014 was recorded in Negombo, Sri Lanka where a fish market was also located. TSS and turbidity are changed due to the watershed hydrologic process, soil sediment characteristics and land use pattern (Amarathunga *et al.,* 2010). The high turbidity and TSS can be caused either by extensive soil erosion that flows down into the coastal water through river or canal. Finally, it is markedly depends on the tidal pattern. The turbidity can be increased in the coastal region due to a rise of the river that is closely related to precipitation (Fukuda *et al.*, 1975). Because of this, turbidity and TSS were higher during the rainy season and low levels were determined during the dry weather condition. For Kiwalan, the high turbidity could be attributed to the industrial wastes and ships and thus has oil spills and pollutants.

Substrate Type

The type of substrate varies from one sampling site to another. Barangay Kiwalan had sandy- rubble type of substratum. Sta. Fe and Saray had sandy substratum. Slow moving or still water such as Saray area, has the substrate bed sandy with the increased of light penetration (Water and Rivers Commission, October 2001) influence to increase high nutrient levels (Kobingi *et al.*, 2009).

Nitrate and Phosphate

Nitrate and Phosphate are important parameters of coastal waters showing the pollution status and anthropogenic loads. The highest nutrient level in the three sites conducted within 3 periods was recorded in Saray (nitrate= 4.5 mg/l; phosphate= 0.09 mg/l) while Kiwalan area has the lowest nutrient levels recorded (nitrate= 0.1 mg/l; phosphate= -0.09 mg/l). The month of February obtained the highest nutrient levels of phosphate (0.01 mg/l to 0.09 mg/l) and nitrate (3.7 mg/l to 4.5 mg/l) while in April month obtained the lowest nutrient levels of nitrate (0.1 mg/l -0.4 mg/l) and phosphate (-0.09 mg/l).

Saray site recorded the highest values in nitrate and phosphate might possibly be due to human activities and sewage disposal near the site. Excessive use of nitrate fertilizers and runoff from human and animal waste are the main sources which affect to the variation of nitrate in water. Also, Amarasiri (2007) stated that the large amount of nitrogenous fertilizers has contributed to increased high levels of nitrate in water in many countries. High concentrations of these nutrients can cause low DO (Kobingi *et al.*, 2009). The least values of nitrate and phosphate was recorded in Kiwalan can be explained by the nature of the type of industry. These could also be attributed to high salinity and utilization of nutrients by the primary producers (Senthilkumar *et al.*, 2002; Rajasegar, 2003) which decreased the level of nitrate and phosphate.

Biological Water Quality Parameter

Microbiological factors monitor the parameters of coastal waters used for recreational activities or shellfish harvesting for human consumption. Besides the marine microbiota, sediments and seawater can contain a significant nonindigenous microbiota composed by bacteria, virus and protozoan that are discharged to the environment from domestic sewage and urban drainage water (Sato *et al.,* 2005; Oliveira *et al.,* 2007; Oliveira and Pinhata, 2008). Among the sampling months, March has the highest value recorded for heterotrophic plate count (89 MPN/ 100ml- 177 MPN/ 100 ml) which is located in Saray site and the least was in Sta. Fe (56 MPN/ 100 ml – 98 MPN/ 100ml) on the month of February. Total coliform was recorded high on the month of March (>16 MPN/ 100ml) to three sampling sites and February has the least value obtained (9.2- >16 MPN/100 ml) located in Sta. Fe. Fecal *E.coli*, an indicator bacteria, was recorded high in the month on February (9.2 100 MPN/100ml to >16 MPN/ 100 ml) located in Sta. Fe and the highest was on the month of March (>16 MPN/ 100 ml).

Anderson (2005) showed that a combination of the biological, chemical and physical makeup of seawater all affect the presence of indicator bacteria. Previous studies conducted by Metris *et al.*, (2014) and Xianghao *et al.* (2014) determined that the higher the salinity, the more stressed the sample of *E. coli* becomes. But other studies indicate that it is not just the presence of salt in the water but also the presence of predators that affect the elimination of *E. coli* (Enzinger,1976; Mc Cambridge, 1981; and Rozen and Belkin, 2001). The pH level of the water affects the E. coli survival. Fecal coliform elimination peaks at pH values greater than 9 and when exposed to pH values ranging from 7.5 to 7.75 little die off was observed (Pearson, 1987). Storms also affect the concentration of E. coli in the water column because this storm may flush *E. coli* from the soil banks and then this takes roughly two days to noticeably increase to levels that affect the water column (Solo- Gabriele, 2000).

Pearson correlation between variables

Correlation coefficients of two elements were very useful as this could reduce the dimensionality of the original data set and of less significant variables obtained (Wang *et al.,* 2013). In the present study, there is a positive significant correlation between DO and temperature (.778), pH and DO (.692), conductivity and salinity (.782), TDS and conductivity (.699) and nitrate and conductivity (.751) shown in Table 3. The significant positive correlation between DO and temperature indicates that DO is largely influenced by the temperature. The correlation of DO with water body gives direct and indirect information e.g. bacterial activity, photosynthesis, availability of nutrients, etc. (Premlata, 2009).

The high DO in summer is due to increase in temperature and duration of bright sunlight has influence on the % of soluble gases (O_2& CO_2). During summer the long days and intense sunlight seem to accelerate photosynthesis by phytoplankton, utilizing CO_2 and giving off oxygen. This possibly accounts for the greater qualities of O_2 recorded during summer (Krishnamurthy R, 1990). According to Adeniji, (1991) decomposition of organic matter also reduced the amount of oxygen, while increasing the amount of carbon dioxide in the affected environment that gave a positive correlation between pH and DO. Negative significant correlation was observed between conductivity and temperature (-.712), TDS and TSS (-.751), HPC and TDS (-.747), nitrate and DO (-.798) and phosphate and pH (-.790).

Principal component analysis

PCA is a powerful tool for the characterization of anthropogenic loads. In the implementation of principal component analysis, any factor component with eigenvalue greater than unity (eigenvalue >1) is statistically, considered as significantly different from the rest (Kim and Mueller, 1987; Webster, 2001; Xiaolong *et al.,* 2007; and Arslan, 2013) and are retained in order to understand the underlying data structure (Jackson, 1991). Table 4 shows the results of the PC loadings with a varimax rotation, as well as the eigenvalues, % variance explained and % cumulative variance. Among the 14 principal components, only the first 4 PC's were found to be significantly different from the rest of the variables, hence construed as the most important factor capturing the character of seawater quality.

Four major PCs were extracted which accounted 88.3% variance of the original data structure (Table 5). The first PC explained 38.191% of the total variance and was best represented by nitrate, phosphate and conductivity. The second PC was dominated by DO and TDS, accounting for 26.062% of the total variance. The third PC explained 13.787% of the total variance and loaded heavily on transparency and substrate type. The fourth PC accounted for 10.212% of the total variance which is dominated by hetero plate count, total coliform and E coli. As can be seen in Table 5, PC 1 is related mostly with the nutrients. Thus, it can be said that PC 1 explains the nutrient amounts that originate from coastal sites. PC 2 represents the organic pollution, since it was represented primarily by DO and TDS. Given that the third PC was mainly represented by transparency and substrate type, PC 3 represents the physical characteristics and PC 4 is the biological characteristics of the water.

In PC1 outputs, the positive loadings of nutrients along with negative loadings of DO, pH and temperature indicate that nutrients contribution relates with pollution sources. Several authors (Singh *et al.*, 2005, Bong *et al.,* 2008, Babu *et al.*, 2010, Praveena *et al.,* 2013), suggested that it might be due to the consumption of large amounts of oxygen by the organic matter. The PC1 has the largest proportion of the total variance indicating that nutrients are the major source of water contamination in the three sampling sites.

The second component (PC2) has significant positive loadings on DO level and TDS and negative loadings on TSS, nitrate and phosphate. This component might be due to different sources of organic pollutants and inorganic nutrients as well as the morphology of the area and the circulation of the waters. Most industries have been using a large volume of water which induced a large number of wastewater discharge into river nearby without any form of treatment. Other researchers also provided the similar issue (Ho and Hui, 2001; Zhu *et al.*, 2002; Ouyang *et al.*, 2005; Ali *et al.*, 2011; and Gyawali *et al.*, 2012). Among these literatures, Ali *et al.* have mentioned that the major agro-industrial effluents of sugarcane and starch industries pose a serious threat to surface waters of Nile River.

The PC3 has significant positive loadings on transparency and substrate type and negative loadings on TDS, conductivity, DO and E.coli. These variables originated primarily from run-off with high load of solids and wastes from point sources of pollution such as domestic and industrial wastewater discharges (Wondie, 2009; Abdel-Raouf *et al.*, 2012; and Gazzaz *et al.,* 2012). High turbidity and the associated suspended solid concentrations have important ecological impacts, because of light suppression effects. According to Yap *et al.,* 2011, those sampling sites with high turbidity are sandy places with plenty of organic and inorganic wastes flowing into the coastal water from the residential areas especially near a wet market which could be the cause of the high turbidity.

Finally, the PC4 is significantly and positively loaded on E. coli, total coliform and heterotrophic plate count but negatively loaded on TSS which is suspected to originate from animal faeces, surface runoffs and discharges from sewage treatment plant

(Cabral, 2010; Chigor *et al.*, 2010; and Fadaei, 2014). According to the study of Anderson and Rounds (2003) and Hamilton & Luffman (2009), a positive correlation between E. coli bacteria and turbidity indicates that E. coli were either transported to streams attached to particles bound to resuspended stream bed particles, or they had an affinity for sediments in water.

In summary, the four extracted Principal Components represent four different processing which are: seasonal effects, agricultural drainage, storm water effects of the river basin and wastewater pollution from domestic and industrial organic load. This PCA analysis identified the potential contamination sources of selected coastal waters of Iligan Bay that is mainly due to a mixed source including natural processes and anthropogenic activities. The discharging untreated urban wastewater into surface water system constitutes the major point anthropogenic contamination source (Ritter *et al.*, 2002; Barakat *et al.,* 2016). The non-point source which also contributes immensely in the bay contamination is from agricultural activities such as intensive culture and livestock farming that flow to river, estuaries and coastal waters.

Conclusion

Human activities present a potential risk to the environment, including water resources. This study demonstrates the utility of multivariate analysis techniques to obtain better information on water quality and prevent pollution caused by human factors.

The results for physico-chemical analysis showed that the selected sites in Iligan Bay generally, did not comply with the limits of quality set by the DENR, especially for surface water temperature and pH. The results for bacteriological analysis showed that the three sites suggest bad water quality. Bacteriological analysis stressed water samples have high concentrations of fecal contamination in almost all sources studied, which is undoubtedly a threat to residents for recreational and fishing activities. In general, Microbiological seeds were more directly related to human activities that took place in the area (big industries, corporations, harbors/docklands and depots).

The management of domestic and industrial wastes is required to lower the accumulation of pollutants in water and soil and minimize environmental degradation. This is achieved by providing proper treatment of municipal and industrial wastewater before being released to the environment, and the improvements in agricultural practices.

The results also showed the importance of multivariate statistical assessment of large datasets to get better information about the quality of surface water which can help the environmental managers to make better decisions regarding action plans. These will help in developinga strategy for good governance of water resources in accordance with the requirements of sustainable development.

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References

Abdel-Raouf N, Al-Homaidan AA, Ibraheem IBM. 2012. Microalgae and wastewater treatment. Saudi Journal of Biological Sciences **19(3)**, 257–75. http://dx.doi.org/10.1016/j.sjbs.2012.04.005

Adeniji HA. 1991. Limnology and biological production in the pelagic zone of Jebba Lake (Nigeria).

Al-Zamel AZ, Al-Sarawi MA, Khader SR, Al-Rifaiy IA.2009. Benthic foraminifera from polluted marine environment of Sulaibikhat Bay (Kuwait). Environ Monit Assess **149,**395–409. http://dx.doi.org/10.1007/s10661-008-0216-7

Ali SM, SabaeSZ, Fayez M, Monib M, Hegazi NA. 2011. The influence of agro-industrial effluents on River Nile pollution. Journal of Advanced Research **2(1)**, 85-95.

Amarasiri S. 2007. Declining Water Quality and its effect on Water Security, In: Water Resources Research in Sri Lanka, De Silva R.P. and Dayawansa N.D.K. (Ed.) Symposium proceedings of The Water Professionals' Day, Geo- Informatics Society of Sri Lanka (GISSL), 1-10 p.

Amarathunga AAD, Weerasekara KAW, Sureshkumar N, Azmy SAM, Shirantha RRAR. 2010. Total Suspended Solids and Turbidity co-relation and its impact on aquatic community in Kotmale sub-catchment in the Upper Mahaweli Watershed in Sri Lanka. Water Resource Research in Sri Lanka, 115-124 p.

Anderson CW, Rounds SA. 2003. Phosphorus and E. Coli and their relation to selected constituents during storm runoff conditions in Fanno Creek, Oregon, 1998-99: U.S. Geological Survey Water-Resources Investigations Report 02-4232, 35 p.

Anderson KL, Whitlock JE, Harwood VJ. 2005. Persistence and differential survival of fecal indicator bacteria in subtropical waters and sediments. Appl. Environ. Microbiol **71(6),**3041-3048. http://dx.doi.org/10.1128/AEM.71.6.3041-3048.2005

Anderson SA, Turner SJ, Lewis GD. 1997. Enterococci in the New Zealand environment: implications for water quality monitoring. Water SciTechnol**35,** 325–331. http://dx.doi.org/10.1016/S0273-1223(97)00280-1

Arslan WR. 2013. Spatially weighted principal component analysis (PCA) method for water quality analysis**40**, 315. http://dx.doi.org/10.1134/S0097807813030111

Azmy SAM, Weerasekara KAWS, Hettige ND, Wickramaratne C, Amaratunga AAD. 2012. Determination of the current status of water quality in commercially important water bodies mainly the Puttalam Lagoon, Giant's Tank and Akurala water bodies of Sri Lanka through rapid assessment surveys. In: International Symposium on Urban Lakes Monitoring and Management, PGIA, Peradeniya, Sri Lanka, 135-144.

BabuMT, Das VK, Vethamony P. 2006. BOD–DO modeling and water quality analysis of a waste water outfall off Kochi, west coast of India. Environment International **32(2)**, 165-173.

Babu KN, Omana PK, Mohan M. 2010. Water and Sediment quality of Ashtamudi estuary, a Ramsar site, southwest coast of India - A statistical appraisal, Environmental Monit Assess, **165,**307–319, http://dx.doi.org/10.1007/s10661-009-0947-0. 217

Balachandran KK. 1990. Does subterranean flow initiate mud banks off the southwest coast of India. Estuar Coast Shelf Sci 2004; **59,** 589 98. http://dx.doi.org/10.1016/j.ecss.2003.11.004

Banat I, Puskas K, Esen I, Al-Daher R.1990.Wastewater treatment and algal productivity in an integrated ponding system.Biological Wastes **32(4)**, pp.265-275. http://dx.doi.org/10.1016/0269-7483(90)90058-Z

Barakat A, Ennaji W, El Jazouli A, Amediaz R, Touhami F. 2017. Multivariate analysis and GIS-based soil suitability diagnosis for sustainable intensive agriculture in Beni-Moussa irrigated subperimeter (Tadla plain, Morocco). Modeling Earth Systems and Environment **3(1)**, 3. http://dx.doi.org/10.1007/s40808-017-0272-5

Basualto S, Tapia J, Cruces F, Peña-Cortés F, Hauenstein E, Bertrán C, Schlatter R. 2006. The effect of physical and chemical parameters on the structure and composition of the phytoplankton community of Lake Budi (IX Region, Chile). Journal of the Chilean Chemical Society **51(3)**, 993-999.

Bong CW, Lee CW. 2008. Nearshore and Offshore Comparison of Marine Water Quality Variables

Measured During SESMA 1, Malaysian Journal of Science **27(3)**, 25–31. http://doi.org/10.1.1.517.2136

Bremner JM, Mulvaney CS. 1982. Methods of soil analysis, part 2 chemical and microbiological properties, 595-624.

Cabral JP. 2010. Water microbiology. Bacterial pathogens and water.International journal of environmental research and public health **7(10)**, 3657-3703.

Chigor VN, Umoh VJ, Smith SI, Igbinosa EO, Okoh AI. 2010. Multidrug resistance and plasmid patterns of Escherichia coli O157 and other E. coli isolated from diarrhoeal stools and surface waters from some selected sources in Zaria, Nigeria. International Journal of Environmental Research and Public Health. **7**,3831–3841. http://dx.doi.org/10.3390/ijerph7103831

Colford JM, Wade TJ, Schiff KC, Wright CC, Griffith JF, Sandhu SK, Burns S, Sobsey M, Lovelace G, Weisberg SB. 2007. Water quality indicators and the risk of illness at beaches with nonpoint sources of fecal contamination. Epidemiology **18(1)**,27–35. http://dx.doi.org/10.1097/01.ede.0000249425.32990.b9

Dallas H. 2008. Water temperature and riverine ecosystems: An overview of knowledge and approaches for assessing biotic responses, with special reference to South Africa. Water Sa **34(3)**,393-404.

Denr-Administrative order NO. 34, 1990 Revised Water Usage and Classification of Water Quality Criteria Amending Section Nos. 68 and 69, Chapter III of the 1978 Rules and Regulations. Manila,

Dixit PR, Kar B, Chattopadhyay P, Panda CH. 2013. Seasonal variation of the physicochemical properties of water samples in Mahanadi Estuary, East Coast of India. J. Environ. Prot. **4**,843-848. https://doi.org/10.4236/jep.2013.48098

Donovan E, Unice K, Roberts JD, Harris M, Finley B. 2008.Risk of gastrointestinal disease associated with exposure to pathogens in the water of the Lower Passaic River. Appl Environ Microbiol. **74(4)**,994–1003. http://dx.doi.org/10.1128/AEM.00601-07

Duran M, Tuzen M, Kayim M. 2003. Exploration of biological richness and water Quality of stream Kelkit, Tokat Turkey. Fresenius Envir. Bull **12(4)**, 368.

Fadaei A. 2014. A Comparison of the Bacteriological Quality of Drinking Water for the Rural of Hooreh and Arjnk, Iran. Resources and Environment **4(5)**, 215-219.

Feng P, Weagant SD, Grant MA, Burkhardt W, Shellfish M, Water BBAM. 2002. Enumeration of Escherichia coli and the Coliform Bacteria. Bacteriological analytical manual. 13–19 p.

Fleisher JM, Fleming LE, Solo-Gabriele HM, Kish JK, Sinigalliano CD, Plano L, Elmir SM, Wang JD, Withum K, Shibata T, Gidley ML. 2010. The BEACHES Study: health effects and exposures from non-point source microbial contaminants in subtropical recreational marine waters. Int J Epidemiol. **39(5)**,1291–8. http://dx.doi.org/10.1093/ije/dyq084

Freeze RA, Cherry JA. 1979. Groundwater, 604 pp., Prentice- Hall, Englewood Cliffs, N. J.

Fukuda M, Inoue N, Nishizawa S. 1954. Investigation of trubidity in the sea. 1. Design of a turbidity meter and preliminary observation. Bull. Fac. Fish. Hokkadio Univ. **5**, 99-104.

Garcon V, Kriest I, Levin LA. 1991. Carbon dioxide production in the North Atlantic, Ocean Life **7(2)**, 61-65.

Gazzaz, Yusoff, Ramli, Aris, Juahir 2012. Characterization of spatial patterns in river water quality using chemometric pattern recognition techniques Marine Pollution Bulletin, **64(4),** (2012), 688–698 p.

Guimarães DO, Pereira LC, Monteiro MC, Gorayeb A, Costa RM. 2009. Effects of the urban influence on the Cereja River and Caeté Estuary (Amazon littoral, Brazil). J Coastal Res SI56: 1219-1223.

Gyawali S, Techato K, Yuangyai C. 2012. Effects of industrial waste disposal on the surface water quality of U-tapao River, Thailand. In IntConf Environ SciEng**3,** 109-113.

Hamilton JL, Luffman I. 2009. Precipitation, pathogens, and turbidity trends in the Little River, Tennessee, Phys. Geogr**30**, 236–248.

Helena B, Pardo R, Vega M, Barrado E, Fernandez JM, Fernandez L. 2000. Temporal evolution of groundwater composition in alluvial aquifer (Pisuerga River, Spain) by principal component analysis, Water Research **49**, 359-372. http://dx.doi.org/10.1016/S0043-1354(99)00225-0

Ho KC, Hui KCC. 2001. Chemical contamination of the East River (Dongjiang) and its implication on sustainable development in the Pearl River Delta. Environ Int**26(5–6)**, 303–308. http://dx.doi.org/10.1016/S0160-4120(01)00004-6

Jackson JE. 1991. A user's guide to principal components. New York: Wiley.

Jones JRE. 1952. The reactions of fish to water of low oxygen concentration, Journal of Experimental Biology **29**, 403-415.

Jouhara H, Czajczyńska D, Ghazal H, Krzyżyńska R, Anguilano L, Reynolds A J, Spencer N. 2017. Municipal waste management systems for domestic use. Energy **139**, 485-506.

Kim JO, Mueller CW. 1987. Factor Analysis: Statistical Methods and Practical Issues, Sage University Paper Series on Quantitative Applications in the Social Sciences, series no 07–014.Sage Publications, Beverly Hills. http://dx.doi.org/10.4135/9781412984256

Kim RH, Yum BW, Chang HW. 2002. Hydrogeochemical and isotopic characteristics for salinization of a shallow groundwater in coastal area, Youngkwang, Korea, Proc. 17th Salt Water Intrusion Meeting, Delft, The Netherlands, 227–237.

Kobingi N, Raburu PO, Masese FO, Gichuki J. 2009. Assessment of Pollution Impacts on the Ecological Integrity of the Kisian and Kisat Rivers in Lake Victoria Drainage Basin, Kenya. Afr. J. Sci.Tech. Accepted.

Kravchuk A. 2006. Benthic foraminifera as indicators of pollution in the north-western shallow part of the Black Sea.Geophysical Research Abstracts **8,** 00518.

Krishnamurthy R. 1990. Hydro-biological studies of Wohar reservoir Aurangabad (Maharashtra State) India. J. Environ. Biol**11(3)**,335-343.

Kuppusamy MR, Giridhar VV. 2006. Factor analysis of water quality characteristics including trace metal speciation in the coastal environmental system of Chennai Ennore. Environment international **32(2)**, 174-179. http://dx.doi.org/10.1016/j.envint.2005.08.008

Lawler DM. 2004.Turbidimetry and nephelometry. In: Townshend, A. (Ed.) Encyclopedia of Analytical Science, 2nd edition. London: Academic Press 343-351 p.

Levén L, Eriksson AR, Schnürer A. 2007. Effect of process temperature on bacterial and archaeal communities in two methanogenic bioreactors treating organic household waste.FEMS microbiology ecology **59(3)**, 683-693.

Mee CJ, Farquhar MJ, Harris HJ, Ramma W, Ahmed A, Maurel P, Bicknell R, Balfe P, Mc Keating JA. 2009b. Hepatitis C virus infection reduces hepatocellular polarity in a vascular endothelial growth factor dependent manner. Gastroenterolgy [Epub. ahead of print]. http://dx.doi.org/10.1053/j.gastro.2009.11.047

Metris.2014. A. Metris, S.M. George, F. Mulholland, A.T. Carter, J. Baranyi Metabolic shift of Escherichia coli under salt stress in the presence of glycine betaine Appl. Environ. Microbiol**80**, 4745–4756 p. http://dx.doi.org/10.1128/AEM.00599-14

Morales MM, Marti P, Liopis A, Campos L, Sagrado S. 1999. An environmental study by factor analysis of surface sea waters in the gulf of Valencia (Western Mediterranean). Analytica Chimica Acta **394(1),** 109-117. http://dx.doi.org/10.1016/S0003-2670(99)00198-1

OgidiakaEfe. 2012.Physico-Chemical Parameters and Benthic Macro-invertebrates of Ogunpa River at Bodija, Ibadan, Oyo State European Journal of Scientific Research **85(1)**, 89-97.

Oliveira AJFC, Hollnagel HC, Mesquita Hde SL, Fontes RFC. 2007. Physical, chemical and microbiological characterization of the intertidal sediments of Pereque Beach, Guarujá (SP), Brazil. Marine Pollution Bulletin **54,** 921–927. http://dx.doi.org/10.1016/j.marpolbul.2007.03.003

Oliveira AJFC, Pinhata JM. 2008. Antimicrobial resistance and species composition of *Enteroccocus* spp. Isolated from waters and sands of marine recreational beaches in southern Brazil. Water Research.**42,** 2242–2250.

U.S. EPA. 2000. (United State Environmental Protection Agency). Ambient aquatic life water quality criteria for Dissolved Oxygen (saltwater), Cape Cod to Cape Hatteras. EPA/822/R-00/12.

Ouyang TP, Zhu ZY, Kuang YQ. 2005. River water quality and pollution sources in the Pearl River Delta, China. J Environ Monit, **7(7)**, 664–669.

Pearson HW, Mara DD, Mills SW, Smallman DJ. 1987. Physico-chemical parameters influencing faecal bacterial survival in waste stabilization ponds. Water science and technology **19(12)**, 145-152.

Pezard PA. 1990. Electrical properties of mid-ocean ridge basalt and implications for the structure of the upper oceanic crust in hole 504B. J. Geophys. Res **95**, 9237–9264. http://dx.doi.org/10.1029/JB095iB06p09237

Praveena SM, Aris AZ. 2013. A baseline study of tropical coastal water quality in Port Dickson, Strait of Malacca, Malaysia, Marine Pollution Bulletin **67**, 196–199, http://dx.doi.org/10.1016/j.marpolbul.2012.11.037

Premlata V. 2009. Multivariant analysis of drinking water quality parameters of lakePichhola in Udaipur, India. Biological Forum, Biological Forum- An International Journal **1(2)**, 97-102 p.

Miroslav R, Vladimir NB. 1999. Practical environmental analysis. UK: Royal Society of Chemistry, 289, 314.

Rajasegar M. 2003. Physico-chemical characteristics of the Vellar estuary in relation to shrimp farming. J. Environ. Biol. **24,** 95-101.

Ritter L, Solomon P, Sibley K. Hall P, Keen G, Mattu B. 2002. Sources, pathways, and relative risks of contaminants in surface water and groundwater: a perspective prepared for the Walkerton Inquiry. Journal of Toxicology and Environmental Health, Part A **65,**1–142.

Rozen Y, Belkin S. 2001. Survival of enteric bacteria in seawater. FEMS Microbio. Rev **25**, 513–529.

Sato MIZ, Bari MD, Lamparelli CC, Truzzi AC, Coelho MCLS, Hachich EM. 2005. Sanitary quality of sands from marine recreational beaches of Sao Paulo, Brazil. Brazilian Journal of Microbiology **36(4)**, 321–326. http://dx.doi.org/10.1590/S151783822005000400003

Shammas MI, Jacks G. 2007. Seawater intrusion in the Salalah plain aquifer. Oman, Environmental Geology **53**, 575– 587. http://dx.doi.org/10.1007/s00254-007-0673-2

Shuval H. 2003. Estimating the global burden of thalassogenic diseases: human infectious diseases caused by wastewater pollution of the marine environment. Journal of Water and Health **1(2)**, 53-64 p.

Singh KP, Malik A, Sinha S. 2005.Water quality assessment and appropriation of pollution sources of Gomti River (India) using multivariate statistical techniques – a case study, Analytica Chimica Acta, **538**, 355-374. http://dx.doi.org/10.1016/j.aca.2005.02.006

Signh S, Bhaduri B, Banerjee P, Datta S. 2012. Assessment of Coastal Water Quality at Bakkhali, Assessment of Coastal Water Quality at Bakkhali, West Bengal (India) West Bengal (India) J Environ. Science and Engg. **54(2)**,217- 226.

Solo-Gabriele HM, Wolfert MA, Desmarais TR, Palmer CJ. 2000. Sources of Escherichia coli in a coastal subtropical environment. Appl Environ Microbiol**66**, 230– 237. http://dx.doi.org/10.1128/AEM.66.1.230-237.2000

Tampus AD, Apuan DA, Jabbar MM, Salapuddin FB. 2014. Characterization of seawater quality in stressed coastal zone of Iligan Bay. Advances in Environmental Sciences **6(1).**

Tampus AD, Tobias EG, Amparado RF, Bajo L, Sinco AL. 2012.Water quality assessment using macroinvertebrates and physico-chemical parameters in the riverine system of Iligan City, Philippines. Advances in Environmental Sciences, **4(2)**.

Tucker CS, D'Abramo LR. 2008. Managing high pH in freshwater ponds. Southern Regional Aquaculture Center.

Upadhyay S. 1988.Physico-chemical characteristics of the Mahanadhi estuarine ecosystem. East coast of India. Ind. J. Mar. Sci**17**, 19-23.

Wang HW, Zhang B, Hao YJ, Huang J, Tian AG, Liao Y, Zhang JS, Chen SY. 2007. The soybean Dof-type transcription factor genes, GmDof4 and GmDof11, enhance lipid content in the seeds of transgenic Arabidopsis plants. The Plant Journal **52**, 716–729. http://dx.doi.org/10.1111/j.1365-313X.2007.03268.x

Wang Y, Wang P, Bai Y, Tian Z, Li J, Shao X, Li BL. 2013. Assessment of surface water quality via multivariate statistical techniques: a case study of the Songhua River Harbin region, China. Journal of hydro-environment research **7(1),** 30-40.

Webster M, Sheets HD, Hughes NC. 2001. Allometric patterning in trilobite ontogeny: testing for heterochrony in Nepholenellus. In M.L. Zelditch (ed.), Beyond Heterochrony: the evolution of development. Wiley-Liss, Inc., New York, 105-144.

Wondie TA. 2009. The impact of urban storm water runoff and domestic waste effluent on water quality of lake Tana and local groundwater near the city of Bahir Dar, Ethiopia (Doctoral dissertation, Cornell University).

Xiao-long W, Yong-long L, Jing-yi H, Gui-zhen H, Tie-yu W. 2007 Identification of anthropogenic influences on water quality of rivers in Taihu watershed. J Environ Sci**19**, 475–481.

Yap CK, Fairuz MS, Yeow KL, Hatta MY, Ismail A, Ismail AR, Tan SG. 2009. Dissolved Heavy Metals and Water Quality in the Surface Waters of Rivers and Drainages of the West Peninsular Malaysia. Asian Journal of Water, Environment and Pollution **6(3),** 51-59.

Zhu ZY, Deng QL, Zhou HY, Ouyang TP, Kuang YQ, Huang NS, Qiao YL.2002.Water pollution and degradation in Pearl river Delta, South China. AMBIO: A Journal of the Human Environment**31(3)**, 226-230 p.

http://dx.doi.org/10.1579/0044-7447-31.3.226