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Environmental risk assessment of Macabalan creek water in Cagayan de Oro, Philippines

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Abstract

Creek water carries both domestic and commercial wastewater consequently draining organic and inorganic pollutants to coastal water. The present study dealt on the environmental risk assessment of creek water stretching in Macabalan-Cagayan de Oro, Philippines. Selected physicochemical analyses of water samples were carried in both temporal and spatial variations. Risk quotient (RQ), water quality index (WQI), and brine shrimp lethality test (BSL) was employed to draw environmental risk estimate. Overall, dissolved oxygen (DO) concentrations were below the standard set regardless of temporal and spatial variations. Both RQ and WQI showed good statuses on creek water quality despite the low DO. The BSLT similarly indicated a higher concentration for LC50 to be established. The study was preliminary and further monitoring may be essential.

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Introduction

The city of Cagayan de Oro in the southern part of the Philippines had shown potential economic growth recently, becoming the business district in the region. Consequently, the need to ensure sustainable resources in this key city is seen vital to secure both the economy and the environment. Studies on water quality can provide basis for environmental policies securing environmental health. Locally, studies on drinking water quality (Besagas *et al*., 2015; Alambatin *et al*., 2017; Bansilay *et al*., 2017; Salvane *et al*., 2017) and wastewater (Achas *et al*., 2016; Nacua *et al*., 2016) do not show potential water related risks.

However, site specific studies on river (Lubos and Japos, 2009) and coastal water (Lago, 2013) showed coliform contamination. This in return may pose potential ecological ill effects if poor monitoring system is employed. Thus, the need to conduct the present study on a city creek water was essential.

Existing findings on water quality similarly focused on river waters (Martinez *et al*., 2011; Flores and Zafaralla, 2012; Labajo-Villantes, 2014; Maglangit *et al*., 2014; Maglangit *et al*., 2015) with pronounced level of biological oxygen demand (BOD). At present there is less literature on water quality studies of creek water leading to coastal bodies in the Philippines. Creek water must be assessed considering the refuse runoff it assimilates from adjacent domestic and commercial districts. Both organic load and inorganic nutrients are present in domestic wastewater are dumped in creek waters. Consequently, contaminated surface water may have adverse effect on the adjacent coastal resources.

The present study focused on Macabalan creek in Cagayan de Oro. Surface water on the creek potentially carrying contaminants flows through the adjacent Macajalar Bay. This study was conducted to quantitatively determine selected physicochemical parameters on the creek with reference to existing standard. The environmental risk assessment was deduced from the assessed Risk quotient (RQ), Water quality index (WQI), and toxicity testing.

Materials and methods

Description of Sampling Site

Three sampling sites were chosen along Macabalan creek in Cagayan de Oro. All sites were surrounded by residential buildings, warehouses, and commercial establishments (see Fig. 1). The creek surface water flows through the Macajalar Bay. Table 1 presents the coordinates of the study sites.

Fig. 1. Area of the study sties a) site 1; b) site 2; c) site 3.

Table 1. Coordinates of the study sites.

Study site	Specific location	Latitude	Longitude
1	Celri Macabalan	8°30'03.3"N	124°39'37.3" E
2	Piaping Itum-Puti Macabalan	8°30'01.3"N	124°39'43.7"E
3	Punta Macabalan	8°30'05.4"N	124°39'51.1"E

Sampling technique procedures

Samples were stored in pre-washed polyethylene containers (PET) with distilled water in triplicates. Prior to collection the container itself were washed with the flowing creek water on site. Within an hour after collection the water samples were analyzed to prevent sample loss or chemical absorption (Galarpe and Parilla, 2014).

Physicochemical Analysis

The pH, temperature, conductivity, salinity, and TDS were analyzed using Oyster meter. The DO of the water samples were analyzed using Acorn Series DO Meter OAKION Manufacturing (code 01X555902). Titrimetric method of analyses was employed for determination of alkalinity and acidity (APHA-AWWA and WEF, 2012). All analyses were conducted in triplicates.

Brine shrimp lethality test (BSLT)

The toxicological potency of the Macabalan creek water was tested using BSLT (Bernas *et al*., 2004). The method involved preparation of creek water concentrations (% v/v) in fraction with seawater. Control medium was seawater. Prior to testing the eggs of brine shrimp was hatched for 48 h and the fertilized nauplii were subjected to analysis.

Statistical analysis and risk assessment

Both descriptive and inferential statistics were employed to analyze the obtained data. One Way-ANOVA was employed to compare the physicochemical parameters in all study sites (0.05 level of significance).

The Pearson correlation was similarly used to determine association among parameters studied. To derive an environmental risk estimate all results were subjected to RQ and WQI analysis. The RQ was calculated as the ratio between the determined concentration and the available standard (GEF/UNDP/IMO 2004). The calculated RQ >1 can gauge the physiochemical parameter to likely pose environmental risk. The reference standard used for estimating RQ is shown in Table 2.

Table 2. Water quality reference for the study sites.

Standard	Description
Philippines DENR/DAO 34 Class SA	Waters suitable for the propagation, survival, and harvesting of shellfish for commercial purposes.
Philippines DENR/DAO 34 Class SB	Recreational water class I –Areas regularly used by the public for bathing, swimming, skin diving, etc). Fishery water class I – Spawning areas
US EPA	Reference standard for the US Environmental Protection Agency
EPA AUS	Reference standard for the Environmental Protection Agency of Australia
WHO (2011)	Reference standard for alkalinity

The WQI analysis was calculated by the measured values of physicochemical parameters as presented by other studies elsewhere (Bordalo *et al*., 2006; Alobaidy *et al*., 2010; Meher *et al*., 2015; Naubi *et al*., 2016). Briefly, the calculations used are presented below:

$$Wr = Wai / \sum_{i=1}^{n} Wai \quad \text{(Eq. 1)}$$

$$Qi = [Ci / Si] \times 100 \quad \text{(Eq. 2)}$$

$$Qi\,(DO) = [(Ci-Vi)/(Si-Vi)] \times 100 \quad \text{(Eq. 3)}$$

$$SIi = Wr \times Qi \quad \text{(Eq. 4)}$$

$$WQI = \sum SIi \quad \text{(Eq. 5)}$$

Where

Wr = relative weight, Wa = assigned weight of each parameter, n= number of parameters considered for the WQI analysis (Eq. 1).

The Qi (Eq. 2) refers to the quality rating scale for every parameter. Qi were calculated as the ratio of Ci = determined concentration and Si = water quality standard. The Qi for DO employed another method (Eq 3) adopted from other studies (Alobaidy *et al*., 2010; Meher *et al*., 2015) where Vi is the ideal value for DO set as 14.6. Further, sub-indices (SIi) as shown in Eq. 4 were calculated to determine the WQI (Eq 5). Reference scale for WQI is shown in Table 3.

Table 3. WQI Scale (Yadav *et al*., 2010; Meher *et al*., 2015).

WQI	Water quality
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
Above 100	Unsuitable

Toxicity testing was statistically calculated. The average mortality and LC50 in toxicity was expressed using Probit analysis method.

Results and discussion

Summary of Physicochemical analyses

The summary of physicochemical properties studied in Macabalan creek is shown in Table 4-6. All sampled water in all study sites had a pH range of 7.68-7.82. Water temperature values of the three sampling were 27.58°C-27.92°C considered within the permissible standard. The determined temperature indicates absence of thermal activity (e.g. dumping of industrial wastewater) in the creek (Galarpe and Parilla, 2012).

The DO was within the range 0.91-0.97 ppm, considerably lower than the permissible limit. The amount of organic material can be a factor to affect DO levels. The study site is a refuse end of domestic and commercial wastewaters carrying organic load, consequently lowering the DO (Chapman, 1996). The DO levels <0.02 mg/L may somehow impair marine life by deprivation of bio-available oxygen leading to fish death (Chapman, 1996). Variability of TDS, conductivity, and salinity.

Were also recorded with higher levels on the third sampling period. Overall these parameters were lower in all sites and sampling period. The studied alkalinity in all sites was comparable to the findings of Achas *et al.* (2016) on community wastewater in the same city.

Table 4. Summary of results in study site 1.

Sampling period	pH	Temperature (°C)	DO (ppm)	Conductivity (µS/cm)	Salinity (ppm)	TDS (mg/L)	Acidity (mg/L)	Alkalinity (mg/L)
March 18	7.51	23	0.46	4.93	2.63	3.88	143.2	251
March 25	7.87	29.87	1.14	9.4	4.78	6.39	66	201.6
April 1	7.67	28.87	1.32	13.67	7.16	9.45	85.2	81
Mean	7.68	27.58	0.97	9.3	4.86	6.55	98.13	177.86
SD	0.18	3.97	0.45	4.37	2.27	2.83	32.87	71.402
Standard	6.0-9.0 DAO 34	25-32 DAO 34	2-5 DAO 34	250 ppm US EPA	1000 ppm EPA AUS	500 mg/L US EPA	N/A	300 mg/L WHO (2011)

Table 5. Summary of results in study site 2.

Sampling period	pH	Temperature (°C)	DO (ppm)	Conductivity (µS/cm)	Salinity (ppm)	TDS (mg/L)	Acidity (mg/L)	Alkalinity (mg/L)
March 18	7.51	23	0.78	5.11	2.67	3.41	102.6	153
March 25	7.92	29.87	0.99	12.02	6.02	8.31	55.2	130.7
April 1	7.86	29.40	1.06	15.48	7.75	10.37	124	84
Mean	7.76	27.42	0.94	10.87	5.48	7.36	108.7	122.56
SD	0.22	3.84	0.15	5.28	2.58	3.58	35.69	28.75
Standard	6.0-9.0 DAO 34	25-32 DAO 34	2-5 DAO 34	250 ppm US EPA	1000 ppm EPA AUS	500 mg/L US EPA	N/A	300 mg/L WHO (2011)

Table 6. Summary of results in study site 3.

Sampling period	pH	Temperature (°C)	DO (ppm)	Conductivity (uS/cm)	Salinity (ppm)	TDS (mg/L)	Acidity (mg/L)	Alkalinity (mg/L)
March 18	7.63	23	0.66	5.65	2.70	3.77	66.6	324
March 25	7.92	31.13	1.20	16.02	7.92	10.60	234.3	234.3
April 1	7.91	29.63	0.86	13.44	6.75	9	92	87
Mean	7.82	27.92	0.91	11.7	5.79	7.79	130.96	215.1
SD	0.16	4.33	0.27	5.40	2.74	3.57	73.79	97.702
Standard	6.0-9.0 DAO 34	25-32 DAO 34	2-5 DAO 34	250 ppm US EPA	1000 ppm EPA AUS	500 mg/L US EPA	N/A	300 mg/L WHO (2011)

Spatial and temporal variations of water quality parameters

The result of the statistical analyses is summarized in Table 8. The pH, temperature, conductivity, salinity, TDS, and alkalinity showed statistical difference (p <0.05) indicating site specific difference. This difference can be associated to increasing trend of concentrations on the third sampling period.

Table 7. One-way ANOVA of the studied sites and parameters.

Parameter	Variation	F-value	P-value	Decision towards the null hypothesis
pH	Site	26.89	0.0047	Significant
	Date	3.76	0.1205	Non-significant
Temperature	Site	297.38	4.4628 E-05	Significant
	Date	2.31	0.2145	Non-significant
DO	Site	4.87	0.0845	Non-significant
	Date	0.07	0.9278	Non-significant
Conductivity	Site	16.64	0.0115	Significant
	Date	1.06	0.4266	Non-significant
Salinity	Site	16.59	0.0115	Significant
	Date	0.65	0.5684	Non-significant
TDS	Site	15.32	0.0133	Significant
	Date	0.59	0.5943	Non-significant
Acidity	Site	0.05	0.9509	Non-significant
	Date	0.22	0.8047	Non-significant
Alkalinity	Site	10.63	0.0250	Significant
	Date	3.54	0.1302	Non-significant

Correlation analysis of water quality parameters

A positive correlation (Table 8) was observed on the following parameters temperature-pH (r-0.919), conductivity-temperature (r-0.907), salinity-temperature (r-0.905), TDS-temperature (r-0.906), salinity-conductivity (r-0.9982). TDS-conductivity (r-0.9933), acidity-conductivity (r-0.9946), alkalinity-conductivity (r-0.9979), TDS-salinity (r-0.9984). Although no direct associations can best explain these correlations it was likely common that conductivity, salinity, and TDS were positively correlated (Jain *et al.*, 2006; Bansilay *et al.*, 2017; Alambatin *et al.*, 2017).

Table 8. Correlation analysis of studied parameters.

Parameter	pH	Temp	DO	Conductivity	Salinity	TDS	Acidity	Alkalinity
pH	1							
Temp	0.919	1						
DO	0.604	0.821	1					
Conductivity	0.801	0.907	0.783	1				
salinity	0.778	0.905	0.796	0.9982	1			
TDS	0.788	0.906	0.776	0.9933	0.9984	1		
Acidity	0.081	0.164	0.097	0.9946	0.3196	0.324	1	
Alkalinity	-0.34	-0.517	-0.503	0.9979	-0.614	-0.596	0.1945	1

Environmental risk assessment

RQ and WQI

The RQ analysis (Table 9) showed no potential risk except for DO which were considerably below the standard set. These results were in agreement with further WQI analysis (Table 10-12). The WQI analysis was adopted from Meher *et al.* (2015). Calculated mean WQI value was 46.54, ranging from 45-49, classified as good (Meher *et al.*, 2015; Yadav *et al.*, 2010).

Results of WQI can ranked as site 3 (48.12) > site 1 (46.28) > site 2 (45.23). Despite the moderately acceptable WQI the current situation in Macabalan creek can be aggravated owing to proliferation of adjacent establishments (within the 20 m buffer zone).

In return the effluent runoff from the residential area, salt factory, and other establishments may consequently alter the water quality.

Table 9. RQ analyses of the studied sites.

Parameter	Site 1	Site 2	Site 3
pH	1.28-0.85	1.29-0.86	1.30-0.87
Temperature	1.10-0.86	1.10-0.86	1.12-0.87
DO	0.49-0.19	0.47-0.19	0.46-0.18
Conductivity	0.02	0.03	0.03
Salinity	4.86 x 10-3	5.48 x 10-3	5.79 x 10-3
TDS	0.01	0.01	0.02
Alkalinity	0.39	0.41	0.72

Table 10. WQI of study site 1.

Parameter	Weight (Wa)	Relative weight (Wr)	Qi	Si
pH	4	0.1667	86	14.34
Temperature	1	0.0417	86	3.59
DO	5	02083	108.58	22.62
Conductivity	5	0.2083	2.38	0.50
Salinity	3	0.1250	0.58	0.07
TDS	4	0.1667	1.31	0.22
Alkalinity	2	0.0833	59.29	4.94
WQI				46.28

Table 11. WQI of study site 2.

Parameter	Weight (Wa)	Relative weight (Wr)	Qi	Si
pH	4	0.1667	86	14.34
Temperature	1	0.0417	86	3.59
DO	5	02083	108.83	22.67
Conductivity	5	0.2083	4.35	0.91
Salinity	3	0.1250	0.55	0.07
TDS	4	0.1667	1.47	0.25
Alkalinity	2	0.0833	40.85	3.40
WQI				45.23

Table 12. WQI of study site 3.

Parameter	Weight (Wa)	Relative weight (Wr)	Qi	Si
Ph	4	0.1667	87	14.50
Temperature	1	0.0417	87	3.63
DO	5	02083	109.08	22.72
Conductivity	5	0.2083	4.68	0.97
Salinity	3	0.1250	0.579	0.07
TDS	4	0.1667	1.56	0.26
Alkalinity	2	0.0833	71.70	5.97
WQI				48.12

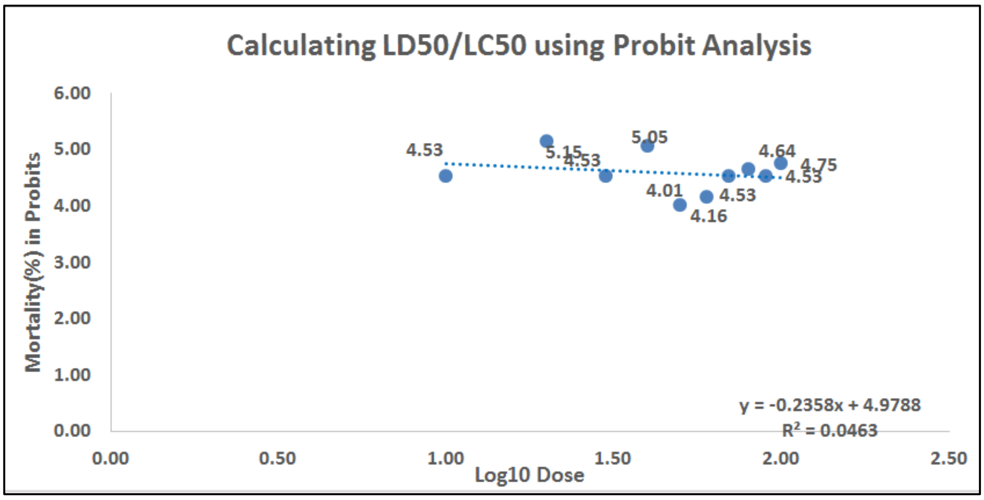

Fig. 2. Probit graph of site 1 toxicity test.

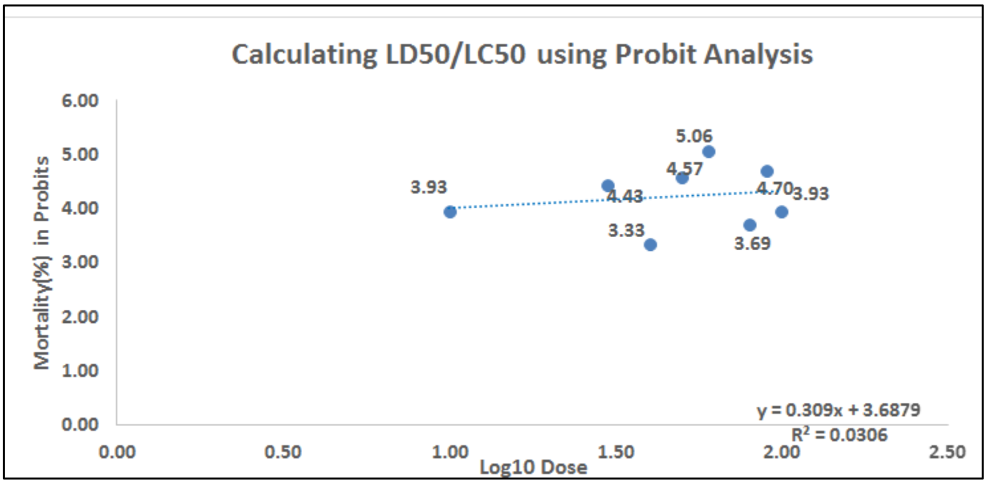

Fig. 3. Probit graph of site2 toxicity test.

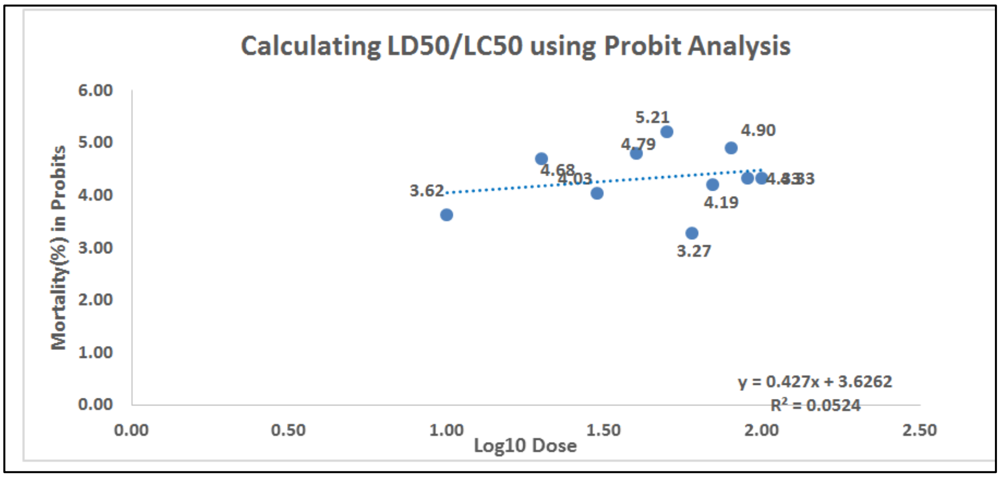

Fig. 4. Probit graph of site 3 toxicity test.

Table 13. Summary of LC50 per sampling site.

Station	Slope	Intercept	R^2	LC50
1	-0.236	4.979	0.046	0.980
2	0.309	3.688	0.031	3331.348
3	0.427	3.626	0.052	1201.062
Mean				1511.13

Toxicity test

Toxicity test using BSLT was performed to extrapolate potential risk of the studied creek wastewater. Results showed variability per site studied (Fig. 2-4) using probit analysis.

Calculated LC50 was higher in site 2 (3331.348) than site 3 (1201.062) and site 1 (0.980). Overall the calculated mean LC50 in Macabalan creek was 1511.13 (Table 13).

Conclusion

The overall water quality of Macabalan creek, Cagayan de Oro was within the standard set except for the extremely low DO concentration. Site specific variation was evidenced among studied parameters with positive correlation for TDS, salinity, and conductivity. Environmental risk analysis using RQ, WQI, and toxicity test similarly indicate a moderately acceptable estimate for water quality. Extrapolating from this the studied site needs monitoring to ensure water quality of creek water/wastewater discharged to coastal bodies.

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