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Environmental risk assessment of sediment and water in Cansaga Bay, Philippines

Van Ryan Kristopher R. Galarpe*[1], Jacquelyn Tanjay[2], Jemma Lucitte Aaron[2], Ma. Ligaya Suico[3], Anthony Ilano[2]

[1]*Department of Environmental Science and Technology, University of Science and Technology of Southern Philippines, Cagayan de Oro, Philippines*

[2]*Biology Department, University of San Carlos, Cebu, Philippines*

[3]*Chemistry Department, University of San Carlos, Cebu, Philippines*

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Abstract

Physicochemical analysis of Cansaga Bay, Cebu, Philippines was conducted to evaluate bay water and sediment for environmental risks brought by proposed reclamation and development. The main objective was to provide baseline data about the bay prior to development. Analyzed parameters for bay water were dissolved oxygen (DO), pH, % salinity, temperature, total phosphate (PO_4^{3-}-P), ammonia-nitrogen (NH_3-N), and total heavy metals (chromium (Cr), lead (Pb), and cadmium (Cd)) and for bay sediments were Pb, Cd, and Cr in total form. Overall, the temperature, pH, DO, and % salinity of bay water were within the permissible limit. However, nutrient loading was pronounced as evidenced by high PO_4^{3-}-P and NH_3-N with RQ values > 1. Particularly, Pb and Cd in bay water exceeded the threshold indicating higher environmental risk (RQ >1). The Cd in sediment reached the midrange effect for sediment quality guideline, indicating strong contamination (CF > 6). Despite the high levels of Cd in sediment the bay was less likely polluted as evidenced by PLI values <1.

***Corresponding Author:** Van Ryan Kristopher R. Galarpe ✉ vanryangalarpe@gmail.com

Introduction

The state of development in Cebu, Philippines had brought environmental ill effects to its resources evidenced by the studies on landfill (Nazareno *et al*., 2011; Galarpe and Parilla, 2012; Galarpe and Parilla, 2014) , water quality (Flores and Zafallara, 2012), and plants (Mendoza and Hipe, 2008).

In the province, recent studies on river water quality similarly showed potential anthropogenic inputs (Oquiñena-Paler and Ancog, 2014; Maglangit *et al*., 2014; Maglangit *et al*., 2015) from industries and domestic wastewater. Water carrying dissolved and suspended contaminants are drained to adjacent coastal waters.

Locally, Cansaga Bay which is located in the metropolitan district is home to heavily industrialized city in the northeast coastline part of Cebu. Common threats in the bay involved pollution of the coastal area which was previously ringed by natural wetlands. Among the residual patches of mangroves are commercial developments such as ship building, aquaculture, and housing projects. Reclamation of the bay was planned by the local government to expand the province areas of jurisdiction. This was viewed to constrict the bay leading to poor hydrodynamic circulation and loss of habitat.

Cansaga Bay is classified as Class SC under the Philippine government environmental legislation intended for propagation of fish, commercial and sustenance fishing, boating, breeding sites for fish and other aquatic life (marine sanctuary) (Crawford, 2000). It is a priority wetland (inland and freshwater) listed in the National Wetlands Action Plan for the Philippines 2011-2016 (DENR PAWB, 2011). The bay was also identified by the International Union for Conservation of Nature (IUCN) with Identified Bird Area (IBA) number of seventy (Mackinnon *et al*., 2012). Biodiversity assessment also revealed species of mangroves, fish, algae, and invertebrates in the bay (Ancog *et al*., 2012). The socio-ecological importance and pressing development in the bay necessitates the conduct of this study.

Globally, studies conducted on wetlands revealed that anthropogenic activities contaminated the water, sediment, aquatic life (Herve *et al*., 2010; Chen and Jiao, 2008) and mangroves (Praveena, 2007). Considering the occuring developments in the bay it was seen timely to carry an environmental quality monitoring and risk assessment. The main objective was to provide baseline data about the bay. This was carried by conducting physicochemical analyses of both bay water and sediment to evaluate if pollution and contamination loading is occuring. To further estimate the environmental quality of Cansaga Bay an environmental risk analysis was employed by using risk quotient (RQ), contamination factor (CF), and pollution load index (PLI) of the studied parameters.

Materials and methods

Location and Land Area of the Municipality of Consolacion-Cansaga Bay

Cansaga Bay occupies an area of approximately 850 ha located in the northeast coastline portion of Cebu Island. It is within the political jurisdiction of Mandaue City and the Municipalities of Consolacion and Liloan (see Fig. 1). Specifically, it is the Municipality of Consolacion, which fringes the larger area of the bay.

It is located along the foreshore of Barangay Tugbongan and Nangka to the northwest; Barangay Pitogo and Jugan to the northeast; Barangay Tayud to the southeast and the proposed Mandaue North Reclamation Project to the southwest.

It is part of identified IBA of which includes a complex of shallow sea bays and channels, extensive intertidal sand flats and mudflats, mangrove swamps, fishponds, saltpans and seaweed culture ponds, with coral reefs offshore. The area includes the mangroves, sand flats and fringing coral reefs of southern and western Mactan Island; the narrow Mactan Channel which separates the island from the Cebu mainland; the adjacent mainland coast (including Kalawisan Bay, Cansaga Bay and the estuary of the Cansaga River) (Birdlife International, 2014).

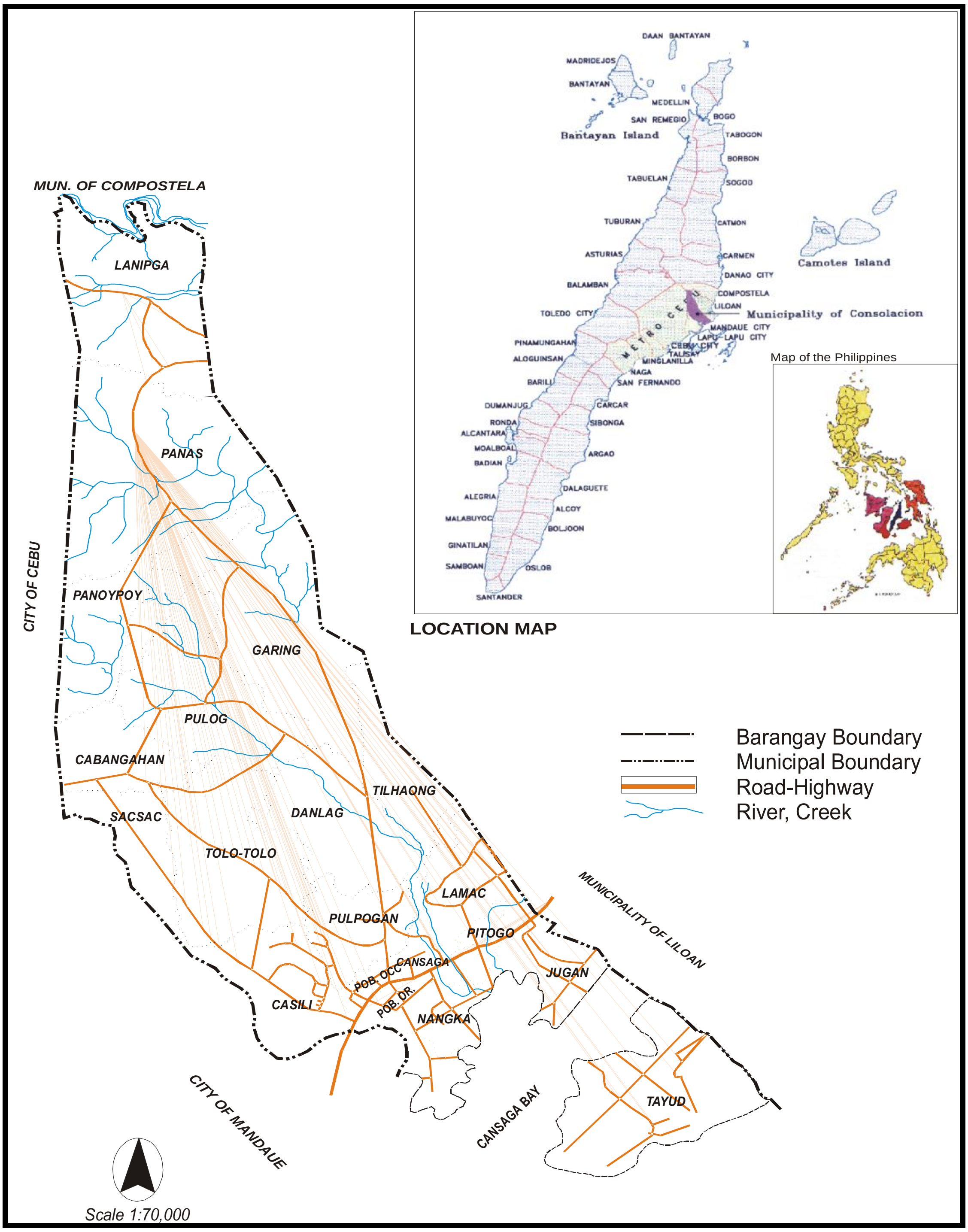


Fig. 1. Administrative map of the study site.

Collection of bay water and sediment samples

Three stations were chosen consisting of three clusters for sampling both water and sediments (see Table 1 and Fig. 2). The three clusters per station were estimated at 15-20m apart. This was employed to have a composite sample per station owing to resource constraint. Sediment samples were taken using round borer (approximately of 2 in diameter). Sediments samples of 1000 g/cluster were stored into a polyethylene plastic bag. Composite samples were prepared of the collected sediments. Air drying was employed to eliminate moisture prior to metal analysis. Seawater samples were collected for each area such as that of sediments.

Approximately 1 L of water samples were collected into prewashed polyethylene containers. Composite sample was prepared by mixing homogenously the collected samples per station with three clusters. Samples for NH_3-Nitrogen and PO_4-P analyses. Were preserved with conc. H_2SO_4 subjected to pH<2 and were stored at below 4°C. Samples for heavy metals were acidified with conc. HNO_3 at pH <2 and were stored below 4°C below until analysis (APHA, 1998).

Table 1. Location and description of studied areas and its cluster.

Area code	Studied Area	Cluster description	Latitude	Longitude
A	Commercial area	1-bay area near ship yard	10°21'00'3"	123°58'11.31"
		2-bay area adjacent to reclaimed lot	10°22'01.2"	123°58'21.8"
		3-bay area adjacent to a dumpsite	10°22'12.9"	124°00'28.7"
B	Aquaculture area	1-inner bay area with mangrove cover	10°20'56.1"	123°58'05.5"
		2-inner bay area with fish ponds	10°22'01.2"	123°58'21.8"
		3-inner bay area with oyster plots	10°22'11.1"	124°00'27.4"
C	Industrial area	1-facing Mactan Channel	10°20'59.5"	123°58'04.3"
		2-facing Mactan Channel	10°22'01.2"	123°58'32.4
		3-facing Mactan Channel	10°22'09.8"	124°00'25.5"

Fig. 2. DOST-Project NOAH Location Map of Cansaga Bay, Philippines (given with codes A-commercial area cluster, B-aquaculture area cluster, and C-industrial area cluster).

Physicochemieal and lyses of bay water

In-situ analysis for dissolved oxygen (DO), % salinity, pH, and temperature were carried to directly assess physicochemical properties of seawater in Cansaga Bay. Temperature was measured using the temperature probe found in the DO meter. Pre-calibrated pH meter with buffers 4 and 7 were used to determine the pH. Salinity measurements were done using a refractometer. Dissolved oxygen was measured using pre-calibrated DO meter. The samples were analyzed for ammonia-nitrogen and total phosphate (phosphorous) using phenate and stannous chloride method, respectively. Analyses were conducted in DENR-EMB Region 7 Laboratory

Heavy metal analyses in sediments and bay water

Acid digestion for both seawater and sediment samples were done using conc. HNO_3 acid and 1:1 HCl. About 100 mL of the acidified seawater samples were heated near to dryness, cooled to room temperature and added with 5mL conc. HNO_3 acid (APHA, 1998).

The cooled seawater samples were further added with 5mL of 1:1 HCl and heated almost to dryness until sufficient digested samples were collected. The digested samples were filtered with Whatman no. 41 filter paper and diluted with distilled water to a final volume of 100mL prior to spectrophotometric analysis.

Air dried sediment samples were corrected for its percent moisture by heating the pre-weighed samples for 24h in the oven set at 105°C. Digestion was done using conc. HNO_3 and 1:1 HCl. About 1g of the percent moisture corrected sample was added with 3mL conc. HNO_3, heated near to dryness and was cooled. The cooled samples were added subsequently with 3mL conc. HNO_3 covered with watch glass and heated near to dryness until sufficient digestion process occurs. The digested samples were filtered with Whatman no. 41 filter paper and diluted with distilled water to a final volume of 100mL. Diluted samples were analyzed using Atomic Absorption Spectrophotometer for total lead (Pb), total cadmium (Cd) and total chromium (Cr). Pre-calibration were carried at the instruments detection limit using the following standards: 0.10ppm, 0.25ppm, 0.50ppm, 0.75ppm, and 1.0ppm for all assessed metals. A blank analysis for sediment was also employed. All glassware's used throughout the study were prewashed with 20% HNO_3 to eliminate traces of metal residues as potential contaminants.

Data analyses

Q-test was employed to eliminate outliers in the physicochemical analyses. One-way ANOVA was also used to test if there was a significant difference on the nutrient load between sampling sites. Arithmetic mean and standard deviation were also determined for the rest of the parameters. To estimate the risk brought by studied parameters in the bay water, RQ was determined. It is the ratio between determined concentrations of analyzed parameter to that of the available standard. A calculated RQ < 1 means low risk, whereas RQ $\geq$1 means high risk (GEF/UNDP/IMO, 2004). To evaluate sediments environmental index both CF and PLI were calculated.

CF in sediments was calculated using the following ratio CF = [Conc. $_{\text{heavy metal}}$]/[Conc. $_{\text{background}}$]. The background level of the metal was based from the World Shale Value (Turekian and Wedepohl, 1961). The contamination levels was then classified based on their intensities on a scale ranging from 1 to 6 (0 = none, 1 = none to medium, 2 = moderate, 3 = moderately strong, 4 = strongly polluted, 5 = strong to very strong, and 6 = very strong) (Bentum *et al.*, 2011). PLI was also determined in a given site acording to the following equation (Tomlinson *et al.*, 1980): PLI = $(CF_{Cd} \times CF_{Cr} \times CF_{Pb})^{1/3}$. A PLI > 1 indicates pollution whereas a PLI <1 indicates no pollution (Barakat *et al.*, 2012).

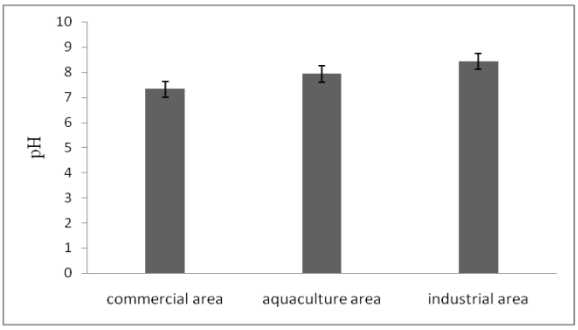
Results and discussion

Physicochemical quality of bay water

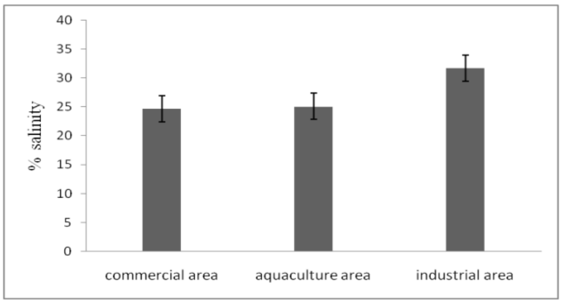
The determined DO values for each site essentially differ with concentrations commercial area: 2.99111mg/L, aquatic are: 5.34778mg/L, and industrial area:1 0.4167mg/L (see Fig. 3). The commercial area showed the lowest DO as well as the highest transparency among the three stations. This is typical in most polluted water bodies owing to close proximity to human settlements. By observation the commercial area was adjacent to a dumpsite and a small scale ship building firm. Presence of water pollutants can lower the DO substantially as a result of organic matter discharges (Chapman, 1996). The commercial area for bay water sample failed to meet the minimum threshold value for national standards (DENR-DAO Directive for Class SC water). This was in agreement with the monitoring conducted by in 2002 obtaining DO <4mg/L (DENR EMB, 2007) Further, DO levels <0.02mg/L may somehow impair marine life by deprivation of bio-available oxygen leading to fish death (Chapman, 1996). Consequently, levels of DO in water decreases as temperature and salinity increases (Chapman 1996). This parameter may not however conclusively suggest water pollution index.

Relative to this, the determined pH is within the standards set by DENR-DAO Directive for Class SC water. Further, the obtained temperature values signify absence of possible thermal activity or thermal discharges to the bay. Comparable results were also obtained for % salinity common among seawater's to be characterized as higher.

The general trend for physiochemical parameters can be ranked in the following order: industrial area > aquaculture area > commercial area

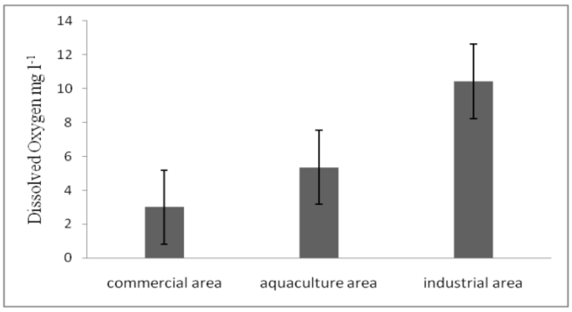


A



B

Fig. 3. Selected physicochemical water quality in Cansaga Bay a) pH; b) % salinity.



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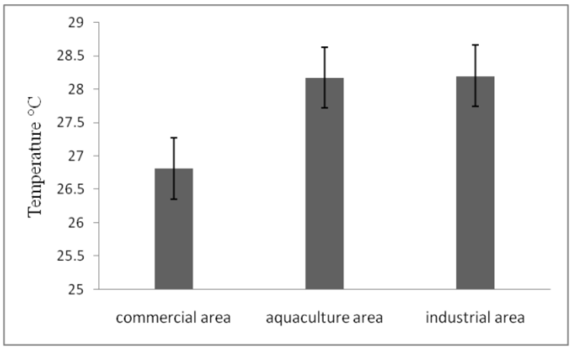

D

Fig. 3. Selected physicochemical water quality in Cansaga Bay c) DO; d) temperature (continued..).

Nutrient loading in bay water

The determined NH_3-N in Cansaga Bay can be ranked in the following order: commercial area > aquaculture area > industrial area. Elevated NH_3 was found in the commercial area ($p = 0$; $F = 217.103$) as a result of domestic waste load to the bay. Generally, all areas studied for NH_3-N were beyond the general standard which is 0.02mg/L (PHILMINAQ, 2006).This is one determining factor (Chapman, 1996) which may bring detrimental ecological imbalances in the water bodies. Overall, the NH_3-N in Cansaga Bay was beyond the standards set. Table 2 presents the summary of results. The obtained PO_4^{3-}-P value indicated less variability ($p = 0.825$; $F = 0.199$) among stations. Potential sources of phosphorous are wastewater and septic effluents, detergents, fertilizers, soil run-off (as phosphorous bound in the soil will be released), phosphate mining, industrial discharges, and synthetic materials which contain organophosphates (Miller, 2000) which were seen to be likely drained in the bay.

Table 2. Nutrient loading in bay water, Cansaga Bay.

Station	PO_4^{3-}-P (mg/L)[a]	NH_3-N (mg/L)[b]
Commercial area	0.258734 ± 0.003393	0.444308 ± 0.046313
Aquaculture area	0.388047 ± 0.002490	0.019159 ± 0.013798
Industrial area	0.000652 ± 1.33×10^{-19}	0.036833 ± 0.008200
Mean ± S.D.	0.21581 ± 0.19723	0.16677 ± 0.24052
ASEAN-AMEQC 1999 Standard [c]	0.015	0.07
Australian-ANZECC 2000 Standard [c]	<0.05	<0.01

[a] not significant ($p > 0.05$); [b] statistically significant ($p<0.05$); [c] (PHILMINAQ, 2006).

Another factor to consider is the susceptibility of marine environment to phosphorous fluctuation associated to algal blooms (Wahab *et al.*, 2011), red tides, and fish kills. Other than external sources are the dissolution of inorganic and organic bound nutrients in the sediment as a result of waves, upwelling currents, wind generated by currents, and storms (Wahab *et al.*, 2011). In comparison, the determined nutrient load in Cansaga Bay associated to PO_4^{3-}-P and NH_3-N were found to be lesser compared to Manila Bay which was highly eutrophicated (Chang *et al.*, 2009). Generally the determined PO_4^{3-}-P in Cansaga Bay were beyond the standards.

Table 3 presents the computed RQ for inorganic nutrients in the bay water. The RQ for PO_4^{3-}-P was higher in the aquaculture area maybe associated to the feeds and waste discharges although calculated RQ for NH_3-N contradicts the findings. Overall, both nutrients showed RQ values >1 indicating high environmental risk to water quality

Table 3. Environmental Risk Quotient (RQ) of inorganic nutrients in Cansaga Bay water.

Parameter and stations	Environmental risk quotient (RQ) [a]			
	ASEAN-AMEQC (1999) Standard[b]	RQ	Australian-ANZECC (2000) Standard [b]	RQ
PO_4^{3-}-P (mg L^{-1})	0.015		<0.05	
Commercial area		17.24		0.52
Aquaculture area		25.87		7.75
Industrial area		0.04		0.01
Mean		14.38		2.76
NH_3-N (mg L^{-1})	0.07		<0.01	
Commercial area		6.35		44.43
Aquaculture area		0.27		1.92
Industrial area		0.53		16.68
Mean		2.38		21.01

[a]RQ < 1 low risk; RQ $\geq$1 high risk, [b] (PHILMINAQ, 2006).

Heavy metals in bay water

Results for studied metals (total form of Pb, Cd, and Cr) in Cansaga Bay are shown in Table 4. All studied areas were beyond the threshold value for Cd (0.01ppm).

This metal can be generated as waste from electroplating, nickel plating, smelting, engraving, batteries, sewage sludge, fertilizers, paints, pigments, plastics and waste disposal yard (Alloway and Ayres, 1997; Manahan, 2001; Bagchi, 2004; Cumar and Nagaraja, 2011; Galarpe and Parilla, 2014). Deposition of Cd may be associated to anthropogenic sources considering that it was uniformly distributed in the bay (Velasquez *et al.*, 2002).

Primarily commercial and industrial activities proximal to the bay. Although it was not clearly demonstrated in this study owing to lack of sample size but Cd to PO_4^3 has been studied to have association (Hendry *et al.*, 2008). This was evidenced by r^2=0.75 for Cd-PO_4^{3-} in this study. Overall, the Cd concentration can be ranked in the order: industrial area > aquaculture area > commercial area.

Table 4. Selected heavy metals (total form) in bay water.

Station	Heavy metals (ppm) in total form		
	Cr	Cd	Pb
Commercial area	0.07	0.085	0.047
Aquaculture area	0.052	0.092	0.075
Industrial area	0.105	0.12	0.048
Mean ± SD	0.07567 ± 0.02695	0.099 ± 0.01852	0.0567 ± 0.01589
Philippines DENR DAO 1990 Standard	NA	0.01	0.05

Cr was also determined to be relatively higher among sampled stations. Considerably, Cr can be associated to subsequent production of stainless steel, paint pigments, and wood preservatives (Hughes, 1996). Existing practices such as local ship building and the adjacent dumpsite may have contributed to possible contamination of the bay water.

Presence of Cr in a water body can be detrimental since it is considered as contact allergen and carcinogenic (Hughes, 1996). The Cr levels among the studied areas can be ranked in the following order: industrial area > commercial area > aquaculture area.

Likewise, Pb was also determined to be higher in the aquaculture area (0.075ppm) where most of the oyster plots and aquaculture ponds in the inner bay area were found owing poor water circulation. Comparatively, Pb concentrations in the commercial area (0.047ppm) and the industrial area (0.048ppm) passed national regulation (0.0500ppm) although the mean value (0.0567 ppm) of the entire site exceeded the regulation.

However, this may still pose health and environmental implications considering that it nearly exceeded the standard limit. It is inevitable that these values may likely increase as gradual bioaccumulation occurs. The high Pb concentration reflects the characteristic of industry pollution (Wang *et al.*, 2010). Further, Pb can be deposited from condensation of vehicular exhausts in the atmosphere, batteries, lead smelters and sewage discharge (Hughes, 1996).

Similarly, moorings of the ships may likely be associated to the high levels of Pb (Wang *et al.*, 2012). Ship breaking activities can slightly pollute seawater with Pb and Cd (Wang *et al.*, 2012). In general, the industrial area was found to have higher concentrations of the studied metals compared to the commercial and aquaculture areas, respectively.

To quantify the environmental risk brought by Cansaga the RQ values were determined for both Cd and Pb with available standards in total form. RQ for Cd in studied areas can be ranked industrial> aquaculture> commercial, whereas for Pb aquaculture> industrial> and commercial. Regardless of studied stations it was found out that Cd in Cansaga Bay water posed high risk given that RQ >1.

For Pb environmental risk was found to potentially cause chronic effect to marine ecosystem (US EPA marine chronic criteria) but unlikely to acute criteria. Nonetheless, the calculated RQ for Pb in Cansaga Bay water $\geq$ 1. Both Cd and Pb posed environmental risks (RQ >1). The RQ for total Cr was not determined owing to absence of reference standard. Summary of results are shown in Table 5.

Table 5. Environmental Risk Quotient (RQ) of Cd and Pb in Cansaga Bay water.

Parameter and Station	Environmental risk quotient (RQ) [a]							
	Philippines DENR DAO 1990		ASEAN Marine water quality criteria		US EPA marine chronic criteria		US EPA marine acute criteria	
	Standard (ppm)	RQ	Standard (ppm)	RQ	Standard (ppm)	RQ	Standard (ppm)	RQ
Cd	0.01		0.01		0.0088		0.04	
Commercial area		8.50		8.50		9.66		2.13
Aquaculture area		9.20		9.20		10.45		2.30
Industrial area		12.00		12.00		13.64		3.00
Mean		9.9		9.9		11.25		2.48
Pb	0.05		0.0085		0.0081		0.210	
Commercial area		0.94		5.52		5.80		0.22
Aquaculture area		1.5		8.82		9.26		0.36
Industrial area		0.96		5.65		5.93		0.23
Mean		1.13		6.66		6.93		0.27

RQ < 1 low risk; RQ $\geq$1 high risk.

Heavy metals in Cansaga Bay water compared to studies elsewhere

Table 6 presents the comparative analysis of the studied metals in Cansaga Bay to studies elsewhere. The mean Cd level in Cansaga Bay were found to be higher than the cited studies (Meng *et al.*, 2008; Basha *et al.*, 2010; Wang *et al.*, 2010; Wang *et al.*, 2012; Hasan *et al.*, 2013; Looi *et al.*, 2013) but lower compared to Safaga Bay, Egypt (Wahab *et al.,* 2011).

The mean Cr level in Cansaga Bay were found to be higher than the findings in Sitakund Upazilla, Bangladesh-0.04ppm (Hasan *et al.,* 2013), Bohai Bay, China-0.0004ppm (Meng *et al.*, 2008), Straits of Malacca-0.00035ppm (Looi *et al.*, 2013), and Mithapur, Gujarat, India-1.151 x10^{-8}ppm (Basha *et al.*, 2010). The mean level on the other hand was found comparable to the findings in Sitakund Upazilla, Bangladesh- 0.07ppm (Hasan *et al.,* 2013).

Table 6. Selected heavy metals (total form) in Cansaga Bay water compared to other studies elsewhere.

Area	Heavy metals (ppm)			Reference
	Cd	Cr	Pb	
Cansaga Bay	0.099	0.07567	0.0567	This study
Safaga Bay, Egypt	0.13	-	1.12	Wahab *et al.* (2011)
Luoyuan Bay, China	0.00031	-	0.00083	Wang *et al.* (2010
Jinzhou Bay, China	0.00092	-	0.00061	Wang *et al.* (2012)
Sitakund Upazilla, Bangladesh	0.0034	0.04	0.07	Hasan *et al.* (2013)
Bohai Bay, China	0.00012	0.0004	0.00718	Meng *et al.* (2008)
Straits of Malacca	0.00058	0.00035	0.00237	Looi *et al.* (2013)
Mithapur, Gujarat, India	5.004 x 10^{-9}	1.1510x10^{-8}	7.790x10^{-8}	Basha *et al.* (2010)

Heavy metals in sediments

The analyzed heavy metals in sediments can be ranked in the order: Cr> Cd> Pb (see Table 7). The Pb in the commercial area (2.7749ppm) was found higher than the industrial area (0.2315 ppm) and aquaculture area (0.0947).

Although the concentration in the aquaculture area was not found to be detrimental, however enrichment from the commercial and industrial area may likely occur during high tides. Similarly, the Cd level in three areas can be ranked: industrial area (3.7387ppm) >commercial area (2.3927ppm)> aquaculture area (2.2231ppm).

The presence of Cd might originate from anthropogenic sources (Wahab *et al.*, 2011) since it goes beyond the natural background level. The Cr in the commercial area (29.9269ppm) was also found higher as compared to industrial area (19.3798ppm)> aquaculture area (17.3171ppm). All studied metals in sediment samples were found uniformly high in the commercial and industrial areas suggesting metal draining from existing activities. Both commercial and industrial areas were located in a highly urbanized portion of the bay which included a ship building company. Study of Singh and Turner (2009) found out high levels of Pb (1800ug/g) and Cr (1200ug/g) in sediments with antifouling residues from boat facility.

The aquaculture area was located in the inner bay thus enrichment might not be high owing to less hydrodynamic energy and less shipping activities. However, deposition in the surface bay water was found out higher in the aquaculture area (see Table 4) which can be accounted to the lesser levels in sediments.

Table 7. Selected heavy metals (total form)s in Cansaga Bay sediment.

Station	Heavy metals (ppm) in total form		
	Pb	Cd	Cr
Commercial area	2.7749	2.3927	29.9269
Aquaculture area	0.0947	2.2231	17.3171
Industrial area	0.2315	3.7387	19.3798
Mean ± SD	1.0337 ± 1.510	2.7848 ± 0.830	22.2079 ± 6.764

Mangrove patches (*Avicennia* sp., *Sonneratia* sp. and *Rhizophora* sp.) were dominantly found in the aquaculture area which may influence the activity of metal binding in sediments. Mangrove forest sediments can provide a sink for trace metals, promoting the accumulation of fine-grained organic matter-rich sediment, which is usually sulphidic due to the presence of sulphate-reducing bacteria (Clark *et al.,* 1998). Direct adsorption, complexing with organic matter, and the formation of insoluble sulphides all contribute to the trapping of metals (Clark *et al.,* 1998). It was also noticeable that Pb in the aquaculture was lower in sediment (Table 7) but higher in the bay water (Table 4). This can be associated to lower mobilizing capacity of mangroves for non-essential metal like Pb in sediment (Macfarlane *et al*., 2007), as a consequence it may resolubilize in the water column.

Although Cd is nonessential metal it was found out lower in the aquaculture area sediment. Study of reference (Parvaresh *et al*., 2011) Cd in sediments grown with *Avicennia marina* were comparable to this study. On the other hand.

The consistency of lower Cr levels in both sediments and bay water indicated its potential bioaccumulation to mangroves as an essential metal. The capacity of *A. marina* to bioaccumulate Cr than nonessential metal had been studied (Usman *et al*., 2013).

Sediments contamination and pollution indices

To estimate level of contamination and pollution in Cansaga Bay sediment both CF and PLI were calculated. Summary of results are shown in Table 8. Overall, the CF for Pb and Cr were<1 indicating medium contamination whereas for Cd was found 6 <indicating strong contamination. The CF in studied areas can be ranked as industrial> commercial> aquaculture. The PLI of studied areas can be ranked in the order of commercial> industrial> aquaculture.

The calculated PLI were found <1 in all areas indicating less to no pollution (see Table 8). Although pronounced Cd level was found in the industrial area of the bay with high CF considerably the pollution loading was still less. Both indices showed that the studied metals in total form in Cansaga Bay were less likely affected by anthropogenic discharges.

Table 8. Pollution indices of Cansaga Bay sediment.

Station	CF			PLI
	Pb	Cd	Cr	
Commercial area	0.1387	7.9757	0.0266	0.308728
Aquaculture area	0.0047	7.4103	0.0247	0.095107
Industrial area	0.0116	12.4623	0.0415	0.181706
Mean	0.0517	9.2828	0.0651	0.19518

Comparison to sediment quality guidelines and studies elsewhere

The Cd in sediment were comparable to Ha long Bay, Vietnam-0.09ppm (Ho *et al*., 2010) but lower than the study in Quanzhou Bay, China-0.28-0.89ppm (Yu *et al.,* 2008), eastern Beibu Bay.

South China Sea-0.16ppm (Dou *et al.,* 2013), and Bohai Bay, China-0.22ppm (Gao and Chen, 2012). Generally, both Pb and Cr level in Cansaga Bay were generally lower compared to other studies elsewhere (Yu *et al*., 2008; Ho *et al*., 2010; Fang, 2011; Gao and Chen, 2012; Dou *et al.,* 2013) (Table 9). Both Pb and Cr in Cansaga Bay sediments were lower compared to threshold sediment quality guidelines, whereas the Cd exceeded the threshold guidelines (see Table 10). This indicated that Cd reached the midrange effect sediment guideline (Burton, 2002; Long *et al*., 1998; Macdonald *et al*., 2000).

The Cd depositions in sediments were brought by anthropogenic sources and may likely affect aquatic life. This was also evidenced by the CF value for Cd (9.2828) indicating strong contamination. This was found in agreement with the higher RQ values of Cd in bay water.

Table 9. Selected heavy metals (total form) in Cansaga Bay sediment compared to other studies elsewhere.

Area	Heavy metals (ppm)			Reference
	Cd	Cr	Pb	
Cansaga Bay	0.099	0.07567	0.0567	This study
Safaga Bay, Egypt	0.030	-	5.64	Wahab *et al.* (2011)
Luoyuan Bay, China	0.00031	-	0.00083	Wang *et al.* (2010)
Ha long Bay, Vietnam	0.09	27	16	Ho *et al.* (2010)
Quanzhou Bay, China	0.28-0.89	51.1-121.7	34.3-100.9	Yu *et al.* (2008)
Eastern Beibu Bay, South China Sea	0.16	53.65	27.99	Dou *et al.* (2013)
Bohai Bay, China	0.22	101.4	34.7	Gao and Chen (2012)
Marine sediments and coast areas in East and Southeast Asia 2000-2010	0.13-0.18	0.9-96	1-111	Fang (2011)

Table 10. Heavy metals (total form) in Cansaga Bay sediments compared to threshold sediment quality guidelines.

SQG	Heavy metals (mg/kg)			Reference
	Cd	Cr	Pb	
Cansaga Bay	2.7848±0.830	22.2079 ± 6.764	1.0337 ± 1.510	This study
TEL [a]	0.6	37.3	35	Macdonald *et al.* (2000)
ERL [b]	5	80	35	Macdonald *et al.* (2000)
LEL [c]	0.6	26	31	Macdonald *et al.* (2000)
MET [d]	0.9	55	42	Macdonald *et al.* (2000)
CB TEC [e]	0.99	43.4	35.8	Macdonald *et al.* (2000)
EC-TEL [f]	0.68	52.3	30.2	Smith *et al.* (1996)
NOAA ERL [g]	1.2	81	46.7	NOAA (1999)
ANZECC ERL [h]	1.2	81	47	ANZECC (1997)
ANZECC ISQG-low [i]	1.5	80	50	ANZECC (1997)
SQO Netherlands target [j]	0.8	-	85	ANZECC (1997)
Hong Kong ISQG-low [k]	1.5	80	75	ANZECC (1997)

Threshold effect level, [b]effects range low, [c]lowest effect level, [d]minimal effect threshold, [e]consensus based threshold effect concentration, [f]environment Canada, [g]National Oceanic and Atmospheric Administration, [h]Australiza and New Zealand.

Environment and Conservation Council-effects range low, [i]Australiza and New Zealand Environment and Conservation Council-interim sediment quality guideline, [j]sediment quality objective, and [k]Hong Kong-interim sediment quality guideline.

Conclusion

Overall the physicochemical analyses of temperature, pH, DO, and % salinity do not present ecological concerns in the bay. However, the results for nutrient loading in Cansaga Bay was subject to evaluation as evidenced by high PO_4^{3-}-P (0.21581 ± 0.19723mg L^{-1}), NH_3-N (0.16677 ± 0.24052mg L^{-1}), and RQ values > 1. The mean Cd, Cr, and Pb in bay water were relatively high. Particularly, Pb and Cd failed to meet threshold regulations with pronouced RQ values >1 indicating high environmental risk.

The metals in sediment can be ranked Cr>Cd> Pb with Cd exceeding the threshold values reaching the midrange effect for sediment quality guidelines. The CF (>6) for Cd indicate a strong contamination. In contrast the Pb and Cr had CF values <1 indicating medium contamination level. Despite the high levels of Cd in sediment, the bay does reflect pollution load of studied metals as evidenced by PLI values <1.

Given the findings of this study, it is highly recommended to monitor the bay considering that it was classified as a marine sanctuary. Thus, regulation of effluent discharge and reclamation in the bay is recommended.

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