Concentration of Cd, Cr, Cu, Pb and Zn in Water During Southwest Monsoon in Salut-Mengkabong Lagoon, Tuaran, Sabah

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ABSTRACT Concentrations of selected heavy metals (Cd, Cr, Cu, Pb and Zn) in water were determined adjacent to aquaculture sites located in Salut-Mengkabong Lagoon, Tuaran, Sabah. Samples collected from six stations were analyzed by Inductively Coupled Plasma – Optical Emission Spectrometer (ICP-OES). The average concentrations of Cr, Cu Pb and Zn in lagoon water were 3.43 × 10-3, 4.37 × 10-3, 2.55 × 10-2, 1.51 × 10-1mg/L respectively and concentration for Cd was below detection limit. Referring to Malaysia Marine Water Quality Criteria and Standard (MMWQS), concentrations of Cd and Cr were in acceptable range whereas Cu, Pb and Zn were slightly higher than the standard. This study offers result of five heavy metals' concentrations during south-west monsoon which is important reference for aquaculture activities and lagoon water quality management.

KEYWORDS: Heavy metal; Salut-Mengkabong Lagoon; ICP-OES; Southwest Monsoon; MMWQS.
I **Received** 6 August 2019 II **Revised** 10 September 2019 II **Accepted** 27 September 2019 II **Online** 1 September 2019 II © **Transactions on Science and Technology** I
Full Article

INTRODUCTION

Coastline of Malaysia is around 4,800 kilometers long which is bounding with South China Sea. Considering all coasts with direct marine exposure (lagoons, mainland and islands), Sabah has the longest coastline in Malaysia which is around 4,315 km. Sabah borders the South China Sea on its west coast, the Sulu Sea on the northeast and the Sulawesi Sea on its southeast coast. Therefore, Kota Kinabalu's lagoon environment is mostly affected by connected marine environment.

Coastal lagoons are shallow water bodies separated from the ocean by a barrier, connected to it at least temporarily by one or more restricted inlets and usually oriented parallel to the shore (Isla & Iribarne, 2009). Lagoon as one of the main types of coastal ecosystem, it has been explored in variety uses for human activities such as fisheries, aquaculture, port, urban activities and tourist facilities. Lagoon water circulation occurs with sea tide disturbance. Lagoons are vital source of human life in Sabah. Thereinto, Salut-Mengkabong Lagoon is a semi-enclose water body with only one small inlet which located at the west coast of Sabah facing the South China Sea.

The non-stop increase of multiple human activities might result in the lagoon pollution directly or indirectly. Among them, heavy metal concentration in lagoon aquatic system raises considerable attention due to their durability, toxicity and depositional properties. Lagoon acts as an intermediate step in the transport of heavy metals from land to the sea (Kjerfve, 1994). Lagoon is also known as a depositional environment for heavy metals and function as filters by remaining heavy metals from atmosphere, ocean and river for a long time (Kjerfve & Magill, 1989). According to Ohgaki *et al.* (2005), all heavy metals are potentially harmful to most organisms at some level of exposure and absorption. Certain heavy metals from anthropogenic origin are able to accumulate and transfer back to human society through food chain. Heavy metals such as Cd, Co, Cr, Cu, Ni, Pb, Zn could indicate the existence of effluents from industries, households and aquaculture activities (Kjerfve, 1994; Ohgaki *et al.*, 2005).

It is important to carry out long-term monitoring of the lagoon water environment quality especially at area with constant human intervention. Due to the benefits brought by lagoon, numerous studies have been done to investigate the lagoon environment with protentional anthropogenic heavy metal pollution sources in Sabah. Besides atmospheric and fluvial inputs, direct effluents from in situ activities such as shipping and other harbor activities are the most significant source of metals to coastal lagoons (Donazzollo *et al.*, 1981; Lyons & Fitzgerald, 1980).

Thus, the objective of this study is to determine the status of selected heavy metals of cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb) and zinc (Zn) at six stations from May 2016 to September 2016. Monthly variations of heavy metal concentration in water were investigated. The results are compared with Malaysia Marine Water Quality Criteria and Standard (MMWQS). This study, which covers 5 months during the south-west monsoon (SWM) period, serves as a preliminary reference of heavy metal concentration in water adjacent to aquaculture sites in the Salut-Mengkabong Lagoon. It would be a useful reference for future lagoon-based aquaculture activities planning and lagoon environmental management.

METHODOLOGY

Study Area

Salut-Mengkabong lagoon is located in the Karambunai penisula, Tuaran district, which is in the northern part of Kota Kinabalu, the west coast of Sabah, Malaysia. It is a semi-close lagoon with only one small inlet connects with South China Sea. Lagoon water splits into two parts Salut and Mengkabong as shown in Figure 1. The lagoon ecosystem is characterized by mangroves, shallow coastal water and tidal flushing. Increasing pressure of development and anthropogenic activities mainly fisheries and aquaculture along Salut-Mengkabong coastline have raised considerable attention.

Field Sample Collection and Preservation

Water samples were collected from 6 stations (S1-S6) with coordinates given in Table 1. One Station (S1) was set up at lagoon inlet, while three stations (S2-S4) are located in Salut Lagoon and another two stations (S4-S5) are located in Mengkabong Lagoon (Figure 1). Stations S2, S4, S5, S6 are selected as they are adjacent to fish farms.

Field sampling was conducted monthly from May 2016 to Sept 2016. Water samples taken with horizontal Van Dorn sampler were collected using acid-soaked polyethylene bottle (1 Liter) from the surface with approximate depth of 10 centimeters. Icebox was used when transferred water samples from site to laboratory. Afterwards, water samples were filtered with Whatman No.44 filter paper then samples were acidified (pH<2) with concentrated nitric acid (Suprapur 65%) and later kept at 4 ℃ prior to analysis.

Heavy Metal Determination

Hot plate digestions with nitric acid (Suprapur® 65%) were done following method 3030E (APHA, 2005). Exactly 1 ml water sample was digested with 5 ml nitric acid at 100 ℃ for 1 hour until no brown fume was released. Investigated heavy metal concentrations in water samples were analyzed by the ICP-OES (Model: Optima 5300 DV, Brand: Perkin Elmer) straight after digestion were done. The results were then multiplied with dilution factor. The instrument's detection limit for Cd is below 1.0×10^{-4} mg/L. Detection limit for Cr, Cu and Zn is from 1.0×10^{-4} mg/L to 1.0×10^{-3} mg/L while detection limit for Pb is from 1.0×10^{-3} mg/L to 1.0×10^{-2} mg/L.

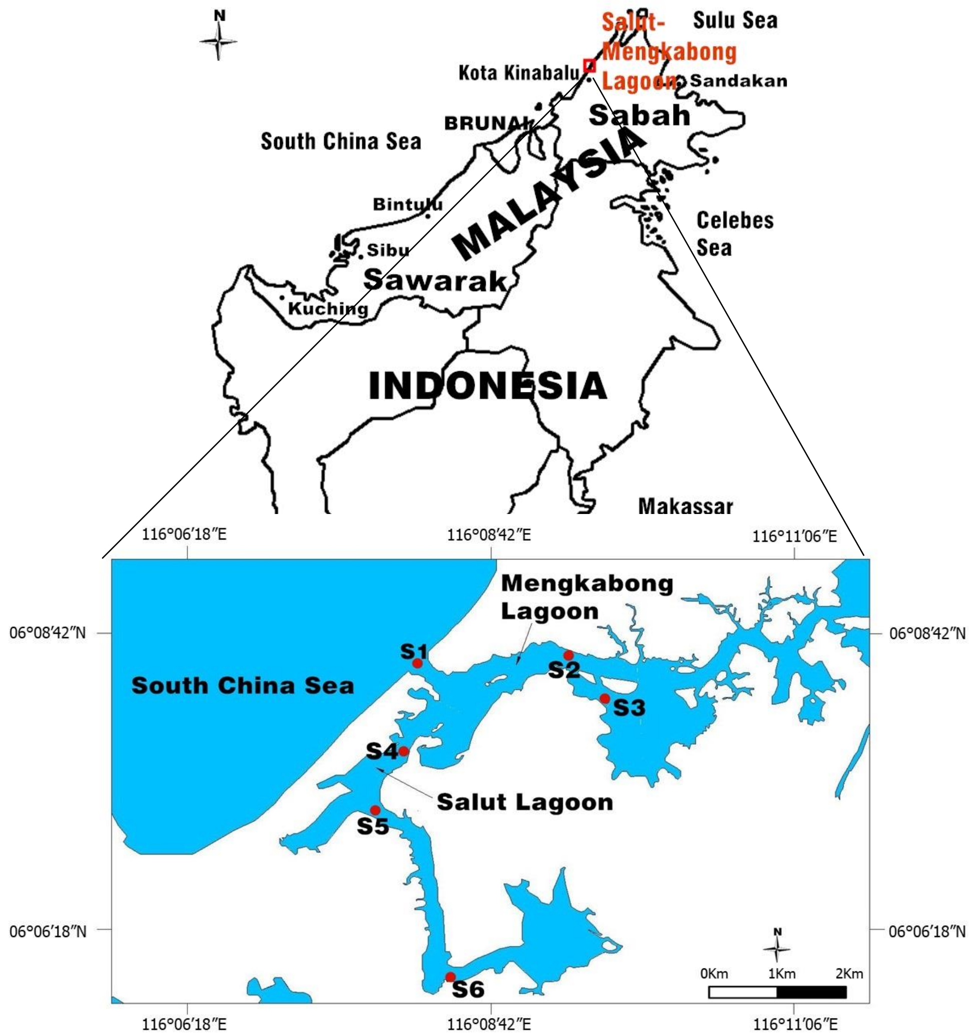

Figure 1. Location of study area and stations (S1-S6) at Salut-Mengkabong Lagoon.

Table 1. The coordinates of sampling stations.

Stations	Latitude	Longitude
1	N 06°08′27.50″	E 116°08′08.55″
2	N 06°08′30.12″	E 116°09′21.28″
3	N 06°08′09.66″	E 116°09′38.53″
4	N 06°07′45.29″	E 116°08′02.33″
5	N 06°07′16.63″	E 116°07′48.77″
6	N 06°05′54.11″	E 116°08′22.68″

RESULT AND DISCUSSION

The heavy metal concentrations except Cd in lagoon water samples for 5 months from May 2016 to September 2016 were summarized in Table 2 and Table 3. Concentrations of Cd of six stations for 5 months were found to be all below the detection limit of ICP-OES. Stations located in Salut and Mengkabong lagoon were considered to be safe from Cd pollution. Mean concentrations of Cr from all stations in water were below MMWQS standard which is 0.01 mg/L, but maximum readings from all stations exceed the standard value. The top two highest mean values of Cr were found in Station 4&6. The concentrations of Cr in water samples were in order of S4>S6>S3>S5>S2>S1.

High concentration of copper was found in Station 2, 5 and Station 6 whereas concentrations for other stations were within the MMWQS standard which is 0.0029 mg/L. Station 6 had the highest mean value of Cu which was 0.0054 mg/L. The concentrations of Cu in water samples at each station with the sequence: S6>S5>S2>S4>S3&S1. Lowest Cu concentration was found in lagoon water inlet Station 1. S5, S6 are located near the innermost lagoon which received less water exchange. Therefore, results indicate that Cu concentration in water decreases from oilgohaline to euhaline water (Annibaldi *et al.*, 2015). Seawater input at high tide shows a dilution effect on Cu concentration in entire lagoon water body. Lagoon water pollution could be attributed from copper-containing fertilizers used for golf club in resorts and domestic waste from nearby villages and resorts, industrial effluents and anti-fouling painted boats are probably the main anthropic sources (Lacerda, 1994). Although Cu concentration was higher than the standard value, Cu-DOM complexes are assumed not to be bioavailable. Thus, high level of Cu may not pose ecological risks to fish in aquaculture area (Hatje *et al.*, 2001).

Table 2. Concentrations (mg/L) of chromium and copper in water during high tide.

Parameter	Cr				Cu			
	Min	Max	Mean	SD	Min	Max	Mean	SD
S1	BDL	BDL	**BDL**	-	BDL	BDL	**BDL**	-
S2	BDL	0.0098	**0.0003**	0.0018	BDL	0.0224	**0.0032**	0.0062
S3	BDL	0.0037	**0.0041**	0.0095	BDL	BDL	**BDL**	-
S4	BDL	0.0728	**0.0078**	0.0184	BDL	0.0112	**0.0028**	0.0065
S5	BDL	0.0372	**0.0025**	0.0086	BDL	0.0552	**0.0095**	0.0165
S6	BDL	0.00451	**0.0059**	0.0132	BDL	0.0777	**0.0107**	0.0232
MMWQS (DOE, 2011)	**0.01**				**0.0029**			

Note: BDL=Below Detection Limit; BDL Cr=1.0×10^{-3}mg/L; BDL Cu=1.0×10^{-4}mg/L

Referring to Table 3, loadings of Pb and Zn were found to exceed the MMWQS standard values. The concentrations of Pb in water samples were in order S1>S2>S3>S4>S5>S6. The concentrations of Zn in water samples were in order S1>S6>S4>S5>S2>S3.

Pb concentration was highest at S1 when seawater first contacts with lagoon water. Pesticide, pigment, industrial waste, discarded wet cell batteries, water pipes, diesel leaking from fishery vehicles and tourism boat transportation could contribute to the enrichment of Pb in water environment (Lewinsky, 2007). Tan *et al*. (2016) argued that high Pb concentration in seawater was determined adjacent to Salut-Mengkabong Lagoon inlet (S1) due to tourist vehicles from resorts. High concentration of Pb in lagoon water might pose potential risk to fish in aquaculture farms. Toxic effects of Pb in fish include disruption of Cl^-, Na^+ and Ca^{2+} regulation and development of black tails, while the principal toxic effects of chronic lead exposure to fish are hematological and neurological (Mager, 2011).

Zn concentration at S1 and S6 showed higher value than other stations. Zn can be considered quite homogeneous at S2, S3, S4 and S5. S6 is located near industrial park which could receive

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industrial discharge under improper management. Lots of resorts involving tourism activities could contribute to Zn pollution in lagoon environment although these are generally widely dispersive in nature (SWA, 2019). More specifically, from other studies, sources of anthropogenic zinc emissions could include: the use zinc-containing products, emissions from power plants, weathering of zinc coated aging pipes and gutters, burning of wastes and leaching from zinc-related fertilizers (IZA India, 2019). Zn can be toxic for fish at increased waterborne levels, while dietary Zn has mild toxic effects on fish. The toxicity of waterborne Zn is mainly harmful to gills by disturbing Ca^{2+} uptake and can lead to hypocalcemia and eventual death (Niyogi & Wood, 2006).

Table 3. Concentrations (mg/L) of lead and zinc in water during high tide

Parameter	Pb				Zn			
	Min	Max	Mean	SD	Min	Max	Mean	SD
S1	BDL	0.1749	**0.0376**	0.0466	BDL	0.6066	**0.2562**	0.2114
S2	BDL	0.1364	**0.0303**	0.0400	BDL	0.3925	**0.1029**	0.1332
S3	BDL	0.0947	**0.0250**	0.0338	BDL	0.2851	**0.0726**	0.0998
S4	BDL	0.1237	**0.0227**	0.0324	BDL	0.5531	**0.1283**	0.1901
S5	BDL	0.1328	**0.0204**	0.0346	BDL	0.3691	**0.1079**	0.1394
S6	BDL	0.1456	**0.0172**	0.0338	BDL	1.4409	**0.2395**	0.4292
MMWQS (DOE, 2011)	**0.0085**				**0.05**			

Note: BDL=Below Detection Limit ; BDL Pb=1.0×10^{-3}mg/L; BDL Zn=1.0×10^{-4}mg/L

Interchange and exchange process of Cu & Zn in water and surface sediment were mentioned by Tan's research (2016) which indicated high Cu & Zn concentration in water mostly was released from surface sediment. High Cu & Zn concentrations were found in lagoon sediment due to anthropogenic pollution in Sabah by other researches. Whereas, concentration of Pb in water and sediment showed significant positive relationship which indicates high background of Pb in the lagoon natural environment other than anthropogenic emission (Tan *et al.*, 2016; Praveena *et al.*, 2007). Praveene *et al.* (2010) also stated anthropogenic source of Cu, Pb and Zn in lagoon environment are mostly due to industrial and domestic sources, construction, tourism and aquaculture activities. In this study, it was noted that pH (7.12-8.26) and salinity (26.87-33.80 ppt) of all stations did not show any role in influencing the concentrations of heavy metals.

CONCLUSION

Concentrations of heavy metals (Cd, Cr, Cu, Pb, Zn) in Salut-Mengkabong Lagoon were determined during the SWM period. The level of heavy metal in lagoon water was different at each station with the sequence: Zn>Pb>Cu>Cr>Cd. The concentrations of Cd, Cr were in the range of MMWQS except for Cu, Pb and Zn. Cu, Pb and Zn concentrations were found to be higher than standard values that might pose risks to aquaculture areas. In consideration of sustainability of aquaculture activities and protection of mangrove environment, more studies are needed to monitor the changing condition of lagoon environment with high anthropogenic activities. For future works, heavy metal analysis in sediment, fishes or other marine organisms could be studied.

ACKNOWLEDGEMENTS

The authors thank the Malaysian Ministry of Education's Niche Research Grant Scheme (NRGS0005) and Universiti Malaysia Sabah for the financial supports.

REFERENCES

[1] Annibaldi A., Illuminati S., Truzzi C., Libani G. & Scarponi G. (2015). Pb, Cu and Cd distribution in five estuary systems of Marche, central Italy. *Journal of Mar Pollut Bull*, **96**, 411-499.

[2] APHA (American Public Health Association). (2005). *Standard Methods for the Examination of Water and Waste Water.* New York, USA: American Public Health Association

[3] DOE (Department of Environment). (2011). *Malaysia Marine Water Quality Criteria and Standard* (https://environment.com.my/wp-content/uploads/2016/05/Marine.pdf). Last accessed on 12 July 2019.

[4] Donazzollo, R., Merlin, O.H., Vitturi, L.M., Orio, A.A., Pavoli, B., Perrin, G. & Rabitti, S. (1981). Heavy metal concentration in surface sediments from the Gulf of Venice, Italy. *Marine Pollution Bulletin*, **12**, 417-425.

[5] Hatje, V., Birch, G.F. & Hill, D.M. (2001). Spatial and temporal variability of particulate trace metals in Port Jackson Estuary, Australia Estuarine. *Coastal and Shelf Science*, **53**, 63-77.

[6] IZA India (International Zinc Association). (2019). *Zinc in the Environment* (http://zinc.org.in/why_zinc/environment/). Last accessed on 12 July 2019.

[7] Isla, F. I. and Iribarne, O. (2009). *Coastal Zones and Estuaries.* Oxford: EOLSS.

[8] Kjerfve, B. (1994). *Coastal Lagoon Processes.* Amsterdam: Elservier Science B.V.

[9] Kjerfve, B. and Magill, K.E. (1989). Geographic and hydrodynamic characteristics of shallow coasrtal lagoons. *Marine Geology*, **88**, 187-199.

[10] Lacerda, L. D. De. (1994). *Biogeochemistry of Heavy Metals in Coastal Lagoons.* Amsterdam: Elsevier B.V.

[11] Lyons, W.B. and Fitzgerald, W.F. (1980). Trace metals fluxes to nearshore Long Island Sound sediments. *Marine Pollution Bulletin*, **11**, 157-161.

[12] Lewinsky, A.A. (2007). *Hazardous Materials and Wastewater: Treatment, Removal and Analysis*. New York: Nova science.

[13] Mager, E. M. (2011). *Homeostasis and Toxicology of Non-Essential Metals.* New York: Elsevier Inc.

[14] Niyogi, S. and Wood, C. M. (2006). Interaction between dietary calcium supplementation and chronic water borne zinc exposure in Juvenile Rainbow Trout, Oncorhynchus Mykiss. *Toxicol. Pharmacol*, **143**, 94–102.

[15] Ohgaki, S., Fukushi, K., Katayama, H., Takizawa, S. & Polprasert, C. (2005). *Southeast Asian Water Environment: Water Intelligence Online (1st ed.).* (http://wio.iwaponline.com/content/4/9781780402987.abstract). Last accessed on 12 July 2019.

[16] Praveena, S.M., Aris, A.Z. & Radojevic, M. (2010). Heavy metals dyanamics and source in intertidal mangrove sediment of sabah borneo island. *Journal of Environment Asia*, **3**, 79-83.

[17] Praveena, S. M., Radojevic, M. & Abdullah, M. H. (2007). The Assessment of Mangrove Sediment Quality in Mengkabong Lagoon: An Index Analysis Approach. *International Journal of Environmental & Science Education*, **2**(3), 60–68.

[18] SWA (Saskatchewan Watershed Authrity). (2019). *Znic*. (http://www.saskh2o.ca/PDF-WaterCommittee/Zinc.pdf on 12th July 2019). Last accessed on 12 July 2019.

[19] Tan, W. H., Tair, R., Aishah, S., Talibe, A., Sualin, F. & Payus, C. (2016). Distribution of heavy metals in seawater and surface sediment in coastal area of Tuaran, Sabah. *Transactions on Science and Technology*, **3**(1-2), 114–122.