# STATUS OF HEAVY METAL POLLUTION WITHIN SEDIMENT IN MANGROVE FOREST OF SEMARANG CITY AND DEMAK MUNICIPAL COASTAL AREA

**Endah Dwi Hastuti**
Faculty of Science and Mathematics, Diponegoro University
Jl. Prof. H. Soedarto, SH., Tembalang, Semarang
Email: endah_pdil@yahoo.com

## ABSTRACT

Heavy metal pollution in Semarang City and Demak Municipal are increasing as the increase of industrial activity at both location. This research aimed to study the difference of heavy metal concentration in sediment, and to study the level of heavy metal pollution within mangrove area of Semarang City and Demak Municipal coastal areas. This research was conducted through sampling and laboratory analysis. At each location, 3 stations was occupied with 3 sampling points at each stations. Sampling was conducted for sediment within mangrove area at both location, while laboratory analysis was conducted in Laboratory of Analytical Chemistry, Chemistry Major, Faculty of Science and Mathematics Diponegoro University. Heavy metals in sediment observed in this research was Co, Cu, Cr, Pb, Zn, Ni, Fe, Mn and Mg. The result showed that heavy metal concentration in sediment on both location was quiet high. Sequentially, the highest to lowest concentration of heavy metal was Fe > Zn > Mn > Mg > Ni > Cu > Cr > Co > Pb at Semarang City and Fe > Mn > Mg > Zn > Ni > Pb > Cu > Co > Cr at Demak Municipal. Heavy metal concentration of sediment for Co, Cu, Cr, Zn and Ni are significantly different between Semarang City and Demak Municipal area. Heavy metal in sediment for Zn, Ni, Fe and Mn at both location had exceeded the recommended limit by ANZECC/ARMCANZ and ISQG.

**Keywords:** *heavy metal, mangrove, pollution state, sediment*

## Introduction

Heavy metal is such compounds which naturally only available in smal amount in the environment. But, the increase of heavy metal concentration can be a threat to the environment and human being [1]. Heavy metal is capable to accumulate within organisms through food chains, either in plants nor animals [2]. Accumulation of heavy metal in organisms, including human while exceeded the limit of tolerance could cause terrible impact, even could cause death.

[3] mentioned that heavy metal pollution generally came from anthropogenic and industrial activities. Furthermore, agricultural activities also contribute significant heavy metal pollution [4]. Heavy metal containing pollution, either anthropogenic, industrial, nor agricultural activities would enter the water body and carried by river stream, either by surface stream nor groundwater stream [3]. While [4] also mentioned that the accumulation of heavy metal in the soil is exist. The concentration of heavy metal varied based on its sources.

According to [5], heavy metal pollution which had entered the water would be accumulated in the sediment of the river and the sea. The distribution of heavy metal is strongly related to the composition of sediment structure inwhich sediment with fine grain size tend to bind the heavy metal which had entered the water. Previously, [6] stated that distribution of heavy metal in the water is significantly influenced by the concentration of dissolved sediment. Hence, the extent of heavy metal distribution is also influenced by the concentration of dissolved sediment in the water.

Estuarine is an ecosystem which accumulate heavy metals in large amount [7]. Concentration of sediment caried by the river stream is the main factor causing the accumulation of heavy metal in the estuarine. Hence, as the accumulation rate of sediment in the river stream increase, the concentration of heavy metal in the water body increase as well. Eventhough, there are several ways to lower the concentration of heavy metal pollution such as bioremediation, which is a method utilizing plants to absorb heavy metal compounds from the sediment [8].

Mangrove ecosystem is coastal ecosystem with active inundation either by tide nor by river flow. [9] mentioned that mangrove also have the capability to decrease the concentration of heavy metal in the soil and water. The capabality of mangrove as phytoremetiator is supported by its capability to accumulate heavy metals in its parts. The bioaccumulation capacity of heavy metal in mangrove is varied by mangrove species [10].

The increase of pollutant concentration, especially heavy metal in the coastal area is a threat to surrounding organisms. Although mangrove ecosystem capable to resist the distribution of pollutant to the water, but it doesn't mean that the pollutant is disappeared. Mangrove ecosystem only capable to decrease the concentration of pollutant which had entered the water [11].

The risk of heavy metal contamination in organisms can be evaluated by the concentration of heavy metal in the environment. The higher heavy metal concentration available in the ecosystem, the potential of organisms to be contaminated by heavy metal increase as well. Eventhough, there is such tollerance limit for the environment to maintain its savety to the surrounding organisms. So, in order to evaluate wether the concentration of heavy metal in such area, especially in the coast is save for surrounding organisms, a research is need to be conducted concerning the existing condition of heavy metal pollution.

Semarang City and Demak Municipal are some region along the northern coast of Cenral Java which had experienced great ecological stress. The increasing industrial, settlement and agricultural activities had altered the input of pollutant to the coastal area, including heavy metal. The pollution level to the environment increased over years while the condition of mangrove ecosystem had been degraded. Since the lack of information concerning

the pollution, a research need to be conducted to evaluate the condition of heavy metal pollution level in coastal area of Semarang City and Demak Municipal. This research aimed to observe the concentration of heavy metals in the sediment and to evaluate the pollution state of heavy metal in the mangrove ecosystem in Semarang City and Demak Municipal coastal area.

**Materials and Method**

Data collection of heavy metals was conducted in mangrove ecosystem in Semarang City and Demak Municipal coastal area. Sample collection was conducted from February – April 2010 followed by laboratory analysis. Mangrove sediment was taken as sample involving 3 observation stations at each location with 3 replication at each station. Sample analysis was conducted in Laboratory of Analythical Chemistry, Major of Chemistry, Faculty of Science and Mathematics Diponegoro University. Analysis was conducted to measure the concentration of several heavy metal existed within the mangrove sediment at both location. The heavy metal analyzed in this research was including: Co, Cu, Cr, Pb, Zn, Ni, Fe, Mn and Mg.

Data was analyzed by quantitative method to compare the concentration of heavy metal in mangrove area of Semarang City and Demak Municipal. Data analysis was conducted through ANOVA to calculate the significance of heavy metal concentration difference at both locations. While qualitative analysi was also conducted to evaluate the concentration of heavy metal in te sediment wether it had exceeded the allowable limit by comparing to the applied legal regulation concerning the standart of heavy metal concentration in the sediment.

**Result and Discussion**

The result of data collection on heavy metal showed there were differences on the concentration at both location. Heavy metal with highest concentration was Fe either at Semarang City nor Demak Municipal mangrove area. While among all heavy metal observed in the sediment, heavy metals with lowest concentration was Pb at Semarang City and Cr at Demak Municipal. Orderly, the concentration of heavy metal in the sediment in Semarang City was Fe > Zn > Mn > Mg > Ni > Cu > Cr > Co > Pb. While in the mangrove area of Demak Municipal, the concentration of heavy metals in the sediment ordered as Fe > Mn > Mg > Zn > Ni > Pb > Cu > Co > Cr. Detailed of heavy metal concentration in sediment at both location from the laboratory analysis is shown in Table 1.

The analysis result on the heavy metal concentration in mangrove area of Semarang City and Demak Municipal showed some heavy metal had exceeded the recommended limit. Heavy metals such as Zn, Ni, Fe and Mn had exceeded the recommended limit, while Cu, Cr and Pb were still in the allowable concentration. While for Co and Mg there was no recommended concentration limit for sediment quality standard. The analysis result

showed that generaly the concentration of heavy metal in mangrove area of Semarang City was higher than in Demak Municipal. Except for Pb, Mn and Mg which were higher in Demak Municipal than in Semarang City.

The statistical analysis of heavy metal at both location showed that tehre were differences on the concentration of heavy metal in sediment for several heavy metals. Heavy metals which have significant concentration difference were Co, CU, Cr, Zn and Ni. While for Pb, Fe, Mn and Mg there were no significant difference between locations. The significant difference of sediment heavy metal concentration at both location indicate that there were significant difference of heavy metal input from upland area.

Table 1. Concentration of Heavy Metal in Sediment (mg/kg)

| No. | Heavy Metal | Concentration | Location | | Standard (mg/kg) |
|---|---|---|---|---|---|
| | | | Semarang City | Demak Municipal | |
| 1. | Co* | Range | 13,295 – 23,448 | 5,289 – 14,032 | N/A |
| | | Average | ***19,442 ± 4,557*** | ***9,621 ± 2,901*** | |
| 2. | Cu* | Range | 20,161 – 40,380 | 12,042 – 18,578 | 65 (a) |
| | | Average | ***28,268 ± 6,086*** | ***14,428 ± 1,971*** | |
| 3. | Cr* | Range | 6,176 – 29,938 | 1,424 – 13,610 | 80 (a) |
| | | Average | ***21,622 ± 8,849*** | ***7,910 ± 4,442*** | |
| 4. | Pb | Range | 0,000 – 7,982 | 1,040 – 172,183 | 50 (a) |
| | | Average | ***2,498 ± 3,606*** | ***24,778 ± 55,418*** | |
| 5. | Zn* | Range | 117,070 – 2.590,238 | 293,665 – 599,947 | 200 (a) |
| | | Average | ***1.439,699 ± 867,473*** | ***487,733 ± 100,499*** | |
| 6. | Ni* | Range | 30,410 – 195,141 | 22,148 – 36,885 | 21 (a) |
| | | Average | ***130,296 ± 73,713*** | ***29,337 ± 5,010*** | |
| 7. | Fe | Range | 5.275,140 – 55.536,270 | 14.600,070 – 50.878,650 | 21.200 (b) |
| | | Average | ***39.077,647 ± 17.265,882*** | ***29.480,925 ± 15.241,122*** | |
| 8. | Mn | Range | **593,880 – 1.995,000** | **656,268 – 4.152,898** | 460 (b) |
| | | Average | ***1.108,717 ± 449,341*** | ***1.921,466 ± 1.278,798*** | |
| 9. | Mg | Range | 163,749 – 1.576,737 | 409,149 – 1.596,248 | N/A |
| | | Average | ***491,457 ± 529,138*** | ***916,871 ± 436,529*** | |

Note: asterisk (*) showed there was significant difference on the heavy metal concentration between observation locations; (a) standard based on ANZECC and ARMCANZ [12]; (b) standard based on ISQG (2002) [13]

Data collection resulted there were significant heavy metal concentration in sediment of mangrove area at Semarang City and Demak Municipal. The difference of heavy metal concentration was caused by several factors, such as mangrove density, volume of pollutant supply and period of accumulation process. The pollution of heavy

metals had various sources from upland activities such as industrial, agriculture, antrophogenic and even natural atmospheric phenomenon [3][4].

According to [14], types and concentration of heavy metal in sediment and water was strongly influenced by kinds of activities in the upland area. Each heavy metal had enriching factors which are defned by kinds and intensity of the existing activities. [15] mentioned that the increasing agricultural activities and atmospheric phenomenon could cause to the increasing heavy metal concentration in sediment.

Basically, heavy metal is an important component for livelihood of the organisms, either plants nor animals. But, the requirement of heavy metal by living organisms are in a very small amount [16]. Heavy metals in the environment basically released n small amounts. But, the increasing human activities such as anthropogenic, agricultural and industrial had impacted the alteration on the heavy metal concentration significantly. This resulted negative impact for organisms. High heavy metal concentration in Semarang City and Demak Municipal were also supported byt the existence of industrial, anthropogenic and intensive agricultural activities which cause to upland sediment and lime erosion. The indication had been occured in Jakarta gulf which had high heavy metal concentration [17].

Data analysis result and inference of sediment quality standard showed that several heavy metal in the sediment of mangrove area at Semarang City and Demak Municipal had exceeded the recommended limit. These heavy metal were including Zn, Ni, Fe and Mn. The high heavy metal concentration in the sediment increase the risk of accumulation on the benthic organisms and aquatic organisms.

The concentration of heavy metal in the sediment was a threat over heavy metal toxicity to organisms, especially benthic organisms. [18] stated that concentration of heavy metal in the sediment was supported by environment condition such as organic matter compound, concentration of mud and clay and the condition of soil redox at certain range which could increase its bioavailability in benthic organisms. It means that in certain condition heavy metal concentration within organism could increase. The research conducted by [19] also showed the occurence of heavy metal accumulation in fishes and clams. Based on the research, the concentration of heavy metal in clams were relatively higher than in fishes.

Organisms which had been contaminated by heavy metals, while consumed by human could cause toxicity effect. The research by [20] showed the concentration of heavy metal in several fish species had indicated the increasing threat on human health shown by THQ (Target Hazard Qiotient) value more than 1. Heavy metal toxicity on human could be caused by vegetables, fruits or fishes which were contaminated by heavy metals since the utilization of polluted water [21][22].

[23] stated that all kind of heavy metals could cause toxicity risk to human. But, each heavy metals would have different toxicity effect to human body.

Generally, toxicity of heavy metal in human resulted the decrease of organ functions. While [24] mentioned that the effect caused by heavy metal on human can be in the form of neurotoxicity, genotoxicity or carcinogenic. It showed that the negative effect of heavy metal toxicity on human has large scope, hence it should be avoided.

To avoid the extend of heavy metal toxicity on human, such effort had been conducted to formulate solutions of the problems. Several methods recommended including mechanical, chemical and biological [25]. [26] for example, had researched the mechanical method through soilmilling. While [11] studied the effort concerning phytoremediation of heavy metal, which utilized certain plant species to lessen the concentration of heavy metal in the environment. [27] showed the remediation method of heavy metal utilizing chemical compound by binding heavy metals with such bounding compound. Utilization of microbes in the remediation of heavy metal had also been discussed by [28].

[29] had studied the effort of remediation effectivity of heavy metals by combining phytoremediation technique and mircobial supplementary to increase the binding capability of plants over heavy metals. [30] also recommended remediation technique by soil maturation, where mixed mud should be regenerated to soil in upland area. The purpose of this process is to limit the availability of clay which has high capability on heavy metal binding and limit its potential to get drought to the water. But, of all the mentioned method, the most effective method to avoid the heavy metal pollution was by avoiding the pollution to occur by waste management efforts especially wastes with liquid heavy metal compound [31].

## Conclusion

The concentration of heavy metal in the sediment of mangrove area at Semarang City and Demak Municipal was considered as high. Generally, the concentration of heavy metal in mangrove area of Semarang City was higher than in Demak Municipal. The concentration of heavy metal in the sediment in Semarng City and Demak Municial which had significant difference were Co, Cu, Cr, Zn and Ni. Several heavy metals in the sediment had exceeded the recommended limit defined by ANZECC/ARMCANZ and ISQG for sediment standard including Zn, Ni, Fe and Mn.

## References

[1] Mahmood, A. and R.N. Malik. 2014. Human Health Risk Assessment of Heavy Metals Via Consumption of Contaminated Vegetables Collected from Different Irrigation Sources in Lahore, Pakistan. Arabian Journal of Chemistry 7: 91 – 99. http://dx.doi.org/10.1016/j.arabjc.2013.07.002

[2] Wang, J., S. Chen and T. Xia. 2010. Environmental Risk Assessment of Heaby Metals in Bohai Sea, North China. Procedia Environmental Sciences 2: 1632 – 1642. doi:10.1016/j.proenv.2010.10.174

[3] Duruibe, J.O., M.O.C. Ogweugbu and J.N. Egwurugwu. 2007. Heavy Metal Pollution and Human Biotoxic Effects. International Journal of physical Sciences 2(5): 112 – 118.

[4] Wei, B. and L. Yang. 2010. A Review of Heavy Metal Contaminations in Urban Soils, Urban Road Dusts and Agricultural Soils from China. Microchemical Journal 94: 99 – 107. doi:10.1016/j.microc.2009.09.014

[5] Ho, H.H., R. Swennen and A.V. Damme. 2010. Distribution and Contamination Status of Heavy Metals in Estuarine Sediments Near Cua Ong Harbor, Ha Long Bay, Vietnam. Geologica Belgica 13(1-2): 37 – 47.

[6] Menon, M.G., R.J. Gibs and A. Phillips. 1998. Accumulation of Muds and Metals in the Hudson River Estuary Turbidity Maximum. Environmental Geology 34(2/3): 214 – 222.

[7] Kumar, S.P. and J.K.P. Edward. 2009. Assessment of Metal Concentration in the Sediment Cores of Manakudy Estuary, South West Coast of India. Indian Journal of Marine Sciences 38(2): 235 – 248.

[8] Akpor, O.B., G.O. Ohiobor and T.D. Olaolu. 2014. Heavy Metal Pollutants in Wastewater Effluents: Sources, Effects and Remediation. Advances in Bioscience and Bioengineering 2(4): 37 – 43. doi: 10.11648/j.abb.20140204.11

[9] Gupta, S. and S.K. Chakrabarti. 2013. Mangroves – A Potential – Phyto-Remediator and Useful Bio-Indicator Against Heavy Metal Toxicity. International Journal of Bio-Resource and Stress Management 4(2): 322 – 327.

[10] Mullai, P., M.K. Yogeswari, K. Saravanakumar and K. Kathiresan. 2014. Phytoremediation of Heavy Metals Using *Avicennia marina* and *Rhizophora mucronata* in the Uppanar River. International Journal of ChemTech Research 6(12): 4984 – 4990.

[11] Marques, A.P.G.C., A.O.S.S. Rangel and P.M.L. Castro. 2009. Remediation of Heavy Metal Contaminated Soils: Phytoremediation as A Potentially Promising Clean-Up Technology. Critical Reviews in Environmental Science and Technology 39: 622 – 654. DOI: 10.1080/1063380701798272

[12] ANZECC and ARMCANZ. 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality

[13] Interim Freshwater Sediment Quality Guidelines (ISQG). 2002. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Canadian Council of Ministers of the Environment.

[14] Moore, F., G. Forghani and A. Qishlaqi. 2009. Assessment of Heavy Metal Contamination in Water and Surface Sediments of the Maharlu Saline Lake, SW Iran. Iranian Journal of Science and Technology 33(A1): 43 – 55.

[15] Lepane, V., M. Varvas, A. Viitak, T. Alliksaar and A. Heinsalu. 2007. Sedimentary Record of Heavy Metals in Lake Rouge Liinjarv, Southern Estonia. Estonian Journal of Earth Sciences 56(4): 221 – 232. Doi: 10.317/earh.2007.03

[16] Nagajyoti, P.C., K.D. Lee and T.V.M. Sreekanth. 2010. Heavy Metals Occurence and Toxicity for Plants: A Review. Environ. Chem. Lett. 8: 199 – 216. DOI: 10.1007/210311-010-0297-8

[17] Rochyatun, E., M.T. Kaisupy and A. Rozak. 2006. Distribusi Logam Berat dalam Air dan Sedimen di Perairan Muara Sungai Cisadane. Makara Sains 10(1): 35 – 40.

[18] Zhang, C., Z. Yu, G. Zeng, M. Jiang, Z. Yang, F. Cui, M. Zhu, L. Shen and L. Hu. 2014. Effect of Sediment Geochemical Properties on Heavy Metal Bioavailability. Environment International 73: 270 – 281. http://dx.doi.org/10.1016/j.envint.2014.08.010

[19] Arifin, Z. 2011. Konsentrasi Logam Berat di Air, Sedimen dan Biota di Teluk Kelabat, Pulau Bangka. Jurnal Ilmu dan Teknologi Kelautan Tropis 3(1): 104 – 114.

[20] Krishna, P.V., V. Jyothirmayi and K.M. Rao. 2014. Human Health Risk Assessment of Heavy

Metal Accumulation Through Fish Consumption, from Machilipatnam Coast, Andhra Pradesh, India. International Research Journal of Public and Environmental Health 1(5): 121 – 125.

[21] Raikwar, M.K., P. Kumar, M. Singh and A. Singh. 2008. Toxic Effect of Heavy Metals in Livestock Health. Veterinary World 1(1): 28 – 30.

[22] Singh, A., R.K. Sharma, M. Agrawal and F.M. Marshall. 2010. Risk Assessment of Heavy Metal Toxicity Through Contaminated Vegetables from Waste Water Irrigated Area of Varanasi, India. Tropical Ecology 51(2S): 375 – 387.

[23] Jaishankar, M., T. Tseten, N. Anbalagan, B.B. Mathew and K.N. Beeregowda.2014. Toxicity, Mechanism and Health Effects of Some Heavy Metals. Interdisiplinary Toxicology 7(2): 60 – 72. Doi: 10.2478/intox-2014-0009.

[24] Florea, A.-M. and D. Busselberg. 2006. Occurence, Use and Potential Toxic Effecs of Metals and Metal Compounds. BioMetals 19: 419 – 427. DOI: 10.1007/s10534-005-451-x

[25] Yao, Z., J. Li, H. Xie and C. Yu. 2012. Review on Remediation Technologies of Soil Contaminated by Heavy Metals. Procedia Environmental Sciences 16: 722 – 729. DOI: 10.1016/j.proenv.2012.10.099

[26] Montinaro, S., A. Concas, M. Pisu and G. Cao. 2012. Remediation of Heavy Metals Contaminated Soils by Ball Milling. Chemical Engineering Transactions 28: 187 -192. DOI: 10.3303/CET122832

[27] Usman, A.R.A., Y. Kuzyakov, K. Lorenz and K. Stahr. 2006. Remediation of A Soil Contaminated with Heavy Metals by Immobilizing Compounds. J. Plant. Nutr. Soil Sci 169: 205 – 212. DOI: 10.1002/jpln.200421685

[28] Rajendran, P., J. Mutukrishnan and P. Gunasekaran. 2003. Microbes in Heavy Metal Remediation. Indian Journal of Experimental Biology 41: 935 – 944.

[29] Karami, A. and Z. Shamsuddin. 2010. Phytoremediation of Heavy Metals with Several Efficiensy Enhancer Methods. African Journal of Biotechnology 9(25): 3689 – 3698.

[30] Vermeulen, J., T. Grotenhuis, J. Joziasse and W. Rulkens. 2003. Ripening of Clayey Dredged Sediments During Temporary Upland Disposal: A Bioremediation Technique. J. Soils and Sediments 3(1): 49 – 59. DOI: http://dx.doi.org/10.1065/jss2003.01.065

[31] Peng, J., Y. Song, P. Yuan, X. Cui and G. Qiu. 2009. The Remediation of Heavy Metals Contaminated Sediment. Journal of Hazardous Materials 161: 633 – 640. doi:10.1016/j.jhazmat.2008.04.061