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The Spatial Distribution of Heavy Metal Lead and Cadmium Pollution and Coliform Abundance of Waters and Surface Sediment in Demak

Agus Tjahjono[1*], Djoko Suwarno[2]

[1] Engineering Department, Semarang Merchant Marine Polytechnic (Politeknik Ilmu Pelayaran Semarang), Singosari 2 a Semarang, 50242, Central Java, Indonesia

[2] Civil Engineering Department, Unika Soegijapranata Chatolic University, Pawiyatan Luhur IV/1 Bendan Dhuwur, Semarang, 50234, Central Java, Indonesia

[*] Corresponding author's e-mail: a_agus_tjahjono70@yahoo.co.id

ABSTRACT

Various activities such as farming, industry, household waste, fish pond, and fishery can possibly affect the estuarine and coastal ecosystem. Demak waters, located to the east of Tanjung Emas Semarang, become an influential element of fishery industry that mostly produces anchovies and shrimps. This research was aimed at (1) analyzing the spatial distribution of heavy metal Pb and Cd in the surface water and sediment; and (2) investigating the abundance of coliform in Demak waters. Moreover, in this research, water pollution index was also analyzed and compared to other polluted water areas. It was found that the Pb content ranged from 0.6037 to 0.6647 mg·1^{-1} whereas the Cd content ranged from 0.064 to 0.1707 mg·1^{-1}. Both lead and cadmium contents had surpassed the water quality standard. The Pb content in sediment ranged from 0.563 to 0.6823 mg·kg^{-1} whereas the Cd content reached 0.0047 to 0.0577 mg·kg^{-1}. It showed that this sediment was not polluted by Pb and Cd. The analysis of water pollution index revealed that the pollution level found in Morosari, Rejo, Tuntang, and Lohbener estuary was low. On the other hand, Wedung and Serang estuary were heavily polluted. Compared to some previous studies, most of Pb and Cd contents in Demak waters were greater. However, lead and cadmium content in sediment was lower.

Keywords: Demak waters, spatial distribution of Pb and Cd in surface water and sediment, the abundance of Coliform, water pollution index

INTRODUCTION

Demak Regency, located in Central Java, geographically, lies in the coordinates of 6°43'26" South and 110°27'58"–110°48'47" East. This region extends over 89,743 ha. It borders with Jepara regency and the Java Sea to the north, Kudus and Grobogan regencies to the east, Grobogan and Semarang regencies to the south and Semarang to the west. Demak consists of 14 subdistricts. A few rivers flow through Demak, including Tuntang, Buyaran, and the biggest river in Demak, Serang [https://idwikipedia.org].

Demak waters are located to the east of Port of Tanjung Emas Semarang. It became an influential element of fishery industry, as it produces 308.556 tons of anchovies and 139.296 tons of shrimps [BPS, 2013]. However, high ecological pressure was also found in this area [Hastuti *et al*., 2013].

On the basis of the previous studies carried out in Moro Demak waters, it was revealed that the Cd content in the surface water reached 0.116 mg/l whereas the Cd content in the sediment was 1.372 mg/l. It means that it had surpassed the water quality standard. When the concentration of heavy metal Pb in the water and sediment increases, the accumulation of heavy metal Pb in *Anadara granosa* will be elevated as well [Sitorus, 2004]. It leads to a bioaccumulation in the blood clam *Anadara granosa* clam [Wulandari *et al*., 2009].

The coliform bacteria constitute the indicator of patogenic bacteria existence. The more coliform we found within the water, the worse the water quality would be. The coliform bacteria include various bar shaped

bacteria, gram-negative bacteria, non-spore-forming bacteria, and lactose-fermenting bacteria which produce gas and acid when being incubated at 37°C in less than 48 hours [Widyaningsih *et al*., 2016]. The existence of these bacteria is due to pollutants produced by human activities around the river.

Heavy metals are generally defined as the metals with relatively high densities, atomic weights, or atomic numbers. Heavy metals differ from other metals due to the effect they produce when being bound to the living organism. The heavy metal Pb is commonly used in the industry producing batteries and cables. However, the use of water-related contamination, the metal was added as an additive to the engine fuel to increase the octane value. The heavy metal Cd is used as a mixture in the chemical industry [Palar, 2012; Ridhowati, 2013].

This research was aimed at analyzing the spatial distribution of Pb and Cd in the surface water and sediment, as well as the abundance of Coliform in Demak waters. This research also analyzed the water pollution index and compared the results to the previous studies on water pollution.

MATERIALS AND METHODS

Research object

The research was held in May 2017 when the high tide occured at Demak waters, Central Java, Indonesia. The purposeful sampling was done at six stations including station 1, Morosari estuary (6°92'60" South, 110°46'07" East), Rejo estuary (6°85'20" South, 110°51'40" East), Tuntang estuary (6°83'24" South, 110°51'76" East), Lohbener estuary (6°77.09' South, 110°56'85" East), Wedung estuary (6°74.54' South, 110°53'24" East), and Serang estuary (6°71'99" South, 110°54'37" East).

In each station, the sampling was done three times. The Morosari estuary was taken as the sampling location because firstly, it was mangrove area which is the fishery habitat and secondly, absorption of heavy metal possibly occurs in this area. Other estuaries were also used as the sampling locations since they were close to the fishermen settlement and fish farming.

Data collection methods

The materials of this research included the sample of sea water and sediments which contained Pb, Cd, and Coliform taken from Demak waters. In this research, primary and secondary research data were applied. The primary data included the data which were taken directly when the research took place including seawater, pH, DO, TDS, water turbidity, water depth, salinity, current, and the water transparency.

The determination of heavy metal concentration (Pb and Cd) in the seawater.

Firstly, 500 mililiters of sea water was put into teflon separatory funnel. The pH scale was then set at pH 4 by adding liquid HCl. APDC (Amonium Pirolidin Ditio Carbamat) and NaDDC (Natrium Dietil Ditio Carbamat) were also added before it was shaken for one minute. Afterwards, 25 ml of MIBK (Metil Iso Butil Keton) was also added and the solution was shaken again for 30 seconds. The aqueous phase was then separated. Subsequently, 10 ml of distilled and deionized water was poured into the upper phase. It was shaken and the aqueous phase was then separated. After that, 1 ml of HNO_3 was added, shaken, and left standing for about an hour. Then, 19 ml of distilled and deionized water was added, shaken, and aqueous phase was collected to be analyzed by using furnace AAS (Atomic Absorption Spectroscopy) with argon gas and Pb and Cd lamps [Sitorus, 2004; APHA, 2012].

The sample of sediment was dried at 105°C for 24 hours. Then 10–20 grams of the dried sediment was put into a centrifuge tube (polyethylene), 500 ml of distilled and deionized water was added and shaken. It was afterwards centrifuged for 30 minutes in 2000 RPM. The aqueous phase was then discarded. It was dried at 105°C (oven-dry weight) for 24 hours. 1 gram of sediment was put into a sealed teflon beaker. Subsequently, 5 ml of aqua regia and 6 ml of HF (Hygrogen Fluoride) were added. It was then heated at 130 °C until it was dried up. Next, 9 ml of distilled and deionized water was added. It was then analyzed by using furnace AAS with argon gas and Pb and Cd lamps based on the types of the metal which were being analyzed [Sitorus, 2004; APHA, 2012].

The coliform bacteria determination used MPN (Most Probable Number) method [SNI-01–2332–1991; Ijong, 2015]. The method was as follows:

- Presumtive test of coliform

The first step of the presumtive test was to prepare trisalt solution with 10^{-1} to 10^{-3} dilution and to shake until it was homogenous, and to prepare nine tubes of LTB (Lauryl Tryptose Broth) which contained Durham tube for one sample. Then, 1 ml of sample water was added into tube 10^{-1} and shaken until it was homogenous by using vortex. Next, 1 ml of the solution was taken from tube 10^{-1} and put into tube 10^{-2}, and the process was continued until tube 10^{-3}.

By using a sterile pipette, 1 ml of solution of each dilution was moved into each of the three LTB tubes. The process was continued until the sixth sample. The tubes were then incubated at 35°C for about 24–48 hours. Positive tubes would produce bubbles in the Durham tube.

- Confirmative test of Coliform

The method used in this test included moving the cultures from the positive LTB tubes to the tubes with BGLB (Briliant Green Lactose Bile) 2%broth which contained the Durham tube by using inoculation needle. The tubes were incubated for 24–48 hours at 35°C. The positive tubes were those which produced gas in Durham tube. The numbers of the positive tubes were compared based on the MPN value in order to find out the numbers of coliform within the sample.

- Completed test

By using a loopful, the typical colony above was moved to the lactose broth. Then, the formation of acid and gas was re-observed. When the result was positive, aseptically, one eye of loopful was taken and scratched to the NA, and subsequently incubated at 37°C overnight. The growing colony was then used in Gram-Coloring test. The test was regarded as positive if Gram-Negative was obtained and stem cells were formed.

Data analysis

The data analysis method used to examine the density of Coliform bacteria [SNI 2897–2008, Bambang *et al*., 2014] was as follows:

$$Coliform\ Density = \\ = value \text{ of MPN table} \times \frac{1}{Median\ \ dillution} \qquad (1)$$

The data analysis of (1) the heavy metal Pb and Cd content in water and sediment, and (2) the coliform abundance was done by using a comparative analysis of temperature, pH, DO, TDS, salinity, and turbidity. In this analysis, the Spearman's rank-order correlation was applied. This correlation analysis would show the correlation between two variables. The analysis employed SPSS software for Windows, version 22.

The status of water pollution was determined by using the water pollution index based on Ministry of Environment Decree No. 115 year 2003 about the guidelines for water quality assessment. [Nemerow & Sumitomo, 1970].

$$PI_j = \sqrt{\frac{\left(C_i/L_{ij}\right)_M^2 + \left(C_i/L_{ij}\right)_R^2}{2}} \qquad (2)$$

where: L_{ij} – standard water quality parameter for each parameter at specified water quality purpose (j)
C_i – measured water quality parameters
PI_j – the pollution index for a specified water quality purpose (j)
$(C_i/L_{ij})_M$ – maximum value of C_i/L_{ij}
$(C_i/L_{ij})_R$ – average value of C_i/L_{ij}

The pollution level based on the water pollution index of water quality standard as written in Ministry of Environment Decree no. 115 year 2003 is $0 \le PI_j \le 1$ (meet quality standard/good), $1 \le PI_j \le 5$ (lightly polluted), $5 \le PI_j \le 10$ (moderately polluted) dan PIj>10 (heavily polluted).

RESULTS AND DISCUSSION

On the basis of the findings in the six stations at Demak waters, it was revealed that the Pb content at riverbed was higher than what was found at the surface of the water. The Pb content found at surface of the water ranged from 0.6037 to 0.6647 mg·l^{-1}. The highest concentration of Pb was found at the Serang estuary. The concentration was thirteen times higher than the water quality index 0.05 mg.l^{-1}. Serang estuary is the biggest river on which the fishermen often go back and forth to the sea. The condition matched with the high concentration of TSS, which proved that a high concentration possibly decreased the photosyntesis activity of both macro and micro marine plants. It led to the decrease of the oxygen which killed fish [Jiyah *et al*., 2017]. On the other hand, the concentration of Pb in the riverbed was about 0.6207 and 0.7163 mg·l^{-1}; the highest concentration occurred at the estuary of Tuntang river. The concentration surpassed the minimum require-

ment of the water quality index; it was fourteen Times higher than what was required (Figure 2).

The Pb within seawater was able to accumulate to the benthic. The largest accumulation was found in hard branching coral which was followed by soft coral *Alcyonaceae*. For example, the accumulation of *Acropora aspera* and *Pocillopora damicornis,* within ten days, turned into 0.895 mg·kg^{-1} [Samawi *et al*., 2014; Panuntun *et al*, 2012]. The pollution of Pb led to the highest accumulation in the sediment. The accumulation was followed by biota and seawater [Usman *et al*., 2013]. The metal accumulation additionally showed the toxic effect of Pb to *Cromileptus altivelis*. The effect of Pb caused the damage of hepar cell (concentration 0.15 ppm) in the form of fatty degeneration, hydropic degeneration, hemorrhage, congestion, and necrosis hepatica (liver cell death) [Triadayani *et al*., 2010]. The accumulation of Pb in mullet fish *Mugin cephalus* (Linnaeus, 1758) in Cilacap waters was three times higher than those which were taken from 0-500 m and >1000 m from the pollution source point [Heriyanto & Subiandono, 2011].

The content of Pb in the sediment possibly affected the organisms living at the riverbed, such as the *Strombus canarium* snail. The greater content of the heavy metal in the sediment, the higher content of Pb found in the organism [Nasution & Siska, 2011]. Blood clam *Anadara granosa* and mangrove shell *Polymesoda bengalensis* were also found in the sediment. When the content of Pb within the sediment reached 0.823 mg·kg^{-1}, an accumulation of both organisms was twice higher (1.750 mg.kg^{-1}) [Amriani *et al*., 2011]. Moreover, *Anadara granosa* was highly prone to chromium accumulation[Suprapti, 2008].

The content of Cd found in the surface water was about 0.064 and 0.1707 mg·l^{-1}; the highest concentration was found in the estuary of Rejo river. The concentration of Cd had surpassed the water quality index beingseventeen times higher. However, the concentration decreased as it went to the east. The condition did not occur in the estuary of Lohbener river. The concentration in the riverbed was about 0.055 and 0.12 mg·l^{-1}; Cd was also found at the estuary of Tuntang river. The concentration surpassed the water quality index; it was 12 times greater than the index (Figure 3).

The Cd affected the fish such as Gulama *Sciaena russelli* living in Dumai waters. The accumulation of Cd was mostly found in the fins and gills. In terms of Cd, Cu, Pb, and Zn, the highest accumulation was found in the gills, since it constitutes the respiratory organ where gas exchange occurred [Nurrachmi *et al*., 2011].

Cd also correlated to green shell *Perna viridis* in Jakarta bay. In this area, the numbers of spermatozoa (r = 0.64) which influenced the development of the spermatozoon were affected to the greatest

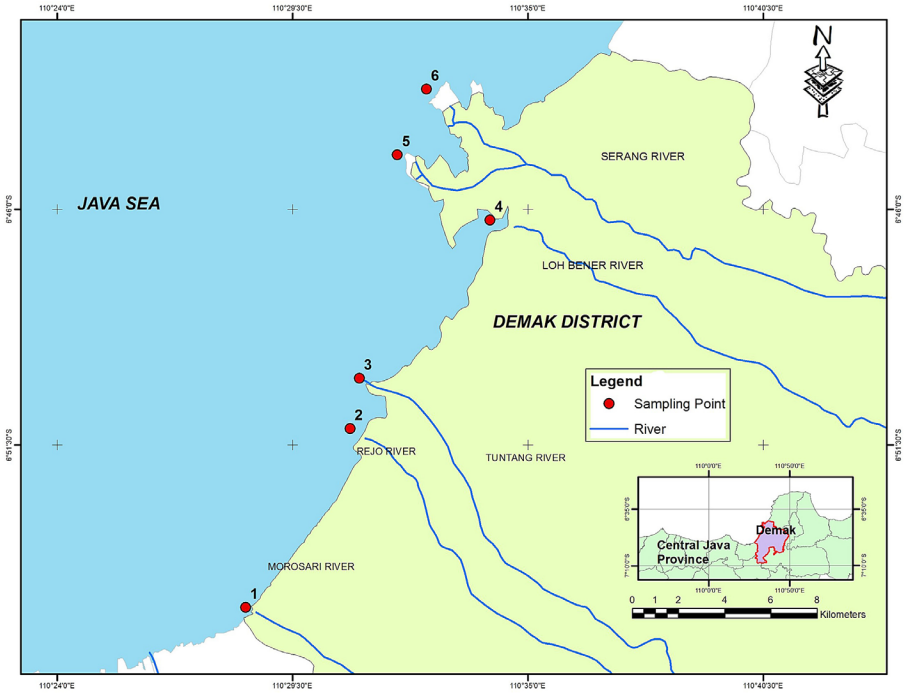

Fig. 1. Research location

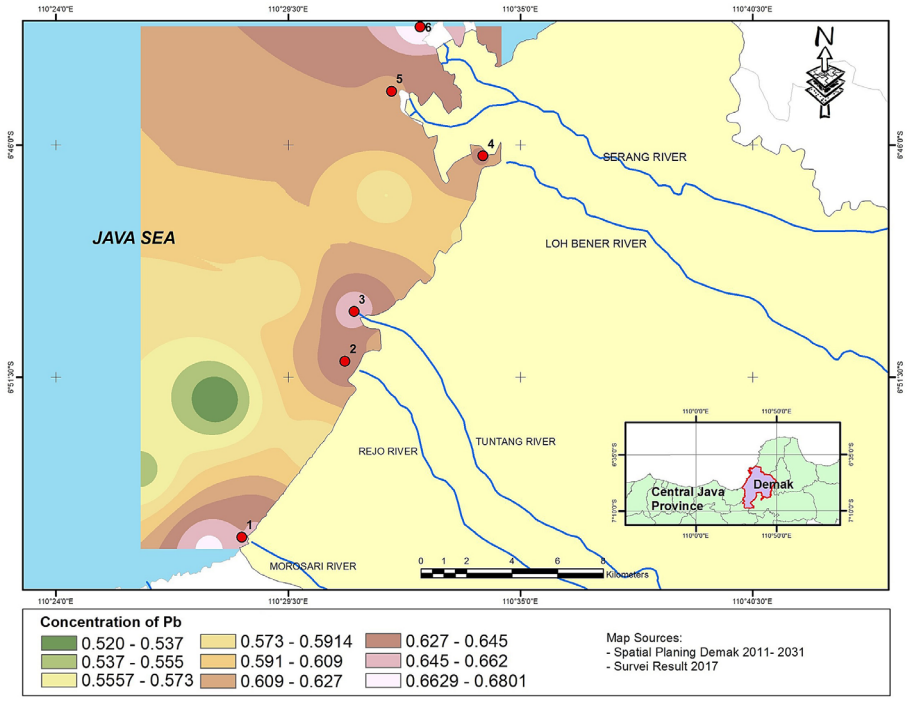

Fig. 2. The distribution of Pb (mg·l^{-1}) in Demak waters

degree. It was followed by the sex cells (r = 0.60) [Jalius *et al*., 2008]. Bioaccumulation also occurred in green shell *Amusim pleuronectes* which was found in Wedung waters, Demak the content in sediment reached 0.4694 mg·kg^{-1} whereas the content on soft tissue became 12.61 times higher (5.9212 mg·kg^{-1}) [Azhar *et al.,* 2012].

The Pb content in the surface sediment ranged from 0.2563 to 0.6823 mg·kg^{-1} whereas the Cd content ranged from 0.0047 to 0.0577 mg·kg^{-1}; the maximum concentration occurred in Lohbener estuary (Figure 4 and 5). The correlation between the sediment particle (sand, mud and clay) and the heavy metal (Pb and Cd) showed that the

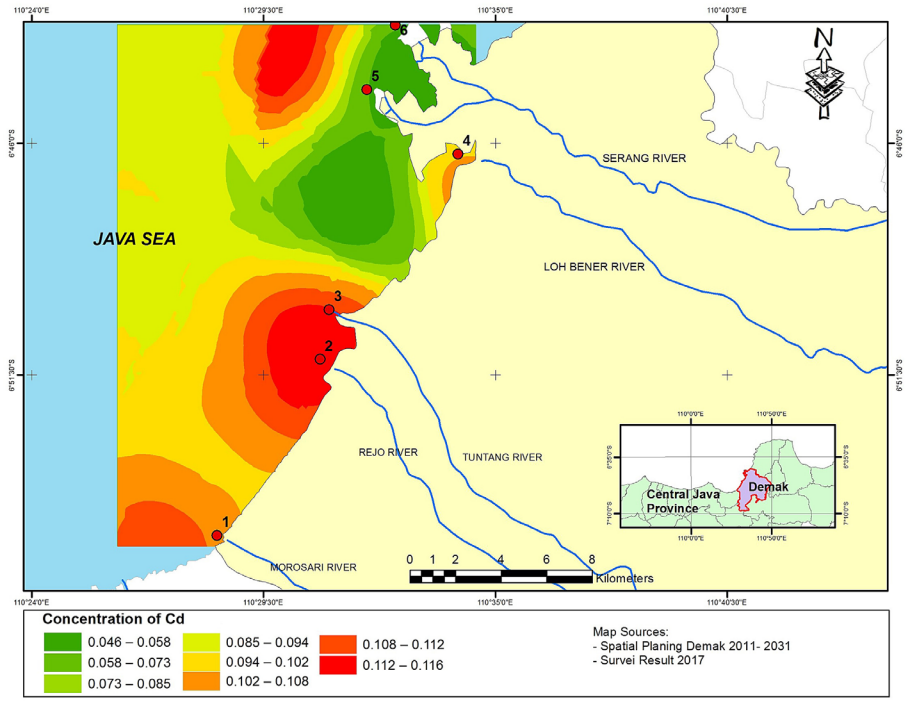

Fig. 3. The distribution of Cadmium (mg·l^{-1}) in Demak waters

heavy metal was positively correlated with sand, mud, and clay fraction. It was found that the more mud there was, they more heavy metal (Pb and Cd) we found [Kinasih *et al*., 2015]. The content of Pb and Cd was below CEQG (Canadian Environmental Quality Guidelines) 2002 which are 30 mg·kg^{-1} and 0.7 mg·kg^{-1}. It is in line with the guidelines of USEPA (United States Enviromental Protection Agency) (1989) which require that the Pb content should be below 40 mg·kg^{-1}. It means that according to this condition, it was regarded as not polluted.

The distribution of coliform bacteria in the six stations starting from the estuary of Morosari river to Lohbener riverhad met the quality standard, except for the station 5 Wedung and station 6 Serang, as each of them surpassing the quality standard of Coliform abundance by 400 times (Figure 6). It was influenced by the polluted ecosystem. Moreover, the household waste produced by human activities also affected the coliform abundance [Kunarso, 2011].

The analysis of the quality and condition of Demak waters included temperature, pH, DO, TDS, turbidity, salinity, current, water transparency, and depth. The water temperature of the six estuaries was about 29.08°C and 30.15°C, which is common tropical water temperature. The solubility of oxygen decreased as the water temperature increased. The increase of water temperature also possibly elevated the content of some materials [Usman *et al*., 2013].

The pH ranged from 7.25 to 7.7475 which was at pH tolerance limit. However, the pH of water was quite low, below 8, which was influenced by the river estuary. It was due to the condition of river estuary. This sea water pH influenced the chemical toxicity [Sindhu, 2005].

The water salinity was about 18.5 and 35.45 PSU. High salinity was found in the estuary of Morosari river. It was observed showed that the seawater's influence was greater than the fresh water, because during the high tide, the sea water flow kept moving toward the river estuary.

The oxygen solubility reached 5.06 mg·l^{-1} and 6.268 mg·l^{-1}. The high oxygen solubility surpassed the minimum quality standard for aquaculture (3 mg·l^{-1}) [Murtini & Peranginangin, 2006]. The solubility showed that the presence of heavy metals influenced the respiration of aquatic organism. The shortage of oxygen could possibly occur due to the increase of the nutrient supply and organic material such as fish farm waste or fertilizer run-off [Rangkuti *et al*., 2017].

Total Dissolved Solids (TDS) is defined as any dissolved and colloid materials which are in the form of chemical compound that are not filtrated by the filter with the diameter of 0.45 [Rao, 1992]. The content of TDS was 3.861 mg·l^{-1} and 6.786 mg·l^{-1}. The maximum TDS was found in the estu-

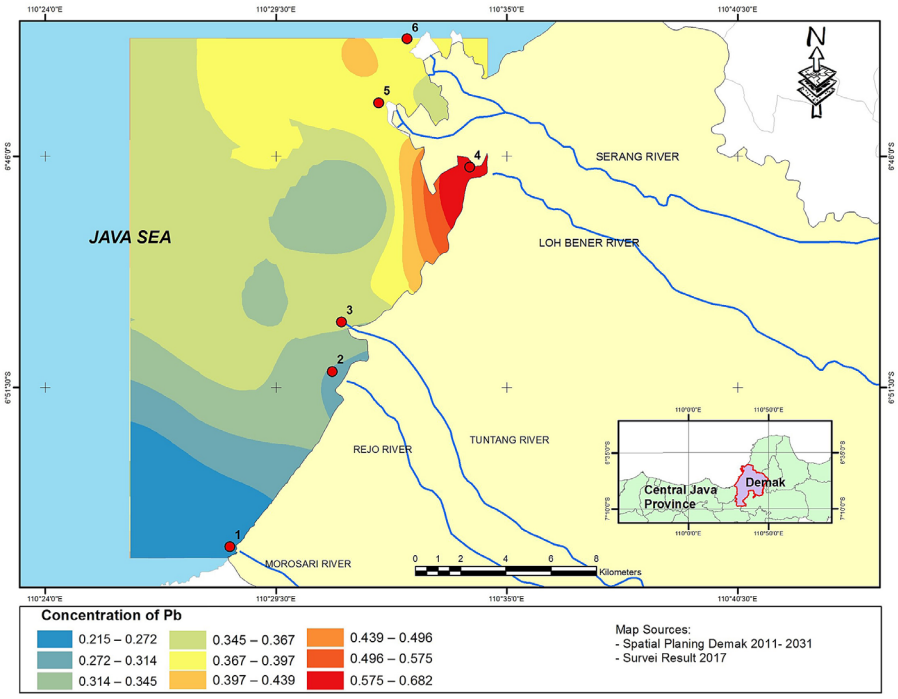

Fig. 4. Pb content in surface sediment (mg·l^{-1}) in Demak waters

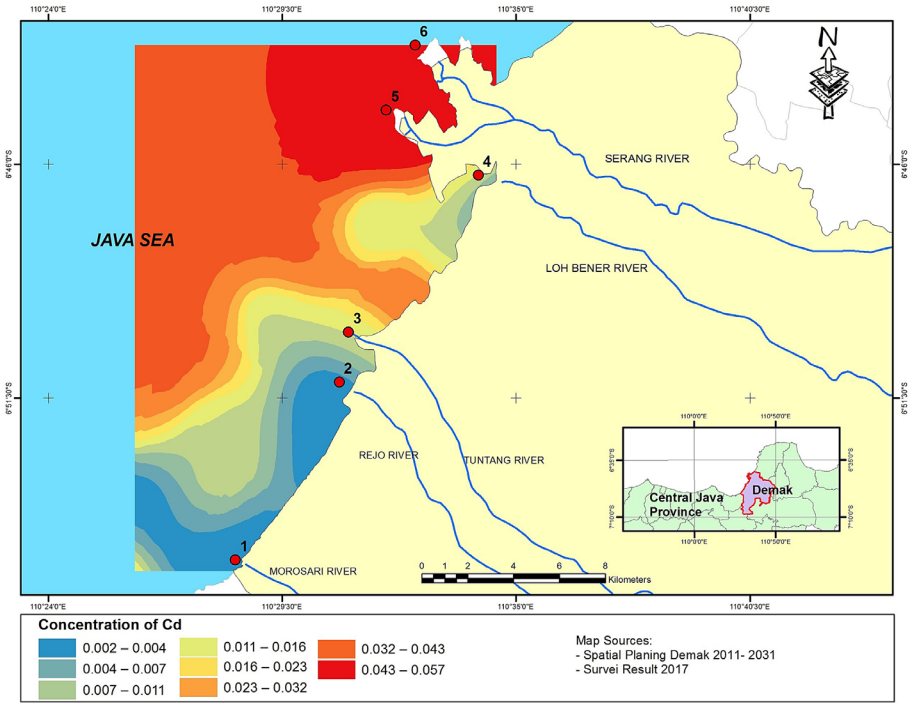

Fig. 5. Cd content in surface sediment (mg·l^{-1}) in Demak waters

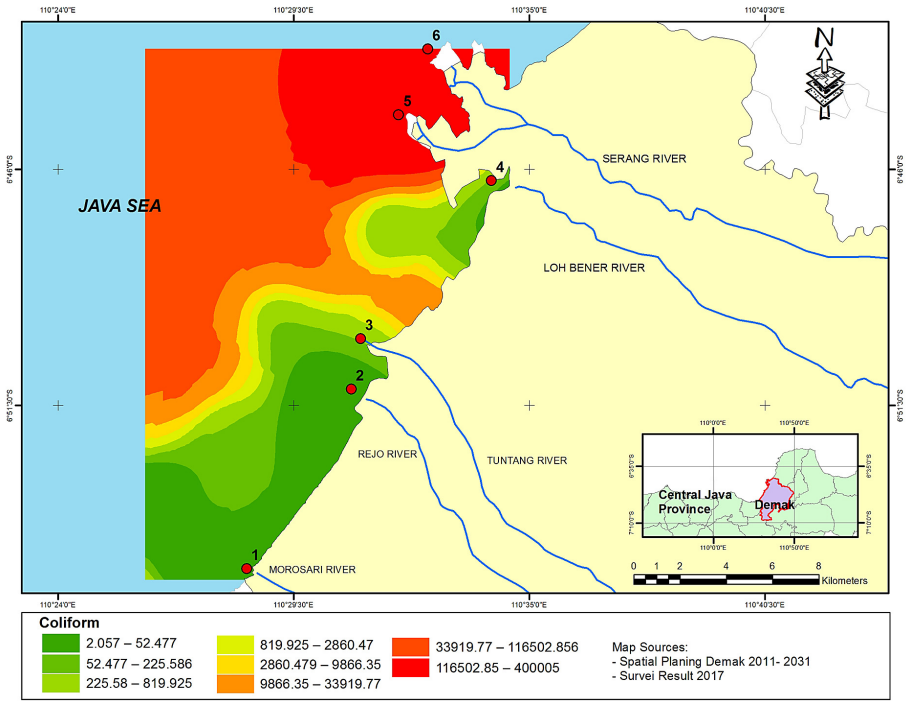

Fig. 6. Coliform abundance (MPN.-1000 ml) in Demak waters

ary of Morodemak river. The river depth ranged from 0.74 to 3.84 m and the water transparency was also low (Table 1).

The flow pattern during a high tide showed that the water moved to the land and the south east. When the observation took place, there was a high tide and a low tide. The highest tide occurred at 09:00 and the diurnal tide occurred at 19:00. This flow pattern caused the creation of the sediment and solution, despite spreading out to the sea, they gathered downstream and at the estuary (Figure 7).

On the basis of the analysis, it was revealed that Pb in water showed a low correlation with the

Table 1. The quality and physical condition of Demak Waters

Parameter/ Station	1	2	3	4	5	6
Temperature (^{0}C)	29.08±0.492	29.35±0.129	29.98±0.39	29.95±0.351	29.8±0.762	30.15±0.47
pH	7.458±0.069	7.38±0.008	7.43±0.17	7.25±0.087	7.375±0.081	7.7475±0.05
DO (mg.l^{-1})	5.06±0.312	6.268±0.102	6.033±0.35	5.635±0.232	5.51±0.872	6.2475±0.59
TDS (mg.l^{-1})	6,786±286.3	4,596±398.9	3,861±2,553	4,240±1,991	5,796±739.1	5,310±308
Turbidity (NTU)	3.623±1.539	1.918±0.319	4.503±1.82	5.035±2.413	10.64±6.371	32.5±4.79
Salinity (ppt)	35.45±0.129	17.65±0.129	19.15±0.47	18.5±0.294	19.1±0.52	18.75±0.13
Current (m.s^{-1})	0.083	0.125	0.143	0.333	0.25	0.125
Transparency (m)	1.05	2.45	1.8	0.91	0.59	0.47
Depth (m)	2.7	3.84	2.9	1.7	0.74	1.2

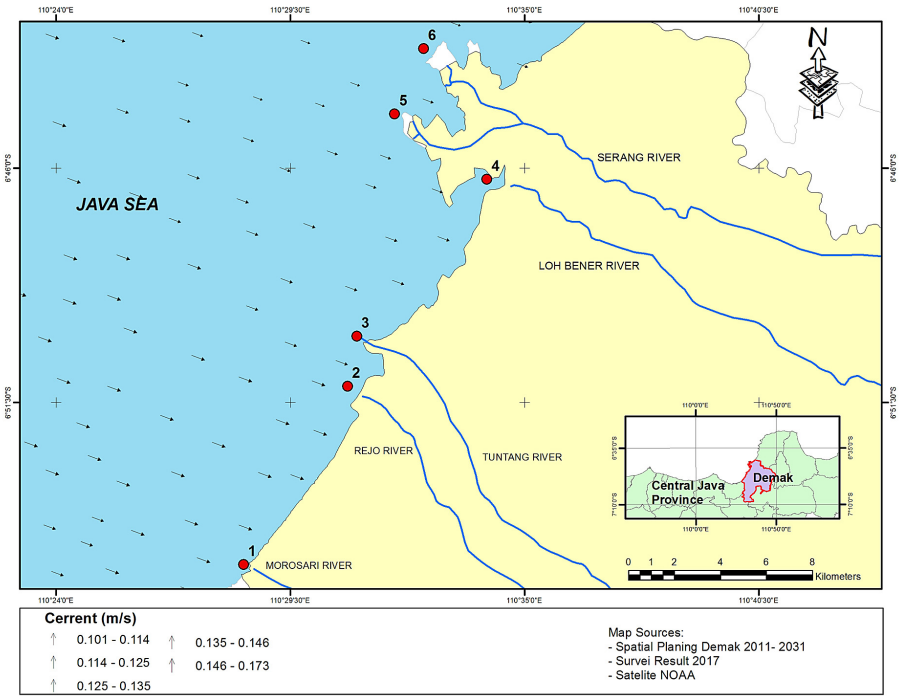

Fig. 7. Currents in Demak waters

temperature, TDS, salinity, and turbidity. However, Pb had a moderate correlation with DO. On the other hand, Cd in water had a very low correlation with TDS and the turbidity. It also had a low correlation with the temperature, DO, and salinity. Moreover, it has a significant correlation to pH. The Pb in sediment had a very low correlation with pH, DO, TDS, salinity, and turbidity. On the other hand, it had a moderate correlation with the temperature. It was also found that the Cd in sediment had a very low correlation with pH, DO, TDS, salinity, and turbidity. However, the Cd in sediment was highly correlated with the temperature. Coliform was also highly correlated with the temperature but had a low correlation with pH, TDS, and salinity. Moreover, it had a very low correlation with DO (Table 2).

The analysis revealed that the estuaries of Morosari, Rejo, Tuntang, and Lohbener were lightly polluted. However, the estuaries of Wedung and Serang were considered as heavily polluted. The pollution was caused by the abundance of coliform, which was 2400 times higher than the water quality standard of 1000 MPN·ml^{-1}. Moreover, the content of TDS also had surpassed the Class II water quality standard, based on Government Regulation No. 82 year 2001 about managing the quality of water and controlling water pollution. This regulation defines the requirement of water usable for fisheries. The highest content of TDS was found in the Morodemak estuary, whereas the lowest was found in the Rejo estuary (Table 3).

Comparing to other studies, the Pb content in Demak rivers was higher than what was found in

Table 2. Spearman correlation between heavy metal and Coliform toward physicochemical variables

	Temperature	pH	DO	TDS	Salinity	Turbidity
Pb in water	-0.314	0.086	0.429	-0.429	-0.143	-0.429
Cd in water	0.257	0.943**	0.2	0.143	0.314	0.143
Pb in sediment	0.543	-0.6	-0.029	-0.314	-0.371	-0.314
Cd in sediment	0.714	-0.371	0.143	-0.371	-0.429	-0.371
Coliform	0.771	0.257	-0.029	0.029	0.2	0.029
** significant at 0.01 (2 tailed)						

Table 3. Pollution Index Test

No.	Parameters	1	2	3	4	5	6	L_{ij}	1	2	3	4	5	6
		C_{imax}							PI_j					
1	Turbidity	4.96	2.25	6.09	7.14	16.14	36.6	4	3.14	2.95	2.95	2.85	145.95	146.45
2	pH	7.56	7.39	7.58	7.33	7.45	7.8	7						
3	TDS	7050	4962	6193	6058	6472	5592	1000						
4	DO	5.34	6.36	6.32	5.82	6.27	6.81	6						
5	Salinity	35.5	17.9	19.5	18.9	20	18.9	34						
6	Cd	0.15	0.171	0.12	0.13	0.064	0.065	0.01						
7	Pb	0.7	0.648	0.72	0.64	0.64	0.695	0.05						
8	Coliform	4	3	1,100	1,100	2,400,000	2,400,000	1,000						

some other water areas in Indonesia, such as Babon waters and estuary, port of Parepare, Katingan & Kahayan waters, Kendari and Kelabat bay. Moreover, the Pb content in Demak waters was 1640 higher than the Pb content in Kelantan, but was equal to the one in Jinzhou bay. The content of Cd in Demak water was also greater than in those areas, except for Kelabat and Jinzhou bay. However, the content of Pb in the sediment found in Demak was lesser than in the areas above, except for Tanjung Tias waters. The Cd content in the sediment investigated in this research was also lower than the contents which revealed in previous studies (Table 4).

Table 4. Comparison of the current research to the previous studies

Waters	Concentration in Sea Water ($mg \cdot l^{-1}$)		Concentration in Surface Sediment ($mg \cdot kg^{-1}$)		References
	Pb	Cd	Pb	Cd	
Demak estuary	0.6506±0.0229	0.0938±0.0264	0.3918±0.1493	0.0247±0.0202	Recent study
Babon estuary	0.02901±0.0114	NA	NA	NA	Kartikasari *et al*., 2002
Tangerang coastal	NA	NA	7.822±6.2786	0.1±1.4629	Hariyadi *et al*., 2017
Ambon island	NA	0.01–0.03	NA	0.17–0.32	Rumahlatu, 2011
Morodemak	NA	0.011	NA	1.372	Wulandari *et al*., 2009
Parepare port	0.3468±0.2591	NA	46.5199±12.4573	NA	Usman *et al*., 2013
Katingan & Kahayan	1.2942±0.1869	0.0053±0.0003	6.1861±1.3302	0.06±0.0037	Harteman *et al*., 2008
Kendari bay	0.0125±0.005	NA	0.7605±0.0587	NA	Amriani *et al*., 2011
Betahlawang	NA	NA	4.78–6.26	2–3.1	Kinasih *et al*., 2015
Sayung estuary	NA	NA	19.899±2.4741	NA	Amalia *et al*., 2014
Tanjung Tias	BDL	0.067	0.126	0.094	Achyani & Salim, 2014
Kelabat Bay	3.925±1.1471	0.825±0.9743	NA	NA	Arifin, 2011
Tanjung Emas port	NA	NA	10.88±3.09	1.05±2.29	Tjahjono *et al*., 2017
Yalujiang estuary	0.0004–0.0018	0.0008–0.0013	12.3–29.9	0.05–0.41	Li *et al*., 2017
Kelantan estuary	NA	NA	52.0133±12.1	0.0733±0.0306	Wang *et al*., 2017
Jinzhou Bay	0.61	0.92	NA	NA	Wang *et al*., 2012

Remarks: NA (Not Avaliable), BDL (Below Detection Limit)

CONCLUSION

The lead content in Demak waters was higher in the riverbed than the content found on the river surface. The content of Pb in the river surface ranged from 0.6037 to 0.6647 $mg \cdot l^{-1}$ whereas the content of Cd in the river surface ranged from 0.064 to 0.1707 $mg \cdot l^{-1}$. Both the content of Pb and Cd surpassed the water quality standard. The Pb content in the sediment ranged from 0.2563 to 0.6823 $mg \cdot kg^{-1}$ whereas the Cd content ranged from 0.0047 to 0.0577 $mg \cdot kg^{-1}$. Both contents found in the sediment revealed that the sediments were not polluted. The pollution index test showed that Morosari, Rejo, Tuntang and Lohbener estuaries were considered as lightly polluted, whereas Wedung and Serang estuaries were heavily polluted. Most of the Pb and Cd contents in Demak waters were higher than in the previous studies. However, the Pb and Cd content in the sediment considered in the current research was lower than what had been found in the previous studies.

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