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POLLUTION LOAD, ASSIMILATIVE CAPACITY AND QUALITY STATUS OF COASTAL WATERS IN POMALAA NICKEL MINING SITE OF SOUTHEAST SULAWESI

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ABSTRACT

Pomalaa Sub-District of Kolaka District, Southeast Sulawesi Province is a sub-district where parts of its region are used for operational locations of several national and multi-national nickel mining companies. The process of nickel smelting produces three types of effluent, i.e. machine-cooling water, slag-cooling water and used oil, in addition to slags as solid waste. Meanwhile in mining process, due to its open-cut nature, the wastes produced are mainly soil and rock (overburden) materials. If such wastes enter water, the quality of the water will decrease. This study aimed to measure pollution load, calculate assimilative capacity and determine the quality status of coastal waters in Pomalaa nickel mining site of Southeast Sulawesi. The result indicates that the pollution load of parameter of Total Suspended Solid (TSS), Copper (Cu), Chromium (Cr^{+6}), Nickel (Ni) and Cadmium (Cd) was higher than their assimilative capacity, while Lead (Pb) was lower. Using STORET, five (5) stations are considered moderately polluted, i.e. station 6 (Pomalaa Offshore), 7 (Tambea Offshore), 8 (Latumbi Offshore), 9 (Sopura High sea) and 10 (Tanjjung Leppe Offshore); while the other five (5) are heavily polluted, i.e. station 1 (Pomalaa Sea), 2 (Tambea Sea), 3 (Latumbi Sea), 4 (Sopura Sea) and 5 (Tanjung Leppe Sea).

Keywords *:* Pollution load, assimilative capacity and STORET.

1. Introduction

Industrial wastes are a matter of great concern all over the world as it pollutes the environment to a great extent. Coastal marine ecosystems are vulnerable to adverse impacts from various urban and industrial developmental activities, which could facilitate the disposal of several chemical agents, with consequent degradation in the water quality causing serious health hazards to the aquatic organisms (Naqvi *et al*., 2000; Jayakumar *et al*., 2001; Balachandran *et al*., 2002). Among environmental contaminants, heavy metals in effluents emerged as one of the most pressing problems because of their inherent toxicity, vast sources, persistence, and non-degradability (Breierova *et al*., 2002; Honjoh *et al*., 1997). Heavy metals from mining, smelting, agriculture, petrochemical industry, printing, aquaculture, electronic industry and municipal waste discharged to the aquatic environment can be bioaccumulated by the organism and biomagnified through food chain (Ciji and Bijoy Nandan, 2014). Metal contamination in aquatic systems is a matter of serious concern from human health point of view as many of the organisms particularly fish forms an integral part of human diet. Therefore a better understanding of the status of heavy metal pollution is inevitable for a sustainable development of the coastal marine ecosystem (Rainbow and Luoma, 2011). Discharge of greater quantity pollutants into the aquatic environment may result into deterioration of ecological imbalance, changes the physical and chemical nature of the water and aquatic biota (Mita *et al*., 1996).

The concept of assimilative capacity has existed for centuries, although not formally stated. The Industrial Revolution produced wastes that had no counterpart in nature or were discharged in vast quantities so that natural systems simply could not assimilate them (Cairns, 1977, 1981). In fact, both laboratory toxicity tests and field stream surveys had the goal of determining the no-bservable-deleterious-effects threshold (assimilative capacity) for a wide variety of aquatic ecosystems. The concept of assimilative capacity has been expanded to include the ability to absorb wastes other than simple organics without being degraded. In addition, natural systems can break down, render biologically unavailable, or disperse some other types of contaminants. Even complex organic chemicals such as pesticides and hydrocarbons are broken down in the environment through both biotic and abiotic processes (Howard, 1991).

Nickel is one of mining products widely produced Indonesia, the fourth biggest nickel producer after Australia, Canada and New Caledonia. The four countries cover around 65% global nickel demand and Indonesia itself covers around 8.6% out of which. Based on data from Geological Agency of Ministry of Energy and Mineral Resources, up to date Indonesia has nickel reserve of around 3.2 billion tons and it is estimated can be mined until the next 50 years. During the last decade, global nickel demand increased from 1,286 kilo ton in 2008 to 1,770 kilo ton in 2013, with average increase per year of 4.2%. This demand's increase and decrease occur in accordance to economic growth.

In Indonesia, one of nickel producers is Pomalaa Sub-District of Kolaka District, Southeast Sulawesi Province. To date, there are two giant companies run nickel mining operation in the sub-district, i.e. PT ANTAM and PT Vale, in addition to 12 other small-scaled private companies covering total concession area of 11,496.70 ha. The increasing nickel demand in global market leads to the increasing competition among nickel mining companies to increase their production. As the result massive land clearing takes place which is responsible for high sedimentation rate in coastal area. Environment Research Center of Southeast Sulawesi University in 2009 reported that the bigger area cleared for mining site, the higher sedimentation rate in coastal area will be. Based on the previous analysis, the sedimentation of mining sludge which flows through rivers around Pomalaa waters is 1,330,281 m^3/year, or in other word the sedimentation rate is 0.507 m/year. It is predicted that in 10 years the contour of 1-3 meter depth will change into 923.4 ha land area and Pomalaa waters will eventually remain only 197.1 ha. According to Widiatmaka *et al.* (2010) using USLE method, soil erosions in several points of Pomalaa nickel mining sites already meet heavy category threshold.

Another big impact is the increase in water turbidity of coastal area. The sea water of Hakatutobu and Tambea Villages has now turned dark brown, leads to the sudden death of sea cucumbers cultivated by local community. Such sea cucumber death case has often occurred, i.e. in 2005, 2007, 2008 and 2010. In addition to sea cucumber, grouper fish cultivated using floating fish net (*keramba jaring apung*- KJA) also experience death. It is strongly predicted that the water entering coastal area thorugh several rivers has been polluted at toxic level for water organisms. According to Hamzah (2009) based on test result of several water quality parameters such as total suspended solid (TSS), Iron (Fe), Zinc (Zn), Chromium (Cr), Lead (Pb) and Nickel (Ni), it is known that the concentration of pollution load has already exceeded the limit of their assimilative capacity.

Technically, mining in Pomalaa Sub-District consists of two main activity, i.e. mining and processing. The processing activity produces slags as solid waste, in addition to slag-cooling water and oil as effluents. Slags are residue/waste that take form as solid clumps and consist of minerals which are the aggregate of waste product residue from the combustion of electric furnace. According to Widiatmaka (2010), two types of feronickel slags are electric furnace slag, dominated by Si and Mg, and converter furnace slag, dominated by Fe, Ca, and Si. Compared to steel slag, ferronickel slag (electric furnace slag) contains more Si and Mg and fewer Ca, Fe, P, and Mn.

In mining, due to its open cut nature, the precence of soil and rock (overburden) materials highly affects the ecological condition of the surrounding area. This will be worsen by heavy rain as the materials will be eroded, enter into sea and eventually be sedimented and change the sea water quality of coastal area (Arsyat, 2010). The present study aimed to determine the quality status of coastal waters of Pomalaa nickel mining site in Southeast Sulawesi, to measure pollution load that enters into coastal waters of Pomalaa nickel mining site in Southeast Sulawesi, to calculate assimilative capacity of coastal waters of Pomalaa nickel mining site in Southeast Sulawesi.

2. Study Method

2.1. Study Location and Time

This study was carried out in Pomalaa Sub-District of Kolaka District, Southeast Sulawesi Province for nine (9) months, starting from February 2014 to October 2014. A total of 10 sea water sampling stations.

For several parameters, water quality analysis was carried out directly on site while heavy metal analysis in Laboratory. The measurement of sea water quality was carried out during flow period, i.e. 07:00-09:00 of the local time and the measurement of river water quality was carried out during sea ebb period.

2.2. Water Sampling and Analysis Method

River and sea water samplings were carried out using Van Dorn water sampler. See Table 1 for measurement tools/methods of water physical-chemical characteristics used for this study.

Table 1 Analysis tools and methods for the measurement of water physical-chemical characteristics

Parameter	Unit	Method/Tool	Note
A. Physical (water)			
1. Temperature	°C	Thermometer	In Situ
2. Turbidity	Nephelometric Turbidity Units (NTU)	Turbidimeter	In Situ
3. Suspended Solid	mg/l	Gravimetrix	Laboratory
B. Chemical (water)			
1. Salinity	Practical Salinity Unit (PSU)	Refractometer	In Situ
2. 2. pH	-	pH-meter	In Situ
3. 3. Dissolved Oxygen (DO)	mg/l	DO-meter	In Situ
4. 4. BOD_5	mg/l	SNI 6989.72:2009	Laboratory
5. Phosphate (PO_4-P)	mg/l	SNI 7554.5:2011	Laboratory
6. Nitrite	mg/l	SNI 6989.79:2011	Laboratory
7. Free Ammonia (NH_3-N)	mg/l	SNI 6989.30:2005	Laboratory
8. Copper (Cu)	mg/l	SNI 6989.6:2009	Laboratory
9. Zinc (Zn)	mg/l	SNI 6989.7:2009	Laboratory
10. Hexavalent Chromium (Cr^{+6})	mg/l	SNI 6989.53:2010	Laboratory
11. Lead (Pb)	mg/l	SNI 6989.46:2009	Laboratory
12. Nickel (Ni)	mg/l	SNI 6989.18:2009	Laboratory
13. Cadmium (Cd)	mg/l	SNI 6989.16:2009	Laboratory

3. Data Analysis

3.1. Pollution Load and Assimilative Capacity

Pollution load was calculated based on the direct measurement of river flow and the concentration of measured parameter using the following model (Mitsch and Gosselink, 1993):

$$PL = Q \times C \times 3600 \times 24 \times 30 \times 1 \times 10^{-6}$$

Note: PL = Pollution load from river (ton/month).
Q = River flow (m^3/second).
C = Waste concentration (mg/L).

Water assimilative capacity was determined by establishing relationship graph between the concentration of effluent parameter and pollution load before being analyzed by cutting the graph with standard quality line based on the Decree of Minister of Environment No.51/Men-LH/2004. The value of assimilative capacity was obtained from the intersection with standard quality value for each tested parameter. The assimilative capacity analysis in this study was based on the following basic assumptions.

1. The value of assimilative capacity only applies for coastal areas within limits established in the study.
2. The value obtained, both for coastal and river areas, is assumed represent the dynamic of the water.
3. The calculation of pollution load is land-based only where pollution from activities in coastal area and sea are not included.

Water quality data is data affecting the water quality of river and coastal areas. Therefore, the linear regression equation is as follow. $Y = f(x)$

Mathematically the linear regression equation is:
$y = a + bx$

Note: a = Coefficient represents y-value at the intersection between linear line and vertical axis.
b = Coefficient of regression for the parameter of river estuary.
x = Pollution load.
y = Pollutant concentration.

3.2. Determining Water Quality Status

Water quality status was approached using STORET (STOrage and RETrieval) method (Decree of Minister of Environment No. 115 Year 2003) while water standard quality referred to Decree of Minister of Environment No. 51 Year 2004.

Table 2 The classification of water class based on STORET index

Class	Score	Category
Class A (very good)	0	meet the standard quality
Class B (good)	-1 to -10	slightly polluted
Class C (moderate)	-11 to -30	moderately polluted
Class D (poor)	≤-31	heavily polluted

4. Result and Discussion

4.1. Water Standard Status

Based on water quality measurement data in Table 4 using STORET method, the water condition of station 1 (Pomalaa Sea), 2 (Tambea Sea), 3 (Latumbi Sea), 4 (Sopura Sea) and 5 (Tanjung Leppe Sea) belonged to poor category or heavily polluted. The poor water quality of the stations was due to the presence of mining company activities that exploit nickel using open cut method. The main drawback of such method is huge amount of soil materials exposed to ground surface. As the result, heavy rain increases TSS which leads to soil erosion, sedimentation, the decrease in water quality and disturbance toward water biota. The other parameters that also decrease the water quality of heavily polluted stations were NO_3-N, PO_4-P and NH_3-N. The high concentration of the parameters were allegedly from the waste of fish pond in Pomalaa coastal area and the remnants of agricultural fertilizer dissolved in run-off water. Heavy metal parameters that contribute to the poor water quality of station 1, 2, 3, 4 and 5 were Cu, Pb, Cd and Ni.

The water condition of Station 6 (Pomalaa Offshore), 7 (Pomalaa Offshore), 8 (Latumbi Offshore), 9 (Sopura Offshore) and 10 (Tanjung Leppe Offshore) belonged to moderately polluted category as shown in Table 3.

Table 3. The STORET score

No	Station	Score	Water Quality Status
1	Pomalaa Sea	-50	Heavily Polluted
2	Tambea Sea	-52	Heavily Polluted
3	Latumbi Sea	-52	Heavily Polluted
4	Sopura Sea	-50	Heavily Polluted
5	Tanjung Leppe Sea	-47	Heavily Polluted
6	Pomalaa Offshore	-27	Moderately Polluted
7	Tambea Offshore	-26	Moderately Polluted
8	Latumbi Offshore	-29	Moderately Polluted
9	Sopura Offshore	-23	Moderately Polluted
10	Tanjung Leppe Offshore	-25	Moderately Polluted

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Table 4. The average of water quality observation result

Parameter	Unit	Standard Quality	The average of water quality observation result in each station									
			1	2	3	4	5	6	7	8	9	10
Total Suspended Solid (TSS)	mg/L	20	53.35	37.76	38.67	45.00	47.89	19.38	24.78	19.78	18.11	16.33
Turbidity	NTU	<5	0.38	0.32	0.75	0.31	0.33	0.12	0.18	0.38	0.23	0.28
Salinity	‰	natural¯3(e)	32.59	32.13	32.08	32.27	32.63	32.21	32.22	32.29	32.29	32.43
pH		6-9	8.14	8.25	8.26	8.22	8.15	8.22	8.22	8.21	8.18	8.20
BOD5	mg/L	20	5.973	9.034	8.839	8.167	6.922	5.905	5.796	5.966	5.614	5.098
Dissolved Oxygen (DO)	mg/L	> 5	7.020	6.530	6.671	6.734	6.617	6.551	6.853	6.889	6.678	6.564
Nitrate	mg/L	0.008	0.590	0.578	0.539	0.520	0.535	0.342	0.373	0.428	0.336	0.378
Phosphate (PO_4-P)	mg/L	0.015	0.223	0.095	0.111	0.111	0.211	0.013	0.014	0.014	0.010	0.007
Total Ammonia (NH_3-N)	mg/L	0.3	2.786	0.621	3.566	3.563	3.624	0.071	0.121	0.116	0.091	0.056
Copper (Cu)	mg/L	0.008	0.023	0.032	0.032	0.031	0.031	0.017	0.029	0.032	0.029	0.018
Zinc (Zn)	mg/L	0.05	0.043	0.026	0.026	0.026	0.030	0.026	0.026	0.028	0.026	0.032
Hexavalent Chromium (Cr(VI))	mg/L	0.005	0.005	0.005	0.005	0.006	0.007	0.004	0.005	0.007	0.004	0.006
Lead (Pb)	mg/L	0.008	0.244	0.193	0.189	0.191	0.154	0.055	0.005	0.198	0.004	0.004
Nickel (Ni)	mg/L	0.05	0.238	0.177	0.165	0.165	0.202	0.038	0.040	0.046	0.034	0.040
Cadmium (Cd)	mg/L	0.001	0.183	0.086	0.077	0.076	0.091	0.010	0.015	0.076	0.072	0.016

Note: [grey box] = Exceeds threshold regulated under Decree of Minister of Environment No. 51 Year 2004.

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Using Ocean Data View (ODV) version 4.7.3 software, the status of water quality is mapped using colors as shown in Figure 1.

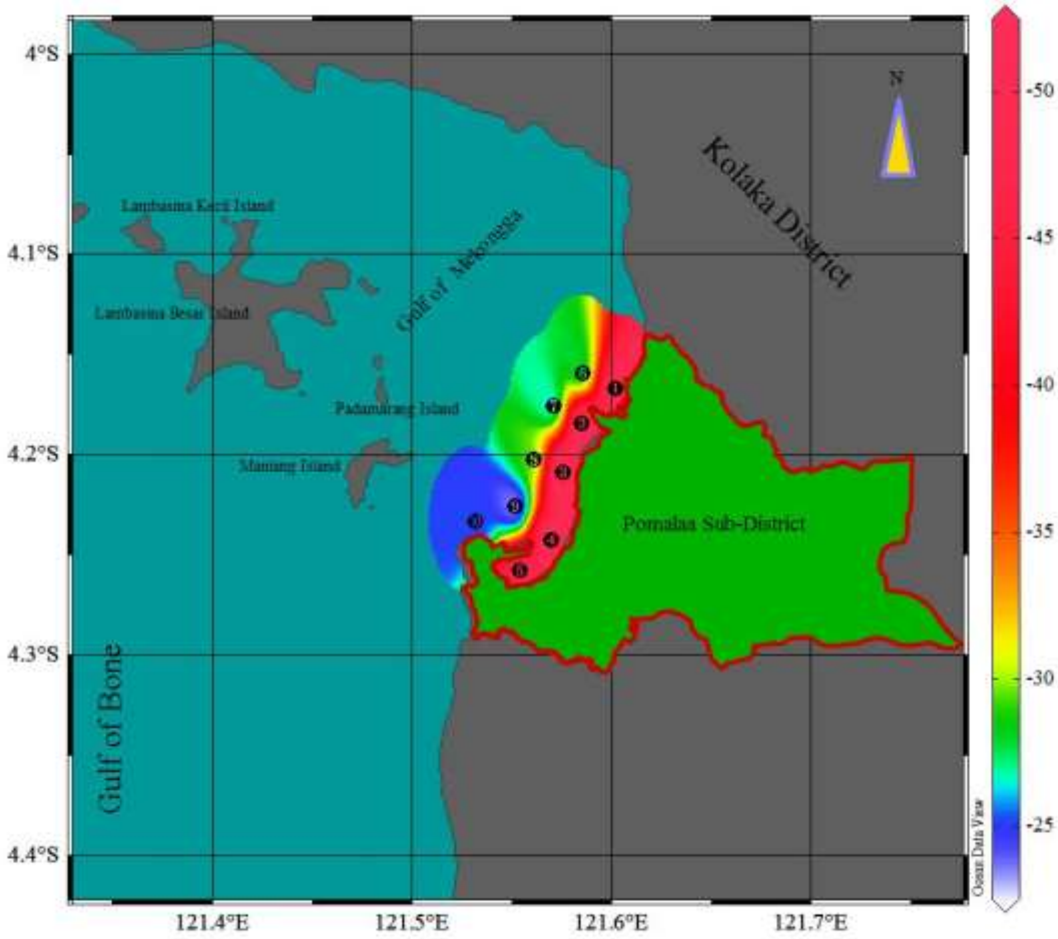

Figure 1. The status of water pollution

4.2. Pollution Load

Pollution load that enters mining site coastal area was from three main sources, i.e. river, mining outlet and check dam. There are four rivers, i.e. Huko-huko, Pelambua, Komoro and Oko-oko, five Check Dams namely Tanjung Leppe, Pesouha, Sitado, Latumbi and Tonggoni, and only one outlet, i.e. Ferronickel mill outlet. See Table 5 for the calculation result of pollution load that enter the coastal area of Pomalaa nickel mining site in Southeast Sulawesi.

Table 5 Pollution load that enter the waters

Parameter	Unit	Pollution Load (ton/month)						Total PL (ton/month)
		Huko-huko River	Pelam bua River	Kumoro River	Oko-oko River	Mill Outlet	Check Dam	
TSS	mg/l	743.336	26.865	416.860	116.119	1,485.994	26.229	2,815.402
Copper (Cu)	mg/l	0.264	0.010	0.010	0.027	1.366	0.035	1.7112
Zinc (Zn)	mg/l	0.662	0.024	0.025	0.061	0.3942	0.0371	1.203
Total Chromium (Cr)	mg/l	0.285	0.111	0.022	0.048	0.9219	0.1100	1.498
Lead (Pb)	mg/l	0.048	0.002	0.007	0.009	0.1860	0.0039	0.2553
Nickel (Ni)	mg/l	0.548	0.012	0.021	0.168	2.8770	0.0611	3.687
Cadmium (Cd)	mg/l	0.076	0.080	0.088	0.009	0.2638	0.0105	0.528

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TSS was parameter whose concentration entering water the highest among all, i.e. up to 2,815.402 ton/month with mill outlet as the biggest contributor (1,485.994 ton/month). The high concentration of TSS from nickel processing mill was due to the wastewater treatment plant (WWTP) has yet to fully run. The second highest contributor was Huko-huko River, i.e. 743.336 ton/month. Although the aggregate of TTS concentration in the river was not too high, the contribution of the river was high due to high river flow. In addition, there were also nickel mining exploitation activities carried out in watershed areas of Huko-huko River. After being exploitated, lands that are previously vegetated become bare. With the addition of high rainfall, erosion rate increases, resulting in more sediments carried out along run-off soils. The order of heavy metal pollution load from the biggest to the smallest is Ni>Cu>Cr>Zn>Cd>Pb. The composition and variability of total suspended solids (TSS) in this river-ocean boundary are affected by sediment–water interactions, changes in metal adsorption–desorption equilibrium along the salinity gradient or both[8] and physical processes (river flow, tidal energy, currents), therefore often difficult to interpret (Turner *et all*, 1994). Sediments of coastal region can be sensitive indicators for monitoring contaminants in aquatic environments (Balls *et all*, 1997., Atgin *et all*, 2000), act as a major reservoir of metals (Caccia *et all*, 2003), and also as a source of contaminants (Adam *et all*, 1992) via several pathways, including disposal of liquid effluents, terrestrial runoff, and leachates carrying chemicals originating from numerous urban, industrial, and agricultural activities, as well as atmospheric deposition (Rivail *et all*, 1996., Karageorgis *et all*, 2002., Mucha *et all*, 2003). Enrichment of heavy metals due to industrialization and urbanization was recorded in sediments of coastal seas all over the world (Pekey, 2006).

Naturally, the entry of organic-rich sediment from land is highly necessary for the life of water biota. Several of them require sediment in particular size for spawning and protecting eggs from predators (EPA, 2012). The high concentration of TSS in water body adversly affects water biota, i.e. it covers fish gills and makes it difficult for particular fish species to avoid predator attack (McNally and Mehta, 2004). Suspended sediment particles control the transport, reactivity and biological impacts of substances in the marine environment, and are a crucial link in interactions between the seabed, water column and the food chain (Turner dan Millward, 2002). The most obvious effect of increased sedimentation is a reduction in light available for photosynthesis. Phytoplankton and free-floating macroalgae are better competitors for light than benthic plants (including seagrasses) (Duarte, 1995), and will tend to out-compete them as light becomes limiting during progressive eutrophication. Competition between the benthos and pelagic communities for light and nutrients also gives rise to hysteresis effects. Notwithstanding these effects, turbidity also controls the phytoplankton biomass that can potentially develop (Monbet, 1992 dan Cloern, 1987), and therefore the extent to which dissolved nutrients can build up in the water column. With high concentrations of nutrients in the water column under turbid conditions, denitrification may become coupled to water column nitrate rather than to nitrification (Eyre and Ferguson, 2002).

Suspended sediment can smother benthic organisms and habitats when it settles, and can cause mechanical and abrasive impairment to the gills of fish and crustaceans (ANZECC/ARMCANZ, 2000). Suspended sediment also transports contaminants (particulate nutrients, metals and other potential toxicants) (ANZECC/ARMCANZ, 2000), promotes the growth of pathogens and waterborne diseases, makes pathogens and waterborne diseases, makes marine pests difficult to detect (Neil, 2002) and can lead to dissolved oxygen depletion in the water column if it is caused by particulate organic matter. Overall, unnaturally high turbidity levels can lead to a reduction in the production and diversity of species. In particular condition, highly sensitive species leave the location (EPA, 2012).

Heavy metal parameters contribute the most to pollution load was nickel, i.e. 3.687 ton/month, mostly from mill outlet (2.887 ton/month), Huko-huko River (0.548 ton/month) and Oko-oko River (0.168 ton/month). Particularly in mill outlet, the high concentration of nickel was allegedly due to the remaining nickel contents in slag remnant dissolved in slag-cooling water and then eventually enter the water body. The high concentration of heavy metal in water body highly endangers living organisms within. Given the heavy metals in water will be accumulated in those organisms (Velusamy *et al.* 2014, Zeitoun 2014 and Riani *et al.* 2014), the metal will endanger living organisms within the water. This is in line with Riani (2015) who stated that high concentration of Pb, Cr and Cd in water can damage tissues of liver, kidney and spleen of carp fish cultivated using floating fish net (KJA). Heavy metals can contribute to the degradation of marine ecosystems by reducing species diversity and abundance and through accumulation of metals in living organisms and food chains (Hosono *et al*., 2011).

4.3. Assimilative Capacity

Water assimilative capacity is defined as "the ability of an area to maintain a healthy environment and accommodate wastes" (Fernandes *et al.*, 2001).

Figure 2 shows the assimilative capacity (AC) of TSS, Pb, Cu, Zn, Cr IV, Ni and Cd while Table 6 shows the relationship between pollution load and assimilative capacity.

Table 6. The Relationship between Pollution Load and Assimilative Capacity

Parameter	Function	R^2	Pollution Load/PL (ton/month)	Assimilative Capacity/AC (ton/month)	Note
TSS	y = 0.1365x + 117.6	0.69	2,815.402	680.54	PL > AC
Copper (Cu)	y = 1.464x – 0.4348	0.43	1.7112	0.129	PL > AC
Zinc (Zn)	y = 0.0211x + 0.0291	0.38	1.203	0.099	PL > AC
Total Chromium (Cr)	y = 0.0301x + 0.0292	0.51	1.498	0.812	PL > AC
Lead (Pb)	y = 0.211x + 0.029	0.38	0.2553	0.886	PL < AC
Nickel (Ni)	y = 0.8397x – 0.2035	0.75	3.687	0.301	PL > AC
Cadmium (Cd)	y = 8.8394x – 2.538	0.45	0.528	0.288	PL > AC

Table 6 show that the pollution load of TSS, Copper (Cu), Chromium (Cr), Nickel (Ni) and Cadmium (Cd) was higher than their assimilative capacity. This indicates that the parameters, particularly heavy metals, need to be aware of, given the metals do not only damage various body organs but also are teratogenic in nature. In line, Riani *et al.* (2014) succeeded to prove that Cr and Pb in water of Saguling Reservoir (Indonesia) are responsible for inherited disability to the antenna of chironomidae *Dicrotendipes simpsoni.* Similarly, Wang *et al.* (2009) also reported that heavy metal Pb, cadmium and mercury in water hinder embryogenesis, development and metamorphosis processes of *Meretrix meretrix* larvae. In addition, Dermeche *et al*. (2012) stated that heavy metal pollution hinder the embryo development of sea urchins. The contamination of heavy metals in water has also been proved potential to hinder the reproduction process of water organisms (Jalius *et al.* 2008a; Jalius *et al.* 2008b, and Riani 2011). Therefore, the high content of heavy metal in water, particularly heavy metals, that have already exceeded their assimilative capacity (Table 6) are needs to be aware of as they are not only endanger living organisms within but also potentially threaten the sustainability of the organisms.

The increases in anthropogenic activities contribute to the accumulation of hazardous chemicals, such as heavy metals, in the environment (Lias *et al.*, 2013; Ismail, 2006; Tucel *et al.*, 2007). Heavy metal discharged into the environment rapidly associates with particulates and ultimately settles in bottom sediments of water bodies, either direct discharge or surface run-offs (Inengite *et al.*, 2010). Most of the living organisms need small amount of essential metals such as Fe, Mn, Cu, and Zn for essential processes such as growth (Kamaruzzaan *et al.*, 2011; Ndome *et al.*, 2010). However, all these metals will give harmful effects when exceeding the standard limits (Beldi *et al.*, 2006). The non-essential metals such as Cd, Pb, Ni, and Cr are toxic even at relatively low concentration and not essential for metabolic activities (Kamaruzzaan *et al.*, 2011, Astudillo *et al.*, 2005).

5. Conclusion

1. Total pollution load of TSS was 2,815.402 ton/month, Copper (Cu) 1.711 ton/month, Zinc (Zn) 1.203 ton/month, Total Chromium (Cr^{+6}) 1.498 ton/month, Lead (Pb) 0.255 ton/bln, Nickel (Ni) 3.687 ton/month and Cadmium (Cd) 0.528 ton/month.
2. The pollution load of TSS, Copper (Cu), Chromium (Cr^{+6}), Nickel (Ni) and Cadmium (Cd) was higher than their assimilative capacity, while Lead (Pb) was lower.
3. Using STORET, five (5) stations are considered moderately polluted, i.e. station 6 (Pomalaa Offshore), 7 (Tambea Offshore), 8 (Latumbi Offshore), 9 (Sopura High sea) and 10 (Tanjjung Leppe Offshore); while the other five (5) are heavily polluted, i.e. station 1 (Pomalaa Sea), 2 (Tambea Sea), 3 (Latumbi Sea), 4 (Sopura Sea) and 5 (Tanjung Leppe Sea).

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