The Impact of Water Quality Detorioration in Mangrove Forest in Semarang Coastal Area

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Abstract
The fast-growing development and industrialization have caused various impacts on nature including heavy metal pollution, especially in the coastal area. Tambakredjo, located in the North Semarang city, is home to a large number of mangrove and animal species. Therefore, water quality is important. This study was conducted to analyze water quality in the coastal area of Tambakredjo based on physical and chemical measurements. Water quality data were collected from different sites. Physical parameters (temperature, pH, DO, EC, TDS, ORP and salinity) and chemical parameters (Total N, Total P, Pb, Cr, Cd) were observed. Multivariate statistical techniques, including Principal Component Analysis (PCA), was applied to evaluate water quality. The results showed first principal component is 76.27%, where the highest conductivity, total dissolved solids and salinity are associated with site 1. Content of Lead 1.289 ppm, Cadmium 0.021 ppm, and Chromium 0.352 ppm exceeds the water quality standard PP. No. 82/2001. It indicated that Site 1 was characterized as the most heavily polluted site because the location received pollutants from rivers and oceans. This study also examined the short-term changes of the mangrove-covered area at the side of Banjir Kanal Timur using historical map satellite images. The results show that mangrove coverage in Tambakredjo near the aquaculture area had decreased from 1,875m2 to 1,401m2. Meanwhile, on the other site, the mangrove planting effort as a restoration program is carried out, especially in the estuary of Banjir Kanal Timur to anticipate more environmental changes.

Keywords: mangrove, metal, land subsidence, water quality

INTRODUCTION

Tambakredjo area has been one of the most rapidly industrialized regions in the Semarang since the last twentieth century. Therefore, it is suitable for studying the environmental impacts of rapid industrialization and accompanying socio-economic changes. The industrialization in Semarang has mainly focused on the coastal area. The existence of the Tanjung Mas Port, West Flood Canal, and East Flood Canal in coastal Semarang has a consequence (Puspitasari & Purbonegoro, 2016).

The Positive consequence of industrialization can be seen throughout Water Resources and Flood Management Project for Semarang (IWRFMP for Semarang). The development of appropriate flood risk management strategies for floods must be considered in a long-term perspective, and the Semarang government has normalized the East Flood Canal or *Banjir Kanal Timur* (BKT) with the passage of the National

Flood Insurance Law to help reduce future flood damage through the community (Putra *et al*, 2020; Samui *et al*, 2018).

Meanwhile, the BKT expansion project for the Semarang water management system has had an impact on the community, both environmental and socio-economic changes (Subianto *et al*., 2019; Siahaan *et al*., 2021). Banjir Kanal Timur is a coastal area surrounded by mangrove ecosystems and ponds, but the changes in environmental conditions could affect the water quality of mangroves. Particularly, the increase in population growth has reduced the green zone (mangrove ecosystem). This ecosystem has been under pressure by the conversion of mangrove areas into aquaculture caused seawater intrusion accompanied by an increase in pollutants from domestic and industrial waste (Nurimansyah *et al*., 2015; Mustofa *et al*., 2020).

Furthermore, increased of anthropogenic activities like aquaculture or domestic sewage, oil spill, PAH contamination through runoff water and the conversion of land use change with anthropogenic activity near catchment area of mangrove has an impact for physical parameter (increased sediment load, Total Suspended Solid (TSS), Turbidity, pH, Temperature) and chemical parameter such as Total Nitrogen, Total Phosphor, Cadmium, Chromium and Lead) on the water quality to support mangroves that have important value in terms of ecosystem services

Heavy metals are used in various industrial processes, agricultural activities, domestic waste and vehicles emission. On the other hand, heavy metals that originated from anthropogenic sources could be found in all environmental components (Patel *et al*., 2018; Almahasheer *et al*., 2018; Armiento *et al*., 2020). Several studies have been carried out on heavy metal pollution within mangrove environments worldwide (Usman *et al*., 2012; Alzahrani *et a*l., 2018; Yan *et al*., 2017), and many studies have been published to evaluate the water quality of Banjir Kanal Timur. But, the research on the water quality of mangrove ecosystems near Banjir Kanal Timur in Semarang is still limited. Therefore, the study of coastal sediments provides useful information on marine pollution.

Mangroves in Semarang are under increasing heavy metal pollution pressure from human activities because of the rapid industrialization and urbanization in coastal areas. Mangroves also have the lesser-known incredible ability to improve the water quality of their ecosystem. The roots hold onto sediments which reduces erosion and leads to better water quality (Chai *et al*., 2018; Kulkarni *et al*., 2018). The function of the mangrove ecosystem aims to anticipate the threat of abrasion and land subsidence in the Tambak Lorok area (Wirasatrio *et al*., 2017).

Mangrove ecosystems also have physical functions to reduce waves and hurricanes, protectors from abrasion, silt retention and sediment capture. Several methods have been developed to maintain the mangrove ecosystem. However, conservation not only has a significant impact on mangrove abundance but also on the management and sustainable development of mangroves related to the maintenance of hydro-geochemical characteristics of the system. Especially water quality which functions to maintain mangrove's ability to support the habitat diversity and the composition of species that inhabit the environment.

The study of the ecological conditions and ecosystems of mangroves in Tambakredjo has not been much done, especially in terms of assessing the water quality. Therefore, this research aims to evaluate the water quality of mangrove ecosystems concerning physicochemical parameters (Total N, Total P) and the determination of heavy metals (Pb, Cr, Cd).

METHODS

Sample collection

The research was conducted at the coastal waters of Semarang, Central Java in July 2021. The sediment samples were taken from different sites locations of the Tambakredjo area as impact site and Maerokoco as the reference condition.

Geographically, the Tambakredjo area is characterized by the land-sea transition system with nearly flat topography, almost at the sea level, definitory for the areas easily affected by the penetration of currents, waves, and wind. Furthermore, Tambakrejo shows indications of land subsidence in Semarang with a high rate of land subsidence is between 9 - 13 cm/year (Soedarsono *et al*., 2012). Observation of sites that represent coastal areas in Semarang District is presented in Figure 1 and Table 1.

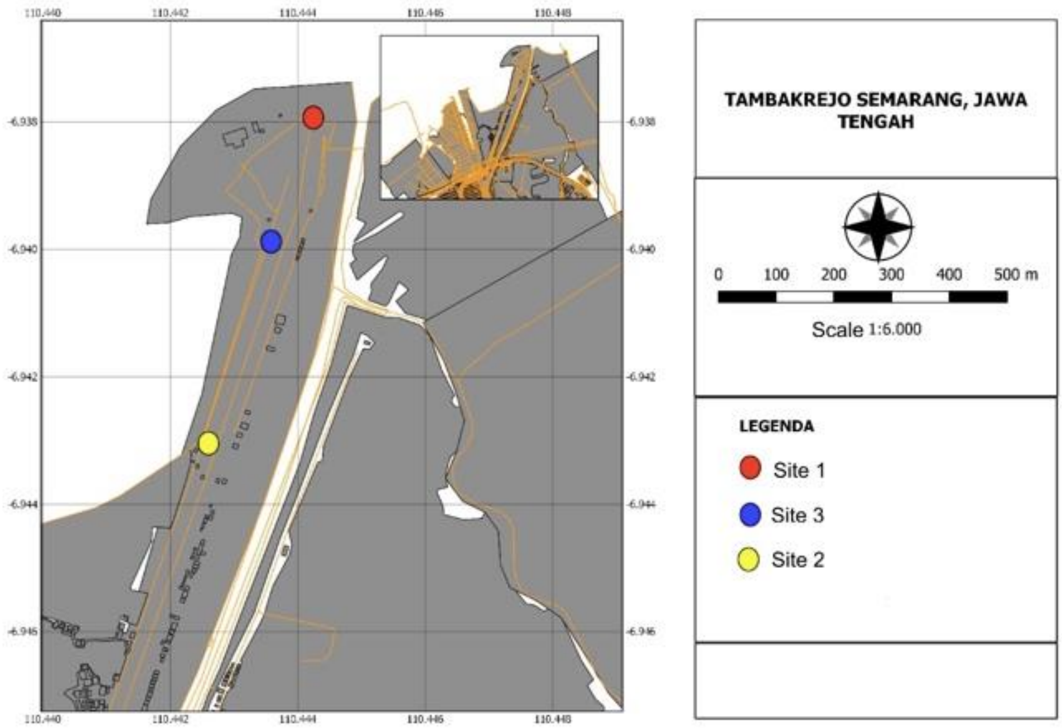

Figure 1. Map of study area

Physical Parameters

A set of basic physicochemical water quality parameters including temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), Total Dissolved Solids (TDS), Oxygen Reduction Potential (ORP), and salinity were measured at all sites during each sampling period. Physical water quality parameters such as pH, temperature (°C), Dissolved Oxygen (DO) (mgL^{-1}), and salinity (ppt) were measured *in situ* using a multiparameter Horiba U-50.

Table 1. Coordinate of sampling area

Site	Location	Coordinate	
		East Longitude	South Longitude
1	Coastal area	110°26'39.27"	6°56'17.75"
2	Mangrove	110°26'30.10"	6°56'43.46"
3	Banjir Kanal	110°26'38.42"	6°56'25.73"
4	Maerokoco	110°23'12.30"	6°57'35.03"

Chemical Parameters

All sampling was conducted during a low tide period. All surface water samples were taken using a van Dorn water sampler and stored in appropriate polyethylene bottles for the laboratory analysis. All the chemical analyses were performed according to standard methods (Buffle, 1990; Greenberg, 2012). Atomic Absorption Spectrometry (AAS) was chosen because of the very common and reliable technique for detecting metals and metalloids in environmental samples (Hauser, 2002; Boyd, 2015) then the sample and standards used to calibrate the AAS instrument is crucial to the analytical accuracy and precision of the results. The analysis was carried out on surface water at several locations in Banjir Kanal Timur (coastal and Mangrove) and Mangrove in Maerokoco to determine the physical parameter.

The method used in this research is to use multitemporal image data, where the data that has been obtained is geometrically corrected to minimize errors due to data acquisition, the data research area based on regional administrative boundaries and research of mangrove coverage area. Standard for physico-chemical characteristic determined in Indonesia based on Government Regulation Number 82/2001 on the Management of Water Quality and Control for measure ecological condition of water.

Data analysis

Descriptive statistics including minimum and maximum values, means and standard error of pH, Dissolved Oxygen /DO (mgL^{-1}), water temperature (°C), salinity (ppt), pH, conductivity ($mScm^{-1}$), turbidity (NTU), total N (mgL^{-1}), total P (mgL^{-1}), Cd (mgL^{-1}), Cr (mgL^{-1}), Pb (mgL^{-1}). Analysis of variance (ANOVA) was used to test means differences of the physico-chemical parameters between four sampling stations.

PCA was performed to see the role of physical and chemical factors on study area. The non-parametric correlation and PCA/FA test were performed using PAST V.9 software package (Hammer *et al*., 2001). PCA helps to reduce dataset and it deducts dominant components which are valuable to have a better interpretation of variables.

RESULTS

Physical and chemical analysis

The mean values of the physicochemical parameters for the Tambakredjo area are summarized in Table 2. Water temperature ranged from 30.72ºC to 33.06ºC with an average value of 32.02ºC.

There were no significant differences ($P < 0.05$) of physical measurement among four different sites. However, there was a high correlation between Site 3 and Site 1, about 0.7728 based on Mann-Whitney pairwise. The reference condition or Maerokoco site showed a low correlation with another site (Table.3).

The highest water temperature is at Maerokoco 33.06ºC, where the site is the tourism of mangroves for the local community. The lowest water temperature is at Site 2 of 30.72ºC, where the Mangrove area is in the Banjir Kanal Timur. The high-water temperature is caused by hot weather due to the intensity of the Sun’s radiation being quite high, and the absence of water plants in the area. Furthermore, the mangrove cover around the area near Banjir Kanal affected the water temperature level. Furthermore, the Semarang temperature rate was quite higher around May when the survey was conducted.

The different water temperatures were affected by different factors such as latitude, sea level, presence of shade (e.g. trees or aquatic plants), wastewater entering water bodies, solar radiation, air temperature, weather and climate time of day, cloud cover, airflow and depth (Boyd, 2015; Muarif, 2016). The increase of air temperature results in an increase in viscosity, chemical reactions, evaporation and volatilization as well as a decrease in the solubility of gases in the air such as O_2, CO_2, N_2, CH_4 and so on (Bricu *et al*, 2020). But, overall the water temperature of the research area is following the criteria for water quality standards based on Government Regulation Number 82 of 2001 for classes I, II, III, and IV, which state that the water temperature is at 3°C deviations from the natural conditions of the surrounding environment.

The TDS values range from 0.065 to 30.1 gL-1 (Table 2), with an average value of 13.52 gL^{-1}. This average value of TDS based on Government Regulation Number 82 of 2001 is suitable for class IV of 2000mgL^{-1}. The main sources for TDS in waters are runoff from agriculture, sewage households, and industry (Rinawati *et al*., 2016). The high TDS in Site 1 was influenced by the normalization project of Banjir Kanal Timur that caused the water more turbid than other stations. Changes in TDS concentrations can be dangerous because they will cause changes in salinity, changes in ionic composition, and their respective toxicity ion. The previous study from Octaviana *et al*., (2020) showed that in 2016 and 2019 TSS distribution has experienced changes. Especially, a significant change occurred at the estuary of the Banjir Kanal Timur which experienced a decrease in the TSS value of 10,146 mgL^{-1} and 9.617 mgL^{-1}.

Table 2. Physicochemical characteristics of water in Tambakredjo

Parameter		Site 1	Site 2	Site 3	Maero koco	PP NO. 82 Year 2001				
						Mean range	Class 1	Class 2	Class 3	Class 4
Temperature	°C	32.16	30.72	32.17	33.06	32.03	Dev. 3	Dev.3	Dev.3	Dev.3
pH		5.47	7.96	7.78	8.04	7.31	6-9	6-9	6-9	5-9
Conductivity	$mScm^{-1}$	50.1	0.098	33.4	7.49	22.77				
Turbidity	NTU	25.4	220	53.1	43.8	85.58				
DO	mgL^{-1}	30.08	10.35	9.32	8.92	14.67				
TDS	mg/L	30.1	0.065	19.2	4.72	13.52	6	4	3	0
Salinity	ppt	32.60	0.04	20.7	4.11	14.36				
Total N	mgL^{-1}	0.971	0.963	0.96	0.922	0.95				
Total P	mgL^{-1}	0.016	0.015	0.016	0.016	0.02	0.20	0.20	1	5
Cd	mgL^{-1}	0.021	0.011	0.014	0	0.01	0.01	0.01	0.01	0.01
Cr	mgL^{-1}	0.352	0.241	0.34	0	0.23	0.05	0.05	0.05	0.01
Pb	mgL^{-1}	1.289	1.18	1.281	0.623	1.09	0.03	0.03	0.03	1

Table 3. Mann Whitney pairwise

	Site 1	Site 2	Site 3	Maerokoco
Site 1		0.1749	0.7728	0.3863
Site 2	0.1749		0.2366	0.7508
Site 3	0.7728	0.2366		0.3554
Maerokoco	0.3863	0.7508	0.3554	

Result of turbidity, an optical determination of water clarity, is varied around 22.4-220 with a range around 85.57. Based on KEPMEN LH No. 51/2004, the threshold value for the water turbidity is < 5 NTU. While the factors that influence turbidity can be comprised of organic and inorganic materials such as sediment, algae, and other contaminants, more specifically water flow, point source pollution, land use, and resuspension (Gaol *et al*., 2019). The research area is located in the estuary and coastal area, where freshwater streams or rivers enter a saltwater estuary caused mixing changes in water flow, which can cause turbidity levels to increase. In addition to the land-use changes during the normalization program of Banjir Kanal Timur, the disturbance of garbage and pollution around mangroves affected the mangrove population and the turbidity level.

Electric conductivity varies from 0.098 mS/cm to 50.1 mS/cm with an average value of around 22.77 mS/cm, this wide range of values is related to vegetation dominance by location. Based on previous research, the optimal value for conductivity for mangrove areas is around 2.7 to 11.4 mS/cm (Kurlapkar and Shaikh, 2014). Electrical conductivity was significantly lower at Site 2, where that location represents mangrove. Overall, electric conductivity was similar between sites in each estuary, except Site 3 was significantly higher than else.

The research area showed a different level of salinity caused by the different locations of the sampling site. Station 1, that quite close to a marine ecosystem, has a high value of salinity of 32.60 ppt. While Site 2 has the lowest value around 0.04 ppt because this site still gets influenced by freshwater. On the other hand, Maerokoco reflected the condition of an estuary with 4.72 ppt. The previous study from Khasani *et al*. (2017) showed that salinity in the Banjir Kanal Timur has different values every year, around 2-30 ppm.

The pH values range from 5.47 to 7.96 (Table 1), with an average value of 7.31. Mangrove forests, different tolerances to salinity among mangrove tree species are proposed to lead to patterns of zonation (Lovelock *et al*., 2021). The average pH value of water is still within the threshold of water quality standards for classes I, II, III, and IV according to Government Regulation No. 82 of 2001, which states the pH should be within the range of 6 – 9. In the present investigation, lower values of pH are recorded from the Banjir Kanal Timur coastal or outlet. The pH at this site is hampered by the addition of domestic waste along with water, which might have resulted in lowering the pH.

The total N at all sampling sites ranged from 0.922 to 0.971 mg/L (Table.1), with a mean value of 0.954 mg/L. On average, TN concentrations in mangrove forests are very similar to each other. The high nitrate concentration is at Site 1, and the high concentration of nitrate is influenced by sediment. In this sediment, nitrate is produced from the biodegradation of organic materials into ammonia which is then oxidized to nitrate. Another parameter, phosphate concentration ranged from 0.015 mg/L to 0.016 mg/L, almost similar in all sampling sites. The average value of phosphate is still below the threshold by Government Regulation Number 82 of 2001 for Class I, II, III, and IV water quality standards. The high concentrations of nitrate and phosphate that accumulate in water tend to be caused by human activities. Other forms of N and P, such as different pools of the exchangeable fractions, may be available for plant uptake and may contribute to soil fertility (Wang *et al*., 2019).

The results of the Pb analysis obtained from all sampling stations were as follows: the Pb metal concentrations ranged from 0.623 to 1.289 mg/L with an average value of 1.09 mg/L. While Cr measurements on the water of mangroves showed the varied result. The Cr content in water ranged from undetectable to 3.52 mg/L. The results showed that the average Cr content in coastal areas was higher than the mangrove area of Maerokoco. The concentration of Cadmium also varied around undetectable to 0.021mg/l (Table. 1). The high value of Pb, Cr, and Cd was increased in the coastal area of Banjir Kanal Timur since metal pollutants from freshwater are carried out through Banjir Kanal Timur. Hence, it caused the heavy metal concentration in this area to be higher than at any site.

The heavy metals concentration was influenced by the amount of waste input into the water body. The concentration of heavy metals in the river increased along with the discharged wastewater volume (Luthansa *et al.*, 2021). The lowest concentration of lead is around 0.623 mg/l, which reflects the condition of the mangrove ecosystem in Maerokoco. The Maerokoco area is less polluted because this area does not have an inlet and this area is protected by the government for tourism purposes. In addition, the condition of mangroves in Maerokoco is quite different from Banjir Kanal Timur. Since 2016, the construction of the mangrove tourism track that surrounds the lake to accommodate tourists to explore the natural environment. Overall, the concentration of Pb, Cr and Cd in the coastal area of Banjir Kanal Timur had exceeded the standards of Government Regulation Number 82 of 2001.

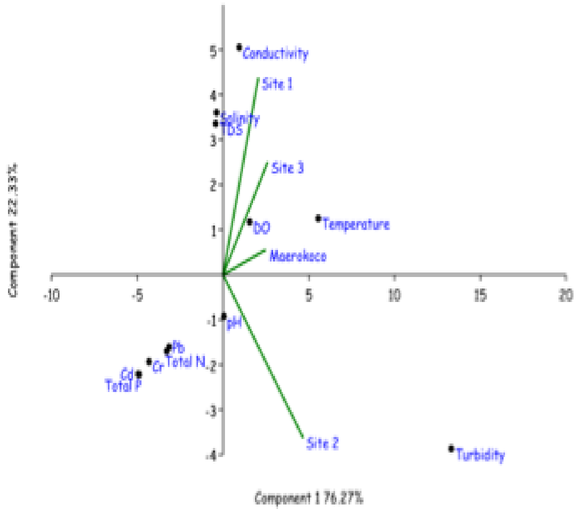

Figure 2. Principle Component Analysis based on the physical and chemical parameters of stream water measured at each site during the experiment.

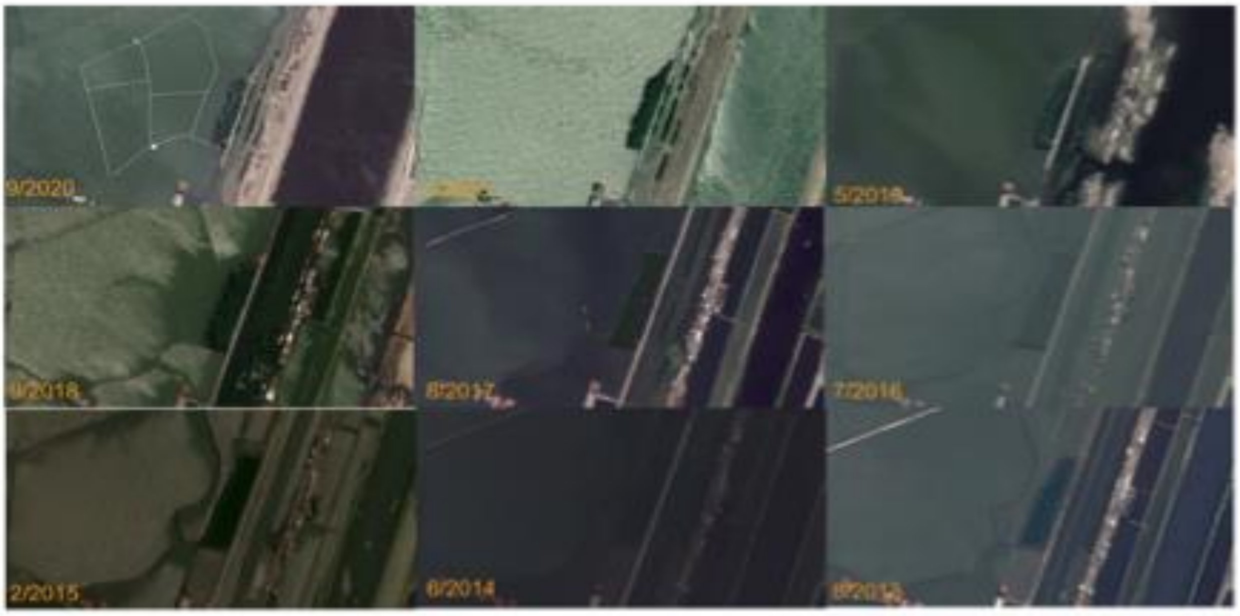

Figure 3. Land use change the area of research from 2013-2020

The presence of Pb, as also an impact of human life activities, is dangerous for human health. Furthermore, it has an impact on coastal plants, especially for mangrove (Kadarsah *et al*, 2020) The presence of Cr in the aquatic environment has harmful effects on the organism, cause disrupt the enzyme's work and accumulate for a period of time until the organism dies (Widiarsa *et al*, 2018).

The Principal Component Analyses (PCA) for the water sample of Tambakredjo are shown in Figure 2. It indicates that the first three principal components together account for 99.4% of the total variance in the dataset. The first principal component is 76.27% where the highest conductivity, Total Dissolved Solids and salinity associated with Site 1, where it represented site near the coastal area, caused by the water from marine-influenced increasing salinity. The second principal component is 22.33% separates Maerokoco with the highest temperature in water. Meanwhile, the third principal component is 0.80% of the total variance. The concentration of chemical analysis was lower at Site 2 than any other site indicating the composition of mangrove influenced the decrease heavy metal concentration in the water. Site 1 and Site 3 were plotted close together in the PCA, indicating that their physical characteristics such as conductivity and salinity were very similar.

DISCUSSION

The land-use change near the mangrove area affected by aquaculture, the satellite imaginary help to simulate and predict the mangrove land cover changes between 2013- 2021. Mangrove forests are subject to deforestation in some of the areas in Tambakredjo in 2020. The mangrove area cover decreased from 1.875m^2 to 1.401m^2 that caused by land subsidence and seawater intrusion, while the highest mangrove land cover area was found in 2017, around 3.505 m^2.

Major changes during this period were observed that soil and water which could be affected with sea level rising. Based on Haryanto (Widiarsa, 2020) showed that Semarang waters occur twice high, and the low tide receded during the day but is different in high and time. The tidal wave in the period 2012 – 2016, which is done each hour, it can be noted that the type of tidal waters in Semarang is mixed, predominantly diurnal tide. The land subsidence is reflected in Figure 5. Global mean absolute sea-level rise is around 3mm.yr^{-1}, groundwater extraction related with rapid urbanization and population growth caused land subsidence in Semarang.

In a coastal city such as Semarang, flood vulnerability increases and affected the abundance of mangroves. Natural losses also remained a significant factor contributing to global mangrove change. The consequences for mangrove is on seedlings during establishment, which may be prevented due to increasing inundation time. Especially the high sea level and land subsidence affected propagule to grow because the seafloor is too depth. Mangrove needs suitable substrate for foraging and for mangrove to colonize. Overall, the high sea-level rise increasing tidal inundation frequency and tidal range cause a decrease in mangrove growth seedlings (Etemadi *et al*., 2018)

Figure 4. Land subsidence in some areas of Tambakredjo Semarang

The decrease of the mangrove ecosystem will be affected because mangroves play a role in increasing estuary water quality, which can be shown through the cycling of nutrients, pollutants, and particulate matter surrounding the mangrove. Inorganic pollutants that can be removed by mangroves include heavy metals, such as *Rhizophora* absorbing a high concentration of cadmium and potential for removal of heavy metal in the environment (Nguyen *et al*., 2020). Also, mangrove ecosystems are dynamic, where they are capable of modifying their environment through the production of organic soils that can increase surface elevation (Breithaupt *et al*., 2017). During the research, many residents had participated in planting mangroves as a protective barrier against saltwater to provide a better environment through NGOs, company and government.

Along the coast of Semarang City, it has been recorded that for the last 20 years there has been a decrease in the coastline of approximately 1.43 – 1.74 km. Rehabilitation and restoration of mangroves have been practised in some areas of Tambakredjo, especially in the estuary of Banjir Kanal Timur, demonstrating success in conservation associated reduction of further anthropogenic loss caused by the restoration of mangrove seed *Rhizophora* periodically (Figure. 5). However, conservation has often been ineffective in preventing continued mangrove loss, primarily due to inadequate monitoring or enforcement (Lee *et al*., 2019; Park & Lee, 2019).

Figure 5. The mangrove restoration near Banjir Kanal Timur as part of mangrove rehabilitation as environmental awareness, in order to maintain increase volume and the extent of mangrove cover

CONCLUSION

The mangrove composition in Tambakredjo is affected by land subsidence during the short period 2013-2021 of research. The condition affected the seedling period of mangrove to grow, where propagule need substrate to attach and colonize. Potential loss of mangroves caused by natural and anthropogenic activity has a serious impact on biodiversity and water quality. Therefore, the influence of pollutant input from rivers and the ocean increases the heavy metal concentration in the water. On the other hand, the restoration and conservation of mangroves in the estuary has been conducted in order to prevent seawater intrusion as strategic management for the environment.

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