Sys Rev Pharm 2020;11(12):888-896
A multifaceted review journal in the field of pharmacy

ASSESSMENT OF COASTAL ENVIRONMENT SUPPORTS IN BATAM'S PEMPING ISLAND-INDONESIA FOR PIPELINE GAS TRANSMISSION

MUBARAK, MUBARAK1*; NURHUDA, AHMAD2; SULAIMAN, ALBERTUS3;

1,2 UNIVERSITAS RIAU, FACULTY OF FISHERIES AND MARINE SCIENCES, DEPARTMENT OF MARINE SCIENCES. INDONESIA.

3 AGENCY FOR THE APPLICATION AND ASSESSMENT OF TECHNOLOGY (BPPT), INDONESIA.

* CORRESPONDING AUTHOR
E-MAIL: MUBARAK@LECTURER.UNRI.AC.ID

ABSTRACT

The coastal waters of Pemping Island in Batam have extensive biodiversity with an ecological system in the form of coral reef and mangrove ecosystems. The island is significantly close to the international trade sea transportation routes. Currently, a gas pipeline construction is built on the island which might affect the environment. This study is aimed to evaluate the coastal waters of Pemping Island, Batam to preserve the marine ecosystem from industrial development. The observation method was carried out by taking sample data directly from several research locations to test the quality of seawater, coral reef ecosystems, and mangrove forests. Retrieval of data for aspects of waves, tides, currents, and bathymetry using the help of satellite imaging systems. Overall seawater quality has a value below the quality standard with a depth of brightness measured up to 4 m above sea level. . Chemically, all parameters are below the standard quality value, except phosphate and nitrate. Waves, tides, and ocean currents are interconnected aspects based on seasonal changes in the west and east. The average depth of the waters of Pemping Island is no more than 30 m including a relatively low or shallow depth. Based on observations of coral reef ecosystems are in the category of damage due to the closure of coral reef ecosystems which are dominated by abiotic and other biotics 80% compared to live and dead corals by 20%. Mangrove vegetation on Pemping Island consists of two types of mangroves, namely Rhizophora mucronata which dominates the number of mangrove tillers and Avicennia marina which dominates the mangrove stands at the observation site.

Keywords: Coastal water, Coral reef, Environmental monitoring, Mangrove forests, Oceanography

INTRODUCTION

Batam island is an archipelago whose waters border directly with Singapore's strait where the strait is 15 km wide and the free trade zone (FTZ) region separates the two regions. Batam island has high economic and ecological dynamics in the form of the natural beauty of waters and abundant biodiversity, especially in waters (Delima et al., 2018). Batam waters have a major influence on the economic growth of the community as a sea transportation route for international trade in the distribution of imported and exported goods (Faturachman et al., 2016). In addition, Batam has several areas with hidden potential in the form of natural energy reserves for human needs that must be utilized as best they can (Bachtiar and Putra, 2019). As currently in the Pemping Island region around the waters of Batam has the potential to contain energy sources in the form of natural gas. Industrial development by the State Gas Company (PGN) in Pemping Island has been going on since two years ago. Observation of the location of industrial development needs to be done which is likely to affect the seawater ecosystem around Pemping Island Batam.

Seawater quality is a water parameter in physical and chemical aspects that is very important for the survival of marine animals and plant organisms (Kammer et al., 2010). Seawater quality observed consists of several materials in different seawater content at each water location with quality raw materials that have been determined by the Minister of Environment Decree No. 51 of 2004. Seawater movements such as waves, tides, and currents affect activities around Pemping Island , Batam. This happens because of the morphological shape or depth of the sea and the movement of wind speeds during the east and west monsoons (Jeffrey 2002; Chust et al., 2010; Pugh and Woodworth, 2014; Lubis et al., 2018). The coral reef and mangrove ecosystems around Pemping Island , Batam are more dominant located in coastal areas. These ecosystems have rich biodiversity and high productivity and have an important role in the survival of marine animals and plant organisms (Harold et al., 2009; Erik et al., 2008).

The main objective of this study is to assess the environmental conditions of Pemping Island regarding gas pipeline construction in the location. The aspects to be considered in the waters and coastal areas of Pemping Island in Batam are the physical, chemical, and biological environments as well as oceanographic variables. The biological observation is focused on coral reef ecosystems and mangrove forests. These research reports can be used to the stakeholders in for guidance the island development and possible impact on the environment.

2. MATERIALS AND METHODS:

2.1. STUDY LOCATION

Pemping Island is administratively located at Batam city with geographical coordinate of 1° 5' 47.7276" N and 103° 39' 43.3656" E. This island is covered a land area of 4.25 km^2 and surrounded by 165.74 km^2 sea region. Figure 1 shows the location of Pemping Island.

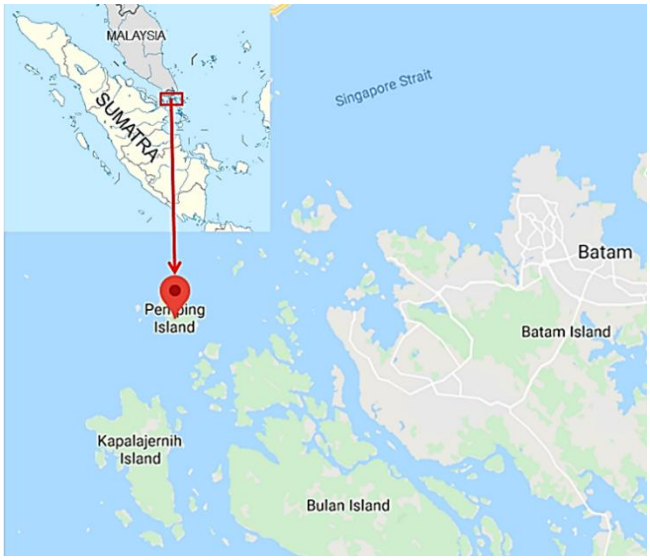


Figure 1. Map of Pemping Island , Batam city-Indonesia.

2.2. Catchment location

In order to evaluate the seawater quality, we collect seawater samples form three locations as shown in Table 1. All locations are located around the gas pipeline construction. The following table is coordinate points of catchment of seawater samples.

Table 1. *Location coordinate of sea water catchment.*

Point	Latitude	Longitude
St 1	01°11'09.09"	103°79'11.02"
St 2	01°11'77.03"	103°78'24.04"
St 3	01°11'71.09"	103°77'39.07"

The seawater samples are carried out directly from the field as primary data. Seawater is sampled using a van dorn air sampler at a depth of half of the sea level (van Dorn, 1953). Samples are then put into cleaned bottles and grouped according to the type of parameters analysis. The seawater treatment such as filtering and preservation is carried out according to standard procedures to avoid contamination. All bottles that have been filled with samples are stored in a cooler which will then be taken to the laboratory for analysis (Rubio et al., 2015; Cole et al., 2014). The parameters measured in water quality follow the regulations based on the Republic of Indonesia's Minister of Environment Decree No. 51 / 2004 concerning quality standards for seawater quality for marine biota.

The evaluation parameters, i.e. physical and chemical variables, are measured and analyzed by standard methods. the physical variables, such as turbidity, brightness scale, and temperature, are directly measured. Meanwhile, the chemical analysis was performed in the laboratory by atomic absorption spectroscopy (AAS) (Krammer et al., 2010).

2.3. Oceanographic parameters

Gas pipeline construction and operation activities from the West Natuna transportation system (WNTS) pipeline to Pemping Island can affect oceanographic parameters in the form of the formation of total suspended solid (TSS). To analyze TSS, modeling technology for ocean waves, tides, currents, and bathymetry is needed. These parameters are explained as follows.

2.3.1 OCEAN WAVE

Retrieval of data about sea waves obtained from journals, articles, and other documents that have been studied in Batam waters from previous studies (Nurhuda et al., 2019; Bachtiar dan Putra, 2019; Lubis et al., 2018). Data tracking is done by accessing satellite imagery via the internet source, such as the Center for Environmental Modeling, NOAA Wave Watch III.

2.3.2 Tides

Tidal data collection is carried out to determine the pattern of sea-level rise and fall and validation of the results of the hydrodynamic model for the benefit of estimated impacts in the study area. Tidal data were obtained from the Indonesian Navy's Hydrographic and Oceanographic Center (PUSHIDROSAL), in Batam waters with AG95 developed by Andersen et al. (1995).

2.3.3 Currents

The current pattern was obtained using the modeling and the results are explained descriptively (Ortiz-Royero, et al., 2008; Borgman, 2012). The water flow patterns at the site were carried out by making flow modeling simulations from bathymetry, wind, and tidal data as the boundary conditions of the domain model (hydrodynamic model). The result of the current modeling process is an estimate of high and low tides due to extreme flow patterns. Modeling results are presented with four tidal conditions consisting of before the highest tide, the highest tide, before the lowest tide, and the lowest tide. Modeling is made by differences or grid systems (Lyard, 2006).

2.3.4 Bathymetry

The bathymetry can be used to describe the depth characteristic of the beach and ocean floor. Bathymetry data at the study site was collected from the map created by PUSHIDROSAL. The location is the sea waters around the pipe which will be the location of the pipe installation. The results of data processing from PUSHIDROSAL Indonesia will be visualized in the form of 2-dimensional and 3D images (Muhari et al., 2019). From the picture then a descriptive analysis is carried out regarding the depth conditions of these waters.

2.2. Biological parameter

The dominant part of the biological environment on the coast of Pemping Island, Batam is the coral reef ecosystem and mangrove forests. The following is an explanation of the methods applied in this study.

2.2.1 Coral reef

Table 2. *Coral reef observation stations in the study area.*

Stations	Coordinate	Depth	Distance to the

	position	(m)	pipeline (m)
1	1.1240 N ; 103.7751 E	3	800
2	1.1096 N ; 103.7908 E	8	30
3	1.1075 N ; 103.7911 E	5	100
4	1.1105 N ; 103.7915 E	9	100

The coral reef ecosystem data collection method is carried out by the line intersect transect (LIT) method at the identified and determined locations presented in Table 2. The LIT method draws biophysical data on coral reefs along the transect line with a transect length of 0 – 100 m and is parallel to the line beach. The transect line starts from the depth at which coral reefs are still found (± 25 m) to the beach following the contour line depth pattern. The determination of sample points is done by field surveys to determine the type, cover, and condition of coral reefs. Sampling for coral reef ecosystems is carried out in the range of 0 – 25 m in the area of the gas pipeline approaching the coast. The method of analyzing coral reef data in the study area was obtained from direct observation at several stations representing the planned pipeline location and not passing through the reef area.

2.2.2 Mangrove forests

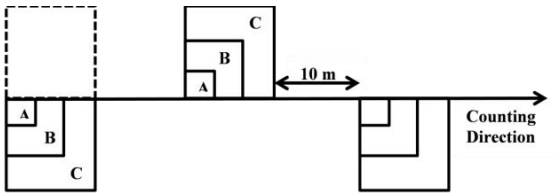


Figure 2. Plot line method scheme for mangrove data collection (Decree of the Minister of Environment No. 201, 2004).

Retrieval of data and information about mangrove ecosystems including distribution, area, and condition of mangroves (density and coverage). The method of observing mangrove ecosystems is to make a plot transect with a size of 10 × 10 m, then count the number of stands, tillers, and tree seedlings and then analyze to get the value of species density, important value index, and dominance of uniformity. Figure 2 shows the pattern of transect plot measurements of mangrove plant ecosystems.

Notes that A is a plot for the seedlings and shrubs (1 × 1 m^2), B is a plot for the peg (5 × 5 m^2), and C is a plot for the tree (10 × 10 m^2). To detect the presence, distribution, and extent of mangrove ecosystems, satellite image analysis was carried out, with a minimum spatial resolution of 15 × 15 m. The results of satellite imagery analysis are used to determine the sampling location, with a sample of 2 observation points at the location of the planned activity.

3. Results AND DISCUSSION:

3.1. Quality of seawater

Seawater quality measurements are divided into two categories i.e. physical and chemical parameters in the samples taken from the observation stations.

Table 3. Sea water quality is based on physical properties around the location of the activity.

Parameters	Quality Standards *)	Result			Unit
		St 1	St 2	St 3	
Brightness (In situ)	Coral > 5 / Mangrove: -	4.0	4.0	4.0	m
Smells (In situ)	Natural	No Smell	No Smell	No Smell	-
Turbidity	< 5	2	2	2	NTU
TSS	Coral: 20 / Mangrove: 80	2	< 2	< 2	mg/l
Temperature (In situ)	Coral: 28-32 / Mangrove: 28-32	27.0	26.6	27.0	°C
Oil spills	Nothing	Negative	Negative	Negative	-
Wastes (In situ)	Nothing	Negative	Negative	Negative	-

*) Based on Decree of Minister of the Environment No. 51, 2004

Table 4. Sea water quality is based on chemical properties around the location of the activity.

Parameters	Quality Standards *)	Results			Unit
		St 1	St 2	St 3	
pH (In situ)	7 – 6.5	9.30	9.10	9.05	-
Salinity	Natural	28.2	28.99	27.3	%
Sulfide (H_2S)	0.01	< 0.002	< 0.002	< 0.002	mg/l
Phenol	0.002	< 0.001	< 0.001	< 0.001	mg/l
Oil & Lipid	1.0	< 0.2	< 0.2	< 0.2	mg/l
Mercury (HS)	0.001	< 0.0005	< 0.0005	< 0.0005	mg/l
Chromium VI (Cr_6^+)	0.005	< 0.0005	< 0.0005	< 0.0005	mg/l
Arsenic (As)	0.012	< 0.0005	< 0.0005	< 0.0005	mg/l
Cadmium (Cd)	0.001	< 0.0005	< 0.0005	< 0.0005	mg/l
Copper (Cu)	0.008	< 0.005	< 0.005	< 0.005	mg/l
Lead (Pb)	0.008	< 0.005	< 0.005	< 0.005	mg/l
Zinc (Zn)	0.05	0.02	0.01	0.02	mg/l
Nickel (Ni)	0.05	< 0.005	< 0.005	< 0.005	mg/l

*) Based on Decree of Minister of the Environment No. 51, 2004

3.1.1 Physical parameters

The results of in situ measurements and ex-situ (laboratory analysis) of several physical parameters measured at the three observation stations is shown in Table 3. The physical parameters of water quality, such as turbidity and TSS values are still below the quality standard. As for the brightness parameters measured up to a depth of 4 meters from the surface of the water. Based on visual observations, no trash or oil spills were found around the surface of the sea..

3.1.2 Chemical parameters

Based on the results of laboratory analysis of twenty chemical parameters of seawater including dissolved metals in Table 4, it is obtained that the condition of the waters in the study area, in general, is still relatively good and meets environmental quality standards. Several chemical parameters are known to not meet quality standards including nitrates and phosphates, while the content of dissolved metals is still below the quality standards.

Figure 3. Dissolved oxygen (DO) and biological oxygen demand-5 (BOD_5) levels.

Based on Figure 3, it can be seen that the results of DO and BOD_5 levels from each sample taken at the observation station point have good results. This shows that the observation station waters have a low level of pollution with the amount of oxygen dissolved in the waters sufficient for marine organisms and biota in their survival (Sarina et al., 2003; Wei et al., 2008; Mubarak et al., 2017).

The concentration of ammonia and anion surfactant of all samples has still met the standards as presented in Figure 4. Also, seawater in the study area has high nitrate and phosphate concentrations based on observations at three stations where values exceed seawater quality standards for biota the sea. The high nitrate and phosphate content can indicate that these waters have a high fertility rate with nitrates which are rich in organic matter (Sigua et al., 2017).

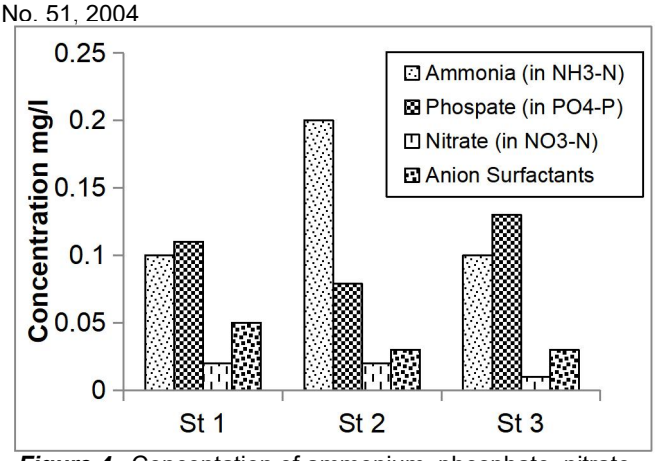


Figure 4. Concentation of ammonium, phosphate, nitrate, and anion surfactants at the three stations.

3.2. Oceanographic findings

The oceanographic analysis was divided into several parameters that can be observed such as waves, tides, and currents influenced by several natural environmental factors that will be explained below.

3.2.1 Sea wave

The wave characteristics that occur during the west monsoon season (December – February) are relatively higher, on average, 0.3 – 0.6 m from the Malacca strait and the north Natuna Sea to the south. Wave heights found on the east side crossing Pemping Island, Batam range from 0.4 to 0.67 m, and the west side reaches between 0.3 to 0.5 m. While in the east monsoon season (June – August) the height of the sea waves has decreased by 25%, increasing between 0.3 – 0.46 m moving from the waters of Java and the north Natuna sea towards the Malacca strait.

3.2.2 Tides

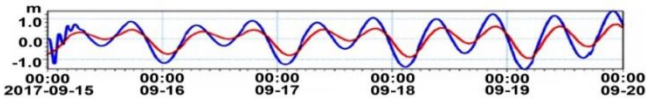


Figure 5. Tidal cylce in Batam waters during September 2017 recording (Ministry of Maritime Affairs and Fisheries, 2017).

The types of tides in the waters of Pemping Island, Batam are semidiurnal type, which is two pairs of the ebb and the flow in one day as depicted in Figure 5. The recorded tidal events have a phase difference of one hour from the time before and after. The highest tide occurs around 22:00 – 23:00 at night with a peak height of 1.4 m which occurs on September 19, 2017. The lowest tides occur on September 19, 2017, around 3:00 to 4:30 in the morning, with a low tide about – 1.5 m. Tides and tidal times are accompanied by currents that are stronger than usual (Bray et al., 1996).

3.2.3 Currents

In general, the pattern of tidal currents in the Singapore Strait that occurs when the tide moves from the direction of the pacific ocean through the waters of the north Natuna Sea to the west. Conversely, at low tide, the

water mass moves outside Malacca strait (in the west) to Pacific ocean (in the east) through north Natuna Sea. Tidal patterns in the waters around the activity site are shown in Figure 6 and Figure 7. The figures show the pattern of current sea level compilation towards the lowest tides, where the current moves east towards the Singapore strait with the current velocity at the monitoring stations at < 0.7 m/s.

The dominant wind direction moves towards the northeast with a percentage of 20% reaching more than 4.8 m/s. While at sea level heading for the highest tide, the mass movement of water moves backward. The mass of water in the strait on Pemping Island is seen moving towards the west at speeds reaching > 1.2 m/s. When sea level is at the highest peak position, there is relatively no movement of the air mass. The direction of the wind moves very dominantly to the southeast with a percentage of 40% reaching a speed of 6.5 m/s.

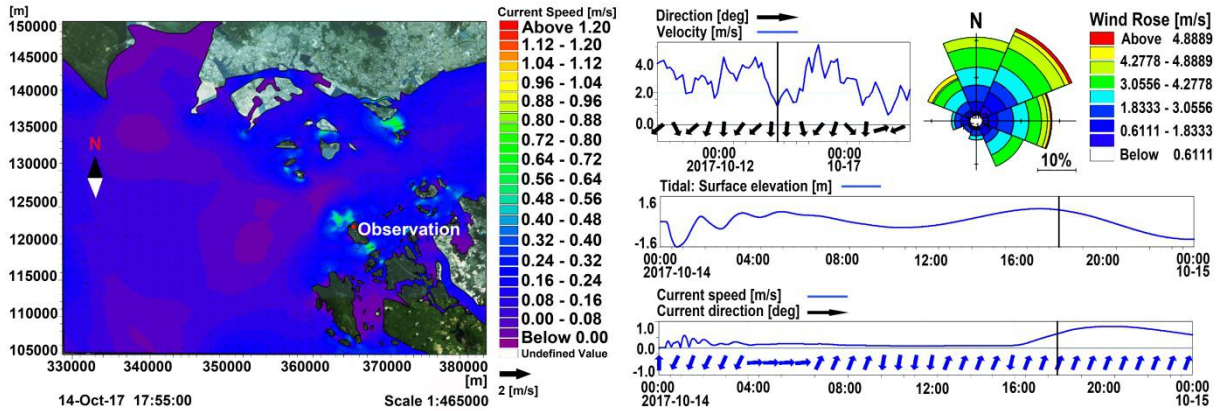


Figure 6. Current patterns at low tide.

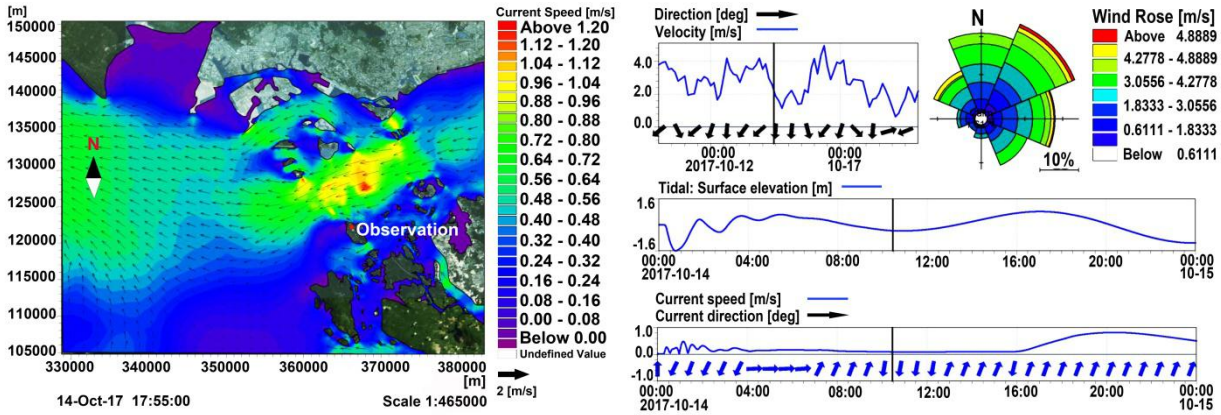


Figure 7. Current patterns at high tide.

3.2.3 Bathymetry

The bathymetry map across Pemping Island which is the location of the pipe installation is presented in Figure 8 below. Based on the bathymetry map of the Batam waters, morphological forms, and contour patterns with relatively low (shallow) sea depths of no more than 30 m. The sea area north of Batam island has a depth of between 4 – 25 m with slightly undulating morphology. The beach around Pemping Island, which borders directly with the Singapore strait, has a sea-level not exceeding 25 m around Pemping Island.

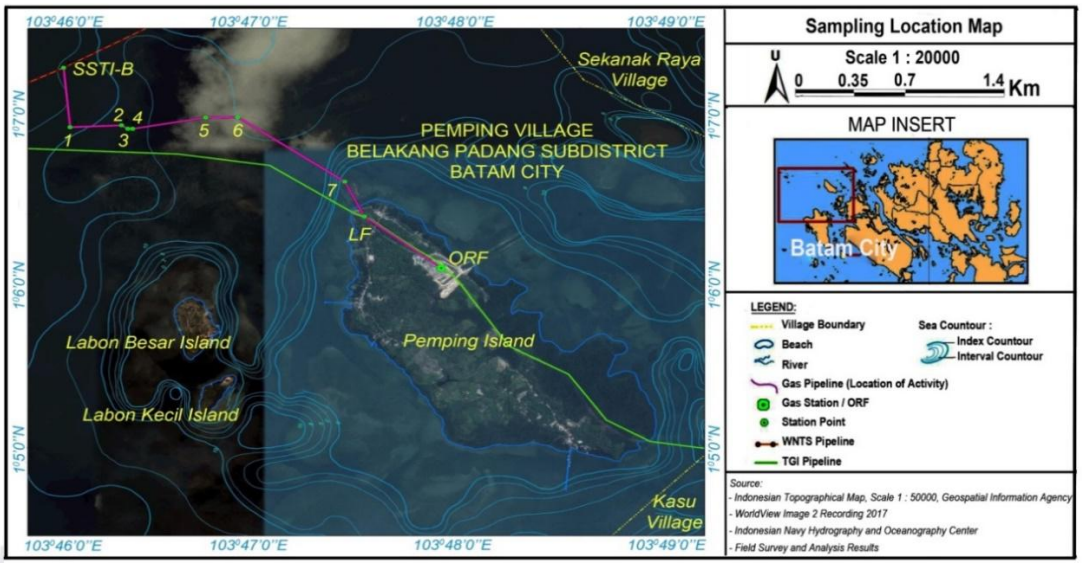


Figure 8. Map bathymetry location of activities.

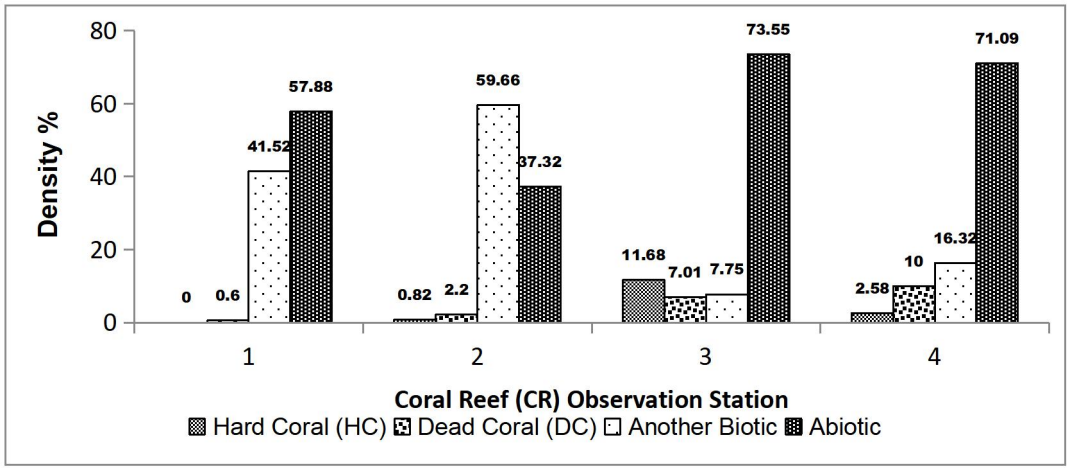


Figure 9. Conditions for coral reef closure at the observation station.

3.3 Coral reef ecosystems

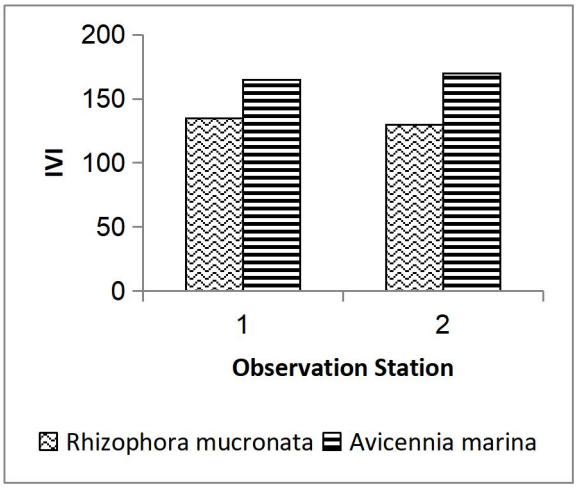
The observations in Pemping Island waters found that around the coral reef consists of live coral or hard coral, dead coral, biotic or other algae, and abiotic. Figure 9 is shown the results of observing coral reefs around the observation station.

Coral reefs were found at the observation site within 0 – 100 m of the planned pipeline location. The highest live coral (in form HC) was found at Station 3 at 11.68% which is 100 m from the pipe distance. While the lowest HC closure of 0.82% is at station 2 within 30 m of the planned pipeline. While at station 1 no coral reefs were found. Based on these results with the condition of coral cover < 25%, this is categorized as a damaged condition as referred to in decree of the Minister of Environment No. 04 of 2001 concerning standard damage criteria for coral reefs.

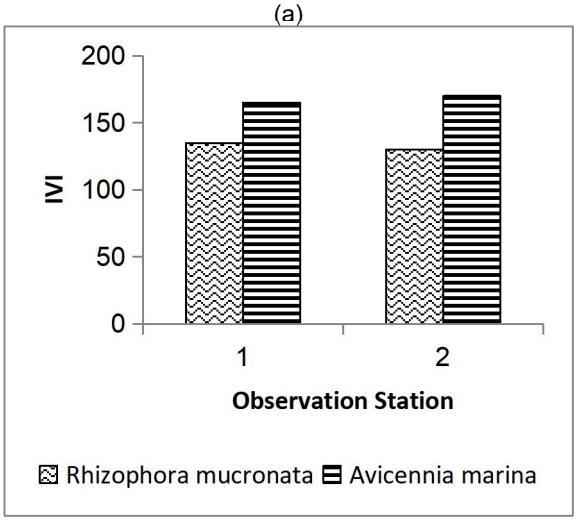
3.4. Mangrove ecosystems

The types of mangroves found on Pemping Island are *Rhizophora mucronata* and *Avicennia marina* around coastal, from basic mud to sandy mud (Dharmawan and Widyastuti, 2017). Based on Saenger's decision (1998) that the position of *Avicennia* species is near the sea, while *Rhizophora* is in the middle of mangrove vegetation.

The mangrove density which depicted in Figure 10 is the number of species stands per unit area. The number of tree stands on Pemping Island for stations 1 and 2 is in the range 325 – 350 individual/hectare, while the number of tillers is in the range of 400 – 1,200 individual/hectare and 12,500 – 30,000 individual/hectare Seedlings. Based on the standard criteria for mangrove damage in Decree of the Minister of Environment No. 201/2004, Pemping Island's mangrove forests are damaged due to sparse density.



(a)



(b)

Figure 10. The importance value index of (a) mangrove tree dan (b) mangrove tillers on Pemping Island

The structure of mangrove vegetation can be arranged using the diversity index (H'), uniformity index (E), domination index (C) and importance value index (IVI). Important value indices are used to provide an overview of the role or role of mangrove species in ecosystems. IVI values range from 0 – 300 for trees and 0 – 200 for seedlings and saplings (Rachmawania et al., 2016).

Further analysis of the IVI value shows that the number of *Avicennia marina* trees is higher in Pemping Island mangrove ecosystem. While, the density of *Rhizophora mucronata* saplings is highest in the mangrove ecosystem.

Table 7. *Diversity index (H '), uniformity (E), and dominance (C) of mangroves.*

Station	H'	E	C
1	0.26	0.75	0.66
2	0.27	0.89	0.57

Mangrove dominance at station 1 is the higher compare to station 2 as seen in Table 7. The dominace index in station 2 is 0.57. This means that the uniformity of mangrove species at station 2 is higher as indicated by uniformity value of 0.89. Lesley and Nola (1971) reports that the increasing in uniformity will eliminate the dominace in mangrove forests.

4. CONCLUSIONS:

The environmental monitoring of Pemping Island as impact of gas transmission construction has been conducted. Based on the results of seawater quality measurements at three stations, it is obtained that the physical and chemical parameters of sea water are still met with the standard. However, nitrate and phosphate content are exceeded the quality standard for sea water by 60% and 80%, respectively. Sea wave characteristics are generally based on changes in the monsoon season west and east. The current pattern that occurs in the waters of Batam follows the process of tides. Pemping Island waters have relatively low or shallow sea depths with an average depth of no more than 30 m with slightly undulating morphology. Closure of coral reefs in the 4 stations is dominated by abiotic and other biotas with an average of 80%. Compared to dead and live corals, coral cover areas have an average below 20%. The types of mangroves found on Pemping Island are *Rhizophora mucronata* dominating tillers and *Avicennia marina* dominating mangrove stands the number of stands in the form of trees and tillers from two mangrove species each is 675 individuals/hectare and 1600 individuals/hectare from 2 stations in the study location observation.

5. ACKNOWLEDGMENTS:

The authors express many thanks PT Umarai Riau Consultant for funding this research (Grant No. 014000.PK/HK.02/PMIII.2/2017) as well as PT PGN in research collaboration. The authors are also grateful to the Universitas Riau for providing some facilities.

6. REFERENCES:

1. Andersen, O. B.; Woodworth, P. L.; Flather, R. A. (1995). Intercomparison of recent ocean tide models. *Journal of Geop;ysical Research, 100*(C12), 25261-25282. doi:10.1029/95jc02642.

2. Bachtiar, I. K.; Putra, R. D. (2019). OTEC Potential Studies For Energy Sustainability In Riau Islands. *2019 6th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI)*. doi:10.23919/eecsi48112.2019.8976969.

3. Borgman, C. L. (2012). The conundrum of sharing research data. *Journal of the American Society for Information Science and Technology, 63*(6), 1059-1078. doi:10.1002/asi.22634.

4. Bray, N. A.; Hautala, S.; Chong, J.; Pariwono, J. (1996). Large-scale sea level, thermocline, and wind variations in the Indonesian throughflow region. *Journal of Geophysical Research: Oceans, 101*(C5), 12239-12254. doi:10.1029/96jc00080.

5. Cole, M.; Webb, H.; Lindeque, P. K.; Fileman, E. S.; Halsband, C.; Galloway, T. S. (2014). Isolation of microplastics in biota-rich seawater samples and marine organisms. *Scientific Reports, 4*(1), 4582. doi:10.1038/srep04528.

6. Decree of the Minister of state Environment Number 201. (2004). Standard Criteria and Guidelines for Mangrove Damage Determination, Minister of Environment, Indonesia.

7. Decree of the Minister of state Environment Number 4. (2001) Standard Criteria for Coral Damage, Minister of Environment, Indonesia.

8. Decree of the Minister of state Environment Number 51 (2004)Raw Quality of Seawater, Minister of Environment, Indonesia.

9. Delima, S. P.; Moersidik, S. S.; Wirutomo, P.; Alamsyah, A. T. (2019). Integrating Human Ecology into Sustainable Development to Address Potencies and Challenges of the City of Batam as a Port City. *Proceedings of the 2nd International Conference on Strategic and Global Studies (ICSGS 2018)*. doi:10.2991/icsgs-18.2019.8.

10. Dharmawan, I. W.; Widyastuti, A. (2017). Pristine Mangrove Community In Wondama Gulf, West Papua, Indonesia. *Marine Research in Indonesia, 42*(2), 73-82. doi:10.14203/mri.v42i2.175.

11. Faturachman, D.; Dewanto, Y. A.; Adiatmojo, G. D. (2016). Safety Analysis of Sea Transportation in Indonesia Case study: Crossing Between Countries In Sumatera Island (Batam - Singapore). *International Journal of Advances in Mechanical & Automobile Engineering*, *3*(1), 80-84.

12. Harold, M.; Anne, L.; Manuel, C.; Thomas, E.; Ove, H. G.; Sandra, L.; Georgina, M. M.; Margaret, P.; Robert, S.; Tetsukazu, Y. (2009). Biodiversity, climate change, and ecosystem services. *Current Opinion in Environmental Sustainability*, *1*(1), 46-54.

13. Jeffrey, S. D. (2002). Bedform migration and sediment dynamics in the nearshore of a low-energy sandy beach in southwestern Australia. *Journal of Coastal Research*, *18*(3), 576-591.

14. Kammer, F. V. D;, Ottofuelling, S.; Hofmann, T. (2010). Assessment of the physico-chemical behavior of titanium dioxide nanoparticles in aquatic environments using multi-dimensional parameter testing. *Environmental Pollution*, *158*(12), 3472-3481.

15. Kristensen, E.; Bouillon, S.; Dittmar, T.; Marchand, C. (2008). Organic carbon dynamics in mangrove ecosystems: A review. *Aquatic Botany, 89*(2), 201-219. doi:10.1016/j.aquabot.2007.12.005.

16. Lesley, D. C.; Nola, J. H. (1971). The mangrove swamp and salt marsh communities of the Sydney District: IV. The significance of species interaction. *The Journal of Ecology*, *59*(2), 535-553..

17. Lubis, M. Z.; Anurogo, W.; Mufida, M.; Taki, H. M.; Antoni, S.; Lubis, R. A. (2018). Physical Condition of the Ocean to Global Climate Change Variability: Case Study in The Batam Waters, Indonesia. *2018 International Conference on Applied Engineering (ICAE)*. doi:10.1109/incae.2018.8579397.

18. Lyard, F.; Lefevre, F.; Letellier, T.; Francis, O. (2006). Modelling the global ocean tides: modern insight from FES2004. *Ocean Dynamics*, *56*, 394-415.

19. Ministry of Maritime Affairs and Fisheries, (2015). RZWP3-K: The Formulation Support Document (Zoning Plan for Coastal Areas and Small Islands) in Batam City-Riau Archipelago Province, Indonesia.

20. Mooney, H.; Larigauderie, A.; Cesario, M.; Elmquist, T.; Hoegh-Guldberg, O.; Lavorel, S.,. . Yahara, T. (2009). Biodiversity, climate change, and ecosystem services. *Current Opinion in Environmental Sustainability, 1*(1), 46-54. doi:10.1016/j.cosust.2009.07.006

21. Mubarak, Sutikno, S., Merian, R. D. (2017). Numerical model for pollutant dispersion in the Dumai estuary. MATEC Web of Conferences, 101, Article ID 04001, doi: 10.1051/matecconf/201710104001

22. Muhari, A.; Heidarzadeh, M.; Susmoro, H.; Nugroho, H. D.; Kriswati, E.; Supartoyo; Wijanarto, A. B.; Imamura, F.; Arikawa, T. (2019). The December 2018 Anak Krakatau volcano tsunami as inferred from post-tsunami field surveys and spectral analysis. *Pure and Applied Geophysics*, *176*, 5219-5233.

23. Nurhuda, A., Mubarak, Sutikno, S. (2019). Analysis of coastal vulnerability of Rangsang Island due to climate changes. Journal of Degraded and Mining Lands Management, 6(4), 1907-1914. doi: 10.15243/jdmlm.2019.064.1907

24. Ortiz-Royero, J. C.; Mercado-Irizarry, A. (2008). An Intercomparison of Swan and Wavewatch III Models with Data from NDBC-NOAA Buoys at Oceanic Scales. *Coastal Engineering Journal, 50*(1), 47-73. doi:10.1142/s0578563408001739.

25. Pugh, D.; Woodworth, P. (2014). Sea-level science: Understanding tides, surges, tsunamis and mean seal-level changes, Cambridge University Press, United Kingdom.

26. Rachmawania, D.; Yulianda, F.; Kusmana, C.; Boerd, M.; Parwatie, E. (2016). Study of mangroves ecosystem management at Binalatung in Tarakan City of North Kalimantan. *International Journal of Science: Basic and Applied Research*, *26*(3), 221-234.

27. Rubio, D.; Casanueva, J. F.; Nebot, E. (2015). Assesment of the antifouling effect of five different treatment strategies on a seawater cooling system. *Applied Thermal Engineering*, *85*, 124-134.

28. Saenger, P. (1998). Mangrove vegetation: An evolutionary perspective. *Marine and Freshwater Research*, *49*(4), 277-286.

29. Sarina, P.; Snoeyinkb, V. L.; Bebeeb, J.; Jimb, K. K.; Beckettb, M. A.; Krivena, W. M.; Clement, J. A. (2003). Iron release from corroded iron pipes in drinking water distribution systems: Effect of dissolved oxygen. *Water Research*, *89*(5), 1259-1269.

30. Sigua, G. C.; Stone, K. C.; Bauer, P. J.; Szogi, A. A.; Shumaker, P. D. (2017). Impacts of irrigation scheduling on pore water nitrate and phosphate in coastal plain region of the United States. *Agricultural Water Management*, *186*, 75-85.

31. Van Dorn, W. G. (1953). Wind stress on an artificial pond. *Journal of Marine Research*, *12*, 249-275.

32. Wei, G. L.; Yang, Z. F.; Cui, B. S.; Li, B.; Chen, H.; Bai, J. H.; Dong, S. K. (2008). Impact of dam construction on water quality and water self-purification capacity of the Lancang River, China. *Water Resource Management*, *23*, 1763–1780.