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Does social distancing have an effect on water quality? : An evidence from Chlorophyll-a level in the water of populated Southeast Asian coasts

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Abstract

The COVID 19 related social distancing is hypothesized can affect the environmental quality including the air and water quality. Correspondingly, this study aims to study how the reduction of activities of people living near the rivers and the coastal areas due to social distancing may decrease the discharges of materials and nutrients to the water body. The chlorophyll-a was used as bio indicators of nutrient contents related to the anthropogenic activities in the coast. The study was conducted in the Jakarta coast considering that this coast was surrounded by populated cities with total population equal to 16 million people. The chlorophyll-a was measured in mg/m^3 and monitored using remote sensing data from January to April 2020 representing the period before and after the implementation of social distancing. The determinant environmental factor measured was sea surface temperature (^{0}C). The study considered that there were reductions of levels and areas of chlorophyll-a in the coast. The chlorophyll-a levels were reduced from January to April ($p<0.05$). The chlorophyll-a levels for January, February, March, and April were 7.36 mg/m^3 (95%CI: 6.34-8.37), 7.90 mg/m^3 (95%CI: 7.32-8.47), 6.52 mg/m^3 (95%CI: 5.37-7.66), and 4.21 mg/m^3 (95%CI: 3.34-5.07) respectively. However, the differences of chlorophyll-a were not influenced by the sea surface temperature factor ($p>0.05$). Based on remote sensing data in January and February, the sizes of coastal areas with chlorophyll-a levels >7.00 mg/m^3 were larger than areas observed in March and April. Contrarily, the coastal area sizes with low chlorophyll-a levels <5.00 mg/m^3 were increasing in April. To conclude the dynamic of anthropogenic activities in coastal setting is responsible and associated with the water quality and nutrient contents as indicated by chlorophyll-a levels. **Keywords:** coast, chlorophyll-a, COVID 19, social distancing, water.

1.Introduction

Chlorophyll-a has been considered as a versatile indicator of pollutant presence in the aquatic ecosystems and the origin of the pollutant as well. Furthermore, the availability of chlorophyll-a indicates the presence of phytoplankton. In the aquatic ecosystems, the presence of phytoplankton related to the availability of excessive nutrients. Those nutrients enter the aquatic ecosystems in the form of domestic wastes discharged by nearby anthropogenic activities and settlements near the river. Due to the poor

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waste management, settlements in the Southeast Asian (SA) countries are common and frequently discharging their wastes directly to the river (Setyono and Himawan 2018). The river will transport all the wastes to the coastal area and the wastes will be accumulated in this area. The wastes become the nutrient sources of phytoplankton.

The anthropogenic activities along the river towards the coast were not only determinant factors affecting the water quality and chlorophyll-a level in the coastal area. The anthropogenic activities and presence of settlement in the coastal areas are also contributing to the increasing level of chlorophyll-a in those areas. Bužančić *et al*. (2016) reported that the coastal areas dominated by urban and industrial activities released more chlorophyll-a. The populated coast with anthropogenic activities has chlorophyll-a level equal to 4.73 mg/m^3. While less populated coast with limited activities has chlorophyll-a level equal to 1.26 mg/m^3. Hence this proves that chlorophyll-a level can provide a snapshot yet comprehensive of water quality condition as an effect of population and the magnitude of anthropogenic activities in a coastal area (Gökçe 2016).

Most populated cities especially in SA regions were located in the developing coastal areas. This fact related to the history that those cities were built by the visitors that came as merchant and sailor. As a result, numerous SA coastal areas have experienced pollution and excessive chlorophyll-a levels. Lim *et al*. (2015) reported that the coastal water systems along the Malacca straits has chlorophyll-a level up to 2.76 $mg/m^{3.}$ Another SA coastal area deserves attention is located in Jakarta. This coast surrounded by populated cities and anthropogenic activities has caused the Jakarta coast polluted by significant chlorophyll-a level. It was reported that the chlorophyll-a levels can be high as 17.22 mg/m^3 (Yuliana 2012). The chlorophyll-a in Jakarta coast was related to the domestic wastes discharged from the activities along the river banks in Jakarta cities. Those activities nearby river are including office, home office, market, and hotel. Furthermore the discharged domestic wastes in the river including grey water (detergent, soap, oil, pesticide) and black water (human waste) containing phosphate and nitrogen (Yudo 2010). In the downstream and coastal areas, those wastes were accumulated and providing nutrient for phytoplankton (Örnólfsdóttir *et al*. 2004).

Due to the COVID 19 pandemic, there is a social distancing and restriction that limit people activities. This also affect the activities usually occur near the river and the coastal areas. Even it has been reported that since the activity restriction has been implemented for 1 month since March 2020, the volume of hard wastes accumulated in the coastal area has reduced up to 46% or equal to 620 tons/day. Hence, this study hypothesizes that the reduction of people activities living near the rivers and the coastal areas may also reduce the discharges of materials and nutrients to the water body. At the end, it may affect the population of phytoplankton along with its chlorophyll-a level.

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2.Methods

2.1.Study area and period

The study area was located in the coastal zone of Jakarta, Indonesia (latitude: 5.935962-6.090290, longitude 106.723249-1076.996533) (Figure 1). The length of this coast was 80 km and covered the area of 514 km^2. This coast was receiving discharges from 13 rivers with the length of 1 river can be up to 337 km for example Ciliwung river. This coast was surrounded by 3 populated cities with the total population equal to 16.714.030 people. Since mid of March 2020 and due to the COVID 19 pandemic, the social distancing and activity restrictions have been implemented in those cities. The study period was January, February, March, and April 2020 to cover the coast conditions before the social distancing was implemented (from January, February, to mid of March) and after the social distancing was implemented (from mid of March to end of April).

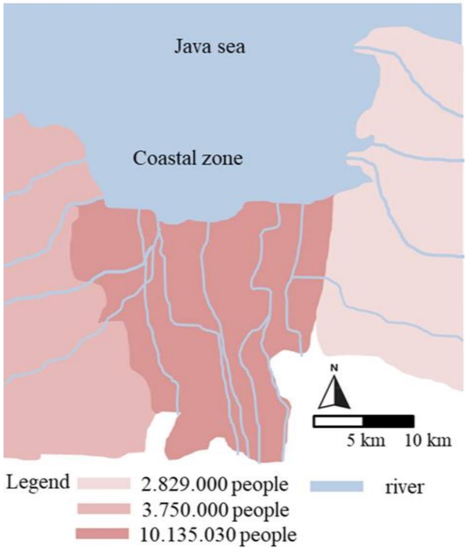

Figure 1. The study area is located in coastal zone (latitude: 5.935962-6.090290, longitude 106.723249-1076.996533) surrounded by rivers and populated cities.

2.2. Chlorophyll-a monitoring

The environmental parameter used as indicators of social distancing effects of coastal city populations on the coastal water quality was chlorophyll-a level. The chlorophyll-a monitoring was conducted in purposively 10 points located from 0 to 10 km from the coast line. Likewise due to its accuracy and coverage, this study has employed remote sensing approach as platform to monitor and obtain the surface chlorophyll-a data (Pahlevan *et al*. 2020) The remote sensing platform and data in this study were retrieved from Copernicus Sentinel-3B Ocean and Land Color Instrument (OLCI). The surface chlorophyll-a level was measured in mg/m^3.

2.3. *Statistic and data analysis*

All the data were represented as spatial data to represent the coastal areas overlaid with the chlorophyll-a interpolation and bean plot graphic presentation. All the data will be calculated for their mean and 95% Confidence Interval (CI). The paired t test was used to determine if there is a significant difference between the means of chlorophyll-a levels between months representing the before and after social distancing periods.

3.Results

Table 1. The chlorophyll-a levels (mg/m^3) comparisons for January, February, March, and April 2020 in Jakarta coast.

Month	Mean (n=10)	SD	95%CI		P value
			Lower	Upper	
January	7.36	1.63	6.34	8.37	p>0.05
February	7.90	0.93	7.32	8.47	p>0.05
March*	6.52	1.84	5.37	7.66	p<0.05
April*	4.21	1.40	3.34	5.07	p<0.05

*Significant at p<0.05

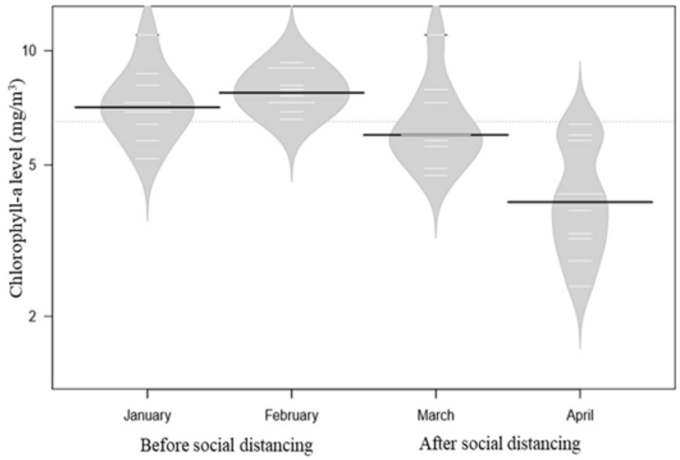

Figure 2. The bean plots for chlorophyll-a levels (mg/m^3) comparisons for January, February, March, and April 2020 in Jakarta coast.

Table 2. The sea surface temperature (^{0}C) for January, February, March, and April 2020 in Jakarta coast.

Month	Mean (n=10)	SD	95%CI		P value
			Lower	Upper	
January	27.4	0.54	26.92	27.87	p>0.05
February	27.2	0.83	26.47	27.92	p>0.05
March*	26.8	2.77	24.37	29.22	p>0.05
April*	28.0	0.70	27.39	28.61	p>0.05

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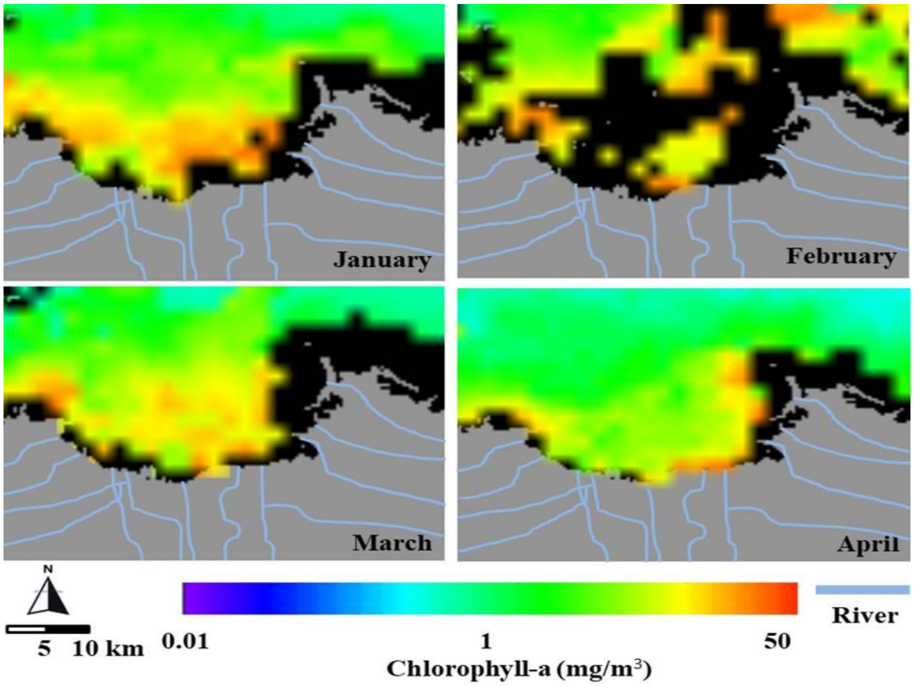

Figure 3. The monthly chlorophyll-a (mg/m^3) levels before social distancing (January-February) and after social distancing (March-April) in Jakarta coast.

Table 1 shows a comprehensive chlorophyll-a level (mg/m^3) by months in Jakarta coast. The order of chlorophyll-a levels by months is February > January > March > April (Figure 2). The chlorophyll-a levels for January, February, March, and April were 7.36 mg/m^3 (95%CI: 6.34-8.37), 7.90 mg/m^3 (95%CI: 7.32-8.47), 6.52 mg/m^3 (95%CI: 5.37-7.66), and 4.21 mg/m^3 (95%CI: 3.34-5.07) respectively. According to the statistical analysis, the chlorophyll-a levels in March and April were significantly different ($p<0.05$) and lower than chlorophyll-a in January and February (Figure 5). While chlorophyll-a in January and February were tends to be similar ($p>0.05$, Table 1). However, the differences of chlorophyll-a levels were not influenced by the sea surface temperature factor ($p>0.05$) (Table 2).

The Figure 3 shows the spatial distributions of monthly chlorophyll-a in the Jakarta coast overlaid with the river networks. In January and February, more dark color (orange) in map shows a high chlorophyll-a level (>7 mg/m^3) distributed widely across all the water of Jakarta coast. The chlorophyll-a was also distributed evenly from east to the west parts of the coast. In March, the size of coastal area that before has dark (orange) color was reduced. It means that the coastal areas having high chlorophyll-a levels were reduced. While coastal area sizes with medium and low chlorophyll-a levels (< 5 mg/m^3) were increasing and replacing previously high chlorophyll-a areas. The reductions of coastal area sizes with high chlorophyll-a were more significant as can be observed in April. In this month coastal areas with low chlorophyll-a levels were increased as well. In some particular coastal parts, high chlorophyll-a level was observed. This related to the coast position which is located near the river mouth that still receive high amount of nutrient compared to other rivers. The chlorophyll-a level tends to be high near the coast where

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the river mouth is located. While in the water located far from the river mouth, the chlorophyll-a will increase or decrease (Figure 5). The river mouth has higher chlorophyll-a level in general compared to other locations because the materials discharged from the upstream and river banks are accumulated in here before transported offshore.

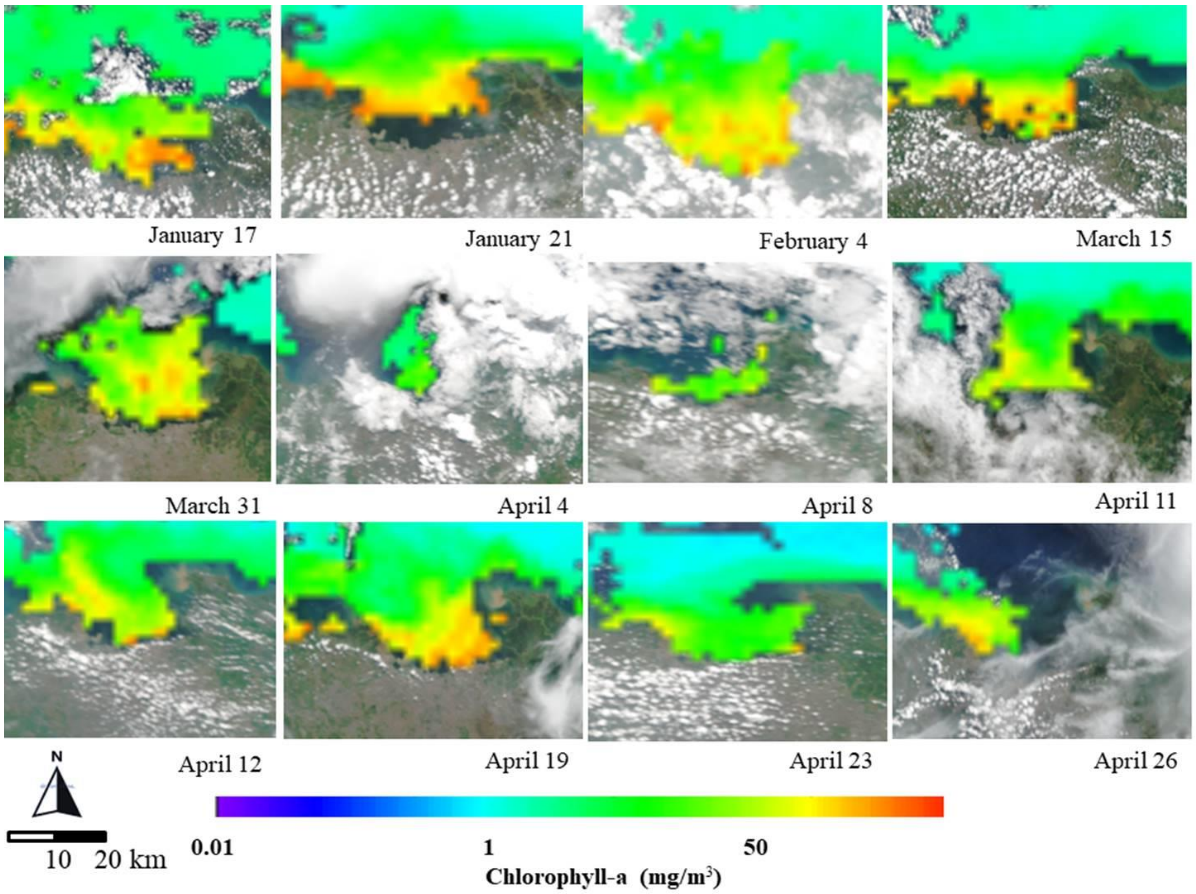

Figure 4. The daily chlorophyll-a (mg/m^3) levels before social distancing (January-February) and after social distancing (March-April) in Jakarta coast.

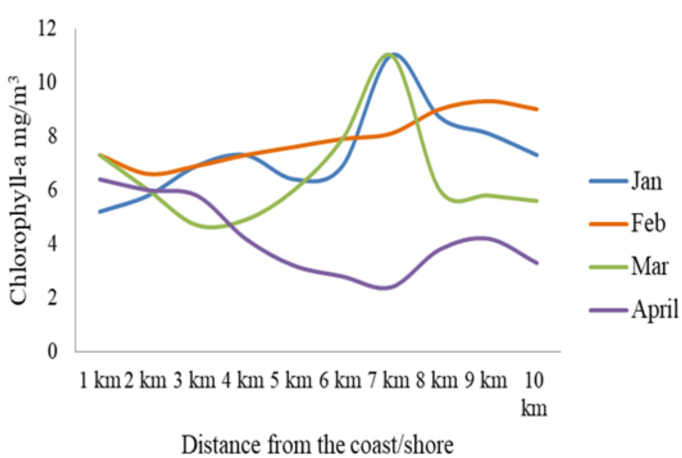

Figure 5. The chlorophyll-a (mg/m^3) levels measured by distance from the coast before social distancing (January-February) and after social distancing (March-April) in Jakarta coast.

The spatial distributions of daily chlorophyll-a in the Jakarta coast for 4 month periods were presented in Figure 4. The data were obtained from NOAA and Copernicus Sentinel-3B OLCI. It is clear that from January to March 15, coastal areas with chlorophyll-a levels >7 mg/m^3 were more common. While after the social distancing has been implemented in cities nearby the coast in mid of March, the sizes of coastal areas with chlorophyll-a levels >7 mg/m^3 were gradually reduced. Even 1 month after the social distancing has been implemented, a large size of coastal areas with low chlorophyll-a level (<5 mg/m^3) was observed on April 23.

4. Discussions

The coastal zone of Jakarta is known for its productive fishery resources which plays important role in this region. This coast can be divided into the 3 coastal parts includes south, west, and east parts. Due to the population numbers in the coast, the south part has very differences in anthropogenic characteristics. Chlorophyll-a distribution in this coast was under effects of some combined factors such as river discharges, population numbers, anthropogenic activities, and land uses along the waterways.

Spatio-temporal chlorophyll-a levels in the waters of Jakarta coast are under the influencing of freshwater quality of numerous rivers discharged to the coast. In the south part of the coast bordered directly with the populated city, loaded freshwater containing nutrient rich domestic waste and pollutants resulted from anthropogenic activities in the land uses dominated by the settlement and industry has influenced the chlorophyll-a level. Here especially before the social distancing when the anthropogenic activities were high in January and February, high chlorophyll-a levels were observed. This was also observed in the west and east parts of the coast.

The finding of this study regarding the connection of rivers-population numbers-anthropogenic activities-coast-chlorophyll-a are comparable to the findings from other studies. The combination of socio-physical determinants including anthropogenic activities along the river have been discussed as the causal factors of chlorophyll-a loading in the coastal areas. Kunzmann *et al*. (2018) have confirmed that the most important stressors of coastal areas worldwide include Jakarta coast were coastal development, growing urbanization, and industrialization. In their study, they found that the river discharges from the urban areas of Jakarta were the most significant contributors to nutrient concentrations within the Jakarta coast. As a result, the chlorophyll-a levels were between 5 and 15 mg/m^3 and this far above the Eutrophication Threshold Concentration for chlorophyll-a of 0.2–0.3 mg/m^3.

Meanwhile due to the COVID 19, a social distancing has been implemented and daily routine activities have been limited and restricted. This regulation has been hypothesized has a positive effect on environment including increasing air quality and water quality. It has been reported for example in Venice canal, Italia, due to the lockdown the water in canal has become much clearer. While those assumptions are lacking scientific justifications including methodology, data, and data analysis. This study tries to

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present how the social distancing followed by activity restrictions at the end can affect the water quality. This considering that in SA regions, anthropogenic activities are taking places also along the river. Those activities also contribute to the material discharges to the river and accumulated in the coast. Besides that in SA region, a land use in coastal area was also dominated by settlement and industry. Those kinds of activities have great potential to release pollutant to the coastal ecosystems. To illustrate, the size of natural areas in the form of wildlife sanctuary in Jakarta coast is only 3 km or equal to 4% of the total Jakarta coast line. The other 96% comprises of settlement, industrial, and agricultural land uses.

In the developing countries with poor waste management, the anthropogenic activities are correlated with the domestic waste discharges into the river and downstream areas. In Jakarta coast, commercial and industrial activities have significant contributions following domestic activities. The percentages of wastes released by commercial and industrial activities were 17% and 9% respectively (Sachoemar and Wahjono, 2007). A sample collected from the coast near business area confirmed a blooming of *Stephanopyxis* algae and this indicated excessive nutrients have been discharged to the coastal areas. Considering the association of anthropogenic activities with the nutrient release and chlorophyll-a level, hence the anthropogenic activity restrictions may affect the nutrient release and chlorophyll-a level as well. Correspondingly, this study has provided an empirical evidence how the anthropogenic activity restrictions in the form of social distancing have an association with the reduction of chlorophyll-a level. Several cities in Indonesia have reported the reduction of waste volumes due to the implementation of social distancing. In east and central Jakarta, the domestic wastes were reduced to 17% and 20%. While in the normal day or without social distancing, it was estimated that 8.32 tons/day of wastes entering Jakarta coast. In detail, the discharged wastes contained PO_4 and SO_4 with volumes equal to 160 tons/month and 31387 tons/month respectively (Firmansyah *et al*. 2012). Wastes containing PO_4 and SO_4 were nutrient sources for phytoplankton (Deng *et al*. 2014). Hence by taking the percentage of waste volume reduction due to the social distancing, it can be estimated how large and significantly are the nutrient uptakes by the coast can be reduced.

Besides anthropogenic factors, the sea surface temperature is also known as a determinant factor that can increase the chlorophyll-a level (Torres *et al.* 2001). However, that correlation was not observed in this study and this finding is comparable to study by Nababan (2016). Hence, it indicates that anthropogenic activities are the determinant factors explaining the most variation of chlorophyll-a levels among months in Jakarta coast.

The use of remote sensing has been viewed as a versatile tool to monitor the surface parameters of water quality. One of the recent remote sensing tools is the Copernicus Sentinel-3B Ocean and Land Color Instrument (OLCI). The Sentinel-3B provides data that is a proxy for chlorophyll-a and phytoplankton biomass and as such is an important for water quality monitoring. The chlorophyll-a and other light-harvesting pigments in plankton cause a visible change in the color of the water. This allows identification of the spatial location of phytoplankton through satellite monitoring. By using the remote sensing data obtained from NOAA and Copernicus Sentinel-3B OLCI, this study has succeeded to map the daily and monthly spatio-temporal distribution of chlorophyll-a mainly in Jakarta coast. The spatial variations of chlorophyll-a before and after social distancing are very clear as observed in this study. Before the implementation of social distancing, high chlorophyll-a levels observed in large portions of coastal areas consistently from January to February. While from March to April, sizes of coastal areas with high chlorophyll-a levels were reduced and replaced with low chlorophyll-a levels. The use of remote sensing platform to monitor chlorophyll-a in this study is also comparable with the locally other researches. Suhadha and Ibrahim (2019) have introduced the use of Sentinel-3 OLCI to monitor chlorophyll-a in whole Indonesia sea. The chlorophyll-a levels in their study observed in October 2019 were also considerably high.

5. Conclusions

This study is the first that provide empirical evidences of association of social distancing and water quality by taking the Southeast Asian populated coast as an example. Our analyses using the chlorophyll-a level as bio indicator and combined with the remote sensing monitoring have confirmed that the dynamic of anthropogenic activities in the coastal setting is responsible and associated with the water quality and nutrient contents as indicated by chlorophyll-a levels. The analysis shows that there were reductions of levels and areas of chlorophyll-a in the coast as function of social distancing and activity restrictions.

6. Recommendations

The main problem facing by coastal cities are waste discharges and water quality declines. Growing anthropogenic activities have outnumbered the capacity of waste managements. By using chlorophyll-a bio indicator, this study has informed that the regular anthropogenic activities with their waste discharges as the consequences can be limited and controlled. In this case the control routine is in the form of social distancing. Hence the social distancing should be incorporated as an alternative solution to limit anthropogenic activities and manage the water quality to balance the impact of rapid developments in the coastal areas in particular Southeast Asian regions.

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