Water-air CO2 flux estimation in Banyuasin river estuary, South Sumatera Province, Indonesia

by Wike Ayu Eka Putri

Water-air CO_2 flux estimation in Banyuasin river estuary, South Sumatera Province, Indonesia

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Abstract. Banyuasin Estuary is one of the estuaries surrounded by mangroves and two different water masses enter it. This study aimed to analyse the sink and carbon source status in Banyuasin estuary waters, and to estimate the water-atmospheric carbon flux in these waters. The following parameters were analysed: dissolved inorganic carbon (DIC) content, total alkalinity and water pCO_2. The results showed that the Banyuasin estuary watershed areas had carbon sink status, except those near ports, with carbon fluxes ranging from -542.5 to 5.911 mmol m^{-2} d^{-1}. This showed that the waters of Banyuasin estuary were unsaturated in CO_2 content.

Key Words: DIC, total alkalinity, pCO_2, unsaturated, carbon sink.

Introduction. CO_2 is one of the emission gases that cause global warming which get considerable attention, because due to the complexity of biogeochemical cycles CO_2 will affect various other environmental factors. The complexity of such cycles is particularly visible in coastal and estuarine areas. Gattuso et al (1998) mention that coastal waters have a major role in the biogeochemical cycles; moreover the transport of matter and energy from the coast to the deep seas also influence the biogeochemical cycles (Nasprianto et al 2016). Approximately 0.25 to 0.4 x 10^5 g of organic carbon per year was carried by river water flows and released on the deep seas by passing coastal waters (Milliman & Syvitski 1992). The level of CO_2 content in the waters will affect the ability of the water to absorb or release carbon from and into the atmosphere. A previous study has found that estuaries which are limited by shoreline mostly have higher CO_2 values than atmosphere (Cai et al 2013).

Banyuasin river estuary is one of the great estuaries of the tropics located in South Sumatra Province. Similar to other estuaries, the Banyuasin estuary also has a complex ecosystem especially in controlling the flux of carbon elements, as confirmed by Regnier et al (2013). The estuary is surrounded by mangroves and gets the mass of water from two different major rivers, the Lalan River and the Banyuasin River. In addition, there are several small rivers that also flow into the estuary. Banyuasin estuary has a very important role for the economy of South Sumatra Province. In addition to this area as a Special Economic Zone, the estuary area also becomes one of the potential and important fishing grounds for the community. Mangrove area in estuary waters has decreased from 2005 to 2016 by 10.85% (Purwiyanto & Agustriani 2017a). Decrease in mangrove land cover will indirectly affect the ecological function of mangroves associated with global warming. The approach that can be done to study the ecological functions of waters in relation to the biogeochemical cycle is by analysis of the total inorganic carbon concentration (DIC), pH and alkalinity. The data will then be used to calculate the CO_2 partial pressure to determine the role of the water as an absorber or carbon release. The purpose of this study was to analyse the sink and carbon source status in Banyuasin estuary waters, and estimate the water-atmospheric carbon flux.

Material and Method

Description of the study sites. The research was conducted in September 2017 in the waters of Banyuasin estuary, Banyuasin Regency, South Sumatra Province, Indonesia. This estuary is a downstream part of the Lalan River and Banyuasin River, and also directly opposite to the Strait of Bangka. Those conditions make the estuary a special economic area. Within the estuary, there is a transport port (Tanjung Api-Api Port) on the east side and fairly thick mangrove areas on the east and west sides. This study used 22 stations covering the entire estuary area (Figure 1).

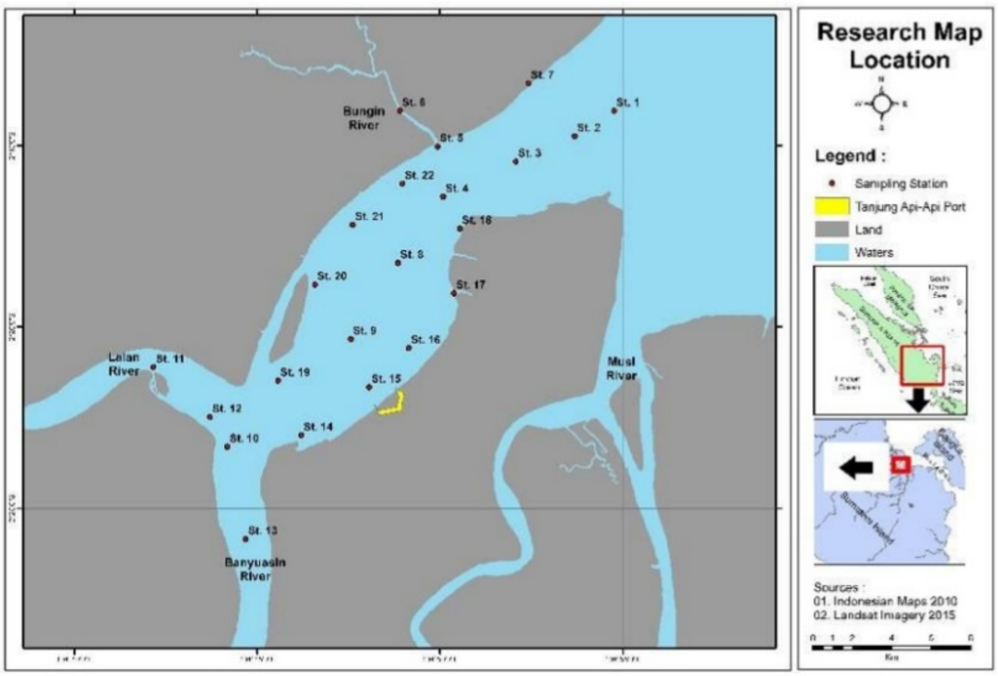


Figure 1. Location of Banyuasin Estuary, South Sumatera, Indonesia.

Sampling and analysis procedures. Sampling was done on the surface layer of water with sampling method referring to Dickson et al (2007). Samples were brought to the laboratory for analysis of phosphate, silicate, dissolved inorganic carbon (DIC) concentrations, and total alkalinity. Phosphates and silicates were analyzed using spectrophotometry method according to APHA (2005). DIC and total alcalinity were analyzed by titration method according to Giggenbach & Goguel (1989). Water quality parameters such as temperature, salinity, pH, currents and air CO_2 were measured in situ. pCO_2 was calculated by using CO2Calc software in counting sink and source status according to Rustam et al (2014) :

$$\Delta pCO_2 = pCO_{2\,seawater} - pCO_{2\,atmosphere}$$

The calculation of the carbon-flux between water and atmosphere was obtained with the help of the same CO2Calc software. The parameters which used in the calculation were pCO_2 and wind speed.

Results and Discussion

Physico-chemical water parameters. The physico-chemical parameters which were measured in this study were pH, temperature, salinity, current, phosphate, silicate and total alkalinity. The distribution of each parameter is presented in Figure 2.

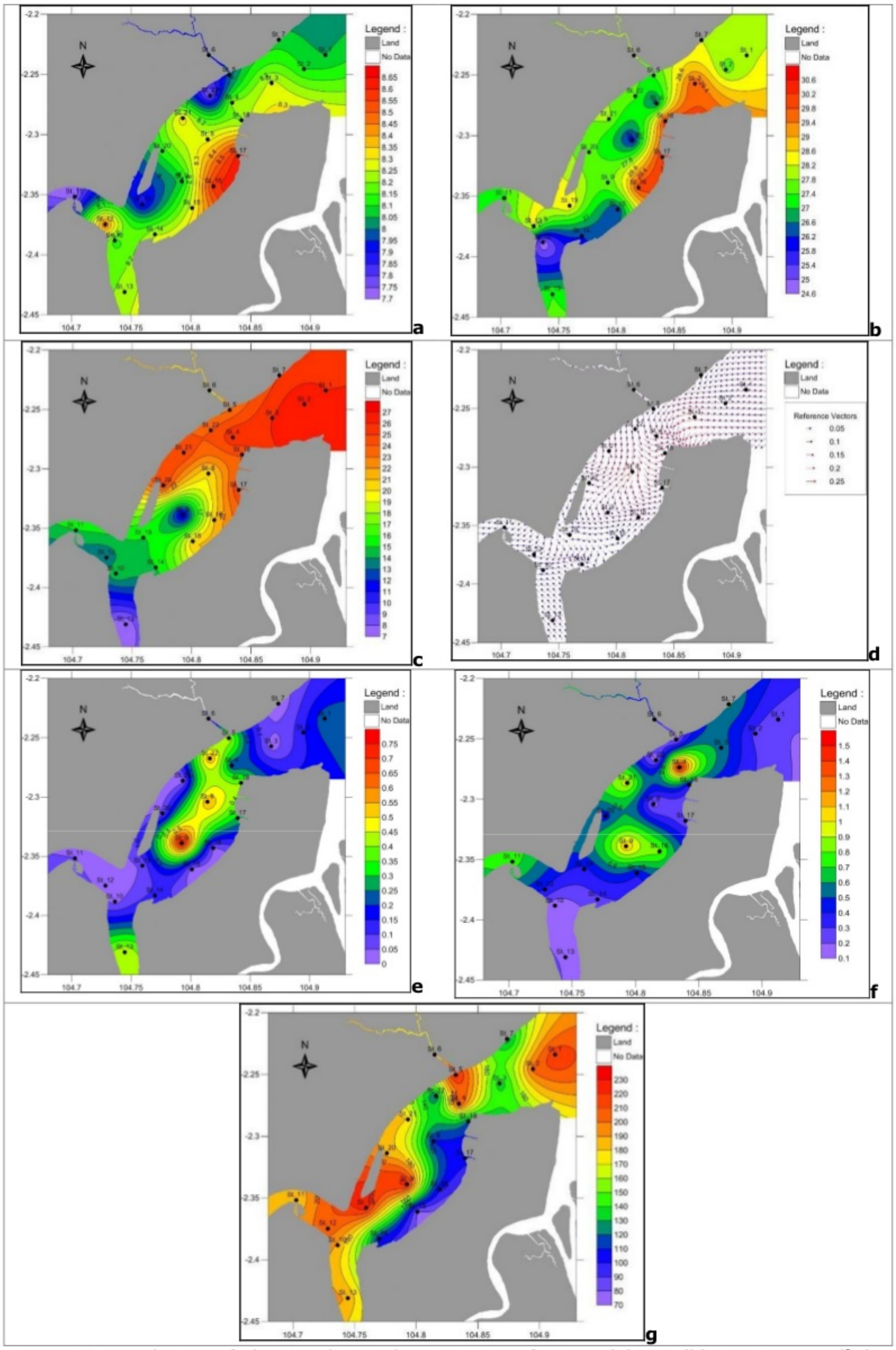


Figure 2. Distribution of physico-chemical parameters of water: (a) pH; (b) temperature (°C); (c) salinity (‰); (d) direction and current velocity (m s^{-1}); (e) phosphate (μmol L^{-1}); (f) silicate (μmol L^{-1}); (g) total alkalinity (μmol L^{-1}).

The pH of Banyuasin Estuary had a range of 7.72-8.62 with the highest pH on the upper eastern side of the Estuary adjacent to the mangrove area and the lowest pH at the station which is located on the Lalan river. The waters around the mangrove area tend to be alkaline, and this condition was also found by Sari & Harlyan (2015) in Mangrove Center Tuban, East Java, Indonesia and by Susiana (2015) in Mangrove Estuarine Perancak, Bali, Indonesia. This water pH difference occurred because of differences of water mass flowing in each sampling location. However, these pH values were also obtained in previous researches which were done in Banyuasin Estuary by Zulhaniarta et al (2015) and Prasetio et al (2016).

Water temperature of Banyuasin Estuary ranged from 24.6 to 30.2°C with the lowest temperature at station 10 and highest at station 17. This temperature difference was caused by the difference of measurement time that affects the intensity of sunlight absorbed by the waters. In addition, different atmosphere conditions at each point location when the measurements were made in the field also become one of the factors that determine the temperature of the waters.

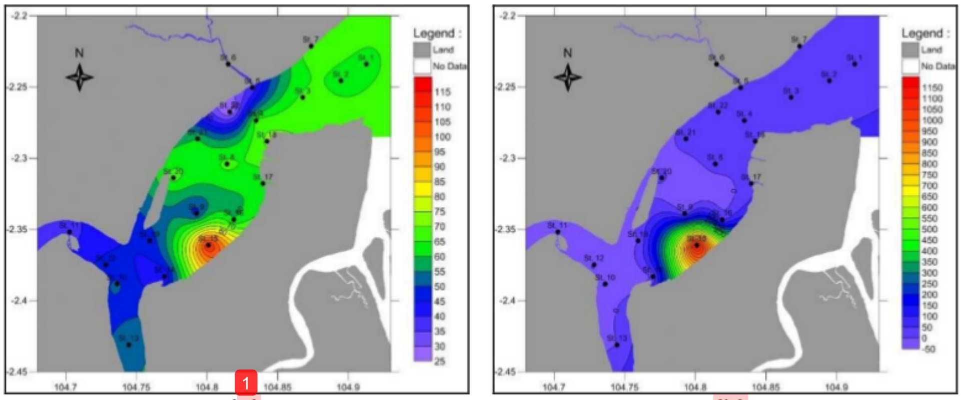
Salinity of Banyuasin Estuary ranges from 7 to 27‰ with highest salinity at station 2 and lowest at station 13. High salinity of station 2 is due because of its location which was outside the estuary and exposed to the sea water directly. While the low salinity was at station 13 which was located within the body of the Banyuasin River and there is still an influence of fresh water from the river. This resulted in a significant difference in salinity between the river and mouth of the estuary which is directly opposite the sea.

The current velocity at Banyuasin estuary ranged from 0.033 to 0.232 ms^{-1} with direction tending to enter the estuary. The weakest current was located at station 16 (the east side of the estuary) and the fastest current at station 9 (the middle of the estuary). Overall, the current direction to the upstream indicated that sampling was done during high tide. Except for station 13 where the current was still flowing to the downstream. This current movement affected the parameters of hydro oceanography, such as pH and salinity. The rotating current at stations 16 and 17 allegedly resulted in the highest water pH occurring in these two stations. While the current of station 13 signified the sampling period occurred in low tide, so the mass of fresh water dominates. This was as argued by Afdal et al (2012) where the variability of pH in the waters can be caused by the difference in the mass of water carried at high and low tide, i.e. carrying water masses with high pH at high tide and low water pH at low tide. The same process has also happened in the salinity parameter.

The phosphate concentration at Banyuasin Estuary ranged from 0.0103 to 0.781 μmol L^{-1} with lowest value at station 7 and the highest at station 9. While the silicate ranged from 0.115 to 1.552 μmol L^{-1} with the lowest value at station 10 and the highest at station 4. Those conditions are due to input and the distribution of organic matters from mainland through the rivers. The water mass movement and current velocity gives important influences in the distribution of both, phosphate and silicate.

Total alkalinity obtained from titration ranged from 78.433 to 226.481 μmol L^{-1} with lowest alkalinity at station 15 and highest in station 9. Station 15 was a station located in front of the passenger port, while station 9 was located in the middle of the estuary. The total value of alkalinity in Banyuasin estuay was much smaller than the total alkalinity in the Donan estuary which ranged from 1954,27 to 2032,44 μmol L^{-1} (Afdal et al 2011).

Carbon cycle. The water carbon cycle included the dissolved inorganic carbon (DIC) and CO_2 partial pressure (pCO_2) which are presented in Figure 3.



(a) (b)

Figure 3. Carbon distribution: (a) DIC (μmol kg^{-1}); (b) pCO_2 (μatm).

DIC in Banyuasin estuary ranged from 23,884 to 112,316 μmol kg^{-1}, whereas pCO_2 ranged from 0.43 to 1167.707 μatm. The highest DIC and pCO_2 were at a location adjacent to the port. This was allegedly due to the reduction in the number of mangroves around the port area that indirectly affected the potential for buffering of the waters. In addition, the construction of harbour resulted in changes in land function and affected the aquatic organisms, so indirectly the process of absorption of carbon also will be affected. This was because the high pCO_2 was due to the interaction of biological and physicochemical processes such as the high activity of bacteria that produce organic and inorganic carbon due to anthropogenic input (Frankignoulle et al 1998; Hunt et al 2010). This was thought to be seen from the abundance of phytoplankton as the major carbon producer through photosynthesis. Parapat (2011) obtained results where phytoplankton at the site in front of the harbour had the lowest abundance compared to other Banyuasin estuary areas. In this case, according to Afdal et al (2011), the rate of photosynthesis will be inversely proportional to the pCO_2 of the water. Thus, the less abundance of phytoplankton as the perpetrator of photosynthesis will result in higher pCO_2. However, there was no definitive data on changes in plankton and carbon inorganic, so this still requires further research.

The values of DIC and pCO_2 in Banyuasin estuary were much lower than the DIC and pCO_2 values obtained in Payung Island waters, i.e. 144.69-1080.91 μmol kg^{-1} for DIC and 63.097-1601.322 μatm for pCO_2 (Purwiyanto & Agustriani 2017b). This showed that the condition of Banyuasin estuary so far can still be a buffer for carbon compared to the waters of Payung Island, considering the location of the two waters was not too far away, which is approximately 35.18 km and each area receives two water masses from different rivers.

Status and carbon flux. The carbon cycle status in the water was indicated by the water-atmosphere carbon sink and source process obtained by calculating ΔpCO_2 between water pCO_2 and atmospheric pCO_2. If the value of ΔpCO_2 shows negative results, then the waters will have carbon sink status. The carbon status of Banyuasin Estuary waters can be seen in Figure 4.

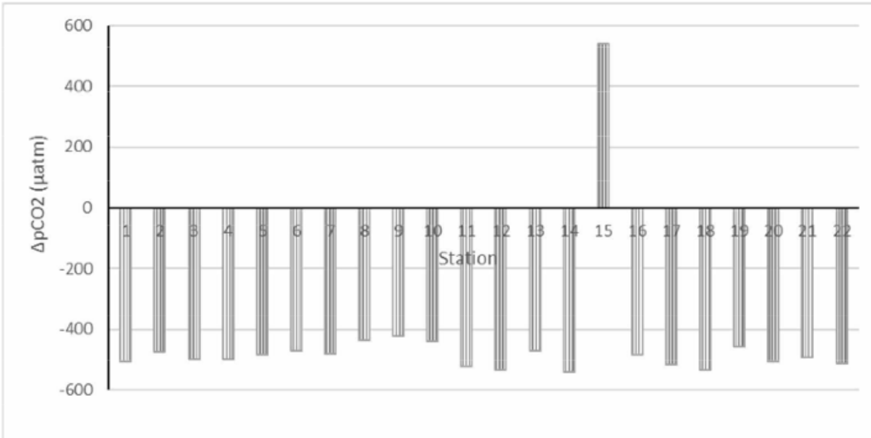


Figure 4. ΔpCO_2 of Banyuasin estuary.

In general, Banyuasin estuary waters had negative ΔpCO_2, except for station 15. This indicated that in general, Banyuasin estuary was a carbon sink, except for station 15 which was a carbon source. The condition of waters surrounded by mangroves was suspected to be the cause of the waters being able to absorb carbon from the atmosphere. Akhand et al (2016) also found that open estuary waters contain more saturated CO_2 than estuaries dominated by mangroves, so that estuaries with mangrove dominance are able to absorb more CO_2 from the atmosphere.

CO_2 flux in Banyuasin Estuary waters ranged from -542.5 to 5,911 mmol m^{-2} d^{-1}. The positive flux value (5.911 mmol m^{-2} d^{-1}) occured at station 15. This was because the CO_2 flux was directly proportional to the value of ΔpCO_2, where the higher ΔpCO_2, the higher CO_2 flux value will also be. This was evidenced by correlation analysis that r = 0.9985. Even the pattern of CO_2 fluxes would also follow the changing pattern of ΔpCO_2 (Figure 5).

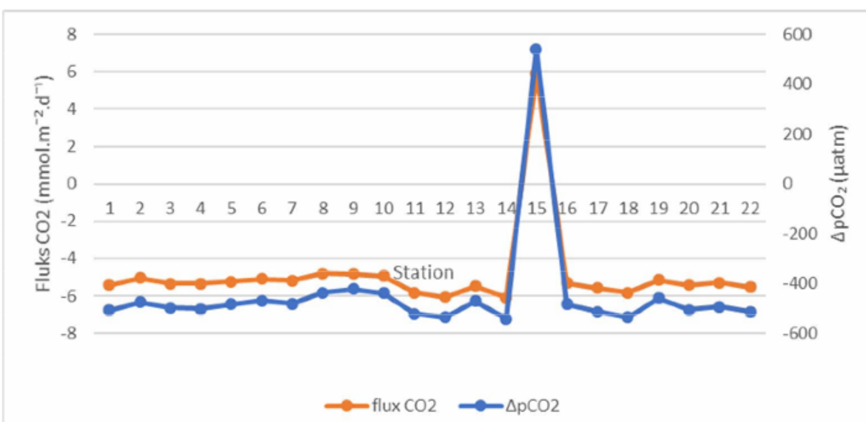


Figure 5. The pattern of ΔpCO_2 and CO_2 fluxes.

The range of CO_2 flux values in Banyuasin estuary was greater than the carbon source flux obtained in Donan Estuaries which ranged from 6.76 to 7.72 mmol m^{-2} d^{-1} (Afdal et al 2011). The magnitude of the CO_2 flux range in Banyuasin estuary was thought to be due to the mangrove area located on the estuary side. This is in accordance with Jennerjahn & Ittekkot (2002) study, where mangroves along tropical continental margins, generally contribute about 11% of the total carbon in the waters.

Conclusions. In general, the results showed that the CO_2 content in waters is smaller than in the atmosphere, except in areas around the harbor. The carbon flux between water and atmosphere ranges between -542.5 to 5,911 mmol m^{-2} d^{-1}. Those indicates that the waters are unsaturated in CO_2. This condition shows that the waters of Banyuasin Estuary generally play a role as carbon sink.

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