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ROFI Zone (Region of Freshwater Influence) and Its Impact on Total Dissolved Solids in the Coastal District of Sukadana Kayong Utara

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Abstract

Coastal areas are characterized by complex dynamics between freshwater entering through the estuary from land and seawater from open water. This study aims to calculate the salinity anomaly found on the sandy coast of Mayang, estimate the number of fractions and the volume of mass transport of fresh water entering the waters through the river flow and measure the total dissolved solids (TDS) in the west season. Water mass characteristics data collection using Water Checker. The determination of 17 data collection stations is assumed to be representative in representing the overall condition of the research location. The results of the anomaly salinity calculation show the low anomalous salinity values that are distributed horizontally on the coast. The distribution of salinity as anomaly values transversely on lines 1 to 4 ranges from -1 to -15. Freshwater fraction is concentrated as far as 1.16 km from the coast of Pasir Mayang with concentration values ranging from 0.44% to 0.13%. The mass transport of fresh water in the Pasir Mayang coastal waters is 1,130 m3s -1. The value of the transport volume of fresh water depends on rainfall and the flow of fresh water through rivers and then into sea waters. The total dissolved solids at the study site at each station ranged from 7.88 ppm to 17.8 ppm.

Keywords: ROFi, Total Disolved Solids, District of Sukadana Kayong Utara

1. Introduction

Pampang Harapan is a village in Sukadana sub-district, North Kayong Regency, West Kalimantan Province, Indonesia. Pampang Harapan Village has an area of 2,080 Ha or about 20.80 Ha^2. To the south, it is directly adjacent to the sea which is a mayang sand beach. Coastal areas are characterized by complex dynamics between fresh water entering through the estuary from land and sea water from open water (Bellafiore, 2019). Rivers transport fresh water and suspended sedimentary materials such as clay, silt and sand from land to sea which propagate through estuaries to the coast and open ocean waters (Hoshiba and Yamanaka, 2013; Hoshiba, 2019). Circulation in wide estuaries and bays has attracted the attention of researchers for a long time to carry out research with relatively easy access to waters which has made it possible to conduct field observation studies (Maljutenko, 2019). Coastal waters have many oceanographic phenomena that are still being studied. One of these phenomena is how the influence of fresh water on the water mass in coastal waters (Zibar, at al., 2018). Fresh water supply entering coastal areas through estuaries is very important information for coastal areas because dynamic mixing is the result of various physical processes (Zimmerman, 1986; Dam, et al., 1999).

Samson (1997) defined the Region of Freshwater Influence (ROFI) as the area between the ocean shelf and the estuary where the local input of freshwater buoyancy from a coastal source is proportional to, or exceeds the seasonal input of buoyancy as heat that occurs across the entire ocean shelf. Matano and Palma (2010) stated that in ROFI the strength and changes in the horizontal movement of river particles and circulation that occur vertically in the estuary depend on the density between river water and sea water.

In the scale where the Earth's rotation is effective, the input of freshwater buoyancy induces a counterclockwise flow of water masses (Anticyclone). Such mass flows of water sometimes grow towards the sea and/or extend to the left towards the sea in the Northern Hemisphere.

Such mass flows of water sometimes grow towards the sea and/or extend to the left towards the sea in the Northern Hemisphere. Zibar (2017); Zibar, et al (2018) stated that the main characteristic of ROFI is the significant buoyancy input from freshwater sources, which has important implications for the structure and dynamics of the water column. If the spatial scale is limited by coastal features and weak agitation, freshwater inflows tend to induce longshore currents where the effects of the Earth's rotation (Coriolis force) act to limit dispersion and form a baroclinic (density driven) that can affect hydrodynamics of hundreds of kilometers. coastal waters with transport volumes of fresh water carried out of the river more along the coast towards the south-southeast and south of the bay (Anticyclone) in the southern hemisphere.

The distribution of dissolved particle concentrations in water bodies from rivers modulates exchanges in coastal areas and the water column that play a role in transporting larvae, nutrients, sediments and pollutants to the open ocean (Lentz and Fewings, 2012). Research on ROFI has begun to focus more on turbulence interactions, stratification, and mixing. Total dissolved solids transport in studies similar to ROFI studies have also been carried out at Liverpool Bay ROFI (Souza and Lane, 2013), studies of hydrodynamic seasonal variations and sediment dynamics in subtropical shallow estuaries (Maren and Hoekstra, 2004). Sulardi (2020) regarding the seasonal volume, heat, salt and fresh water transportation in the Balikpapan Bay to the Makassar Strait stated that the average annual transportation volume, heat, salt and fresh water is influenced by external forces such as circulation currents and tidal waves, as well as rainfall in the area bay.

So far, research on the ROFI (Region of Freshwater Influence) zone and its impact on total dissolved solids on the coast of the Sukadana Kayong Utara sub-district has not been done. This study aims to calculate the salinity anomaly, freshwater fraction, Volume Transport of Freshwater and determine the total dissolved solids (TDS) in the west season. The results of this study are expected to produce useful information in the management and utilization of marine area for marine tourism activities, aquaculture, marine capture fisheries, and can be used for further management, both government agencies and research.

2. Methods

2.1. Time and Location of Reseacrh

This research was conducted on the coast of Pasir Mayang, Pampang Harapan Village, Sukadana District, North Kayong Regency in January 2022.

2.2. Tools and Materials of Research

The material used is sea water to measure oceanographic parameters consisting of oceanographic physical and chemical parameters, a logbook to record measurement data.

2.3. Data Collection

The data collection location consists of four lines that are directed straight towards the shoreline. This is based on initial information related to the distribution pattern of the turbidity of the waters from the coast to sea waters from image monitoring forming formations from the coast to sea waters. Each row consists of a data collection station with a depth of less than 10 meters which is considered as a station near the coast because it still gets the influence of fresh water supply from land. Stations located far from the coast are considered reference stations.

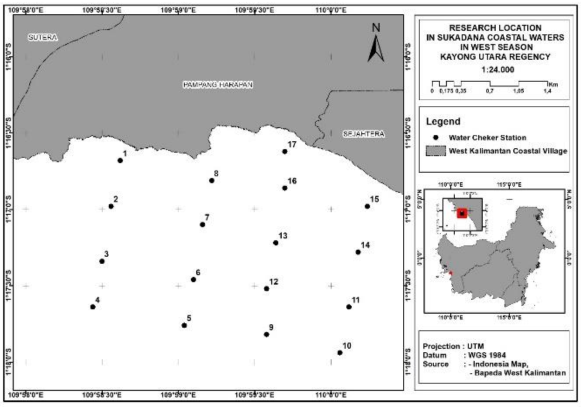

Fig 1. Research Location

2.4. Data Analysis

2.4.1. Salinity Anomaly

Calculation of anomaly salinity refers to Gilbert et al. (1996); Nurjaya (2022); Zibar at al. (2018) with the following equation:

$$S'(x,z) = S(x,z) - Sref(z) \quad (1)$$

Where S'(x,z) is the salinity anomaly value, S(x,z) is the salinity value measured at the site and Sref(z) is the reference salinity.

Freshwater fraction for unit volume is defined by referring to the equation of Gilbert et al. (1996); Nurjaya (2022); Zibar at al. (2018) as follows:

$$F(x,z) = \frac{Sref(z) - S(x,z)}{Sref(z)} \quad (2)$$

If the salinity distribution is a coastal-trapped structure, the salinity is expressed as S(y)= So-S'exp(y/a) where a is the scale of salinity variation So is the salinity in the open ocean, and (So-S') is the salinity in coastal waters (y=0). The reference salinity used in this study is 24.1 PPt, which is the salinity value of the research station located far from the coast and river mouths, in other words, it gets a not so large influence from the supply of fresh water flowing from river mouths and coasts. The average value of the freshwater fraction along the section can be defined:

$$Fr = \frac{1}{h}\int_{h}^{0} \frac{S_{ref} - S}{S_{ref}}\, dz \quad (3)$$

Fr is the average value of freshwater fractions along the transect, h is the depth of the waters of each depth of the station (m).

Freshwater transport volume can be estimated by following Petrie and Buckly (1996); Nurjaya (2000); Zibar at al. (2018) with the following formula:

$$V_{fw} = \int_{A} FrudA \quad (4)$$

Where V_{fw} is volume transport of freshwater (m3 s^{-1}), Fr is the average value of freshwater fractions along the transect, A is the area of low salinity water band (m^2) and u is the average alongshore velocity across section A (ms^{-1}).

The TDS value can be determined from data simplification of the electrical conductivity (EC) value, the greater the EC value of the waters, the more minerals contained in the water (Effendi, 2003), which is closely related to TDS which is often used as a water quality parameter.

3. Discussion Results

3.1. Salinity anomaly

The results of the calculation of the salinity anomaly indicate the low value of the salinity anomaly which is horizontally distributed on the coast. Salinity anomaly transversely in rows 1 to 4 ranging from -1 to -15. The salinity anomaly on line 2 has a very low value from the surface to the bottom of the water with a range of -15 to -10 as far as 0.5 km from the coast to the open sea, then continues to change in value with increasing water depth and further away from the coast. Zan Zibar (2017) states that the value of the salinity anomaly obtained cannot be separated from the influence of the freshwater supply input to the water column, so that it can affect or decrease the value of the salinity value, but the influence of the freshwater supply input weakens as it moves further away from the river mouth.

The pressure of the water mass from the mass of seawater and fresh water can be seen on each line. Line 1 occurs advection of seawater masses from the bottom of the water to the surface leading to the coastal area so that there is pressure with fresh water masses. The confluence of these two water masses occurred as far as 0.75 km from station 4 which was far from the coast to near station 1 which was not far from the coast (Figure 2, Section 1). Su et al. (2011) stated that the input of fresh water from rivers to sea waters can cause interactions between incoming river water and sea water so that it can cause changes in the characteristics of the water mass. The transverse distribution of salinity anomaly on line 2 ranges from -15 to -2.5 from the surface to the depths of the waters. The salinity anomaly value on the surface gets smaller as it approaches the coast. This happens because the waters close to the coast are affected by fresh water input from the mainland. The results of research by Jamshidi and Bakar (2012) in the southern coastal waters of the Caspian Sea stated that the salinity value in autumn with high rainfall intensity, causing salinity values of less than 10 PSU to 12.5 PSU. Then it increases with increasing depth and reaches 12.4-12.45 in the bottom layer of water. along sections 3 and 4 the salinity anomaly values range from -1 to -4.5 with values that continue to change as they move away from the coastal area. However, at the bottom of the waters, it was found that the anomalous salinity values weakened as far as 1.75 km in section 3 and as far as 1.5 km in section 4. The low salinity anomaly is thought to be due to groundwater runoff. Gómez at al. (2014) conducted a study on sources of salinity variation in a coastal lagoon in a karst landscape stating that shallow coastal lagoons are characterized by salinity gradients determined by fresh water supply from a combination of runoff, groundwater runoff and tidal influences which are directly related to the open sea.

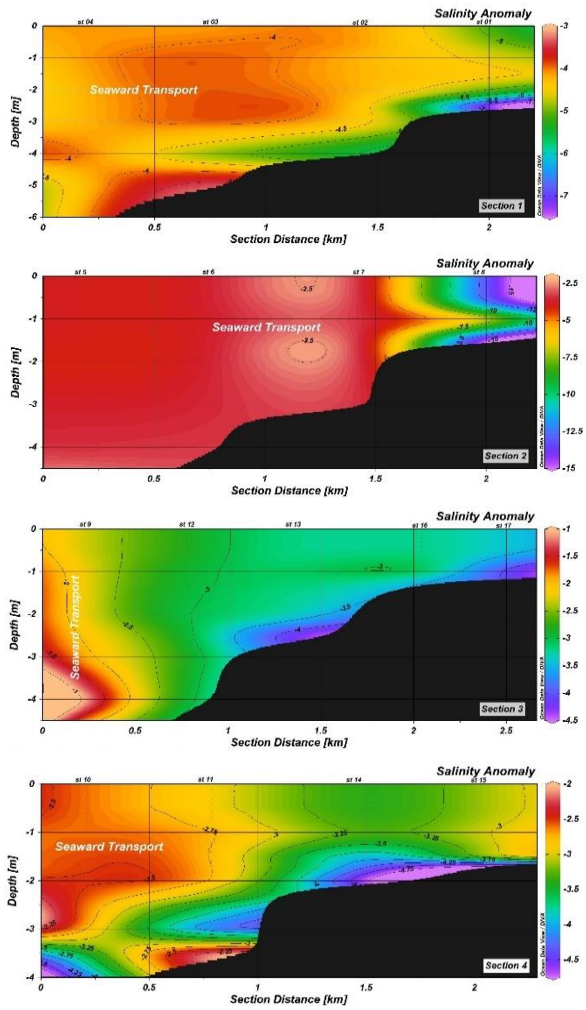

Figure 2. Vertical cross section salinity anomaly section 1, 2, 3 and 4.

3.2. Freshwater Fraction

The results of analysis data collection carried out at the research location, showed that the freshwater fraction was concentrated as far as 1.16 km from the Pasir Mayang coast with concentration values ranging from 0.44% to 0.13%. Concentration of fresh water fraction 0.12% to 0.079% is as far as 1.11 km. The value of the freshwater fraction decreases with increasing water depth with a value range of 0.025% to 0.1%, but in some bottom waters at the research location, the freshwater fraction value is large as in line 4. The concentration of freshwater fraction on line 4, is concentrated from the bottom waters up to the water column with a thickness of 0.1 to 0.8 meters from the coast to the offshore as far as 1.5 km.

The large value of the water fraction indicates the presence of submarine groundwater discharge (SGD) that enters the bottom of the sea from the mainland which is a nature reserve area. Krishan at al. (2015) stated that coastal and marine areas where there are many river flows resulted in a large amount of groundwater entering coastal areas through the discharge of underwater groundwater (SGD). The condition of the groundwater discharge at the coastal boundary is very interesting and complex, because it is more dominantly influenced by the tides of sea water with a periodicity of 2 times a day. The tidal period is the same as the research location, namely, there are 2 high tides and two low tides a day.

The distribution of the freshwater fraction line 1 at the research location shows the high value of the freshwater fraction which is concentrated on the coast as far as 0.5 km with a thickness from the bottom of the water to the water column of 0.5 m. The high concentration of the fresh water fraction in the water column is more influenced by the freshwater fraction sourced from the submarine groundwater discharge (SGD), the supply of fresh water entering the river flow to the coastal area and the tidal pressure that pushes the fresh water mass in the water column. Lecher at al. (2018) stated that groundwater discharges, including subsea groundwater discharges, discharges into lakes and rivers, and subglacial discharges, affect freshwater and marine ecosystems worldwide. SGD observations around the world indicate that groundwater seepage from land to sea occurs in many environments along the world's continental margins, and has a significant influence on the environmental conditions of many nearshore marine environments (Taniguchi at al. 2022).

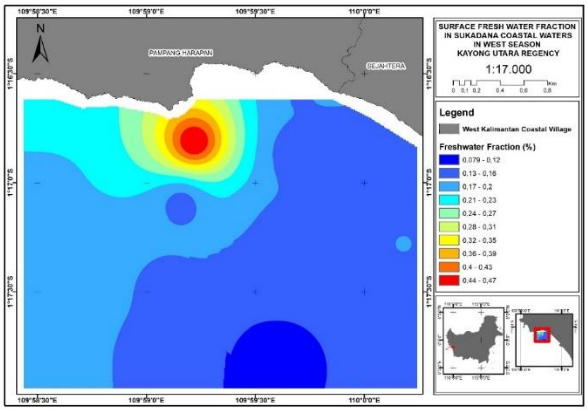

Fig. 3. Surface Freshwater Fraction

The distribution of the fresh water fraction on line 2 is almost evenly distributed from the surface to the bottom of the water and gets pressure from the seawater mass so that it is only concentrated as far as 0.25 km from the coast. Likewise, what happened on line 3, the concentration of freshwater fractions was almost evenly distributed from the surface to the bottom of the waters and further away from the coast. This is caused by the large value of the freshwater fraction which is distributed from the river to the coast to sea waters as well as tidal conditions. Broton (2010) states that the freshwater discharge from terrestrial sources that enter sea waters will tend to move horizontally towards the offshore and the interface between fresh water and sea water is located where the incoming fresh water discharge meets the sea edge.

3.3. Volume Transport of Freshwater

The mass transport of fresh water in the Pasir Mayang coastal waters is 1.130 m^3s^{-1}. The value of the transport volume of fresh water depends on rainfall and the flow of fresh water through rivers and then into sea waters. Cherukuru, et al. (2014) on the research on the effect of river discharge and ocean currents on the optical properties of the coast in Tasmanian coastal waters stated that the volume of fresh water transport that enters coastal waters through river mouths follows the spatial pattern of rainfall. Neshyba and Fonseca (1980); Royer (1979); Xiong and Roy (1984) stated that the large volume of freshwater supply discharge entering the coastal area can cause salinity anomalies and density dynamics in coastal areas. This applies to areas with high levels of rainfall. Wang et al. (2016) who conducted research on the evaluation of underwater groundwater discharge into northern Bohai Bay, China using 226Ra stated that the high flow of fresh water entering the sea waters at the study site caused the low salinity and pH values of these waters. Jennings at al. (2020) stated that the large supply of fresh water transport volume that enters marine waters is accompanied by high suspended particulate content and low salinity values.

Table 1. Current velocity, freshwater fraction, area of low sanity water and volume transport of fershwater

Month	Freshwater fraction (%)	Current velocity (m/s)	Area of low salinity water (m^2)	Volume transport of freshwater (m^3s^{-1})
January	0.91	0.17	7.306	1.130

3.4. Total Dissolved Solid

The total dissolved solids at the research location at each station ranged from 7.88 ppm to 17.8 ppm. The total distribution of dissolved solids is concentrated based on the distribution of fresh water fraction and salinity anomaly. This value meets the quality standard of 1000 mg/l. According to Soemirat (2002) that the amount of TDS of dissolved solids, usually consists of organic substances, inorganic salts, and dissolved gases such as Hg, Pb, As, Mg, Cd. If the TDS increases, the hardness will increase. Rusydi (2018) explains that conductivity (EC) and total dissolved solids (TDS) are water quality parameters used to describe the salinity level of the waters. Previous research also explained, in pure water samples (natural water) with a water ratio of 0.55 - 0.75 (seawater ratio 0.7) the TDS value is directly proportional to salinity, while the TDS value in wastewater or polluted waters is directly proportional. with dissolved organic matter such as hydrocarbons and urea (Thompson, 2006). The accumulation of organic matter from feed residues and the process of excretion of aquatic organisms or the process of regeneration of organic matter (increased concentration of TDS), as well as reduced light entering the water column causes a decrease in dissolved oxygen concentration to occur in the halocline layer (Sigman, 2010).

4. Conclusions

Hydro-oceanographic characteristics in the coastal waters of the Mayang sand are strongly influenced by the supply of water that enters the seas through rivers and estuaries so that the interaction between incoming river water and sea water can cause changes in the characteristics of the water mass. The results of the anomaly salinity calculation show the low anomalous salinity values that are distributed horizontally on the coast. The pressure of the water mass from the mass of seawater and fresh water can be seen on each line. Line 1 occurs advection of seawater masses from the bottom of the water to the surface leading to the coastal area so that there is pressure with fresh water masses. The meeting of these two water masses, occurs as far as 0.75 km.

The transverse distribution of the salinity anomaly on line 2 ranges from -15 to -2.5 from the surface to the depths of the waters. The salinity anomaly value on the surface gets smaller as it approaches the coast. Throughout sections 3 and 4, the salinity anomaly values ranged from -1 to -4.5 with continuously changing values when moving away from the coastal area. However, at the bottom of the waters, it was found that the anomalous salinity was weakening as far as 1.75 km on line 3 and as far as 1.5 km on line 4. Rendahnya salinitas anomaly ini diduga karena adanya lipasan groundwater.

The results of the analysis of data collection carried out at the research location, showed that the freshwater fraction was concentrated as far as 1.16 km from the Pasir Mayang coast with concentration values ranging from 0.44% to 0.13%. The magnitude of the concentration value is more influenced by the supply of fresh water that enters through 3 streams around the research location. Concentration of fresh water fraction 0.12% to 0.079% is located as far as 1.11 km with a transport volume of fresh water 1.130 m3s-1. The total dissolved solids at the research location at each station ranged from 7.88 ppm to 17.8 ppm. The total distribution of dissolved solids is concentrated based on the distribution of fresh water fraction and salinity anomaly. This value meets the quality standard of 1000 mg/l.

5. Reference

Bellafiore, D., Ferrarin, C., Braga, F., Zaggia, L., Maicu, F., Lorenzetti, G., De Pascalis, F. 2019. Coastal mixing in multiple-mouth deltas: A case study in the Po delta, Italy. Estuarine. Coastal and Shelf Science, 226, 1-15.

Bratton, J. F. 2010. The three scales of submarine groundwater flow and discharge across passive continental margins, J. Geol, 118(5), 565–575.

Cherukuru, N., Brando, V. E., Schroeder, T., Clementson, L. A., & Dekker, A. G. 2014. Influence of river discharge and ocean currents on coastal optical properties. Continental Shelf Research, 84, 188–203.

Dam V G C, Ozmidov R V, Korotenko K A and Suijlen J M. 1999. Spectral structure of horizontal water movement in shallow seas with special reference to the North Sea, as related to the dispersion of dissolved matter Journal of Marine Systems, 21, 207-228.

Effendi, H. 2003. Study of Water Quality. Canisius Publisher. Yogyakarta.

Gilbert, P S., Lee, T N and Podesta, G P. 1996. Transport of anomalous low-salinity waters from the Mississippi River flood of 1993 to the Straits of Florida Cont. Shelf Res 16, 8 p 1065-1085.

Gómez M, I., Kjerfve, B., Mariño, I., & Herrera-Silveira, J. (2014). Sources of Salinity Variation in a Coastal Lagoon in a Karst Landscape. Estuaries and Coasts, 37(6), 1329–1342.

Hoshiba, Y., Matsumura, Y., Hasumi, H., Itoh, S., Nakada, S., & Suzuki, K. W. 2019. A simulation study on effects of suspended sediment through high riverine discharge on surface river plume and vertical water exchange. Estuarine, Coastal and Shelf Science, 228, 1-11.

Hoshiba, Y., Yamanaka, Y. 2013. Along-coast shifts of plankton blooms driven by riverine inputs of nutrients and fresh water onto the coastal shelf: a model simulation. J. Oceanogr.69, 753–767.

Jamshidi, S., Bakar, N.B.A. 2012. Seasonal Variations in Temperature, Salinity and Density in the Southern Coastal Waters of the Caspian Sea. Oceanology, Vol. 52, No. 3, pp. 380–396.

Jennings, W. C., Cunniff, S., Lewis, K., Deres, H., Reineman, D. R., Davis, J., & Boehm, A. B. 2020. Participatory science for coastal water quality: freshwater plume mapping and volunteer retention in a randomized informational intervention. Environmental Science. Processes & Impacts.

Krishan, G., Rao, M. S., Kumar, C. P., Kumar, S., & Rao, M. R. A. 2015. A Study on Identification of Submarine Groundwater Discharge in Northern East Coast of India. Aquatic Procedia, 4, 3–10.

Lecher, A., & Mackey, K. 2018. Synthesizing the Effects of Submarine Groundwater Discharge on Marine Biota. Hydrology, 5(4), 60, 1-21.

Lentz, S. J., & Fewings, M. R. 2012. The Wind- and Wave-Driven Inner-Shelf Circulation. Annual Review of Marine Science, 4(1), 317–343.

Maljutenko, I., & Raudsepp, U. 2019. Long-term mean, interannual and seasonal circulation in the Gulf of Finland — The wide salt wedge estuary or gulf type ROFI. Journal of Marine Systems, 195, 1–19.

Matano R P , Palma E D. 2010. The Spindown of Bottom Trapped Plumes. Journal of Physical Oceanography. (40),1651 – 1658

Maren, V D., & Hoekstra, P. 2004. Seasonal variation of hydrodynamics and sediment dynamics in a shallow subtropical estuary: the Ba Lat River, Vietnam. Estuarine, Coastal and Shelf Science, 60(3), 529–540.

Neshyba, S., Fonseca, T. 1980. Evidence for counterflow to the West Wind Drift offSouth America. Journal of Geophysical Research 85, 4888–4892.

Nurjaya, I W. 2000. Behavior of Low Salinity Water Near The Mouth of Tokyo Bay [Disertasi].

Royer, T.C., 1979. On the effects of precipitations and runoff on coastal circulation in the Gulf of

Alaska. Journal of Physical Oceanography 9, 555–563.
Rusydi A F. 2018. Correlation between conductivity and total dissolved Solids in various type of water: a review. IOP Conf. Ser.: Earth Environ. Sci. Vol. 118 : 6 pages.
Simpson J H.1997. Physical processes in the ROFI regime J. Mar. Sys. 12 p 3-15
Souza, A. J., & Lane, A. 2013. Effects of freshwater inflow on sediment transport. Journal of Operational Oceanography, 6(1), 27–31.
Soemirat. J. 2009. Environmental HealthYogyakarta : Gajah Mada University-Press Nature Vol. 466 : 47-55.
Sigman DM. 2010. The polar ocean and glacial cycles in atmospheric CO2 concentration. Nature, 466, 47-55.
Sulardi A., Nurjaya, I W., Hartanto, M T. 2019. Seasonally volume, heat, salt and freshwater transports within Balikpapan Bay to Makassar Strait. IOP Conf. Ser. Earth. Environ. Sci 429 012058.
Su J, Wang J, Pohlmann T, Xu DF. 2011. The influence of meteorological variation on the upwelling system off eastern Hainan during summer 2007–2008. Oce. Dyn. 61 (6):717–730.
Taniguchi, M., Burnett, W. C., Cable, J. E., & Turner, J. V. 2002. Investigation of submarine groundwater discharge. Hydrological Processes, 16(11), 2115–2129.
Thompson K. 2006. AWWA Research Foundation, WateReuse Foundation, & Water Quality Association. Characterizing and Managing Salinity Loadings in Reclaimed Water Systems. USA : American Water Works Association
Wang, X., Li, H., Jiao, J. J., Barry, D. A., Li, L., Luo, X., Qu, W. (2015). Submarine fresh groundwater discharge into Laizhou Bay comparable to the Yellow River flux. Scientific Reports, 5(1).
Xiong, Q., Royer, T.C., 1984. Coastal temperature and salinity in the Northern Gulf of Alaska, 1970–1983. Journal of Geophysical Research 89, 8061–8068.
Zibar Z, Nurjaya I W and Natih M N. 2018. Seasonally physical characteristics of ROFI zone (Region of Freshwater Influence) in Pelabuhan Ratu Bay IOP Conf. Ser. Earth. Environ. Sci 176 p 1-11.
Zibar Z. 2017. Seasonally physical characteristics of ROFI zone (Region of Freshwater Influence) in Pelabuhan Ratu Bay (thesis).
Zimmerman J T F. 1986. The tidal whirlpool: a review of horizontal dispersion by tidal and residual currents Netherlands Journal of Sea Research, 20, 133-154.