Distribution of DO (Dissolved Oxygen) and BOD (Biological Oxygen Demand) in the Waters of Karimunjawa National Park using Two-Dimensional Model Approach

N Rizki1, L Maslukah1, D N Sugianto1,2, A Wirasatriya1,2, M Zainuri1, A Ismanto1, A R Purnomo3 and A D Ningrum4

1Department of Oceanography, Faculty of Fisheries and Marine Science, Universitas Diponegoro, Tembalang Campus, Jl. Prof. Soedarto S.H., Semarang, Central Java, Indonesia
2Center for Coastal Rehabilitation and Disaster Mitigation Studies, Diponegoro University, Semarang, Indonesia
3Karimunjawa National Park Management Office, Semarang, Indonesia
4IHE Delft Institute for Water Education, Delft, The Netherlands

Email: nabilahrizki@gmail.com

Abstract. Massive mangrove conversion into intensive pond farming has become environmental problem in Kemujan Island and Karimunjawa Island which affect the water quality. This research aimed to examine the dispersion of DO and BOD related to the current pattern in the seas west of Kemujan Island and Karimunjawa Island by using two-dimensional modelling simulations. Quantitative and descriptive methods were used to provide interpretation and analysis of the modelling simulation results. Modelling simulations were conducted in September 2019. The validation results show that the model and the field measurements has a very good. The results show that the current characteristics are dominated by tidal current, which moves westward with an average magnitude of 0.078 m/s. Furthermore, divergence, convergence and turbulence are also identified. Based on the simulation results, the prediction of DO and BOD concentrations fluctuate in Lagoon Mrican. During spring tide, the DO concentration changes from 7.95 - 8.1 mg/L into 8.55 - 9.45 mg/L and during neap tide, it changes from 8.55 - 8.7 mg/L into 9.15 - 9.45 mg/L. On the other hand, the BOD concentration increases from 0 - 0.08 mg/L to 0.88 - 0.96 mg/L during spring tide and neap tide.

1. Introduction
1.1. Background
Karimunjawa Islands have a coastal area that is dominated by mangrove ecosystems. In Karimunjawa was found that the phenomenon of mangrove deforestation in the Karimunjawa National Park area was 20.69 ha, which was dominated by the conversion of mangrove land to aquaculture ponds [1,2]. There is urgent need to develop of sustainable management in the utilization of mangrove forests [3], as well as corals [4], seagrass [5] and other ecosystems. In fact, marine and coastal ecosystems are part of the biodiversity and the most vulnerable globally [6]. One of the factors affecting the condition of the coastal ecosystem is the activity of utilizing coastal resources, such as the waters of the Karimunjawa...
National Park, which is a conservation area that needs to be monitored for the condition of the quality of the waters in order to realize sustainable sustainability as a national park. This also supports the UN's target in the Sustainable Development Goals point 14, which is to conserve oceans, seas, and marine resources in a sustainable manner for sustainable development [7].

The condition of the waters of the Karimunjawa National Park area has the potential for vulnerability to changes in water quality parameters. The main change in water quality due to pond activity is an increase in BOD (Biological Oxygen Demand) which at one time can reduce DO (Dissolved Oxygen). The conditions of BOD and DO are closely related to water temperature and salinity. In addition, the distribution and changes in concentration that occur have factors due to tidal dynamics and water currents [8].

Water quality is a basic parameter for the creation of a healthy marine ecosystem. Degradation of water quality can be influenced by scattered pollutant factors. Pollutants are divided into conservative and non-conservative pollutants. Non-conservative pollutants are compounds that can be degraded in waters, such as BOD and DO [9]. This can be analyzed by building assumptions from biological and chemical factors along with constants in a numerical equation. DO and BOD parameters play a major role in determining the quality of the waters due to the presence of pollutant input and the process is influenced by advection and diffusion dynamics in the waters [10].

Pollutants are scattered by water moving in all directions following turbulent diffusion [11]. The scattered of pollutants are strongly influenced by advection factors. The development of a hydrodynamic model can explain the reactions and processes of coastal ecosystems, namely two-dimensional water quality in a mathematical model. However, the mathematical model used in this study is limited in nature, it can only be used to simulate the model in east coastal Tabasco [12].

Observation of water quality conditions requires monitoring in time series to get the best results. However, there are limited tools in the field, so the forecasting approach with the mathematical model can be a solution to describe water quality conditions in time series. In this research used a numerical model simulation by finite element method, that can overcome quite a complicated coastline area such as in the Karimunjawa National Park.

1.2. Study Area of Modelling

The study area of this research is located in waters of the Karimunjawa National Park Area are astronomically located at coordinates 5°49'36.90" S and 110°27'52.56" E. Total area about shown in Figure 1, it has a land boundary involved the coastal area of Karimunjawa National Park Area as well as two open sea boundaries. This waters have 3 lagoons, there are Mrican Lagoon, Tengah Lagoon, and Ujung Lagoon. Around the coast lies a mangrove ecosystem and several intensive aquaculture ponds. Due to the sources of intensive pond farming wastewater in to the water. First, the leachate of intensive pond farming is not treated suitably according to standards based on Kepmen LHK RI 2005. Second, wastewater from the intensive pond farming is untreated. Third, it is influenced by the character of dynamic water. This study will simulate the water quality, both DO and BOD of the Waters of Karimunjawa National Park which is affected by tide and currents. Water samples are taken at the locations described in the yellow dots on the map. The number of water quality sampling stations is 10 stations and the parameters measured include temperature, salinity, DO and BOD. The red dot is the tide and current velocity measurement station.
2. Materials and Methods

2.1. Hydrodynamic Model

In this study, the hydrodynamic model based on numerical solution of 2D incompressible Reynolds on the mean of continuity, conservation of mass momentum, temperature, salinity and density [13].

Continuity equation is calculated as:
\[
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = S
\]

(1)

Mass conversion equation is calculated as:
\[
\frac{\partial \xi}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = \frac{\partial d}{\partial t}
\]

(2)

Momentum of mass equation in the X-direction is calculated as:
\[
\frac{\partial p}{\partial t} + \frac{\partial}{\partial x} \left[ \frac{p q}{h} \right] + \frac{\partial}{\partial y} \left( \frac{p q}{h} \right) + \frac{q}{h} \frac{\partial z}{\partial x} + \frac{g p}{h} \frac{\partial h}{\partial x} + \frac{g p^{2} + q}{C^{2} h^{2}} - \frac{1}{\rho_{w}} \left[ \frac{\partial}{\partial x} \left( h \tau_{w} \right) + \frac{\partial}{\partial y} \left( h \tau_{w} \right) \right] = -\Omega + \frac{h}{\rho_{w} \partial x} (p_{w}) = 0
\]

(3)

Momentum of mass equation in the Y-direction is calculated as:
\[
\frac{\partial q}{\partial t} + \frac{\partial}{\partial x} \left[ \frac{q p}{h} \right] + \frac{\partial}{\partial y} \left( \frac{q p}{h} \right) + \frac{q}{h} \frac{\partial z}{\partial y} + \frac{g h}{h} \frac{\partial h}{\partial y} + \frac{g p^{2} + q}{C^{2} h^{2}} - \frac{1}{\rho_{w}} \left[ \frac{\partial}{\partial x} \left( h \tau_{w} \right) + \frac{\partial}{\partial y} \left( h \tau_{w} \right) \right] = -\Omega + \frac{h}{\rho_{w} \partial y} (p_{w}) = 0
\]

(4)

Where:

- \( h(x,y,t) \) = water depth [\( \zeta - d \), m];
- \( d(x,y,t) \) = water depth varies with time [m];
- \( \zeta(x,y,t) \) = surface elevation [m];
- \( p,q(x,y,t) \) = flux density in the x and y directions [m^3/s/m] = (uh,vh);

Figure 1. Domain of research (Source: base map Indonesia)
(u,v) = average velocity of depth in direction x and y;
C(x,y) = Chezy resistance [m$^{1/2}$/s];
G = acceleration due to gravity [m/s$^2$];
f(V) = wind friction factor;
V, Vx, Vy(x,y,t) = wind speed and component in the direction x and y [m/s];
Ω(x,y) = coriolis parameter, depend on latitude [s$^{-1}$];
Pa(x,y,t) = atmosphere pressure [kg/m /s$^2$];
ρw = water density [kg/m$^3$];
x, y = coordinate distance [m], t (time) [s];
τxx, τxy, τyy = shear stress component

2.2. Water Quality Model
The distribution of water quality parameters was conducted by Numerical advection-dispersion equation. The equation based on hydrodynamic conditions of local waters and dynamism of a substance to be modelling in the advection process can be expressed by the equation of transport, which for non-conservative form can be written as follows [14]:

\[
\frac{\partial c}{\partial t} + u \frac{\partial c}{\partial x} + v \frac{\partial c}{\partial y} + w \frac{\partial c}{\partial z} = Dx \frac{\partial^2 c}{\partial x^2} + Dy \frac{\partial^2 c}{\partial y^2} + Dz \frac{\partial^2 c}{\partial z^2} + Sc + Pc
\]

(5)

\[
\frac{\partial c}{\partial t} = ADc + Pc
\]

(6)

\[
ADc = \frac{c \times (t + \Delta t) - c^n (t)}{\Delta t}
\]

(7)

\[
Pc = \frac{dc}{dt} = \sum_{l=1}^{n} \text{process}_l
\]

(8)

Where:
c : concentrarion of ECO-Lab variable;
u, v, w : currents component;
Dx, Dy, Dz : coefficient of dispersion;
Sc : source and sink component;
Pc : ECO-Lab process;
ADc : concentration changed because advection and dispersion affect;

2.3. Validation Model
Validation of the result hydrodynamic model was carried out on the tidal parameters and the current velocity using Root Mean Square (RMS). The RMS formula has 2 tolerance limits, there are; Tidal tolerance limit is ± 0.1 meter and current speed is ± 0.1 m/s. On the other hand, water quality model used Mean Absolute Percentage Error (MAPE) for validation, with criteria there consist; < 10% very good; 10 – 20 % good; 20 – 50% poorly; and > 50 % bad. The equation of both method, there are:

\[
RMS = \left( \frac{\sum_{n} \Delta X^2}{n} \right)^{1/2}
\]

(9)

Where :
\[\Delta X_n : b_n - a_n\]

Mean Absolute Percentage Error is calculated as [16]:

(10)
\[ MAPE = \left( \frac{1}{n} \sum_{i=1}^{n} \left| \frac{a_n - b_n}{a_n} \right| \right) \times 100\% \]

Where:
- \( a_n \): Field data
- \( b_n \): Model data
- \( n \): Amount of data

2.4. Modelling scenarios

In this research used two scenarios is divided into four major parts of the existing condition (without source) and the ultimate condition (include source). Due to limited data and time available, simulating started on 1 - 30 September 2019 so expect the resulting condition can approach the actual conditions. Simulation chosen with timescales low tide and high tide. Data validate of the current, used from measured data on May 2016.

The concentration source is the input source data in the simulation of the waste distribution model. This data uses with the assumption that the selection of waste data in the study is based on the similarity in type and location with the Karimunjawa and Kemujan ponds. Value of the parameters used include DO: 4.33 mg / L; BOD: 3.28 mg / L; temperature: 31.27 °C; salinity: 12.3 ‰ [17].

3. Results and Discussion

3.1. Validation of Modelling

The validation of hydrodynamics model is performed by comparing the water elevation from observed data and simulation results at Bajak Harbour station in Karimunjawa (110°28'37.20" E, 5°47'16.44" S based on WGS 1984) with the magnitude and direction of currents from observed data in the edge of Karimunjawa (110°28'37.20" E, 5°47'16.44" S based on WGS 1984). The model is initially validated with the water level tide data from 1st to 31st September 2019.

The validation is used to compare the field data in the form of current velocity of U and V component with the results of the current velocity model for U component has a result value of 0.02 m/s and V component has a result value of 0.03 m/s. The result of the validation on the two components shows that the current model built has a very good fit. With the result that simulation model is able to representative the conditions from field observations very well. On the other hand, the results of the water quality model with MAPE validation are also good fit, with an error rate of less than 10%. This means that the simulation results of Water Quality model are close to the actual conditions in the field.

![Figure 2. Comparison of water level elevation data from modelling and field observations](image-url)
3.2. The analysis of dynamic model
The waters of Karimunjawa National Park are in the western waters of the Karimunjawa Islands, which are indirectly influenced by the waters of Java Sea. These waters have a single daily tilted mixed tides. This is confirmed by the research that has been done, that Karimunjawa waters have water conditions that occur once the tide rises and one tide falls. With tidal conditions, there were 2 (two) times spring tide and 2 (two) times neap tide [18]. The bathymetry conditions are shallow. In September, the wind characteristics in these waters are predominantly moving westward (transition season II) with an average magnitude of 6.125 m/s. With tidal conditions occurring 2 (two) times the spring tide and 2 (two) times neap tide. The bathymetry conditions in the waters are shallow water. In September, the dominant wind characteristics in these waters move to the west (transition season II) with an average magnitude of 6.125 m/s. However, in this study, the tidal conditions of a single daily tilt mix with the occurrence of two tides and two ebbs which have a difference in tide riding values ranging from 0.3 - 1 m. Thus, according tide category, there are micro-tidal ups and downs [19]. The direction of the wind is to the west. This refers to the condition of the research conducted in September 2019. In which September is a month which is included in the transitional phase II. The wind patterns in Indonesia are very dependent on the influence of the monsoon wind system [20]. Basically, monsoons are wind patterns that blow periodically (at least 3 months). Based on the division of seasons, September is included in the month of transition season II. In this season, the wind in Indonesia experiences a movement from the southeast.

Current movements in small domain simulations are relevant to simulations in the global domain that have been simulated on Figure 4 and Figure 5, experiencing movements to the west during spring and neap times, the movement of current patterns following the water elevation pattern in the waters of Karimunjawa National Park [21]. In September, the waters of Java Sea experienced an east monsoon where the water mass mixing conditions from the South of Makassar had a relatively high flow velocity. However, because the western side of Indonesia has a more closed area (Sumatra and Java Islands) than the eastern side of Indonesia, thus the direction of the current to the west experiences a lower speed than when the current is eastward (influence from South China Sea) [22].

Therefore, in the small domain of research on Figure 6, it describes the conditions of the divergent current direction at high tide and the convergence at low tide. This occurs due to the geomorphological conditions of the research location, which is shaped like a bay with deep and calming waters and irregular coastlines (limited by mangrove ecosystems). At several points in the research domain experiencing turbulence, marked by a vortex. This has been stated, that turbulence can arise due to silting conditions in these waters [23]. According to the turbulence location formed from the simulation results,
if it is verified by conditions in the field, the water is shallow and has mounds with the formation of charred coral reefs.

Figure 4. Simulation of the current model at highest tide condition

Figure 5. Simulation of the current model at lowest tide condition

Figure 6. Pattern of currents at lowest tide (convergent) and highest tide (divergent), also turbulence at the study location
3.3. The analysis of concentration DO and BOD model

The result of the water quality model that includes the parameters of BOD and DO shows that the overall concentration pattern is the same, in which the concentration in the sea area is higher than in the coastal area or lagoon. The DO parameters in the existing scenario in sea waters during spring and neap range from 7.95 to 8.85 mg/L on Figure 7. In transitional waters, DO concentrations are in the range less than 7.05 - 7.35 mg/L. The highest concentration is ranges from 7.65 to 8.25 mg/L at the spring tide and the lowest concentration is around 7.35 - 7.8 mg/L at the lowest tide. While in neap conditions, the highest DO concentrations in lagoon waters ranged from 7.95 to 8.25 mg/L at the highest tide and the lowest DO concentrations ranged from 7.35 to 7.65 mg/L at the lowest tide. At the ultimate time on Figure 8, the distribution of DO concentrations in Mrican Lagoon has increased in the maximum spring conditions when it reaches the tide in the range of 8.55 to more than 9.45 mg/L and reaches the minimum at low tide of the range 7.35 - 7.5 mg/L. When neap, the maximum time to tide is in the range of 9 - 9.45 mg/L and the minimum at low tide is 7.5 - 8.1 mg/L. In the ultimate condition in the edge and centre of lagoon waters, the DO concentration is the same as the concentration during the existing conditions.

BOD concentrations during existing conditions in marine waters, when spring and neap on Figure 9 ranged from 0.32 to 1.12 mg/L. The closer to the lagoon and land, the BOD concentration decreased relatively. During spring and neap conditions, BOD concentrations in semi-closed waters ranged from 0 - 0.16 mg/L while throughout the lagoon ranged from 0 - 0.08 mg/L. The change in BOD...
concentration occurs when the spring at the lowest receding time to the tide has the highest concentration change ranging from 0.8 to 0.96 mg/L. Meanwhile, during neap the highest BOD concentrations ranged from 0.88 to 0.96 mg/L occurred only during the lowest tide. In the ultimate condition in the edge and centre of lagoon waters, the BOD concentration in Figure 10 is the same as the concentration during the existing conditions. DO concentrations in the sea waters have an important role for aquatic biota and the concentration of BOD can be one of the parameters determining the level of pollution and health of the waters.

The presence of DO in waters cannot be separated from the influence of temperature and salinity of the waters, and also affect the concentration of BOD. For example: in the waters of Karimunjawa National Park, there is a variation in the value of DO and BOD concentrations when existing conditions in marine waters are compared in coastal and lagoon waters. Because the current factor in the sea has a higher speed, which causes the DO concentration in the sea to increase, hence the diffusion process or the entry of oxygen (O₂) from the atmosphere into the waters will be maximized and can result in the DO concentration in the waters increasing. In the BOD distribution, conditions that are comparable to DO are found. This is different from the old research, which states that the relationship between BOD and DO is inversely related [24]. Possibly, this is because of several limitations that affect the BOD...
model process, such as the relationship between the presence of inorganic nutrients, toxic substances and other factors that affect the reaction process. The study of hydrodynamic conditions, the distribution of DO and BOD is strongly influenced by the dynamics of the tidal current movement. This is related to the nature of DO and BOD which are non-conservative compounds, so that they are easily dissolved and follow the dynamic movements of the waters. The tidal characteristics have a pattern directly proportional to the dynamics of DO concentration in the waters. When low tide, DO have a lower concentration than when high tide.

The DO concentration increases during high tide due to tidal factors and there is higher oxygen mixing towards the coast [25]. This phenomenon describes a decrease in temperature parameters, therefore the dissolution of oxygen becomes higher. DO concentration decreased salinity concentration during neap tide, which is thought to occur due to differences in evaporation or precipitation. However, when the ultimate simulation was carried out, the condition of the salinity concentration in the waters of Mrican Lagoon experienced a decline. If this continues, the waters of Mrican Lagoon will become waters that can interfere the life of marine biota. Because, salinity will greatly affect the level of water osmotic pressure and affect aquatic corpses based on the ability to control specific gravity and the diversity of osmotic pressure [26]. The solubility of oxygen (DO) is closely related to temperature and salinity conditions in the waters. The DO has an inverse correlation with temperature. If DO concentration is increasing, the temperature will decreasing [27]. This is also the case in this research, when the temperature goes down, the concentration of DO also decreases. This process occurs because the nature of the cold waters will more quickly absorb and accommodate oxygen.

4. Conclusions
The conclusions from this paper are the characteristics of the currents in the waters of Karimunjawa National Park in September 2019 are tidal dominant currents with an average speed of 0.078 m/s with dominant westward and divergent, convergent and turbulent phenomena and the most significant change in the concentration of Mrican Lagoon as a result of the ultimate simulation, where the DO concentration increased in concentration ranging from 9.15 - 9.45 mg/L and an increase in BOD ranged from 0.88 to 0.96 mg/L and in general the pattern the distribution of DO and BOD in the waters of National Park area is strongly influenced by tidal factors and the distribution of concentrations occurs because the water currents that experience an increase in concentration during the tide flow to land lagoon and vice versa at low tide decreases in concentration with the direction of the flow towards the sea.

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References
[1] Suryanti 2010 Degradasi Pantai Berbasis Ekosistem Di Pulau Karimunjawa Kabupaten Jepara (Semarang: Sekolah Pascasarjana Universitas Diponegoro) p 38
[2] Yusidarta I, Sutris H, Yusuf Syafituddin ND, Armojo Mulyadi and Agung Setiyadi 2019 Mangrove–Tambak – Taman Nasional Karimunjawa http://kolom-marinblogspotcom/2018/06/gambar-peta-aerial-perambahan-mangrovehtml
[3] Prasetya J D, Ambarinya A, Supriharyono and Purwanti F 2017 Mangrove health index as part of sustainable management in mangrove ecosystem at Karimunjawa National Marine Park Indonesia. Advanced Science Letters 23 3277-3282
[4] Maynard, J.A., Anthony, K.R.N., Afatta, S., Angraini, L.F., Haryanti, D. and Ambarinya, A., 2008. Rock anchoring in Karimun Jawa, Indonesia: Ecological impacts and management implications. Pacific Conservation Biology, 14 242-243.
[5] Irawan, A., Supriharyono, S., Hutabarat, J. and Ambariyanto, A., 2018. Seagrass beds as the buffer zone for fish biodiversity in coastal water of Bontang City, East Kalimantan, Indonesia. *Biodiversitas Journal of Biological Diversity*, 19 1044-1053.

[6] Mustofa A 2017 *J. DISROTEK* 8 1

[7] Badan Pusat Statistik 2014 *Kajian Indikator Sustainable Development Goals (SDGs)* (Jakarta Badan Pusat Statistik) p 172

[8] Sakinah W 2016 *Pemodelan Sebaran Kualitas Air Estuari Wonorejo dan Dampaknya Terhadap Ekosistem Perairan Estuari* (Surabaya: Program Magister Institut Teknologi Sepuluh Nopember Surabaya) p 108

[9] Handiani DN 2004 *Studi Sirkulasi Arus dan Transpor Polutan Cobalt dan COD (Chemical Oxygen Demand) di Perairan Pantai Cilegon untuk Memonitor Buangan Limbah Industri* (Bandung: Magister Program Magister Teknik Lingkungan ITB)

[10] Mukhtasor 2007 *Pencemaran Pesisir dan Laut* (Jakarta: PT Pradnya Paramita)

[11] Chatwin 1971 *J. Fluid Mech* 48 4 p 689 - 702

[12] Bejarano F, Torres H R, Leon C R, Cuevas I E H, Diaz J J H, Gomez H B, Pina and C C Castaneda 2018 Modelling Transport and Assessment of Aquatik Toxic metals in Coastal ecosystem

[13] DHI 2012a *Mike 21 Flow Model Hydrodinamic Module – scientific Documentation* (Denmark: DHI)

[14] DHI 2012b *Mike 21 Flow Model – ECOLab Module – User Guide* (Denmark: DHI)

[15] Evans GP 1993 A Framework for Marine and Estuarine Report No FR0374

[16] Nurvianti, I BD Setiawan and FA Bachtiar 2019 *J. Pengembangan Teknologi Informasi dan Ilmu Komputer, 3* 6 p 5257-5263

[17] Bara’padang B, A Fahrudin and I Effendi 2019 *J. Ilmu Kelautan dan Perikanan Papua, 2* 2 p 75-81

[18] Direktorat Konservasi Kawasan and Jenis Ikan 2015 *Profil Kawasan Konservasi Jawa Tengah* (Jakarta: Kementerian Kelautan dan Perikanan) p 45

[19] Magori C 2009 *Tidal analysis and prediction in the Western Indian Ocean Regional Report Western Indian Ocean Marine Science Association (WIOMSA) and Intergovernmental Oceanographic Commission (IOC)* p 44

[20] Musa Muhammad, Gentur H, and Heryoso S 2013 *J. Oceanografi, 3* 1 p 1-7

[21] Dinda, Muh. Yusuf and Denny Nugroho Sugianto 2016 *J. of Oceanography, 12* p 186 – 196

[22] Siregar S N, Lintang P S, Noir P P, Widodo S P and Mega L S 2017 *DEPIK J. ilmu – ilmu perairan, pesisir dan perikanan*

[23] Pawar P R 2013 *Marine Pollution Bulletin, 7* 5 p 291 – 300

[24] Tubalawony S E Kusmanto and Muahdirjin 2012 *Suhu dan Salinitas Permukaan Sebagai Indikator Upwelling* (Jakarta: LIPI)

[25] Kusumawati I 2016 *J. Perikanan Tropis, 3* 1 p 1-10

[26] Mocuba J Joaquim 2010 *Dissolved Oxygen and Biochemical Oxygen in The Waters Close to the Quelimane Sewage Discharge* (Norway: Program Magister Chemical Oceanography Geophysical Institute Universitas Eduardo Mondlane University Norway) p 42

[27] Tanjung R H, Rechnelty, Baigo, Hamuna and Alianto 2019 *J. of Ecological Engineering* p 84