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Transplantation of *Acropora* sp. for coral rehabilitation on faba substrate in Baluran National Park, Indonesia

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ABSTRACT

The purpose of this research is to analyze the success of transplantation method using kerbstone media from blocks made of coal waste (fly ash and bottom ash) from thermal power station (PLTU) as an innovation in waste utilization and rehabilitation efforts to the damaged coral reef due to bleaching phenomena in 2020. The research was done from July 2022 to June 2023 in the waters of Bama Beach, Baluran National Park, East Java, Indonesia. The coral fragments of *Acropora tenuis, Acropora intermedia, Acropora microlados* and *Acropora kirskyae* was 6 cm in average size with 50 repetitions for each size. The average growth rate showed different values during twelve months of research since the transplantation was done. *Acropora tenuis* had the highest growth rate of 1.991 cm/month. *Acropora microlados* 0.950 cm/month, *Acropora intermedia* 1.706 cm/month, and 0.702 cm/month for *Acropora kirskyae*. By using Kruskal-Wallis test for data analysing, obtained a survival rate of over 80% for all types, with *Acropora tenuis* as the highest (80.40%) and *Acropora kirskyae* as the lowest (70.70%). Therefore, kerbstone is considered feasible as a growth media for the coral reef as an effort to support Coral Triangle Initiative program in overcoming global warming as an innovation.

Keywords: *Acropora* sp., faba, coral reef, transplantation, fly ash bottom ash.

INTRODUCTION

The bleached coral reefs could be naturally recovered when the environment pressure decreased. The environment supported the growth of coral reef and symbiont algae could be re-recruited by the corals. This condition was allegedly playing a role in the coral recovery in Bama water. Based on the hard coral cover enhancement as the primary component ecosystem forming coral reef, an increase in hard coral cover occurred. The average percentage of hard coral cover in Bama waters in 2013 was 73.38% (Saptarini, 2010), in 2015 was 75.48%; and in 2018 was 76.96% (Khasanah, 2019). Those value indicated that the coral reefs in Bama waters were in good condition. The return of coral cover after disturbance became one of the recovery measures (Berumen dan Prachet, 2006).

This research carries out a try out in coastal waters around thermal power station PLTU Paiton using fly ash and bottom ash (FABA) kerbstone as the coral transplantation growth media. Faba kerbstone is a product innovation similar to paving blocks/bricks that made of fly ash and bottom ash (80%), which is the dominant waste utilised by PT Jawa Power in the form of ash waste. Ash waste has been utilised as the raw material in paving block and brick making. Faba kerbstone has dimensions of length 40 cm, width 25 cm wide, and height 15 cm. The material was stated as harmless. (SK.183/MenLHK/Setjend/PSLB.3/3/2016) (Suprianto, 2016). The laboratory test result of ALS Indonesia about toxicity characteristic leachate procedure (TCLP) test of fly ash and bottom ash indicated that fly ash and bottom ash contained elements including magnesium, calcium, potassium, ferrum (iron) and silicate (SiO_2) which were needed by coral planula larvae to settle in the form of juvenile corals. Therefore, it would give effect and contributed to the life needs of *Acropora* sp. It also supported the speed of growth of *Acropora* sp. and provided a better value in waste utilisation and rehabilitation efforts for the coastal waters environment, especially the coastal waters of the power plant.

There were no artificial media/growth reefs made from ash waste of the power plant for coral transplantation until now. As an effort to enrich the ash waste, an innovation that contributes important values for coastal waters is needed. For this purpose, this research becomes essential as an effort to give a real contribution to supporting the recovery program of the world's coral reef ecosystem.

MATERIAL AND METHOD

Research location

This research was carried out from July 2022 to June 2023 in Bama Beach, Baluran National Park, East Java, Indonesia. The coordinate position of S 7°50'43.40" T 114°27'50.85" and location map of coral reef transplantation activities was presented in Figure 1.

Preparation of substrate and coral transplants

This research used a field experiment method, that was a way to determine causal relationship by giving one or more treatments and comparing the result to see the effect on the research object carried out in the field.

The method used in this result was the basic escape method with H-shaped kerbstone as the substrate with each unit (module) consisting seven blocks of faba kerbstone. One unit of faba kerbstone had a size of 40 × 25 × 15 cm at a depth of 7–8 cm (Figure 2).

Every unit was made six holes as the place to stick out the coral fragment to be transplanted.

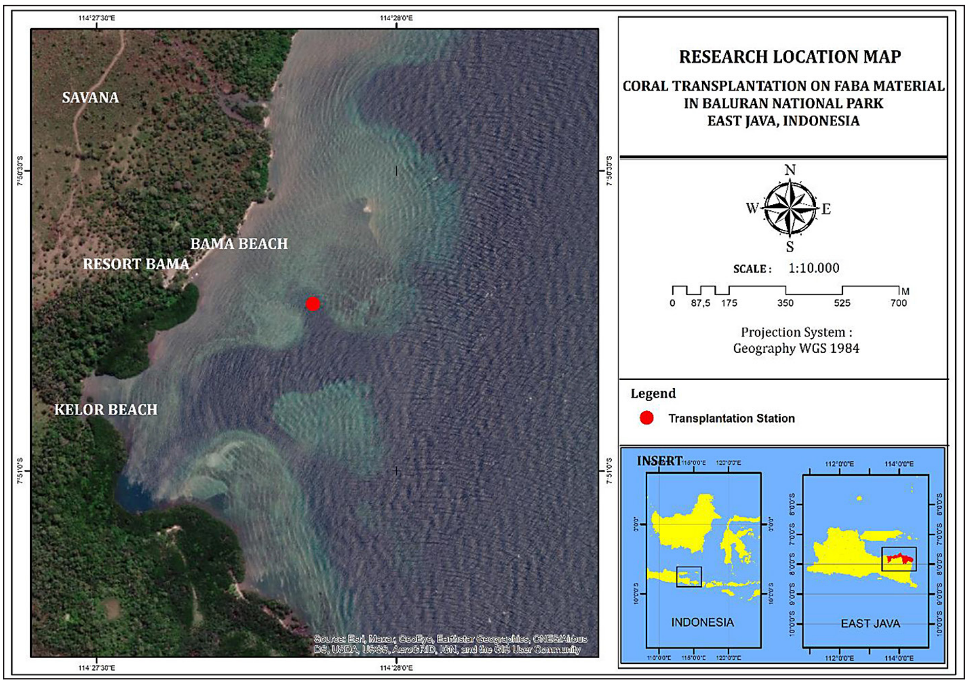

Figure 1. Research site

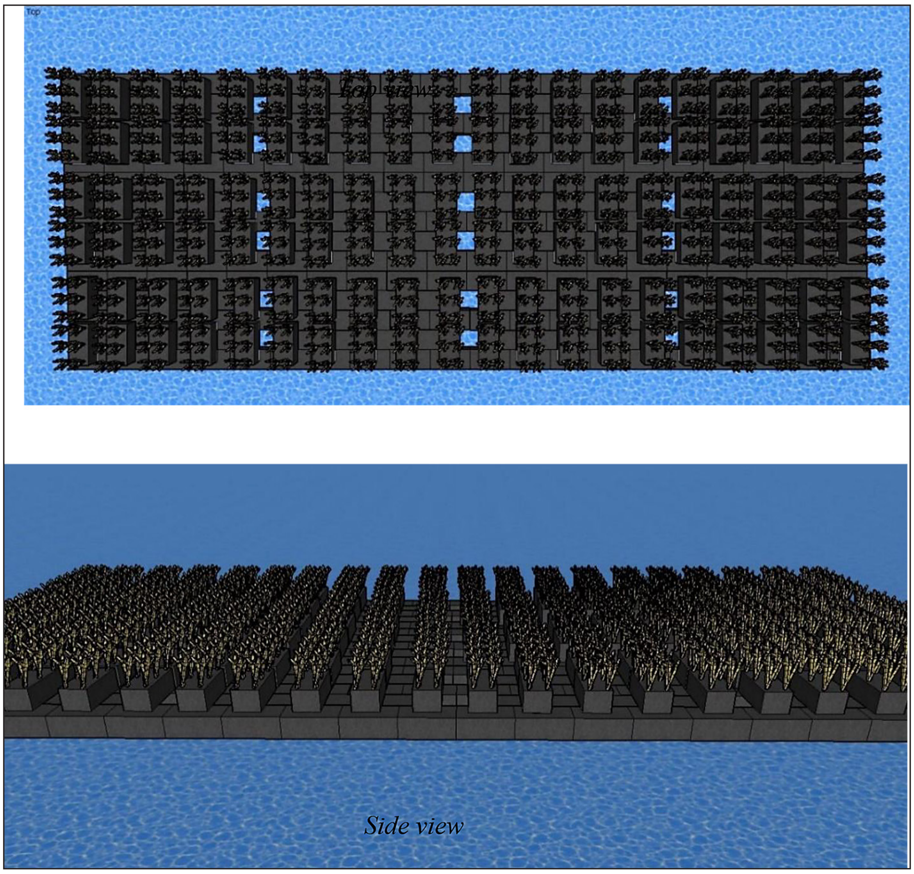

Figure 2. The composition of kerbstone for coral transplantation media

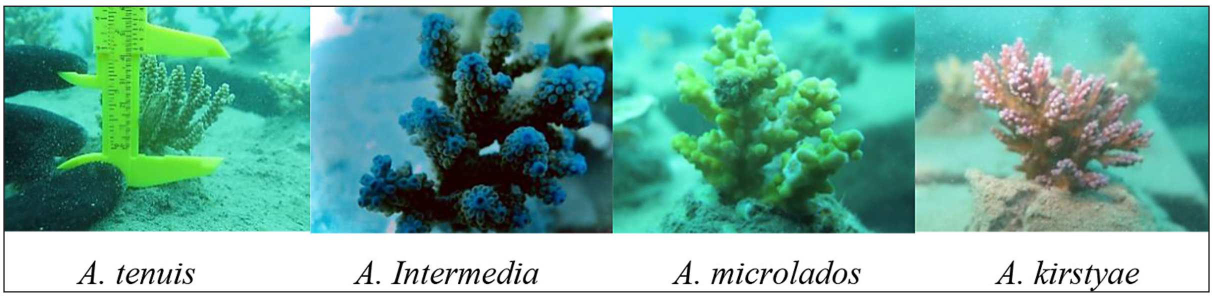

Figure 3. Various types of *Acropora* transplanted on fly ash and bottom ash media in Baluran National Park

The size of *Acropora* coral fragment used was 8 cm. The types that were transplanted were *Acropora intermedia, Acropora tenuis, Acropora microlados* and *Acropora kirskyae.* Each type was transplanted on 1000 units of kerbstone (Figure 3). Coral transplantation was carried out in March 2022. The observations on the growth of coral fragment that was planted once in two months for twelve months (July 2022 – June 2023) with intensive control on monitoring the coral growth by measuring the height of coral fragment using calliper. The care of coral fragment was carried out together with the observation process to prevent coral fragment deaths. Some activities carried out in the treatment process were checking the coral fragment position on the substrate, observing the coral fragment health, and cleaning the kerbstone substrate.

Data collection and analysis

Coral survival rate

In this study, the definition of "survival" for a fragment of coral was a specific fragment coral which still had polyp in the coral structure, whether the coral bleaching occurred. (i.e. a coral was considered alive if there remained some living coral tissue).

Absolute growth

The coral growth within a certain time could be calculated using the following equation (Youngs, 1981):

$$\beta = Lt - Lo \quad (1)$$

where: B – growth (mm), Lt – average height after the t-observation, Lo – average height at the beginning of the study.

Sedimentation rate

The trapped sediment is dried in an oven for 24 hours at 60 °C. The dry weight is classified and the sedimentation rate is analyzed through the equation (Roger et al., 1994):

$$LS = Bs/Number\ of\ days \cdot \prod \cdot r^2 \quad (2)$$

where: LS – sedimentation rate, Bs – dry weight of sediment (mg), $\prod$ – constant (3,14), R – radius of the sediment trap circle.

RESULTS AND DISCUSSION

The growth rate of transplants

The result of the growth rate of coral fragment *Acropora tenuis, intermedia, microlados* and *kirskyae* in Beach Bama water is presented in Figure 4 below. During twelve months since the Acropora corals transplanted, a different average growth rate was obtained. *Acropora tenuis* had the highest rate of 1.991/month, *Acropora microlados* of 0.950 cm/month, *Acropora intermedia* of 1.706 cm/months; and 0.702 cm/month for *Acropora kirskyae* (Figure 3). The growth rate of the four types of Acropora were not to be compared since each of them had different morphological characters. The use of Acropora branching coral fragments is based on the ability of high survival and a relatively fast growth rate compared to other types (Nurman et al., 2017). Morphological differences between the types of fragments planted in this study will have various influences such as the number of branches produced and the size of the fragment branches. This will affect the number of zooxhantellae associated with corals and affect the rate of photosynthesis produced. Apart from being influenced by internal factors such as morphological form, the growth rate of transplanted corals is also influenced by various external factors, including the media used.

The type of media used and the method of transplantation used will affect the success of coral transplantation activities. This is related to the level of adaptation and stress of the transplanted fragments which greatly affect the life and growth of these fragments. This study intended to clarify if kerbstone was the suitable media for all types of Acropora.

One of the differences in the growth rate of coral fragments in this transplant is influenced by internal factors such as the shape of the branching. According to Effendi and Ainurrahim (2013) that the type of coral that has more branching forms will have a more abundant

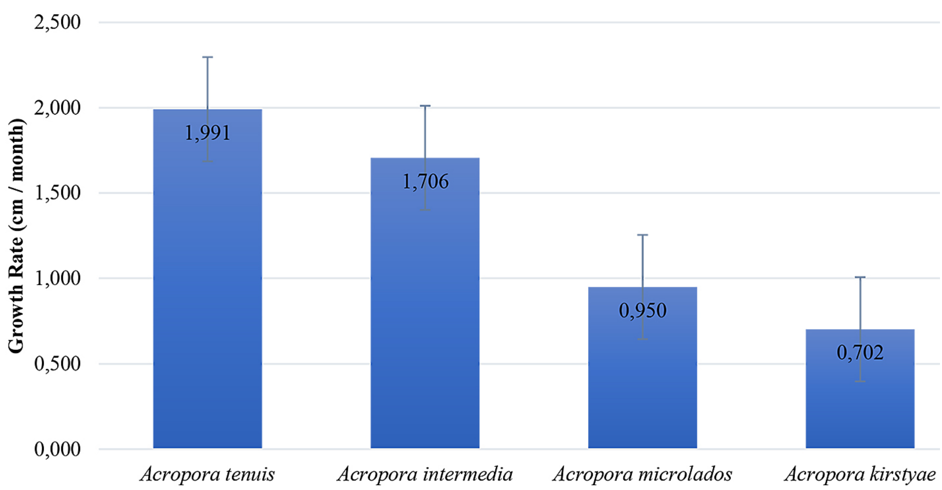

Figure 4. The growth rate of transplanted *Acropora* sp. on faba kerbstone for twelve months

number of zooxhantellae. A greater number of zooxhantellae will accelerate the process of photosynthesis carried out by corals so as to produce a lot of calcium carbonate to support the growth rate of the transplanted corals. This difference is also influenced by the level of adaptation of each transplanted fragment. The transplanted coral fragments will be ready to grow both vertically and horizontally after the fracture wound healing process has stopped. Coral fragments will carry out the process of recovering from the cut marks shortly after being transplanted with relatively large energy use so that the growth process is still disrupted (Febry, 2017). Newly transplanted corals will also secrete mucus as a sign that the coral is under stress. This mucus secretion also functions as self-protection against unstable conditions and will return to normal after the corals are able to adapt to these new conditions. The duration of this process is influenced by the suitability of the water conditions and the media used (Nurman et al., 2017).

In addition to internal factors, the transplant media as an external factor also influences the growth rate of transplanted coral fragments. The test results for faba content, which is the main ingredient for making kerbstone by Sucofindo Surabaya Branch in 2016, showed that this media contains several chemical compositions needed to support coral growth, such as SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, and TiO_2. These results are in accordance with what was conveyed by Guntur (2018) that transplant media containing these elements will support the growth of the transplanted coral fragments.

Survivorship of transplant

After twelve months Acropora was being transplanted on faba kerbstone substrate, they had different survival rate. *Acropora tenuis* had a survival rate of 80.40%; *A. intermedia* had a lower survival rate of 70.70%; *A. microlados* had 82.61 %; and 80.60% for the survival rate of *A. kirskyae*. It was indicated that both types of Acropora were commonly found in natural habitat in Beach Bama Waters environment (Figure 5).

When the Kerbstone exposed to seawater, it would experience leaching as a result of a chemical and physical process (Suprenant 1991). This such leaching allowed calcium, magnesium, aluminium, and silicates (and other compounds in the kerbstone) to be diluted in the seawater, providing the minerals needed by the corals for biomineralisation. Regarding this, coral fragments in the kerbstone were expected to have a higher growth rate than other types of transplantation media. The result of this result indicated that the growth rate of coral fragments of these four types of Acropora was not significantly different. This result was thought due to the relative needs of Acropora to those compounds. The difference in particle size of fly ash and bottom ash caused the washing process did not occur in a short time (Muzaki, 2019).

The survival rate of transplanted coral fragments is influenced by various determinants such as light, sedimentation, temperature, salinity, pH, and depth. The occurrence of death of transplanted coral fragments usually occurs due to unsuitable water conditions or the length of the stress phase after planting. This can be marked by the overall

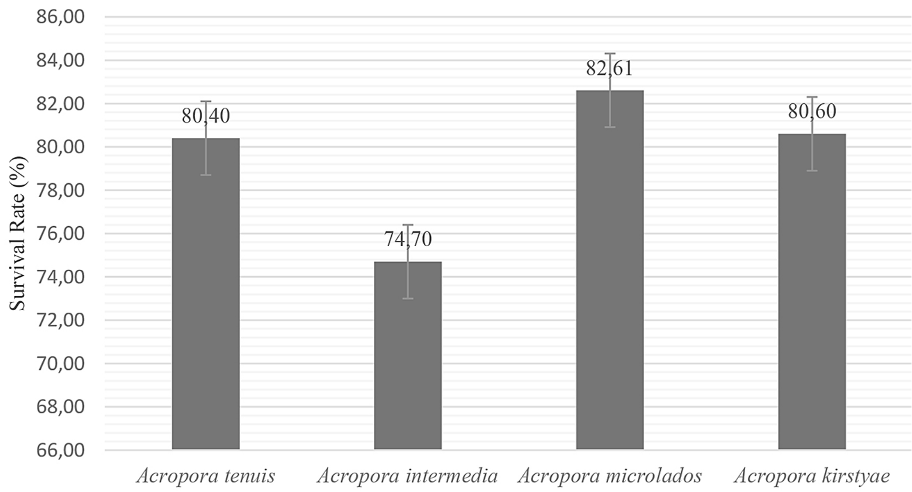

Figure 5. The Survival rate of *Acropora* sp. transplanted by FaBa kerbstone for twelve months

bleaching of coral fragments. Bleached corals indicate that the zooxhantellae symbiont algae in the coral tissue have come out or died. This phase causes a reduction in the food supply produced by zooxhantellae through the process of photosynthesis, causing coral death (Nurman et al., 2017).

In addition, waves and currents also have an important effect on the survival of transplanted corals, namely as a sediment rejector. The existence of currents will help corals accelerate the process of sediment rejection of sedimentation that settles on the surface of the coral body thereby minimizing the risk of stress and death (Jipriandi, 2017). Corals that live in currents also have a better survival and growth rate. This relates to the ability of currents to carry oxygen supplies and food sources such as plankton for coral colonies along with circulation that occurs. However, waves and currents that are too high can also cause the transplanted corals to escape from the media, causing coral transplant failure. Sedimentation rate is also a determining factor for the success of transplantation activities. The sedimentation rate at the study site showed a value of 13.4 mg/cm^2/day which was included in the medium-hazard category according to Pastorok and Bilyard, 1985. This category can cause a reduction in the number of species (death) in transplanted coral fragments. These results are thought to be the cause of the death of coral fragments due to sedimentation stress through the shading and covering processes. The high rate of sedimentation in coral ecosystems will reduce the growth rate and increase the mortality rate of coral reef ecosystems (Supriyadi, 2019).

The survival rate of corals is also influenced by the origin of the seeds used, that is, if the transplanted fragment seeds come from a location far from the planting site, it will have an adverse effect due to changes in the environment, both in terms of depth and other water quality parameters (Nurman et al., 2017). Based on this, the mortality rate which reached 17.31–26.09% is suspected to be due to the seed factor. Seed fragments taken from Grand Watu Dodol beach Banyuwangi Regency must be transported a relatively long distance to the planting site, Bama Beach, Baluran National Park, Kab. Situbondo. This is thought to be one of the factors that trigger stress on coral fragments so that they cannot survive in their new location. In addition, this movement also allows changes in water quality, which triggers an increase in coral stress, which causes death. The survival rate of coral fragments is also influenced by the media and transplantation technique used. The use of artificial media as a place for transplants is as stable as possible, not easily shifted by currents/waves, has a three-dimensional structure with an angled surface that is preferred by coral larvae to attach. In addition, as much as possible, artificial media should be able to prevent abrasion and overturning and be in a higher position than the bottom substrate so as to minimize sediment accumulation (Fadli, 2008). Based on this, the use of faba kerbstone media is deemed to meet the criteria of artificial media as a place for transplantation. The results showed that the survival rate of the four coral species ranged from 73.91–82.61% and was included in the successful category from a biological point of view. These results are in accordance with Iswara (2010) that coral transplantation activities will be declared successful from a biological point of view if the survival rate is between 50–100%.

CONCLUSIONS

The result of this research indicated that kerbstone made of coal ash waste (fly ash and bottom ash) could be used as the artificial reef unit for coral transplantation of *Acropora sp*. The utilisation of coal ash waste from the power plant was an effort to give a real contribution to support the world's coral reefs ecosystem recovery. Transplantation media made from fly ash and bottom ash are feasible and suitable for growing coral reefs.

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REFERENCES

1. Berumen M.L., Pratchett M.S. (2006). Recovery without resilience: persistent disturbance and long-term shifts in the structure of fish and coral communities at Tiahura Reef, Moorea. *Coral Reefs*. 25(4): 647–653. http://doi.org/crw3cq
2. Effendi, F.W. dan Aunurohim. (2012). Densitas Zooxanthellae dan Pertumbuhan Karang *Acropora formosa* dan *Acropora nobilis* di Perairan Pembangkit Listrik Tenaga Uap (PLTU) Paiton, Probolinggo, Jawa Timur.
3. Fadli, N. (2008). *Tingkat Kelangsungan Hidup Fragmen Karang Acropora formosa yang Ditransplantasikan pada Media Buatan yang Terbuat dari Pecahan Karang (Rubble).* Berita Biologi. 9(3).
4. Febry H. N., Batu S., & Ratna D. P. (2017). Tingkat Kelangsungan Hidup Karang *Acropora Formosa* Hasil Transplantasi Di Perairan Sawapudo Kecamatan Soropia. *Sapa Laut,* 2(4), 119–125.
5. Guntur, Abu Bakar S., dan A. A. Jaziri. 2018. *Rehabilitasi Terumbu Karang.* Malang. UB Press. Hlm 69–70.
6. Iswara, Sudono. (2010). *Analisis Laju Pertumbuhan dan Kelangsungan Hidup Karang Acropora spp., Hydnopora rigida, dan Pocillopora verrucosa yang Ditransplantasikan di Pulau Kelapa, Kepulauan Seribu.* Skripsi. FPIK Institut Pertanian Bogor. Bogor.
7. Jipriandi, Arief P., dan Henky I. (2017). *Pertumbuhan Karang Acropora formosa dengan Teknik Transplantasi pada Ukuran Fragmen yang Berbeda.* http://reaearchgate.net/publication/322055700
8. Khasanah, R.I. (2019). Growth rate of Acropora formosa coral fragments transplanted on different composition of faba kerbstone artificial reef. *Biodiversitas.* 20(12), 3593–3598. [Indonesian]
9. Muzaki, F.K. (2019). Growth rate of *Acropora muricata* coral fragments transplanted on dome-shaped concrete artificial reef with different composition. *Biodiversitas* 20(6), 1555–1559. [Indonesian]
10. Nurman F.H., Sadarun B., dan Palupi, R.D. 2017. *Tingkat kelangsungan hidup karang Acropora formosa hasil transplantasi di Perairan Sawapudo Kecamatan Soropia.* Sapa Laut. 2(4), 119–125.
11. Pastorok, R.A. dan G.R. Bilyard. (1985). *Effect of Sewage Pollution on Coral Reef Communities.* Marine Ecology Progress Series, 21, 175–189.
12. Dian, S., Muzaki, F.K. (2010). *Study On Coral Lifeform And Species That Susceptible Of Bleaching In Pltu Paiton Water, Proceeding Japan - Indonesia Workshop on Estuary and Climate Change 2010*, Institut Teknologi Sepuluh Nopember, Surabaya August 8–10th [Indonesia].
13. Suprenant B. (1991). *Designing Concrete for Exposure to Seawater.* Magazine Engineering, University of Colorado, USA.
14. Suprianto. (2016). Inovasi *Pengelolaan Limbah Bahan Berbahaya dan Beracun PLTU Paiton Unit 5&6.* Jawa Power. Fillapress. Probolinggo. [Indonesian]
15. Supriyadi. (2019). *Pengaruh Faktor Oseanografi dan Suspensi Sedimen terhadap Pertumbuhan dan Mortalitas Karang Transplantasi (Acropora spp.) di Paiton Probolinggo.* Skripsi. UIN Sunan Ampel. Surabaya.
16. Wikana I, Wantutrianus. (2014). Pengaruh pemakaian fly ash abu batu sebagai pengganti sebagian semen pada kuat tekan beton mutu tinggi. *Majalah Ilmiah UKRIM* 1, 41–52. [Indonesian].