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Growth rate of *Acropora formosa* coral fragments transplanted on different composition of faba kerbstone artificial reef

RULY ISFATUL KHASANAH[1,♥], ENDANG YULI HERAWATI[2], ANIK MARTINAH HARIATI[2], MOHAMMAD MAHMUDI[2], AIDA SARTIMBUL[2], DEWA GEDE RAKA WIADNYA[2], EVRON ASRIAL[3], YUDATOMO[4], ERRY NABIL[4]

[1] Fisheries and Marine Sciences Graduate Program, Faculty of Fisheries and Marine Sciences, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia. Tel./fax.: +62-341-553512, ♥email: ulick.Isfatul@gmail.com

[2]Faculty of Fisheries and Marine Sciences, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia

[3]Department of Fisheries Resources, Faculty of Fisheries, Universitas 45 Mataram. Jl. Imam Bonjol 45, Mataram 83239, West Nusa Tenggara, Indonesia

[4]PT. YTL Jawa Timur – PT. Jawa Power. Paiton Coal Fired Power Station Unit 5&6, Probolinggo 67291, East Java, Indonesia

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Abstract. *Khasanah RI, Herawati EY, Hariati AM, Mahmudi M, Sartimbul A, Wiadnya DGR, Asrial E, Yudatomo, Nabil R. 2019. Growth rate of* Acropora formosa *coral fragments transplanted on different compositions of faba kerbstone artificial reef. Biodiversitas 20: 3593-3598.* A counter measure and an alternative technique to reduce coral reef destruction is through transplantation, which requires the relocation or cutting of a live coral, planted in a designated place containing damaged varieties. Faba kerbstone is a product innovation similar to paving block/brick, made from fly and bottom ash (FABA), which is the dominant waste product from PT Jawa Power, Probolinggo, Indonesia. In addition, it has also been widely utilized as a raw material in the creation of paving and concrete blocks, composed by harmless material, with a length, width, and height of 40, 25 and 15 cm, respectively. This study aims to observe the growth rate of *Acropora formosa* coral fragments transplanted on a faba kerbstone, using five different fly and bottom ash compositions: K1 = 0% Fa, K2 = 25% Fa and 75% Ba, K3 = 50% FA and 50% Ba, K4 = 75% Fa and 25% Ba, while K5 = 100% Fa and 0% Ba. Furthermore, the observations were conducted underwater, using scuba diving for six months, observing the parameters of fragment length, colony diameter, and branches number. In addition, the highest elongation rate of *A. formosa* coral fragments was identified at K2 (1.313 ± 0.447 cm/month), and K1 (1.185 ± 0.642 cm/month), while the most significant increment in colony diameter was observed in K2 (0.077 ± 0.060 cm/month) and K1 (0.063 ± 0.071 cm/month), and the largest number of branches was also found in K2 (29.50 or 4.28 branches/month) and K1 (25.25 or 3.67 branches/month). Furthermore, the one-way ANOVA and Tukey's HSD test ($p = 0.05$) showed was no significant difference in the fragments elongation and colony diameters in the K1 and K2 models, although there was substantial variation from the K3, K4, and K5.

Keywords: *Acropora formosa*, artificial reef, bottom ash, fly ash, growth, kerbstone, transplantation

INTRODUCTION

Coral reefs are highly essential ecosystems well known for biodiversity, as they play a crucial role in marine ecology, protection of coastlines, as well as in providing food and other resources for coastal communities (Hoegh-Guldberg et al. 2007; Burke et al. 2011; Osinga et al. 2011). Unfortunately, coral reefs areas have recently experienced rapid degradation, due to the combination of natural and anthropogenic factors, encompassing climate change (Baker et al. 2008; Munday et al. 2008; Ateweberhan et al. 2013), pollution (Burke et al. 2011; Feary et al. 2013; Riegl et al. 2012), sedimentation (Wolanski et al. 2004; Fabricius et al. 2005; Wooldridge 2009), destructive fishing (Jackson et al. 2001; Chabanet et al. 2005; Fox et al. 2005; Hughes et al. 2007; Caras and Pasternak 2009), and coral mining (Caras and Pasternak 2009).

Faba kerbstone is product innovation, including paving block/bricks, which are made from an 80% mixture of fly ash and bottom ash (FABA), 10% cement, and 10% water. In addition, FABA has been identified as the dominant waste released by PT Jawa Power, Probolinggo, Indonesia as a raw material used in the creation of paving and concrete blocks, with a dimension of length 40 cm, width 25 cm, and height 15 cm, composed of harmless material (SK.183/MenLHK/Setjend/PSLB.3/3/2016) (Suprianto 2016).

The Toxicity Characteristic Leachate Procedure (TCLP) test conducted at ALS Indonesia laboratory determined that it contain some elements encompassing magnesium, calcium, potassium, and Ferrum (iron), as well as silicate (SiO_2), which is needed by coral planula larvae to settle in the form of juvenile coral. These further tend to influence, contribute, and support the growth speed of *Acropora* sp. corals ultimately supporting better value for waste utilization and rehabilitative efforts in the coastal waters, especially on the power plant. Furthermore, the material of Faba Kerbstone is relatively sturdy, durable, and also not easily shifted or swept away by waves (Alfeche 2002; Soong and Chen 2003).

Artificial reefs are man-made structures deployed on the seabed, and designed to imitate some characteristics of natural variety. Moreover, artificial reefs are often built to promote marine life in areas of lower sections, and those that are generally uncharacteristic. Therefore, the spread of artificial reefs is expected to attract more organisms to live and settle, subsequently increasing fisheries production, and also confer a restorative effect on the shallow-water marine environment (encompassing the coral reefs). These are usually made from unused materials, which include tires, wrecks or concrete (Dhiecha et al. 2013).

To this extent, no media or artificial reefs generated from the ash waste in the thermal power plant has been used in coral transplantation. This study aims to observe the growth rate of Acropora formosa coral fragments transplanted on a faba kerbstone, using five different fly and bottom ash compositions. Therefore, an attempt to promote the utilization of ash requires the adoption of innovations that contribute to coastal water's ecosystem. Furthermore, this research is geared towards creating a real contribution to support the recovery program of coral reef ecosystem worldwide.

MATERIALS AND METHODS

Study area

The research was conducted in the back area of coal stockpile, which was an east jetty in the Paiton thermal power plant, managed by PT. Jawa Power, Paiton Beach, Binor Village, Paiton Subdistrict, Probolinggo District, East Java, Indonesia. Faba Kerbstone served as the substratum for coral transplantation, and it was deployed at a 7-8 m depth, situated in empty spaces among colonies on the seabed. In addition, the visibility observed tends to range from 7 m in the rainy season, which exceeds 11 m in dry season, and the surface current velocity was moderate (10.7 cm/s), observed to be mainly generated by tidal activity (Figure 1).

Visual observations in the study area show the coral colonies present on the reef flat to be dominated by massive, encrusting, branching, as well as submassive Acroporids, encompassing Porites, Goniastrea, and Montastrea. Meanwhile, it has also been reported to harbor some branching coral (non-Acroporid) life forms, e.g., Setiatopora and Pocillopora, and several life forms of Acroporid, including the branching form (i.e., *Acropora muricata* (dominant species), *A. florida*, and *A. nasuta*), tabulate (i.e., *A. hyacinthus*), digitate (i.e., *A. humilis*), and submassive (*A. palifera*).

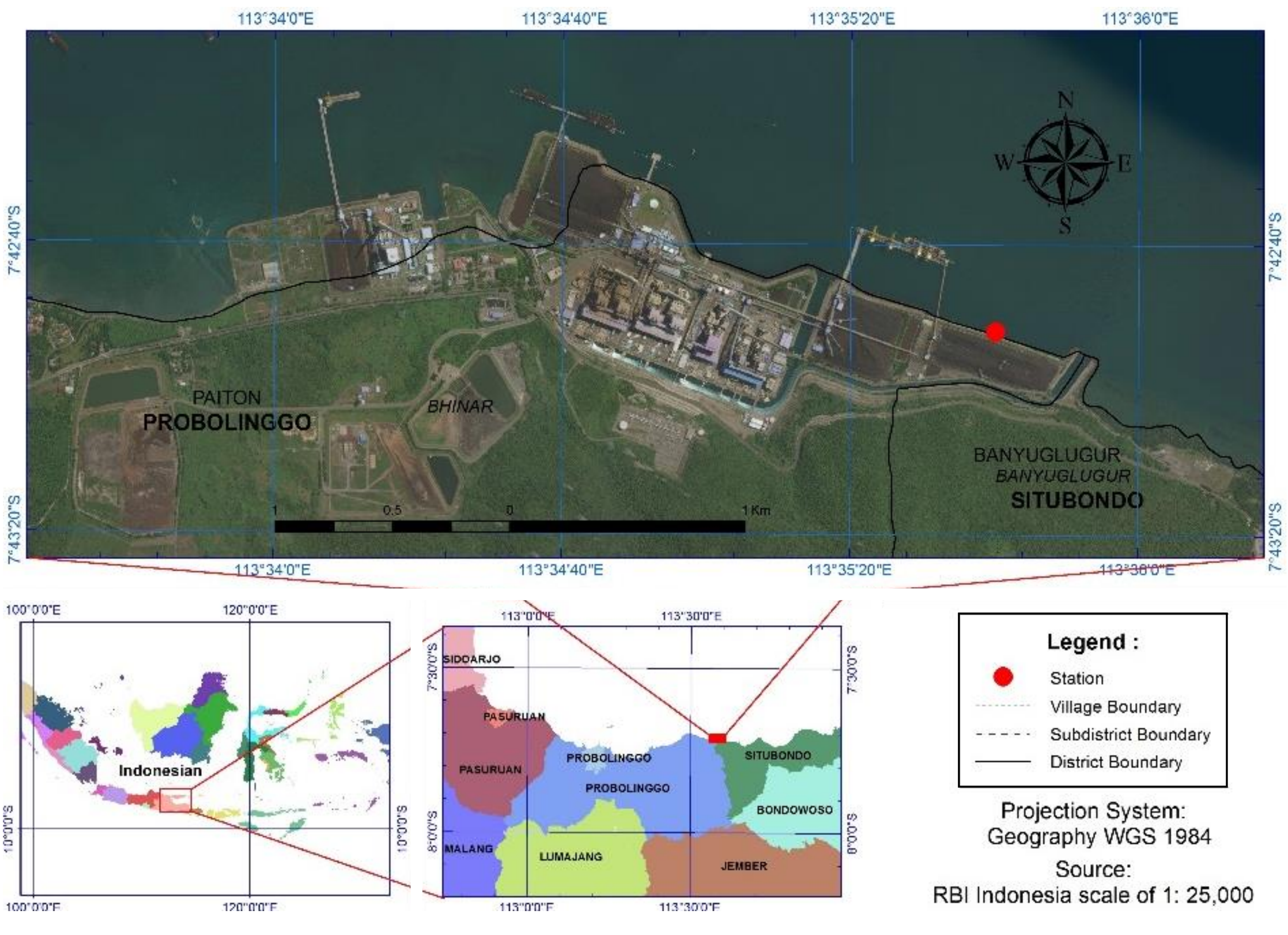

Figure 1. Research situation map in Paiton Thermal Power Station, Probolinggo, East Java, Indonesia (S 07°42'26,96" T 113°34'12,83")

Figure 2. Faba Kerbstone model used as a substratum in coral transplantation

Composition of faba kerbstone

The kerbstone is arranged in the form of the letter H, and each unit consists of 7 faba blocks, with a dimension of 40 x 25 x 15 cm, which possesses 6 holes, placed to transplant the coral fragments. Therefore, five different samples were used, including K1 at 0% Fly ask and 100% Bottom ask, K2 with 25% Fa and 75% Ba, K3, at 50% Fa and 50% Ba, K4 at 75% Fa and 25% Ba, and K5, at 100% Fa and 0% Ba. Therefore, 10 (ten) units were built for each type of stone (60 fragments), and a total of 50 units were available for this study. The model of Faba Kerbstone in coral transplantation can be seen in Figure 2.

Coral transplantation

Fragments of A. *Formosa* for transplantation were collected from large donor colonies situated in an adjacent position. This is expected to be visually healthy, i.e., neither bleached nor partially covered by algae, possessing a size of 10 cm (Muzaki 2008). Furthermore, the fragment was placed in a basket and moved to the transplant site with the media provided, and a mixture of 2 kg glue and 5 kg of white cement, then six coral fragments were planted in each unit that has been drilled prior to submerging and arrangement underwater. This, therefore, creates the need for observations under the water, which must be performed quickly, in order to prevent the coral from stress. In addition, each fragment was labeled with waterproof paper containing datam encompassing the number and type of kerbstone, as well as the number of fragments.

After the transplantation process, the length of coral fragments was re-measured, using a caliper to estimate the gain against the initial (T0). This evaluation was performed once a month, up to the 6th month (T5), data recording was conducted in situ, using SCUBA equipment, then documentation involved the use of an underwater camera (Muzaki 2008). Furthermore, ambient variables including water temperature were measured by hobo pendant logger, salinity by salinometer, level of dissolved oxygen (DO) by DO meter, alkalinity (pH) by pH pen and visibility by Secchi disk.

Data analysis

The length difference of the coral fragment (ΔL) was obtained at the end of the monitoring period (T5) minus the initial (T0), while the elongation rate was determined as the difference in the length (ΔL) per unit time (month) as shown in the equation below:

$$\Delta L = L5 - L0 \qquad (1)$$

$$vL = \frac{\Delta T}{t} \qquad (2)$$

Where, L5 is the length after six months, and L0 is the initial value; vL was the rate of branch elongation, and t is period of research. In addition, a similar approach was applied to calculate the difference in the diameter of the coral colony (ΔD), as well as its rate of increment (vL). Therefore, the variation in growth rate, based on changes in extension and diameter of coral fragments on each type of kerbstone was analyzed with a one-way analysis of variance (ANOVA, at 95% confidence level, p = 0.05), followed by Tukey's HSD test (p = 0.05).

RESULTS AND DISCUSSION

Ambient variables

The average value of the measured ambient variable and quality standard for the marine organism are shown in Table 1.

Based on Table 1, it was observed that all ambient variables, except salinity and temperature, were within the quality standard range for marine life, based on the criteria stipulated by the Ministry of Environment of Republic of Indonesia, Resolution number 51 Appendix III (2004). This was expected to be averaged at 32.68±0.85 or below although some other studies stated the propensity of corals to tolerate conditions between 23.3 and 41.8 ppt (Kleypas et al. 1999). Therefore, it is assumed that all environmental variables in the study area are suitable for coral growth.

Table 1. Results of ambient variables measurement

Parameter	Unit	Average value	QS
Temperature	°C	29.23±0. 37	33 - 34
Salinity	‰	32.68±0. 85	28-30
DO	ppm	8.46±0. 18	> 5
pH		7.06±0. 05	7 - 8. 5
Visibility	m	7.68±1. 85	> 5

Note: QS: quality standard for marine life, based on Ministry of Environment of Republic of Indonesia, Resolution no. 51, Appendix III (2004)

The growth rate of *A. formosa* coral fragments

The skeleton of scleractinian corals is composed of calcium carbonate ($CaCO_3$) crystallized in aragonite (orthorhombic system) (Tambutté et al. 2014), which is built with the supply of calcium and inorganic carbon from ambient seawater (Gattuso et al. 1999; Allemand et al. 2004). This study, however, used coal ash wastes, known as fly ash-bottom ash, which contains calcium, aluminum, magnesium, and a relatively high amount of silicate required (Hutagalung 2013).

After six months, the coral fragments of *A. formosa* transplanted into five different kerbstone compositions tend to exhibit a slightly higher increment in diameter at K1 (0.063 ± 0.071 cm/month) and K2 (0.077 ± 0.060 cm/month) in contrast with K3 (0.038 ± 0.048 cm/month); K4 (0.033 ± 0.049 cm/month); and K5 (0.031 ± 0.048 cm/month). Conversely, the measurement of elongation rate possessed similar tendency, where K1 and K2 showed relatively higher values compared to K3, K4, and K5 (Figure 3). At an average of 1.185 ± 0.642, and 1.313 ± 0.447 cm/month for K1 and K2, while K3, K4 and K5 were 0.101 ± 0.655 ; 1.099 ± 0.528, and 1.059 ± 0.492 cm/month, respectively. In addition, the one way ANOVA and Tukey HSD tests (both at p = 0.05) produced no significant difference in diameter and length increment values of K1 and K2 colony branches, although a substantial variation was observed against colonies of K3, K4, and K5 (Figure 4). Furthermore, a similar tendency also occurred at the production level of new branches, where K1 and K2 had a relatively higher value of 3.67 and 4.28 per month, in contrast with K3, K4, and K5 that were 2.6, 2.47 and 2.54, respectively (Figure 5).

The current study applied a transplantation media created from fly ash and bottom ash, which was originated from (coal burning) and outside the production process (equipment improving) of electricity generation at PT Jawa Power, Probolinggo, Indonesia. The procedure required mostly inorganic materials (metal oxides, etc.) and the remaining percentage of unburnt carbon fall into the SSCC (Submersible Scraper Chain Conveyor) located at the bottom of the boiler. These were therefore collected and labeled Furnace Bottom Ash (FBA), possessing a total ash content of 80% fly ash and 20% bottom ash. In addition, some of these materials that did not burn, and possessing a small size of about 200 mesh tend to flow with flue gas out of the boiler, subsequently called Pulverized Fuel Ash - Fly ash. These wastes are then collected bypassing the combustion flue gas through a dust capture tool, i.e. ESP (Electro Static Precipitator), which possesses a capture efficiency of over 99%. Furthermore, they are channeled to the Fly Ash Silo in the Ash Disposal Area from the ESP Hopper tank, with the assistance of a pneumatic system (compressed air). Therefore, the flue gas is passed to the Sulfur Capture Unit (Flue Gas Desulphurization Plant - FGD), in order to reduce the SOx gas content, with a capture efficiency of 96%. This is followed by passage of gas to the Chimney (Stack) at a height of 220 meters for further dispersion into the environment (Suprianto 2016).

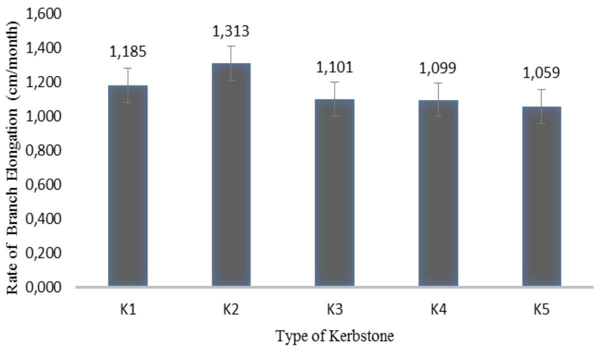

Figure 3. Rate of branch elongation of *A. formosa* transplanted on three different compositions of kerbstone

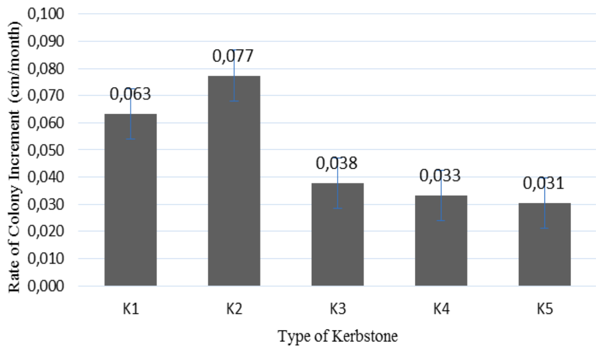

Figure 4. Rate of colony diameter increment in *A. Formosa* transplanted on five different compositions of kerbstone

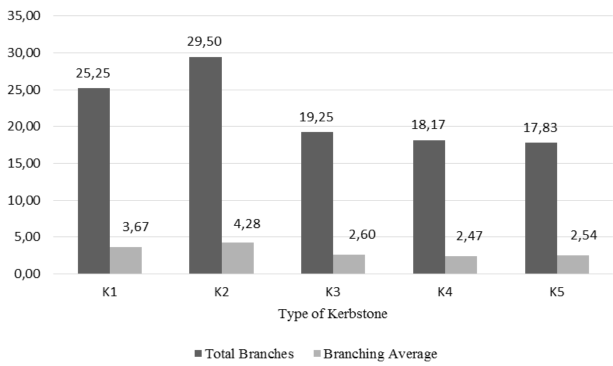

Figure 5. Average of total branches after six months and the rate of new branches production (per month) in *A. formosa* transplanted on five different compositions of kerbstone

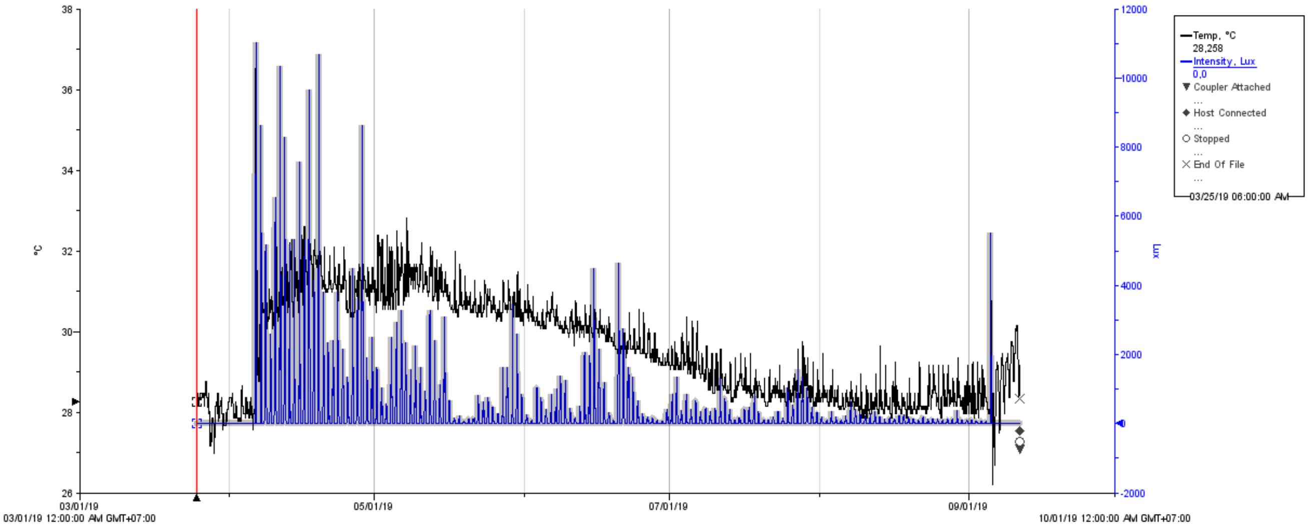

Figure 6. Temperature (°C) and Intensity (lux) Avarage on April - September 2019

Table 2. Measurement of kerbstone elements composition — derived from fly ash and bottom ash (in% of the material)

Kerbstone	**Element composition of kerbstone (%)**			
Treatment	**Silica**	**Calcium**	**Aluminum**	**Magnesium**
K1	49.90	23.24	9.75	5.84
K2	37.43	20.62	10.99	6.74
K3	38.95	18.01	12.23	7.64
K4	33.48	15.39	13.46	8.54
K5	28.00	12.77	14.70	9.44

The exposure of Kerbstone to seawater initiates the incidence of washing, which occurs as a result of chemical and physical processes (Suprenant 1991). This also allows calcium, magnesium, aluminum, and silicate, as well as other compounds in kerbstone, to become diluted, therefore, providing the minerals needed for biomineralization. Hence, it is expected that coral fragments in certain kerbstone possess a higher growth rate in contrast with others, although the results obtained indicate that the growth rates in the five types evaluated were not significantly different, due to the relative needs for these compounds. Furthermore, the differences in particle size of fly ash and bottom ash were identified to elongate the onset of the washing process (Muzaki 2019)

The growth rates of coral fragments were different, although they are made from similar raw materials at varying combinations of fly and bottom ash. This was due to the discrepancy in the amounts of silica, alumina, magnesium, and calcium compounds present in different ratios (Table 2). In addition, Kerbstone K2 was observed to have the most significant fragment elongation, colony diameter, and number of branches, containing 37.43% silica, 20.62% calcium, 10.99% aluminum, and 6.74% magnesium, hence, this consortium is assumed to be of optimum value for the proper growth of A. Formosa.

Silica is an amorphous substance, which easily hardens when mixed with cement, forming calcium silicate compounds that are difficult to dissolve in water (Wikana et al. 2014), thus exhibiting the capacity to inhibit the continuous occurrence of the washing process.

The results obtained indicate the propensity for using kerbstone made from coal ash waste (fly ash and bottom ash) as an artificial reef unit for coral transplantation. In addition, all media variants combination were identified as suitable, based on the fact that they do not confer any significant effect on the elongation rate and increment in diameter of coral fragments or colonies. Therefore, the utilization of coal and its ash from power plants is an effective means to actualize a substantial contribution towards supporting the world's coral reef ecosystem recovery program.

The average sea temperature was decreased in May - September and fluctuated in April - May (Figure 6). If the temperature exceeds 30.11℃, there is a chance of coral bleaching (Brown 1997), Our results showed that the temperature in the studied area does not exceed the threshold during April to September (an average 29,69 ℃). The average light intensity at noon was 2982,2 lux and the average sediment deposition was 25.57 (g m−2 day−1).

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