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Original Paper

APPLICATION OF COPPER OXIDE PAINTS AS PREVENTION FOR MACROFOULING ATTACHMENT ON A MARINE FLOATING NET CAGE

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ABSTRACT

Macrofouling is one of the major problems on a marine net cage culture. The attachment of macrofouling could cover the net cage and thus reduce the water circulation in the cage. Application of copper oxide paints may be able to solve that problem. A field experiment with Completely Randomizes Design was applied with 9 treatments: paint without biocide; paints contained: 5% Copper Oxide; 10% Copper Oxide; 1% Chlorothalonil; 1% Chlorothaloni + 5% Copper Oxide; 1% Chlorothaloni + 10% Copper Oxide; 1% Zinc Omadine; 1% Zinc Omadine + 5% Copper Oxide; 1% Zinc Omadine + 10% Copper Oxide, each treatment was replicated 3 times. The research was done on July – September 2007 at Hanura Bay Lampung. Data of the abundance and diversity of macrofouling were collected weekly. The results showed that the application of copper oxide paints affected the macrofouling attachment significantly (P < 0, 01). The best result was antifouling paints contained Copper Oxide, and combination between Copper Oxide with Chlorothalonil and Zink Omadine. However, from the economical point of view, paint with 5% Copper Oxide could be suggested for preventing macrofouling attachment on the marine net cage.

Keywords: Antifouling paints, Macro-biofouler, Marine Net cage

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INTRODUCTION

Cage culture of fish is a method of raising fish in an enclosed cage in open waters such as lakes, rivers, manmade lakes, coastal waters and offshore. The methods applied in fish cage culture is quite simple compared to others fish culture methods, i.e. earthened ponds, concrete ponds, plastic containers etc. One of the advantages of fish cage culture there is no water management needed, i.e. there is no need to replace water in the cage but all depends on the nature, therefore, it is quite cheap. The main component for a floating net cage for fish culture is the net cage as the holding system, which is mainly made of syntetic fibre: polyamide (PA), polyester (PES) and polypropylene (PP) (Baveridge, 1987). There are problems faced in fish cage culture that can reduce the productivity, one of which is the present of fouling organisms. There are two fouling organisms: micro-fouling and macrofouling which consists of flora and fauna could attach and grow on the net cage (Callow, 1986 *in* Evans and Hoagland's, 1986, Railkin, 2004, Military, 2005).

The first attachment of bio-fouling is microbial film, a chemicals component (mainly protein, proteoglycans and

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polysaccharides). As a results, the surface of the net cage suitable for bacterial growth (Abarzua and Jakubowski, 1995). The attachment of marine bio-fouling on the submerge net cage releases an important substance for others bio-fouling live and grow, included diatoms, macro alga sperm, fungi and protozoan (Raikin, 2004).

The attachment time between first colony of bio-fouling (bacteria and diatoms) and the second colony (macroalga sperm, fungi and protozoan) would attach less than a week after (Abarzua and Jakubowski, 1995; Raikin, 2004). The third colony is known as macro-fouler consists of macro algae, bivalve molluscs and sponge with a larger size (size >0.5 cm) attach on the micro-fouling film layer (Baveridge, 1987).

The macrofouling attachment will cover the net cage, as a result the water circulation in the cage and the disposal of the fish wastes from the cage are disturbed, thus, the oxygen supply reduces and increase net cage weight (Baveridge,1987; Hodson *et al.*, 2000; Phillipi *et al.,* 2001; Tan *et al.*, 2002; Braithwaite and McEvoy, 2005; Willemsen, 2006). These conditions causes a high mortality of the cultured fish (Huang, 2000; Phillipi *et al.,* 2001; Tan *et al.*, 2002; Swift *et al.*, 2006). To prevent bigger loss during cultivation, biofouler attachment is controlled by routine net cage replacement and cleaning weekly, which is time consuming and can stress cause to fish. Since biofouler grow very fast those management controll is considered less effective and ineffective (Baveridge,1987). Therefore, the net used for cage construction should be fouling resistant or unfavourable for biofouler attachment (Baveridge,1987).

Principally, biofouler is the main problem in marine culture activities, especially in a shallow waters with slow current velocity, appropriate water temperature and adequate nutrients availability (Dharmaraj and Cheelam, 1983; CSIRO. 2002, Railkin, 2004, Military, 2005; Cheah and Chua 1979 in FAO, 2007).

Macroalga as a macrofouling can be an advantages for marine fish cage culture activities, because these macrofouling can be used as a natural food in polyculture, can reduce the abration on the net cage, and also can supply oxygen in the sistem especially at night (Braithwaite and McEvoy, 2005). Furthermore, macroalga can also reduce the amonia content in the water, because according to Lojen *et al.,* 2005 some biofouler are able to suspend the organic suspended particles from the aquaculture activity biologically, therefore, they are able to recycle the organic wastes to other forms.

On the other hand, the present of macrofouling which consists of different types of algae and bivalve could cover the net cage. As a results the water circulation in the cage reduces, therefore, the oxygen in the water decreases, reduces the waste disposal from the cage, and also increase the cage weight (Baveridge,1987; Hodson *et al.*, 2000; Phillip *et al.,* 2001; Tan *et al.*, 2002; Braithwaite and McEvoy, 2005; Willemsen, 2006). Those problems can increase disease and the fish mortality (Huang, 2000; Phillipi *et al.,* 2001; Tan *et al.*, 2002; Swift *et al.*, 2006).

Biofouler attachment could be prevented by coating the net cage using antifouling paint. Antifouling paint can prevent biofouler attachment because of its bioside content. The biosides which commonly used in the antifouling paint are Copper Oxide (Cu_2O), Zinc Omadine, and Chlorothalonil that are toxic to biofouler (Evans and Hoaglands,1986; Arch Chemical, 2000a).

According to Beveridge (1987) Copper Oxide (Cu_2O) is a biocide which commonly used as an active substance for antifouling paint to prevent biofouler growth on the ship wall. Copper Oxide is also used as algaecide in intensive aquaculture. Other active substances that are used for antifouling paint are Zinc Omadine and Chlorothalonil as an anti bacteria, fungicide and algaecide. The application of both Zinc Omadine or Chlorothalonil in antifouling paint are usually combined with Copper Oxide (Arch Chemical, 2000a). It was proven by (Arch Chemical, 2000a; Evans and Hoagland's,

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1986) that Zinc Omadine and Chlorothalonil are an effective biocide to prevent the attachment of micro-fouling organisms, whereas Copper Oxide is effective for macrofouling organisms.

The application of antifouling paint contains copper oxide is recommended by EPA (Environment Protection Agents) as the replacement of Tri Butyl Tin (TBT) (CSIRO, 2002). Unlike Copper Oxide, Try Butyl Tin was no longer permitted for biocide because of its negative impacts on the marine environment (CSIRO, 2002), while the Copper Oxide in the water will be bound with others substances, therefore, its toxicity reduces (Brown, 2002). Similarly, the application of antifouling paint which contains Zinc Omadine and Chlorothalonil.

The objectives of this research were to find out the effects of Copper Oxide application and its combination with Zinc Omadine and Chlorothalonil in the antifouling paints on the attachment of macrofouling organisms on a floating marine net, and to find out the proper dosage of Copper Oxide in the antifouling paint that less favourable for macrofouling attachment.

MATERIALS AND METHODS

Experimental Design

A field experiment was done in this research, as an effort which was planed to find out new facts and to strengthen the previous investigation results. This field experiment was engaged with the treatments, i.e. the application of Copper Oxide and its combination with Zinc Omadine and Chlorothalonil in the antifouling paint for coating the floating marine net cage.

A Complately randomized design was used as the experimental design, with 9 treatments. Each treatment was replicated 3 times. The treatments were:

1. Treatment A : Paint Product (PP)
2. Treatment B : PP + 5% Copper Oxide (Cu_2O)
3. Treatment C : PP + 10% Copper Oxide (Cu_2O)
4. Treatment D : PP + 1% Chlorothalonil
5. Treatment E : PP + 1% Chlorothalonil + 5% Copper Oxide (Cu_2O)
6. Treatment F : PP + 1% Chlorothalonil + 10% Copper Oxide (Cu_2O)
7. Treatment G : PP + 1% Zinc Omadine
8. Treatment H : PP + 1% Zinc Omadine + 5% Copper Oxide (Cu_2O)
9. Treatment I : PP + 1% Zinc Omadine + 10% Copper Oxide (Cu_2O)

Research Location

Hurun Bay is a small bay of approximately 1.5 km^2 there was surrounded by sandy sand and mangrove forest. The south-west and the south part of the bay has a bottom slope at the depth of 5 meters with sandy-muddy bottom sediment. Whereas at the south-east part is quite deep, i.e. 10-15 meters with sandy coral bottom sediment. There are 4 small estuaries: 2 estuaries at the south-west and each at the south and the west parts of the bay.

Research steps

Antifouling paints were prepared according to treatments, each 1 kg in weight. The antifouling paints were coated to the framed nets and dried at ambient temperature for 24 hours. The coated nets were then marked using different colours plastic and copper string, and submerged in the coastal water of Hanura bay located approximately 300 m from the coastal line and 10-14 m depth. The treatments was placed in a such away 0.5 m from the water surface parallel to the fish cage in order to get similar environmental condition.

Data collection

The number and type of macrofouling attached on the net and water quality parameters during the research were collected weekly for 8 weeks investigation. The reason of weekly data collection was due to the fast

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growth of macrofouling. Water quality parameters collected were turbidity, current velocity, temperature, salinity, dissolved oxygen, nitrate and phosphate.

Macrofouling sample counting and identification were done by taking out the treated framed net from the water and put it in the Fiberglass tanks filled with sea water from surrounding area to prevent samples mortality. Macrofouling with size ≥ 0.5 cm were counted using hand counter.

A transect of 6x5 cm^2 which was placed randomly on 5 point area of the treated net was used to count the macrofouling that covered the net abundantly. The average of macrofouling found were then multiplied by 50 to get the total amount attachment on 1500 cm^2 area of the treated net. Identification of macrofouling was done using identification Book from Gakken (1975), Trono (1986), Dawes (1981), Robert *et al.* (1982) and Barret and Yonge (1985).

Data analyses

Diversity and abundance of macrofouling. The number and type of macro-fouling attached on the net cage were done by counting the total number per 1500 cm^2 following Odum (1971)

The diversity index of the macrofouling attachment was following Shannon – Weaver (1949) *in* Odum (1971) formula:

$$H' = -\sum_{n=1}^{s} pi \ln pi$$

H' : Diversity index
pi : Ratio of total individual species i to total number of individual
ni : Individual number of species i
N : Total number of individual

Analyzes of variance were applied to find out the effects of anti fouling paints on the macrofouling attachment for eighth week data. The eighth week data was used because the macrofouling attachment was quite high after 8 weeks submerged in the water. If the antifouling paints affected macrofouling attachment significantly, then the data were analyzed further using a multiple range Duncan test to find out the best antifouling paint with the smallest macrofouling attachment.

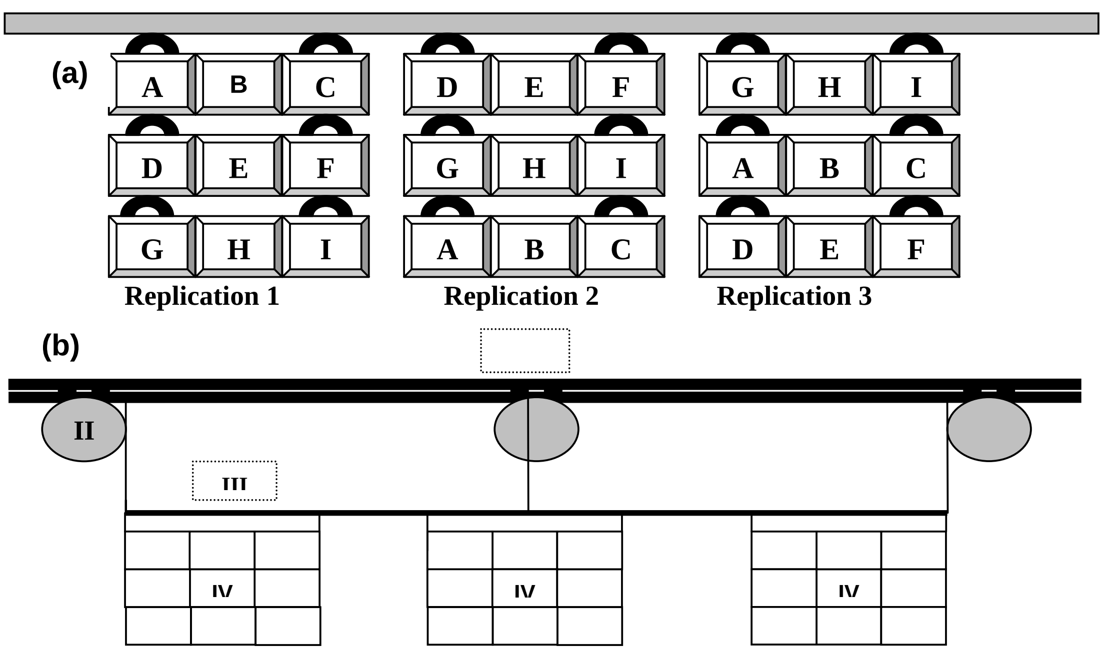

Fig 1. Lay out design of treatments **(a)** and treatment nets **(b)**: I. Floating raft; II. Buoys; III. Water column; IV. Treatment nets

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RESULTS AND DISCUSSION

Macrofouling Composition and Abundance

The data of macrofouling composition and abundance on the treated net cages were collected after 4 weeks (**Table. 1**) and 8 weeks (**Table. 2**) investigation.

The results showed that after 4 weeks inundation, there were three macrofouling organisms attached on the treated net cage, i.e. *Enteromorpha clatharata*, *Ectocarpus* sp and *Enteromorpha* sp. The largest total individual abundance of macrofouling during 4 weeks inundation was treatment A (net cage coated with paint product/PP without active substance biocide), i.e. 377 individuals/1.500 cm^2, followed by treatment D (PP + 1% Chlorothalonil): 147 Ind/1500 cm^2, and treatment G (PP + 1% Zinc Omadine): 137 Ind/1500 cm^2. There were no macrofouling attach on the net at treatment I (PP + 1% Zinc Omadine + 10% Copper Oxide).

Table 1. Composition and individual abundance of the macrofouling (indv/1500 cm^2) attach on the treatment nets after 4 weeks inundation

Macro-foulings	Treatments								
	A	B	C	D	E	F	G	H	I
Macroalga									
Ectocarpus sp.	4	6	3	11	2	1	11	1	0
Enteromorpha clatharata	100	0	0	0	0	0	80	0	0
Enteromorpha sp.	273	0	0	136	0	0	46	0	0
Total	377	6	3	147	2	1	137	1	0

The data showed that during 4 weeks inundation, *Ectocarpus* sp was the lowest population attach on the net cage, but its found at all treatment. *Ectocarpus* sp was found attach on the net cage at treatments without Copper Oxide (treatment A), without Chlorothalonil (treatment E) and without Zinc Omadine (Treatment G) (net coated with paint product without any active substances of biocide).

Enteromorpha clatharata and *Enteromorpha* sp. were not found on the treated net cage which were coated with antifouling paints contained Copper Oxide and the combination between Copper Oxide and others active substances: Chlorothalonil or Zinc Omadin (Treatments B, C, E, F, H and I). *Enteromorpha clatharata* and *Enteromorpha* sp. were more abundantly found at week 4 compared to the weeks before. Data of the composition, individual abundance of macrofouling attachment during 8 weeks inundation were shown in **Table 2**.

Those data showed that there were 3 macro alga (*Demesteria* sp, *Ectocarpus* sp, *Pterosiphoria* sp), 1 species of mollusc (*Saccostrea* spp) and 1 species of sponge (*Myxilla* sp) were found during 8 weeks inundation, however, *Enteromorpha clatharata* and *Enteromorpha* sp were not found attached on the treated nets.

The relative abundance of macrofouling attached on treatment A, D and G (net cage coated with antifouling paints without Copper Oxide content) were higher than the nets coated with antifouling paints contained Copper Oxide (Treatments B, C, E, F, H, I). The total individual macrofouling attached on the treatment G (net cage coated

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with Paint Product + 1% Zinc Omadin) was higher than treatment A (net cage coated with Paint Product without any active substance of biocide) and treatment D (net cage coated with paint product + 1% Chlorothalonil)

Table 2. Composition, Individual Abundance (Ind/1500 cm^2) On the Treatment Nets During 8 Weeks Inundation

Macro-foulings	Treatments								
	A	B	C	D	E	F	G	H	I
Macroalga									
Demesteria sp.	17	5	0	12	0	0	29	0	0
Ectocarpus sp.	10	8	7	12	7	6	16	6	5
Enteromorpha clatharata	0	0	0	0	0	0	0	0	0
Enteromorpha sp.	0	0	0	0	0	0	0	0	0
Pterosiphoria sp.	9	0	0	0	0	0	1	0	0
Mollucsc									
Saccostrea sp.	3	0	0	3	0	0	6	0	0
Sponges									
Maxylla sp.	1	0	0	0	0	0	0	0	0
Total	10	13	7	27	7	6	52	6	5

Ectocarpus sp abundance increased on all treatments. However, *Demesteria* sp, *Pterosiphonia* sp, *Saccostrea* sp and *Myxilla* sp were only being found on treatments without Copper Oxide (Treatments A, D, G).

Saccostrea sp, a macrofouling from molluscs family, is the most harmful macrofouling because it is difficult to be cleaned or removed from the net cage. The data showed that this macro fouling attached on the treated net cages coated with antifouling paints without Copper oxide at weeks 6 and 7.

The results showed that macrofouling composition consisted of 5 macro algae (*Demesteria* sp, *Enteromorpha clatharata, Ectocarpus* sp, *Enteromorpha* sp, *Pterosiphonia* sp), 1 mollusc (*Saccostrea* sp) and 1 sponges (*Myxilla* sp).

At the first 4 weeks, there were only 3 macroalga (*Ectocarpus* sp, *Enteromorpha clatharata* and *Enteromorpha* sp) attach on the antifouling paints net cage. According to Evans and Hoaglands (1986), detritus and macroalga were the first biofouler attach on the ship's wall. Furthermore, it was mentioned that *Enteromorpha clatharata, Enteromorpha* sp and *Ectocarpus* sp were macroalga that were resistant to biocide copper oxide, therefore, they were found attached on the net cages treated with antifouling paints contained copper oxide

After 8 weeks inundation, the number of macrofouling attachment increased by the present of (*Pterosiphonia* sp) on tretment A and G, mollucs (*Saccostrea* spp) on treatments A, D, G, and sponges (*Myxilla* sp) on treatment A. The highest total abundance was found on treatment G (net cage treated with antifouling paint contained Zinc Omadin), followed by treatment A (net cage treated with Paint Product without biocide) and treatment D (net cage treated with antifouling paint contained Chlorothalonil).

The paint product used at treatment A was not an antifouling paint, therefore, its only coated the net cage. Thereas at treatment D and G which were coated with antifouling paints contained biocides Chorothalonil (D) and Zinc Omadin (G). According to Extoxnet PIP (1996) Chlorothalonil is a fungicide. Similarly Zinc Omadin is an antibacterial and an algaecide. Those were because the chloride content in the Chlorothalonile and the Zinc salts of pyrithionine (ZPT) content in the Zinc

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Omaden (Arch Chemical, 2000b). Furthermore, Evans and Hoaglands (1986) explained that the zinc and chlorine content in the antifouling are more effective for controlling the growth of microfouling organisms, such as diatoms and a singe cell algae (blue green algae) but not effective for preventing the attachment of macroalga and molluscs.

Total individual abundance on the treatments B and C (net cage treated with antifouling paints contained Copper Oxide as a single biocide, seemed could prevent the biofouler growth on the nets. Hovewere, the application of copper oxide combined with Chlorothalonile or Zinc Omadine (treatment E, F, H and I) were better on preventing the macrofouling growth. This statement was supported by Arch Chemical (2000) finding that combination of Copper Oxide and Zinc Omadine in the antifouling paints was better than antifouling with Copper Oxide as a single biocide.

Enteromorpha clathrata and *Enteromorpha* sp attachment were abundantly found on week 4th of inundation and *Ectocarpus* sp was found on week 8^{th}. Quantitatively, the attachment of *Enteromorpha clathrata* and *Enteromorpha* sp were higher than the number of *Ectocarpus* sp and *Saccostrea* spp, however, the degree of disturbance and coverage on the net mesh of *Ectocarpus* sp and *Saccostrea* spp are worst. This is because the size of *Ectocarpus* sp and *Saccostrea* spp are larger (5–8 cm) than the size of *Enteromorpha clatharata* and *Enteromorpha* sp (0,5–1 cm) respectively. Moreover, *Sacoostrea* spp is known as the most disturbing macrofouling, since this molluscs attaches its shell at the rope of the net which result in the difficulty during cleaning.

(a) After 4 weeks inundation **(b) After 8 weeks inundation**

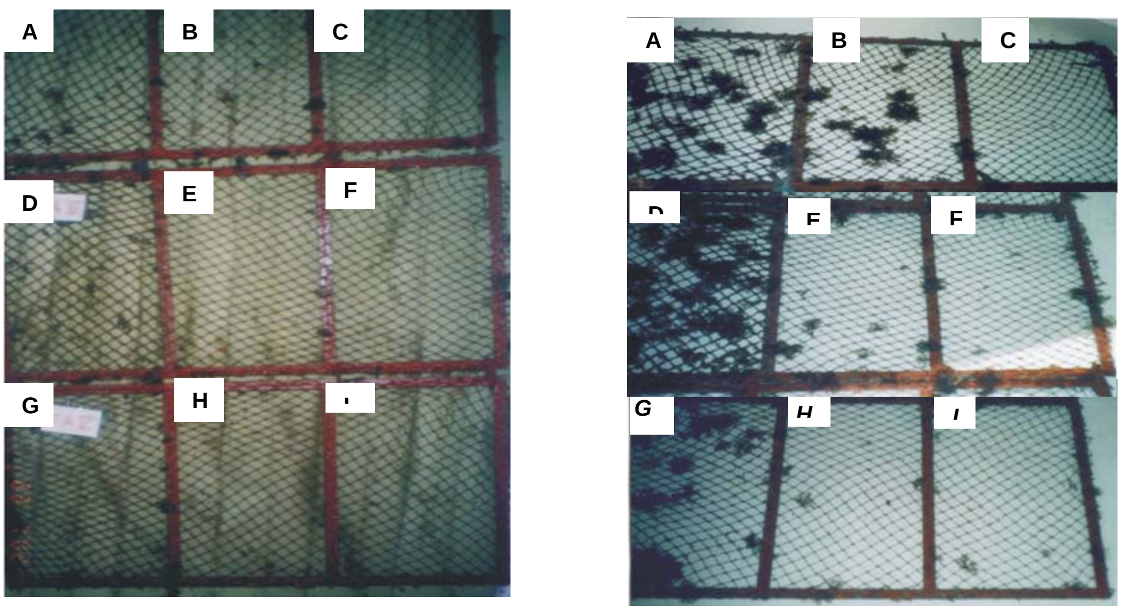

Fig 2. Macrofouling attachment on the net cages in each treatments

The Diversity Index of Macrofouling

The diversity Index describes the organisms structure in a community. The diversity index of macrofoulings attached on the treated net cages during investigation is shown in **Table 3**.

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Table 3. The diversity Index (H') of Macrofoulings attached on the treatmet nets during 4 and 8 weeks inundation

Time of Inundation	Treatments								
	A	B	C	D	E	F	G	H	I
4 weeks	0.64	0	0	0.26	0	0	0.88	0	0
8 weeks	1.33	0.66	0	0.97	0	0	0.69	0	0

The results showed that the highest range of diversity index (H' = 0.634) after 4 weeks inundation was at treatment A (net cage coated with paint product without biocide), and the lowest (H' = 0) was found at treatments C, F, G, H and I where the net cages coated with antifouling paints contained biocides (Copper Oxide, Zinc Omadine dan Chlorothalonil). The diversity index increase in almost all treatments after 8 weeks inundation.

Macrofouling Attachment On the Treatment Nets

The analyses of variance showed that there was a highly significant effect of the application of different antifouling paints with different biocides content on the macrofouling attachment on the treated net cages.

The data were also showed more macrofouling attachment on the net cage treated with antifouling paint contained without any biocide and contained a single biocides Chlorothalonile, and Zinc Omadine (treatments A, D, G) compared to the net cages treated with contained Cupper Oxide or combination of Copper Oxide with other biocides (treatments B, C, E, F, H, I). It was obvious that the application of single biocide in antifouling paints (treatments D, G) were less effective to prevent macrofouling attachment on the treated net cages, since those biocides are ore effective as antifungi and antibacteria (Arch Chemical, 2000b; Extoxnet PIP, 2000b). Whereas Copper Oxide and the combination of Copper Oxide with other biocides: Chlorothalonile and Zinc Omadine (B, C, E, F, H, and I) suggest that Copper Oxide is the most powerfull biocide for preventing mavrofouling attachment (Baveridge (1987). Furthermore, according to Banfield (1980) *in* Evans and Hoaglands (1986), the copper in the antifouling paint had a leaching rate of 10 – 20 µg/cm^2/day could prevent all biofoulers attachment. It was also mentioned by Argent Chemical Laboratories, 2000 that in aquaculture activities, Copper Oxide is used for controlling the growth of phytoplankton, filamentous alga and green alga.

Combination between Copper Oxide and other biocides: Chlorothalonil and Zink Omadin (treatment E, F, H and I) increased their activity on preventing the macrofouling attachment. This finding was supported by Arch Chemical (2000a) who found that combination between Copper Oxide and Zink Omadin was more effective than Copper Oxide alone. Zink and Chlorothalonil as a biocides could not substitute the role of Copper as a component of antifouling paint, however, their combination with Copper Oxide in the antifouling paint would give better results. From the above results it was showed that 10% of Copper Oxide (treatment C) is considered more appropriate as an active substances in the antifouling paint, since Copper Oxide is effective and cheaper. The effects of antifouling paints contained different types of biocides on the attachements of macrtofoulings during 8 weeks inundation is shown in **Table 4**

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Table 4. Total macrofouling attachment (indv/1500 cm^2) on the treatment nets after 8 weeks innundation

Replications	Treatments								
	A	B	C	D	E	F	G	H	I
1	25	10	7	45	10	10	66	7	5
2	45	19	8	23	5	4	53	6	5
3	16	4	5	14	9	5	37	4	4
Total	86	33	20	82	24	19	156	17	14
Average	28.66	11	6.66	27.33	8	6.33	52	5.66	4.66
SD	±14.84	±7.55	±1.53	±15.95	±2.65	±3.21	±15.53	±1.53	±0.58

Analyses of variance of the data showed that the application of anti fouling paints affected the attachment of macrofouling on the treated net cages significantly (P<0.01) (**Table 5)**

Table 5. Analyses of Variance of the total attachment of macrofouling (indv/1500 cm^2) on the treatment netes after 8 weeks inundation

Source of Variance	Degree of freedom	Total square	Mean of total square	F calc	F table	
					0.005	0.001
Treatments	8	72.88	9.11	11.46**	2.46	3.6
Error	18	14.82	0.83			
Total	26	87.73				

** : Highly significant different

To find out the different between mean values of the treatment, a Multiple Range Duncan test was applied as shown in **Table 5**. The multiple range Duncan test showed that there were a highly significant different (*P < 0.01*) between treatment G and treatments A, D, B, E, C, F, H, I; significant different (*P < 0.05*) between treatments A-B; D-B; D-E. However, there were no significant different between treatments A-D and B, E, C, F, H and I

The macrofouling diversity attachced on the net cages showed their community structures. The net cages treated with antifouling paints contained active substances of biocides Copper Oxide and its combination with Chlorothalonil or Zinc Omadine showed a very low diversity index. The low value of diversity index described the domination of one species in the community structure (Odum, 1971)

The attachment of *Enteromorpha clatharata* and *Enteromorpha* sp that are resistant to Chlorothalonil and Zinc Omadine; *Ectocarpus* sp and *Saccostrea* spp that are resistant to Copper Oxide, Chlorothalonil dan Zinc Omadine, play an important rule on the diversity index value. The change on diversity index during investigation showed the change of macrofouling attachment. This was obvious that the present of *Enteromorpha clatharata* dan *Enteromorpha sp* were only found on week 4th, then after that replaced by *Ectocarpus* sp.

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Table 6. Multiple Range Duncan test of total attachment of macrofouling on the treatment nets during 8 weeks inundation

Treatments	Mean Values	Difference Mean Values of Attachment								
G	7,162	G								
A	5,233	1,926**	A							
D	5,082	2,080**	0,154	D						
B	3,173	3,989**	2,063**	1,909*	B					
E	2,799	4,363**	2,437**	2,283*	0,452	E				
C	2,570	4,592**	2,666**	2,512**	0,603	0,151	C			
F	2,466	4,696**	2,770**	2,616**	0,707	0,255	0,104	F		
H	2,466	4,797**	2,871**	2,717**	0,808	0,356	0,205	0,101	H	
I	2,157	5,005**	2,925**	2,925**	1,016	0,564	0,413	0,309	0,208	I

* : Significant different

** : Highly significant different

Water Quality Parameters

The range value of water quality parameters monitored surrounding the research area consisted of salinity, temperature, turbidity, current speed, pH, nitrate and phosphate, dissolved oxygen showed a suitable condition both for marine fish cage culture and for macrofouling growth as shown in **Table 7.**

Table 7. Water Quality Parameters during the Investigation

Parameters	Range	References
Turbidity (m)	5-8	5-10 (Hodson *et al.* 2000; Railkin, 2004)
Current velocity (m/sec)	0,028-0,035	0,10 – 0,50 (Dubost *et al*, 1996; Raikin, 2004)
Salinity (ppt)	32-33	34 – 35 (Dawes ,1981; Railkin, 2004)
pH	7,75-8,26	7,5 - 8,4 (Dawson,1986; Railkin, 2004)
Dissolved Oxygen (mg/l)	4,54-5,88	> 4 (Railkin, 2004; Mejia, 2005)
Temperature (^{o}C)	29-31	20 – 30 (Railkin, 2004; Mejia, 2005)
Nitrate (ppm)	0,001-0,007	0,001 – 0,012 (Railkin, 2004; Mejia, 2005)
Phosphate (pip)	0,001-0,004	0,0012 – 0,0055 (Railkin, 2004; Mejia, 2005)

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CONCLUSION

From the results above it can be concluded that the application of antifouling paints with different active substance of biocides highly significant affected the attachment of macrofouling on the treated net cages ($P<0.01$). The best result was antifouling paints contained Copper Oxide, and combination between Copper Oxide with Chlorothalonil and Zink Omadine. However, from the economical point of view, paint with 5% Copper Oxide could be suggested for preventing macro-bio fouling attachment on the marine net cage.

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