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BIOFOULING EFFECT ON CORRODING BEHAVIOUR OF BRASS IN MALLIPATTINAM SEAWATER

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ABSTRACT

Biofouling studies in the Mallipattinam seawater (0.2806^0 N, 79.3170^0E), south eastern Bay of Bengal, Thanjavur, India, were carried out for six months (January2017-June 2017) to understand the biofouling behaviours of organisms. The fouling organisms of Mallipattinam seawater(MSW)compress of algae(green and red), barnacles, molluscs, polychaetesand worms. The periodic attachment and aggregate of fouling organisms growth on brass over a period of six months have been inspected in the MSW. Assemblages of algae stimulate corrosion on brass. Barnacles and Mollusks cause pitting corrosion underneath their attachment site. Polychaetesexhibitedon last month coupons however, flatworms showed significant season-wise in settlement. Presence of oysters on coupons was enumerated in significant numbers during the present study. In general, the assemblages of biofouling organisms on brass surface over a period of exposure cause the corrosion rate. The extent of origin experienced by brass is highlighted in terms of change in mechanical properties and the surface characteristics of the material.

KEYWORDS: Fouling organisms, biofouling, assemblage, south eastern Bay of Bengal, Mallipattinam Seawater (MSW), corrosion rate.

INTRODUCTION

The sedentary adult forms of marine organisms have the tendency to colonize on any hard substrate. This colonization, often causing undesirable consequences to man-made structures, such as offshore platforms, ship hulls, ship machinery, coastal power plants, desalination plants etc., is termed as 'biofouling'. Biofouling causes great operational hazard indifferent marine installations across the globe. The expenditure incurred on combating biofouling is a standing. It is reported that shut down of a 235MW (e) power station due to fouling, costs 170 lakhs (at Rs. 3.00 per kw/h) per day. Because of this economic implication, biofouling has been a thrust area of study for the marine researchers. A plethora of work has been carried out on biofouling from different parts of the world including India.[1-5]

Biofouling in tropical waters is a year-round phenomenon. Notwithstanding this, seasonal influence has been known to affect fouling settlement variability, their breeding pattern, succession, species composition, distribution and density.[6] The fouling organisms affect the working machinery parts in the sea and cause to a special characteristic of corrosion.[3,4] Whilst the effects of chemical and physical factors are thoroughly analyzed and documented.[5,6,7] The role of fouling organisms[8,9,10] in respect of the growth of corrosion processes is not entirely in-depth and often contradictory. Aim of the present study is finding the role of fouling organisms on the corrosion behavior of brass in the MSW.

EXPERIMENTAL DETAILS

1. Material preparation

Brass metal sheets of 1.6mm thick were cut into pieces of size 110mm x 90mm, to the required numbers. The investigational metal coupons were pickled in the recommended cleaning solution[11], polished[12] and holes were made on the centre of the top and bottom of each panel. The metal coupons were degreased with trichloroethylene and weighed to an accuracy of 10^{-4} g. Triplicate numbers of coupons in each experiments were fixed to wooden racks using brass bolts and nuts with proper insulation of PVC washers. The wooden racks fitted with metal coupons were tied to the stationary piles in the MSW. They were immersed about 0.5 meters below the mean low wave level. The removals of exposed metal coupons were taken as monthly, quarterly and half yearly periods.

2. The Test Site

The experiment location is localized in the Bay of Bengal of MSW. The climate in Mallipattinam is motivated by the SW monsoon. It occurs during March'17 to June'17, in a year respectively. NE monsoon is slowly changing from February'17. The existence of monsoon causes variations in the seawater characteristics. The data such as wind direction, wind

velocity, rainfall and wave action were acquired from Meteorological department, Adirampattinam. The recorded data are presented in **table-1**.

Table 1: Data on climate factors during the exposure period (January'17–June'17) at Mallipattinam sea water, India.

Climate factors/Period	Jan'17	Feb'17	Mar'17	Apr'17	May'17	June'17
WindSpeed (Km/h)*	7	7	7	8	9	8
Wind Direction	NE	NE	SW	SW	SW	SW
Rainfall (mm)	12	10.7	1.0	1.9	2.8	7.4
Wave Velocity# (m/s)	0.8	0.8	0.85	0.9	0.92	0.7

Key to table: * Weekly Average, # Daily Average, Km/h–Kilometer/hour, s– Second, mm-Millimeter, SW-South West, NE- North East.

PROCEDURE

The following ions such as chloride, carbonate, bicarbonate, sulphate, calcium and magnesium were estimated using respective methods and the dissolved oxygen by iodimetric method. The pH of seawater and temperature were perceived periodically, using a digital pH meter and Celsius thermometer respectively. Fouling on metal surface was evaluated in terms of biomass, pattern of fouling community and seasonal recruitment organisms. The exposed metal coupons were pickled in 10% sulphuric acid for two minutes, rinsed with water and dried in an air oven at 60^0 C for an hour after that the coupons were cooled and weighed. From the weight loss of coupons, gravimetric corrosion rates were determined. The metals after evaluation of corrosion rate were analyzed for their pitting corrosion behaviour in terms of probability of pitting, pit density, width and depth of pit (maximum, minimum and average) using a high resolution microscope. The surface characteristics of each exposed metals were analyzed as per ASTM standard using scanning electron microscope (SEM). The change in mechanical properties of brass were distinguished using an INSTRON 1195 universal testing machine.

RESULTS AND DISCUSSION

1. Environmental factors of MSW

Table-1 shows the climatic factors which were recorded during the study period (Jan'17 to Jun'17) at MSW. The North East monsoon is characterized by considerably lower wind velocity than the South West monsoon. During the period (Mar'17 to Jun'17) the Sea Water are in great unrest and get the higher values of wave velocity.[19] The SW monsoon is characterized by higher wind and wave velocity and resulting MSW get low rain fall. MSW becomes more concentration which favours the settlement of fouling organisms on the metal surface.

Table-2 reveals the characteristics of bay of bengal of MSW.

The monsoons cause variations in the sea water characteristics such as surface temperature, dissolved oxygen (DO) level and calcium, magnesium and sulphate ions.[20,21]

Table 2: Characteristic of bay of Bengal of MSW(Jan'17 to June'17).

Characteristics	Maximum (SW)	Minimum (NE)	Average
SurfaceTemperature(^{o}C)	33.3	26.8	30
Chloride (ppt)	35.2	30.6	33
DO (mg/L)	6.0	5.4	5.7
Calcium (mg/L)	484	430	457
Magnesium (mg/L)	1232	1190	1211
Carbonate (mg/L)	0.0168	0,0144	0.0156
Bicarbonate (mg/L)	0.1864	0.1802	0.1833
Sulphate (mg/L)	230.8	196.4	213.6
pH	8.4	8.0	8.2

Key to table: mg/L – milligram/Liter, ppt – parts per thousand, C-Celsius.

2. Seasonal attachment of organisms on brass at bay of Bengal of MSW

The seasonal attachment of organisms of all exposures of brass at bay of Bengal of MSW are presented in table-3&4.

Fouling of Algae is identified on all the exposed metal coupons. Algae or fungal[22,23] is one of the initiator to corrosion. Barnacles and Molluscs are recorded on II quarterly and half yearly exposed metals. Oysters are settled with significant intensity on half yearly exposed metals. Red rust is observed beneath the barnacle shells on the half yearly exposed surface of brass where in the organisms are dead. But it has no considerable protective effect towards the overall corrosion rates. The species namely *Enteromorpha* and Coscinodiscuscentralis are settled in January and February months and Chetomrpha(G) and Naviculaspare identified on March and April months of exposed metals. May month's exposure comprises chaetomorpa(G) and Cladophorasp (G). Rhizosoleniaalata and Cladophorasp (G) are settled on June month of metal coupons.

Table 3: Seasonal attachment of organisms on Brass in Bay of Bengal of Mallipattinam.

Period	Jan'17	Feb'17	Mar'17	Apr'17	May'17	June'17
Organisms	Green algae Enteromorpha, Coscino discuscentralis	Green algae Enteromorpha coscino discus centralis	Green algae Coscino discus centralis Chaetomorpha (G) Naviculasp	Green algae Chaetomorpha (G)Worms Naviculasp	Green algae Chaetomorpha(G) Worms Cladophorasp	Green algae Chaetomorpha(G) Worms Rhizosoleniaalata

Key to table: G-Greensp – species.

Table 4: Seasonal attachment of cumulative organisms on Brass in Bay of Bengal of Mallipattinam sea water, India.

Period	Monthly	1st Qly [Jan'17-Mar'17]	2nd Qly [Apr'17-Jun'17]	Hfly [Jan'17 – Jun'17]
Organisms	Green algae	Green algae Mollucs Enteromorpha Cladophora	Green algae Worms Enteromorpha Barnacles Molluscs	Green algae Worms Enteromorpha Barnacles Molluscs Oysters

Key to table: Qly – Quarterly, Hfly – Half yearly.

3. Corrosion behaviour of brass in the bay of Bengal of MSW

The corrosion rate by weight loss method[24,25] of brass in bay of Bengal of MSW for an exposureperiod of six months are depicted in table-5. The corrosion rate values of brass in sea water ranges from $1.625x10^{-5}$ mmpy to $1.923x10^{-5}$ mmpy. Of all the monthly exposures the February month of brass coupon is met higher corrosion. The nonaggressive rain fall and wind speed dilute the concentration of seawater. The climatic factor favours the settlement of fouling organisms on the surface of exposures. The lowest corrosion rate occurs in the month of June. Corrosion rate value of the June month exposure is a direct indication of the characteristics of seawater, formation of oxygen film and settlement of organisms.

Table 5: Monthly corrosion rates of Brass in Bay of Bengal of MSW.

Month- 2017	Corrosion Rate $x10^{-5}$ mmpy)
January	1.657
February	1.923
March	1.794
April	1.829
May	1.784
June	1.625

Table 6: Cumulative exposure of corrosion rates in Bay of Bengal of MSW.

Period - 2017	Corrosion Rate $x10^{-5}$ (mmpy)
Monthly (February)	1.9230
I Qly (Jan – Mar)	0.4825
II Qly (Apr – Jun)	0.4416
Hfly (Jan – Jun)	0.3519

Key to table : Qly – Quarterly, Hfly – Half yearly.

Table-6, reveals that the corrosion rate values become to decline from monthly to half yearly exposures.
II Quarterly (Apr'17-Jun'17) and half yearly (Jan'17-Jun'17) exposures proficient of lower values of corrosion rates ($0.4416\ x10^{-5}$mmpy & $0.3519x10^{-5}$mmpy). Rain fall level is low in the period. Hence, seawater acquires little bit more concentration which favorable for settlement of organisms on the exposed metals. The attachment of Barnacles and Mollusks are found out on second and half yearly exposed metal surfaces. Pits formation may be shaped underneath of the supplement of animals.

The pitting behavior, pitting probability and width of pit (maximum, minimum and average) of cumulative exposures of brass are presented in table-**7.**

Table 7: Pitting corrosion behaviour of cumulative exposures of Brass in Bay of Begal of MSW.

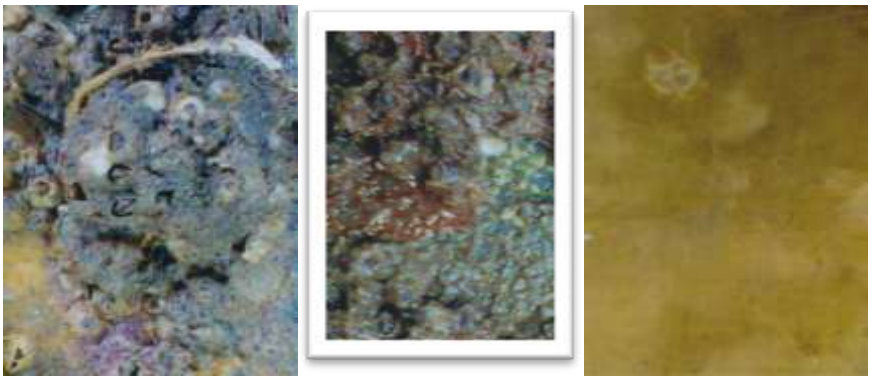
Period	Properties of Pits		
	Probability	Density of pits Nos/Sq.dm	Width of Pits (mm)
Monthly I	14	08 - 10	0.1 - 0.15
Quarterly II	20	10 - 20	0.1 - 0.3
Quarterly	35	18 - 25	0.2 - 0.4
Half Yearly	40	20 - 35	0.3 - 0.6

The maximum pit density (20-35 Nos. / sq.dm) and width of pits (0.3-0.6mm) perceived on half yearly exposed metal surface, implies that more settlement of hard foulers such as barnacles, Oysters and Molluscs during the study period. The monthly exposure (Feb'17) is characterized by the lowest value of pit density (08 -10 Nos./ sq.dm) and width of pit (0.1 - 0.15mm). The II Quarterly exposures characterized by moderate values of pit density (18-25 Nos./ sq.dm) and width of pit (0.2 – 0.4mm). Crevices are faintly noted beneath the settlement of mollusk and barnacles.

4. Change in mechanical properties and surface characteristics of brass due to exposure in bay of Bengal of MSW

The change in mechanical properties such as yield load and % elongation of brass metal coupons is presented in table-8. The metal surfaces of experimentation[26]from immersion in MSW for monthly, quarterly and half yearly are depicted in figures-1,2,3 The surface of polished brass shows α-grains. Quarterly exposures are characterized by bundled of grains and half yearly exposure is characterized by glazed grains. Explanations of the exposed metal coupons have a pattern of dissimilarity over the period of exposure. The percentage of elongation takes a falling trend over the period. The

half yearly exposure gets the lowest yield load. The change in mechanical properties of the cumulative exposed metal coupons could be ascribed to the pitting, seasonal attachment of organisms, ionic species and climatic factors.



(Half Yearly) **(II Quarterly)** (**Monthly**)

CONCLUSION

In the present exploration, identified fouling organisms on all cumulative surfaces of brass are algae, barnacles, molluscs, oysters and worms. The decrease in corrosion rate values of cumulative exposed brass coupons in Mallipattinam seawater over the period indicates the productive nature of algae, sessional attachment of animals and formation of oxygen film. Pitting /crevice corrosion on brass is enhanced by the hard fouler such as barnacles, molluscs, oysters and chloride ions. The changes in mechanical properties of brass over the period of exposed metals are in same alignment with degree of pitting corrosion and weight loss of materials.

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