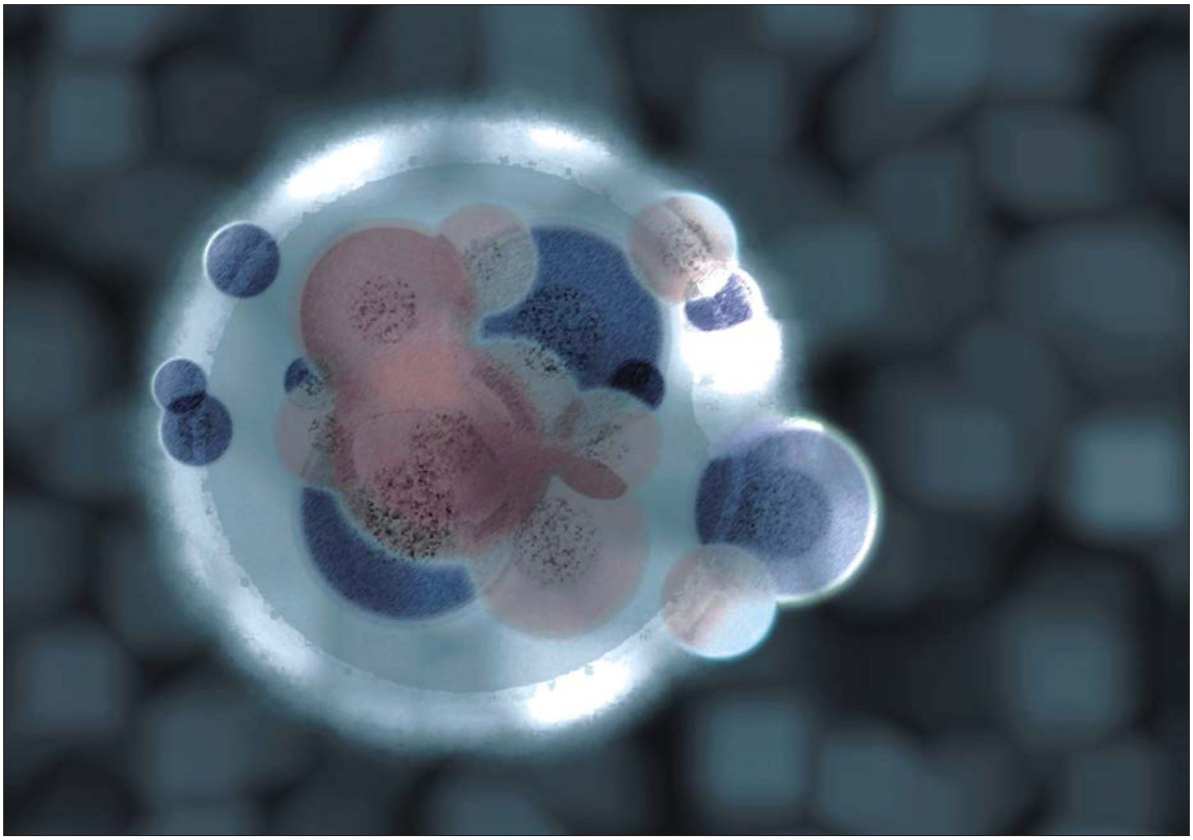

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An Investigation on Use and Durability of Some Industrial and Domestic Woods of Iran Against Destructive Factors in Caspian Sea

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Abstract: In this study the use of domestic and commercial woods of the Caspian Sea forest fringes and evaluation of their durability against marine destructive factors were investigated. The samples of elm (*Zelkova carpinifolia*), oak (*Quercus castanifolia*), beech (*Fagus orientalis*), Maple (*Acer insgin*), Alder (*Alnus subcordata*) and horn beech (*Carpinus betulus*) species were impregnated with CCA (Chrome-Cupper-Arsenic). Treated and untreated (natural as a control) woods have been established for 3, 6, 9 and 12 months in Amir-abad beach of Behsharhre under fishing environment. The results of observations showed that in this beach, the staining fungi and balanus were able to attack control woods or live on them. With increasing woods maintaining in the sea, their presence became longer. The numerical results of samples weight loss showed that durability of control wood samples after one year made less than 5% in weight losses of elm, maple, alder and horn beech. However, control samples of oak and beech had no weight losses. The treated samples not only had no weight reduction, the absorbed salts made their weight increase. Low salinity level of Caspian Sea with respect to salinity of large sea (oceans), made absence of wood drilling worms in Caspian Sea and this may be the main reason of non-destructive wood samples.

Key words: Staining fungi, balanus, CCA, domestic and industrial woods

INTRODUCTION

Wood is one of the building materials which are used in marine industry like jetty, boat and ship building. For the first time perhaps it was Majesty Prophet Noah who made a ship by Gods order to rescue the believers from God punishment. Today to preserve industrial woods for transportation and preservation of marine and terrestrial woods the artificial and natural preservatives like creosote and phenols are used. The remainders of drowned pole timbers and ships with minimum damage on the bottom of big rivers and seas show that durable woods have been used in bridge and jetty buildings industries. Some timbers were discovered at the bottom of London Thames River after hundred years with no damage show important effects of using wood in marine industry (Findlay, 1967). In cooling towers, in which water is used for cooling turbines, the durable and preserved woods are used. In Iranian south coastal area, small fishing and transportation ships are also made of durable timber and use of woods like teak (*Tectona grandis*) which are imported from abroad and are usually flourished.

Many studies have been carried out about durability of woods against drilling destructive factors in saline waters and in seas which are connected to oceans. In these waters generally mollusks attack woods or feed on them. The salinity of those seas is usually very high, so that in waters with less salinity the damage organisms are also limited. In these waters staining fungi may make woods dark in color and reduce their commercial values. In recent years some studies have been carried out on the amount of degradation of motionless marine organisms or drilling woods on imported species like *Tectona grandis*, *shorea laevis*, *Dipterocarpus alatus* and *Balanocarpus heimif* (Rezanejad and Parsapajoh, 2001). In Chah Bahar beaches, the non-preserved woods were degraded after 27 months establishment in the sea and in Bushehr and Bandar Abbas harbors *Balanocarpus heimif* was more durable than other species and can last even 46 months (Rezanejad and Parsapajoh, 2001). Other studies on domestic species show that submergence of non-preserved species of oak, beech, horn beech, alder, eucalyptus and acacia in coastal water of Bandar Abass have caused sever degradation of marine drillers in less than 9 months (Arabtabar *et al*., 1992). Using creosote preservative has increased durability of above species for 30 months, except horn beech and acacia in Bandar Abbas. But use of the preservative like Celchor (ACC) could not increase their durability in Bandar Abbas areas significantly (Arabtabar *et al*., 1993).

Natural durability of about 250 wood species against marine organisms was studied in Indian coastal areas. Among them, species like *Balanocarpus neimif* resisted 12 months and *Cleistanthus collinus* (Roxb.) Benth. Ex.

Hook.f. (Karada) was durable in long time against marine organism attacks (Rao *et al*., 2005). In other investigation it was concluded that use of an organic polymer called Copoly (TBTM-MMA) could preserve wood panels for 42 months against marine wood eaters, whereas, the control species could be durable only for 3 months (Swami *et al*., 2005).

Nowadays in south of Caspian Sea beaches many activities are done. Making boats, jetties and ships for transporting of materials and passengers are also ordered. The aim of the research was to investigate the durability of some important wood species like oak, beech, horn beech, maple, alder and elm that could be applied in forms of natural or conserved with Cupper-Chrome-Arsenic (CCA) as wood structures, in marine industries of Caspian Sea.

MATERIALS AND METHODS

Timbers converted to lumbers and were kept in a covered place to reduce moisture content. Based on instructions of Rao and Krishnan (1992) and similar research (Kandau and Ling, 2005), the lumbers were made by dimensions of 300×100×30 mm. For passing ropes and establish samples in sea sites, 30 mm holes in diameter was made on each wood sample and naps on the surfaces and inside pores of specimens were polished with emery (Fig. 1-4).

The characteristic of species like kind of treatment, date and place of installation, were engraved on each wood species separately. For each treatment and wood species 20 samples were used. At 12% of moisture content, samples were weighed, treated with 5% concentration of CCA preservative and by repeat weight again of samples, absorbed solution of CCA recorded and retentions (kg m^{-3}) were calculated. Saturated samples were kept in a covered place for a month. They transferred to oven and then kept dry in 50°C for 72 h, to speeding up the stabilization of preservative materials in wood cell walls (Karimi and Shaikholeslami, 2000). The control samples were also dried and weighed in similar temperature (50°C). All samples (treated and untreated) were connected to ropes, transferred to sea site and installed under 1-2 m of water levels in Amir-abad Behshahre beach (Fig. 5 and 6).

After samples installation in the sea jetty where boats were presented and the sea water was calm and there was no high sea tides, the samples were attacked by marine organisms for 12 months maximum. The submergence situation and attacks of marine organisms on wood samples were controlled once every two weeks. Then, the first series of samples were taken out of water after

Fig. 1: Alder samples before drilling

Fig. 2: Alder samples after drilling

Fig. 3: Sample of elm before drilling

Fig. 4: Samples of elm after drilling

Fig. 5: Initial site for samples installation in Amirabad coast

Fig. 6: Samples Installation in low wave under jetty

3 months of installation (Autumn) and were transferred to laboratory. After 6 months the second series (Winter), 9 months the third series (Spring) and after 12 months the fourth series of samples (Summer) were taken out from installed place. In the laboratory, observations of marine organisms including balanus and fungi which had been colonized samples, were studied and recorded. Then the samples were put in open air in separate series to reduce the moisture and reach to 12%. After insuring the required moisture content, the samples were transferred to oven in small groups and were dried at 50°C for 72 h. At the end, dried samples weighed and weight losses were calculated.

RESULTS

Quality of sea water: In the first step, data (Data were taken from Institute of Caspian Sea Ecology in Sari) related to sea water including temperature, salinity, dissolved oxygen, pH, ammonia, nitrate, silicon and phosphate in Amir-abad Coast were investigated. Results showed some factors related to sea water change with season alteration. Salinity, temperature and nitrate increased in spring and summer. Oxygen and silicon also were increased in winter. Nitrates and phosphates in addition raised in summer. However, Increase or decrease of mineral elements and chemical compounds in sea water may effect on the life of microorganisms in the marine environment and could change their biology and habitats.

Table 1: Quality of Caspian Sea water in Amirabad Behshahre Station

Parameters	Autumn	Winter	Spring	Summer
Temperature	19.00	10.50	29.00	29.00
Salinity (ds m^{-1})	12.42	11.80	12.46	13.00
pH	8.40	8.41	8.27	8.32
Ammonia NH_4^+ (μg L^{-1})	-	47.30	47.30	7.74
Nitrite NO_2^- (μg L^{-1})	5.60	8.20	3.60	4.90
Nitrate NO_3^- (μg L^{-1})	77.90	77.90	110.80	231.40
Silicon SiO_2 (μg L^{-1})	-	937.00	714.00	618.00
Phosphate PO_4^- (μg L^{-1})	20.19	20.19	10.71	22.95
Oxygen (mg L^{-1})	5.10	8.10	5.80	3.50

Salinity of Caspian Sea was about one third of the salinity in the free ocean, especially in Persian Golf, which means that EC of 13 ds m^{-1} in Caspian Sea was less than the EC of 30 ds m^{-1} in free ocean. Therefore, many of organisms are existing in water of ocean and may they are absent in other watery environments, so that marine drillers are not observed in the Caspian Sea (Table 1).

Observations and numerical results: The mean of retentions (kg m^{-3}) of CCA preservative with 5% concentration, in each wood species were about as follows: Elm = 14, Oak = 16, Beech = 18, Horn beech = 26, Alder = 30 and Maple = 28 kg m^{-3}. The effects of fungi and wood adherents after 3, 6, 9 and 12 months installations indicated that woods are degraded severely. Nevertheless observations in laboratory showed no physically destruction were observed. Wood color changed by the fungi and wood adherents were only related to balanoids and survive on woods (Fig. 7 and 8).

For classification of attacked woods by marine organisms in open waters (Rao *et al*., 2005), four groups could be divided as follows: 1) presence of traces of marine organisms on wood samples without apparent degradation of woods. 2) Presence of low degradation traces. 3) Moderate degradation of woods and 4) Complete degradation of wood samples. In the base of the classification, the installed samples in Caspian Sea were placed in the first group. Therefore, some organisms that have survived on woods, changed the color of wood samples in Amir-abad coast. Also, the calcareous traces of wood coherents (balanus) colonized wood specimens. Fungi have made wood surface dark and their mycelium was observed on all wood blocks. Some of these fungi may possibly be staining and others could be softening. However, wood decaying fungi were not observed.

For studying and evaluation of numerical results, a standard method has not been reported. In Caspian Sea, effect evaluations on the microorganisms, a new

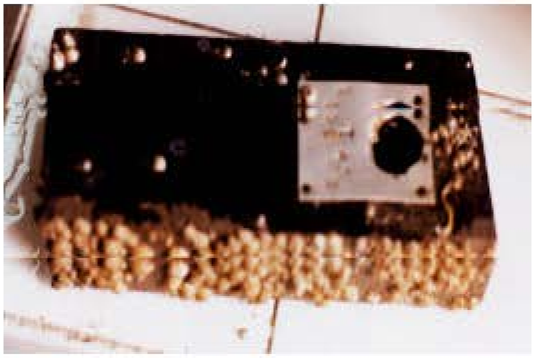

Fig. 7: Change in color and presence of Balanuses around on alder

Fig. 8: Mycelium of fungi and balanuses standing still on elm

classification is required. The amount of the effects of microorganisms on wood samples depends to the wood species and type of the organisms. However, in the research a new method used and all samples before and after exposure to water, oven dried at 50°C and then weighed. Obtained data showed that there are differences in weights of samples. Some of wood samples were decreased and some of them were increased in weight (Table 2).

The quality of wood samples against marine destructive factors by obtained weight differences has been evaluated and each wood species showed different behavior. This performance could be a good guide for future situation of the wood species when they are applied in Caspian Sea services. Curves related to these behaviors are shown in Fig. 9-14.

Elm: The exposure time of elm samples (*Zelkova Castanifolia*) in water of Caspian Sea was 3 to 12 months. Weight losses of Elm Control (EC) samples during exposure were increased by marine factors and most

Table 2: Mean weight decreased or increased in 3, 6, 9 and 12 months in 2003 and 2004 in Amirabad Coast of Caspian Sea

Species	Type of treatment	Spring	Winter	Autumn	Summer
Elm	Untreated	1.71	0.48	3.06	4.03
	Treated	-6.63	-3.34	-7.92	0.77
Maple	Untreated	-0.38	-4.87	-0.58	1.73
	Treated	-1.38	-8.62	-2.91	-6.34
Oak	Untreated	-1.77	-4.96	-7.92	-1.02
	Treated	-1.92	-3.05	-4.06	-1.43
Alder	Untreated	0.45	0.59	0.09	3.51
	Treated	-3.26	-4.69	-5.17	-12.21
Beech	Untreated	-1.88	-3.66	-0.97	-0.14
	Treated	-9.52	-1.10	0.20	-8.87
Hornbeech	Untreated	-0.45	-2.44	-0.86	2.77
	Treated	-7.85	-2.47	-7.86	-7.90

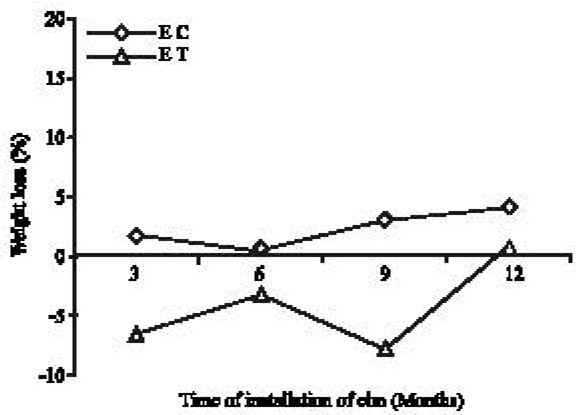

Fig. 9: The weight differences of elm during 12 months exposure in the water of Caspian Sea

reduction of weight loss after one year was 4.03%. Whereas weights of Elm Treated (ET) by CCA preservative after exposure were increased in water (Fig. 9).

The considerable point is that control species had color change and were observed as brick red and were quite obvious among other wood species. This may be due to extraction of materials from elm samples. This causes a weight reduction (maximum 5%) in control samples. The other interesting point is that, although the traces of balanus and fungi were observed on wood control samples, the least fungi-effected symptoms like staining was not observed. Whereas in treated samples the same characteristics were observed and after cleaning of their traces from samples, color and the appearance of the wood were quite undisturbed. The most important point is that use of preservative (CCA) which prevented wood samples of weight losses and also the sea water salts increased the weight of samples during 10 months (ET in Fig. 9).

Maple: The samples of maple (*Acer insgin*) control (MC) showed reduction in weight in sea water by increase in

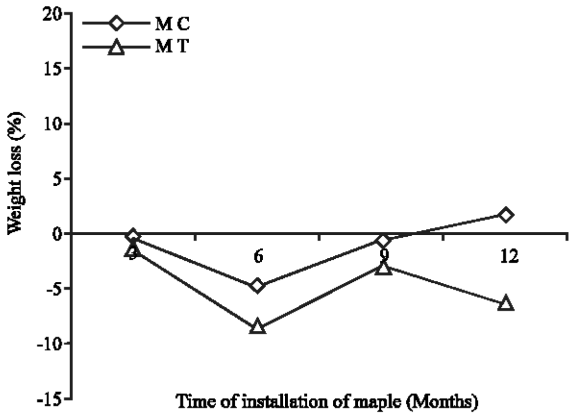

Fig. 10: The weight differences of maple during 12 months exposure in the water of Caspian Sea

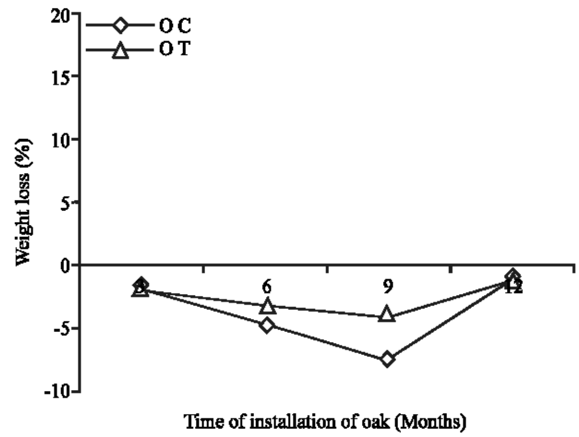

Fig. 11: The weight differences of oak during 12 months exposure in the water of Caspian Sea

time of installation. These results indicated that maple has high sensitivity to staining fungi, but this did not decrease the weight of samples, so that after one year the reduction in sample weights was about 1.73%. Using the samples of Maple Treated (MT) by CCA, increased durability of wood considerably, so that no traces of decay or dyeing were observed in treated samples. Therefore, control samples of maple did not show resistance to attacks by staining fungi and all samples change color severely and became block. But use of preservative prevented the wood samples color change (Fig. 10).

Oak: The samples of oak (*Quercus castanifolia*) control (OC) had the highest resistance to fungi and balanus of the Caspian Sea and staining fungi did not change the color of wood samples in the first six months either. On the other hand, use of Oak Treated (OT) by preservative (CCA), could not increase the resistance of the species. Increase of durability of oak in water from 3 to 12 months did not increase the weight losses of samples either. The trend of the weight process in control and treated specimens are very similar (OC and OT in Fig. 11). The very interesting point is that the amount of weight of control samples among other wood species was not positive. It was under the zero line and its size is bigger than the treated samples (Fig. 11).

Alder: In agreement with previous reports about resistance of alder (*Alnus subcordata*) to water permeability (Hejazi, 1993), the data shows the highest resistance to microorganisms in the sea water, so that after one year, slight weight reduction was observed in control samples. The durability of samples in the sea did not show any significant differences for 3 to 9 months,

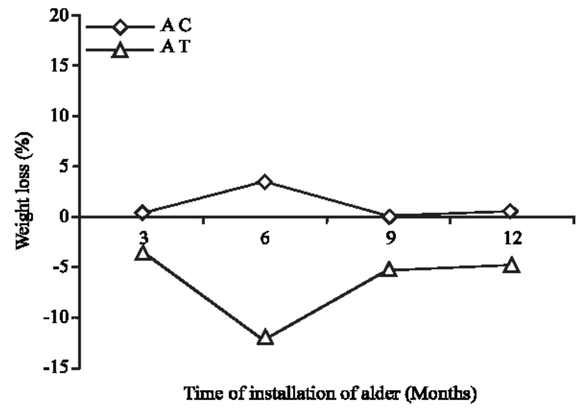

Fig. 12: The weight differences of alder during 12 months exposure in the water of Caspian Sea

but after 3 months less than 5% reduction in weight was observed. Use of preservative material also increased the durability of alder samples and this increase was significant in 3 months process (Fig. 12).

Beech: Beech (*Fagus orientalis*) considered as low durable wood, against fungi attacks in the laboratory (Kazemi, 1988). However, in the field conditions when this wood species exposed to marine organisms and dyeing fungi, it was very durable. So that after 9 months attack by microorganisms only 0.2% weight reduction was observed. The surface of beech samples was block due to dyeing fungi and woods coherent were also observed on the surface of the wood samples. Use of CCA preservative increased durability of the beech and not only weight loss was not appeared but also increased weight of samples in the period of 6 months of the year (Fig. 13).

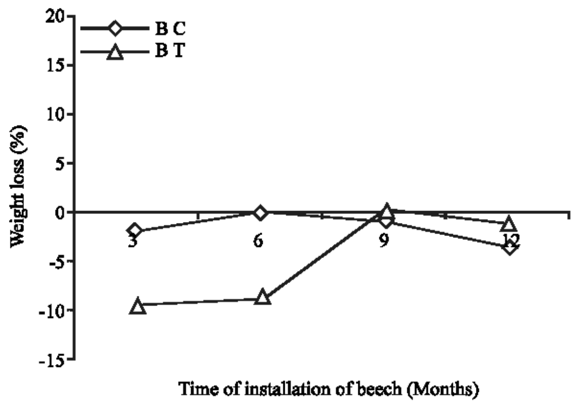

Fig. 13: The weight differences of beech during 12 months exposure in the water of Caspian Sea

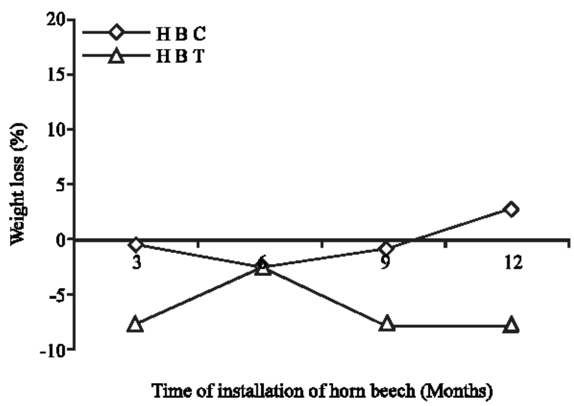

Fig. 14: The weight differences of horn beech during 12 months exposure in the water of Caspian Sea

Horn beech: The horn beech (*Carpinus betulus*) is considered less durable in laboratory conditions (Kazemi, 1999), but the controls of the species showed less than 5% weight reduction after one year. The application of preservative also increased wood samples durability. The concluding point is that industrial and domestic woods of northern Iran like horn beech are in good condition if they are submerged in Caspian Sea water (Fig. 14).

DISCUSSION

One of the main points of this research is non-destruction of wood samples during a year exposure in the sea. So, even control samples (non-preserved) of species like horn beech and maple which have high sensitivity to fungi in wet condition, after 12 months had the least weight reduction in Amir-abad coast of Behshahre area. The trends of weight loss of these two species in control samples also are very similar to each other (Fig. 10 and 14). The other important point is that weight reduction in control samples of elm (one of the most durable species in the Caspian Sea forest areas), which is more than those of control samples of maple and horn beech. This shows that in addition to sensitivity to fungi effects, other factors like extracting of elm materials may cause high weight loss and it might be the reason of reddish of control elm samples (Kazemi, 1992). Water velocity and sea wave intensity are also important. In a pilot test carried out by Kazemi (1999) in Caspian Sea, indicated that putting samples in a region where wave intensity is high, intense abrasion of wood samples occurred, although marine balanus (ship coherent) are rarely seen on the woods.

The interesting point is that the amount of resistance of control samples of oak against microorganisms which is higher than resistance of treated samples and shows probably the presence of tyloses in oak to prevent it in water environments (Bowyer and Haygreen, 1982). The alder is famous for water resistance and this research proves the fact. All these data show that when wood samples are in completely wet or saturated condition can resist against destructive factors as some wood species remained in good conditions after dozens of years on the river beds (Findley, 1967).

The other important factor is the use of preservative (CCA) which prevents weight reduction from all samples and did not change their color. The color change is the first step of decadence in samples, so one can not be sure that the samples that are in good condition after a year and without any preservation can be without any damage for ever. In a study conducted in Malaysia tropical area, 28 commercial species were exposed to drillers for 12 years in a marine test. The effective factors on water quality like water velocity, temperature, salinity, dissolved oxygen and turbidity were recorded. The results of research showed that most species could not be durable more than 6 months. But, some of them, including Belian (*Eusideroxylon zwageri*) are famous as iron wood. They could be durable for 36 months, in the sea in tropical water (Kandau and Ling, 2005). The investigating point is that, some domestic woods like oak and elm and also some African species with high extractable amounts (8-13%) when exposed to destructive agents like fungi and insects are very durable, but when submerged in water, can not be guaranteed to be durable over 6 months. If woods have more than 0.5% silicon they would be more resistant against jaws of drilling of marine animals and decrease damage for 3-4 years. On the other hand, the amount of damage on wooden boats which pass through sweet water are much less than boats move through saline water in the ocean. In tropical regions, the average sea temperature is 30°C, salinity is 30 ppt, pH 7.5 and dissolved oxygen is 5.30 ppm (Kandau and Ling, 2005). However, in non-saline Caspian Sea, although pH is high (8.5) however, salinity is low (10-12 ppt).

The use of wood in marine structures, several factors such as water salinity, water temperature and types of drilling marine animals in the region, wood species and extractable materials nondissolved in water are important. Finally minerals including silicon add wood durability in the water severely. Also, the compressibility and density of wood are very important in wood degradation. Other important point is that in the oceans, especially in tropical region, the drilling marine are of Tredinate type, like Benkia, Lyrodus, Teredo and also pholadidae like Martesia, deteriorate wood species severely and produce high damages, whereas in non-saline water, only balanus may survive on woods or may attack woods. So, applying the preservative materials can increase the coefficient of woods. The wood coherence that was shown on all samples of woods, are on the surface of the woods and had the least damage on woods (Fig. 7 and 8). These show that kind of destructive factors in open sea is quite different with destructive factors in Caspian Sea. Recognition of these marine organisms that are seen on all boats in Caspian Sea can help in future research on durability of species. On the other hand, up to now about dyeing fungi and probably staining fungi, no research has been carried out in Caspian Sea. Anyway the fact is that all non-preserved woods, considering their durability in a different duration and maximum of 12 months, did not show any resistance to dyeing fungi. The mycelium of fungi on these samples proves this fact. But, preservation of samples caused the condition that still there are fungi on woods and can not change the color of samples. At the end, one can conclude that durability of woods in Caspian Sea is completely different from durability of woods in open sea and especially in Persian Golf and Oman Sea and one can use industrial woods and even low durable like maple and horn beech without apprehension and use of preservative resistance to washing water.

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