FIELD TESTING OF WOOD PRESERVATIVES IN CANADA. III - MARINE TESTS

by

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Summary

Red pine coupons treated with a range of preservatives have been in test for 14 years at West Vancouver, B.C. and 8 years at Shediac Bridge and Whitehead Island, New Brunswick. In Pacific coastal waters, the testing revealed the following ranking for the preservatives for a retention range of 28-32 kg/m^3: chromated copper arsenate type C (CCA-C), excellent; ammoniacal copper arsenate (ACA), and modified ACA, good; ammoniacal copper zinc arsenate[1] (ACZA), fair; ammoniacal zinc arsenate (AZA), poor. The following retentions of waterborne preservatives gave equivalent performance to a creosote retention just above that specified in the AWPA C18 standard: 15 kg/m^3 CCA-C, 44 kg/m^3 ACA and 43 kg/m^3 modified ACA. At the Shediac Bridge site, where *Teredo navalis* is the active borer, coupons treated with CCA-C and creosote provided good protection below the minimum value specified in the AWPA C18 standard. At the Whitehead Island site in the Bay of Fundy, where *Limoria lignorum* is prevalent, coupons treated to below standard retentions with CCA-C and ACA preservatives performed well. Creosote-treated coupons have not performed as well as the waterborne treatments. The relative performance of CCA-C and ACA treated coupons would suggest that the marine borer hazard at the West Vancouver and Shediac Bridge sites are similar for wood treated with waterborne preservatives.

1.0 Introduction

Marine testing of preservative-treated wood in Canada was initiated at the request of the Canadian Standards Association Technical Committee on Wood Preservation (CSA O80) to identify the effective preservative retentions required for treated wood in service in coastal waters. The first test site was established in West Vancouver in 1978 using coupons treated with various waterborne preservatives. The treatment, installation and performance results of this material after 8 months of exposure were reported by Hulme and Ostaff (1980) and the results of a second inspection after 27 months were reported by Ruddick (1981).

Because of an apparently higher borer hazard in Pacific waters compared to Atlantic waters, higher creosote retentions had traditionally been specified for the Pacific coast. When waterborne preservatives were introduced for this application one retention was specified for both East and West. To determine whether there should be two different retentions for the waterborne preservatives, the marine testing project was expanded in

1984 to include two additional test sites in Atlantic coastal waters. The establishment of these sites, located originally at Shediac Bridge on the Northumberland Straight and Black's Harbour on the Bay of Fundy, has been reported by Ruddick *et al* (1985). The two sites represent two distinct marine borer environments in eastern Canada, with *Teredo navalis* being most active at Shediac and *Limnoria lignorum* being the major borer in the Fundy region. Test material consisted of both waterborne- and creosote-treated coupons. The Black's Harbour site was relocated in 1986 to Whitehead Island, also in the Bay of Fundy, after a very low level of activity was observed at the former site.

The performance of treated coupons at both the eastern and western marine test sites was last reported by Doyle and Morris (1990). The current paper presents a summary of test results after approximately 14 years of exposure at the West Vancouver site and 8 years at the New Brunswick sites.

2.0 Materials and Methods

2.1 Material in Test (West Vancouver Site)

Red pine (*Pinus resinosa Ait.*) sapwood coupons (0.6 x 5.0 x 20cm) were pressure treated as described by Hulme and Ostaff (1980) with the following waterborne preservative formulations and placed in test in 1978.

CCA-C	47.5%CrO_3:18.5%CuO:34%As_2O_5
ACA	50%CuO:50%As_2O_5
ACA(modified)	63%CuO:37%As_2O_5
ACZA[1]	21%CuO:30%ZnO:49%As_2O_5
AZA	72%ZnO:28%As_2O_5[1]

Thirty-two untreated controls and ten creosote-treated coupons were also placed in test at this time. Coupons pressure treated with ACA preservative to a lower range of retentions were added to the test site in 1986 in order to extend the range of retentions in test. These particular coupons were wrapped in polyethylene immediately after treatment to simulate the drying rate expected for large dimension commodities.

2.2 Material in Test (New Brunswick Sites)

Red pine (*Pinus resinosa Ait.*) sapwood coupons (0.6 x 5.0 x 15.3cm) were pressure treated as described by Ruddick *et al* (1985) with the following preservative formulations and placed in test in July 1984.

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1 This is not the same formulation currently being widely used in the U.S.A. In this formulation, zinc replaces copper. In the U.S.A. formulation, zinc replaces arsenic.

CCA-C	47.5%CrO_3:18.5%CuO:34%As_2O_5
ACA	50%CuO:50%As_2O_5
Creosote	(in perchloroethylene)

A total of 180 coupons were treated with each preservative and these were divided and mounted on twelve different test racks, along with untreated controls. Six racks were installed at each site. Two additional racks containing coupons treated to higher retention levels with ACA preservative were added to each test site in October 1986 in order to test a wider range of retentions for this preservative.

2.3 Inspection of Test Material

In order to examine the test material, the racks were removed from the water and all panels were carefully scraped to remove surface accumulations of barnacles, mussels, seaweeds and other marine organisms. Each individual coupon was then carefully examined for surface erosion and/or entrance holes indicative of marine borer attack. The panel was then either lightly flexed or probed to detect areas with loss in strength, which are indicative of tunnelling. Based on the results of the above inspection, each coupon was assigned a rating, using the rating scale recommended by the International Union of Forestry Research Organizations (IUFRO) for evaluating field test stakes. Results were then converted to the AWPA/ASTM rating scale, as shown in Table 1, in order to permit direct comparison with other North American data.

After completion of the inspection, additional untreated controls were added to each test rack to replace those which had failed in service and as a means of demonstrating the continued activity of the sites. Test racks were then resubmerged for further exposure.

3.0 Results and Discussion

3.1 West Vancouver Test Site (Pacific Coastal Waters)

Untreated controls at this site have been replaced every year because of marine borer attack, thus demonstrating the continued biological activity of the site.

The two registered waterborne preservatives (CCA and ACA) provided good protection at assay retentions at or below the 40 kg/m³ level specified in the AWPA C18 standard (Pressure Treated Material in Marine Construction) for the outer zone of red pine piles and for timbers in a marine environment. The data cannot be compared to the Canadian standard CSA 080.18 since this standard still specifies retention by gauge. AZA-treated coupons, had failed completely at all retention levels by the 69 month inspection, and those treated with ACZA, had deteriorated badly at all levels tested.

CCA-C-treated coupons appeared to be performing best, with only one failure recorded to date at the lowest retention level (15 kg/m³). Coupons treated to retention levels of 22 and 50 kg/m³ were all rated completely sound. There was also one reported failure in the 31 kg/m³ retention group. However, this particular rating was recorded as far back as the 69 month inspection and no further deterioration has been observed since for other samples in this retention group. The overall performance of the CCA-C treated coupons is shown in Figure 1.

ACA-treated coupons also performed well, but signs of surface deterioration were observed at all retention levels involved in the original test, with at least two recorded failures to date in the lowest retention group (29.0 kg/m^3). This group had an average AWPA rating of only 52.5 at the time of the last inspection. However, the average AWPA rating at 44 kg/m^3 was 78.7 and only surface deterioration has been observed to date on a few coupons in this group. The performance of these coupons is shown in Figure 2.

ACA treated coupons at lower retention levels that had been wrapped prior to drying and installed in 1986 were showing initial signs of attack at all retentions less than 35.4 kg/m^3 after only 27 months in service. Wrapping to simulate the drying rate of large sized commodities did not appear to improve the performance of ACA. Coupons with a retention of 30 kg/m^3 showed similar performance after 72 months exposure whether air dried as in the first installations or wrapped prior to drying as in the second installation (Figures 2 and 3).

The increased copper content in the modified ACA formulation did not appear to result in any significant improvement in the long-term performance of the test coupons. For example, after 171 months in service, the average AWPA ratings for coupons treated to 28 and 43 kg/m^3 with the modified ACA formulation were 40.0 and 71.8 respectively, slightly lower than the ratings of 52.5 and 78.7 recorded for coupons treated with the standard ACA formulation to similar retention levels. Figure 4 summarizes the performance of the modified ACA-treated coupons.

As already mentioned, the AZA treatment has proven itself to be completely inadequate, with total failure of all test coupons, including those treated to the highest retention level of 30 kg/m^3, being recorded after approximately five years in test, (Figure 5). ACZA-treated coupons performed slightly better, with those coupons treated to 32 kg/m^3 rated as sound after 69 months. However, all retention levels showed very advanced deterioration after 14 years. These results are shown in Figure 6.

Figure 7 shows the performance of creosote-treated coupons. This preservative, which was tested at only one retention level (348 kg/m^3), has performed very well. This retention is slightly higher than the assay retention specified for red pine in AWPA C18.

An attempt has been made (Figure 8) to directly compare the performance of the five waterborne preservatives at the West Vancouver test site. However, because of the wide variation in retentions used when the test was originated, it was only possible to make this comparison at a retention level of approximately 30 kg/m^3. As shown in Figure 8, the CCA-C treatment was highly effective at this retention, with the ACA and modified ACA formulations showing the next best performance. Replacement of a portion of the copper in the ACA formulation with zinc appears to have a negative effect on long-term performance. Complete replacement of copper by zinc gave very poor performance.

Based on the results to date, at an approximate retention of 30 kg/m^3, the performance of the preservatives can be rated as follows:

CCA-C	-	Excellent
ACA and modified ACA	-	Good
ACZA	-	Fair
AZA	-	Poor (unacceptable)

The difference in performance of CCA-C and ACA at this site may be due to the activity of tunnelling bacteria. The major form of deterioration of ACA-treated coupons at this site was surface erosion which did not appear to be caused by *Limnoria* spp. (Daniel 1992). Microscopic examination revealed extensive bacterial tunnelling which may be related to the amount of silt which settles on the coupons at this site. Morris and Ingram (1991) noted that ACA-treated wood was more susceptible to tunnelling bacteria than CCA-C-treated wood. This appears to be mainly a surface phenomenon thus, although it has a major effect on the structural integrity of a small coupon, it is unlikely to have a major impact on a marine pile.

3.2 New Brunswick Test Sites (Atlantic Coastal Waters)

3.2.1 Shediac Bridge Site

The Shediac Bridge test site is located in an area where *Teredo navalis* (shipworm) is the principal active borer present. The distribution of this species depends on the water temperature exceeding 15-16°C at some period of the year (Bohn and Walden 1970). The water temperature recorded at the time of the August 1989 inspection was 25°C. Attack by this organism is characterized by pinhole entry points on the wood surface and extensive internal tunnelling.

Untreated controls installed at this site showed a pattern of deterioration which varied with a two year period. They showed virtually no sign of attack after one year, but were completely destroyed by the second year. The cause of this apparent yearly variation in borer activity has not been determined. It may, however, be due to the main settlement period for borers being just before the annual date for inspection and coupon installation.

CCA-C treated coupons performed very well (Figure 9). Even at retention levels as low as 7.0 kg/m^3, treated coupons showed only trace levels of attack after five years in service. After 8 years, all of the low retention coupons had failed and there was fairly extensive attack on those coupons treated to the next lowest level (11.7 kg/m^3). However, almost all other coupons, with retentions ranging from 14.5 to 24.1 kg/m^3, were rated as sound.

The ACA-treated coupons originally installed at the New Brunswick test sites were treated to lower retentions than the CCA-C coupons and most of these coupons had failed after 8 years (Figure 10). Only the two highest retention levels (10.7 and 15.9 kg/m^3) survived. Those coupons treated to 10.7 kg/m^3 performed as well as coupons treated with CCA-C to a retention of 11.7 kg/m^3. After 8 years these coupons had average AWPA ratings of 60 and 63 respectively. The coupons treated with ACA to the highest retention level (15.9 kg/m^3) continued to survive but the average AWPA rating for this group fell to 63. The rating for a roughly equivalent group of CCA-C treated coupons (14.5 kg/m^3) was 94. It is important to note that all ACA retention levels in this initially installed group were well below the minimum level of 40 kg/m^3 specified in the AWPA C18 standard. All of the more recently installed coupons treated with ACA to retentions of 25 and 29.7 kg/m^3 (not shown) were rated as sound after approximately five years in service. Nevertheless at roughly equivalent retentions, the CCA-C treated coupons appeared to perform better than ACA at this site.

Creosote-treated coupons showed at least early signs of attack at all retention levels in test, and many of the coupons treated to the lowest retention levels (42.3 and 76.3 kg/m^3) had failed after 8 years exposure (Figure 11). The AWPA C18 standard currently requires a minimum gauge retention of 320 kg/m^3 for the outer zone of red pine piles and red pine lumber in marine applications. Unfortunately, there is no material currently in test that meets these minimum requirements.

Based on results to 1992, all three preservatives provided protection against the borer *T.navalis* at retentions similar to and in some cases even lower than the minimum levels specified in the AWPA C18 standard.

3.2.2 Whitehead Island Site

The Whitehead Island site is located in the colder waters of the Bay of Fundy. Water temperature recorded at the time of the August 1989 inspection was only 12.5 °C. According to the survey of Bohn and Walden (1970), this site is located in an area where *L. lignorum* (gribbles) are active. Attack by *L. lignorum* is characterized by tunnelling at or just below the wood surface, with subsequent gradual erosion of the surface layers.

The 12 and 25 month ratings were recorded at the original Black's Harbour site, as explained earlier. Untreated controls in service showed a steady rate of deterioration, generally failing after 2-3 years in service. The total exposure time at this site (91 months) is less than at the Shediac Bridge site because all test racks were removed by contractors in March 1991 when wharf repairs were carried out. The racks were reinstalled in September 1991 at the same location.

The waterborne treatments performed very well at the Whitehead Island site, but those coupons treated to the lowest retention levels of 7.0 and 11.7 kg/m^3 with CCA-C and 3.5 to 10.7 kg/m^3 with ACA showed advanced deterioration after 8 years exposure. However, these retention levels are well below the 40 kg/m^3 specified in the AWPA C18 standard. Coupons treated with CCA-C to 24.1 kg/m^3 (Figure 12) and with ACA to 25 and 29.7 kg/m^3 (not shown) were all rated as sound after 91 and 57 months respectively. The performance of the CCA-C- and ACA-treated coupons are shown in Figures 12 and 13. CCA-C performed slightly better than ACA. For example, at a retention of approximately 11 kg/m^3, after 8 years exposure the average AWPA ratings for CCA-C and ACA treated coupons were 85 and 78 respectively. At retentions of around 15 kg/m^3 CCA-C coupons were all completely sound while ACA coupons had a rating of 87.

Deterioration of test coupons treated with creosote has been observed at all retention levels since the 35 month inspection and the coupons continue to deteriorate. All individual creosote treated coupons showed signs of *L.lignorum* attack after 8 years exposure. At the lowest retention of 42.3 kg/m^3 all coupons had failed, and at the highest retention level of 206.4 kg/m^3, the average AWPA rating was 76. The current requirement in the AWPA C18 standard is for a minimum creosote retention of 320 kg/m^3 for red pine piling. Figure 14 summarizes the performance of the creosote-treated coupons.

Based on the performance results, attack by *L. lignorum* in the Bay of Fundy on CCA-C- and ACA-treated coupons generally appears to have been somewhat slower than attack of similar coupons by *T.navalis* in the warmer waters of the Northumberland Straight. It is doubtful if the slightly shorter exposure time at the Whitehead site would account for the differences observed. For example, coupons treated with CCA-C (7 kg/m^3) and ACA (3.5 kg/m^3) had average AWPA ratings of 0 after 97 months at Shediac Bridge and 73 and 35 respectively at the Whitehead site after 91 months. However, for the creosote treatment, the opposite was noted. For example, coupons treated with creosote to 76.3 kg/m^3 were rated as 67 at Shediac Bridge, but only as 28 at Whitehead.

4.0 General Discussion

The two major objectives of this work were, first, to identify the preservative retentions required for protection of wood in Canadian coastal waters and, second, to determine whether there should be differences in specified retentions between east and west coasts.

The most important objective was to determine appropriate assay retentions. The use of the existing gauge retentions leads to overtreatment and bleeding of creosote on one hand and makes the standard virtually impossible to achieve with waterborne preservatives on the other. In determining suitable assay retentions for the Canadian standard, one option would be simply to adopt those in AWPA C18 standard. While this may be appropriate for creosote, it appears that the 40 kg/m^3 of CCA specified in AWPA C18 is unnecessarily high for protection of wood in northerly waters. Retentions as low as 15 kg/m^3 have shown excellent performance over 14 years in Pacific waters and 8 years in Atlantic waters.

In a similar study, Ziobro and Baileys (1991) also reported on the performance of CCA-C- and creosote-treated coupons in service in northerly Atlantic waters near Long Island, New York, where both *Limnoria* and *Teredo* are active. Creosote retentions in test ranged from 136-268 kg/m^3 while CCA-C retentions ranged from 8-32 kg/m^3, similar to the retention range tested in our study. The results after 10 years in service showed that coupons treated with CCA-C to retentions of 16 kg/m^3, or higher, provided excellent resistance to marine borer attack, with only trace attack being observed on some test panels. Creosote-treated panels were also found to have performed well, but slightly more attack was found than on the CCA-C-treated panels at the retentions in test. The results were very similar to those found at the New Brunswick test sites after 8 years of service.

In evaluating the results of marine tests, it is important to note that use of small treated coupons is principally a method of assessing the relative performances of various preservatives when exposed to a marine environment. For example, the following retentions of waterborne preservatives have provided equivalent performance to 348 kg/m^3 of creosote over 14 years exposure in Pacific waters: 15 kg/m^3 CCA-C, 44 kg/m^3 ACA and 43 kg/m^3 modified ACA. Having made these comparisons, caution should be exercised when using these data to specify standard retentions. Results obtained by the test may underestimate the performance of piles and timbers when treated to equivalent retentions. This is because the large surface area to volume ratio of the coupons may tend to increase the leaching rates of the preservatives from the wood, thereby increasing the susceptibility of the coupons to borer attack. As an example of the conservative nature of the coupon test, the data from this test can be compared to data on marine piling.

Morris and Barford (1992) reported on a small-scale test of Douglas fir piling set up by the Pacific Biological Station. Since this test was set up 22.5 years ago it includes CCA types A and B rather than type C. Unfortunately no original preservative retention data could be located thus the only retention data available are the residual preservative retentions by analysis in the above-water sections of the piling. ACA-treated (residual 11.1 kg/m^3) and CCA-A-treated piling (residual 12.2 kg/m^3) were all still sound after 22.5 years exposure. Creosote-treated piling (residual 309 kg/m^3) showed minor signs of borer attack in some knots. CCA-B-treated piling (residual 19.2 kg/m^3), which had inadequate preservative penetration, had an average service life of about 20 years. In contrast untreated piling had a service life of one year.

The second major objective of this project was to compare the marine borer hazards in Atlantic and Pacific coastal waters. Based on the performance of untreated control coupons at the three test sites over the years, it would appear that there is a more severe marine borer hazard in the Pacific coastal waters. However, when comparing test results for some CCA-C- and ACA-treated coupons at all three sites, the marine borer hazard for treated wood at the West Vancouver and Shediac Bridge sites appears similar. Coupons treated with CCA-C to approximately 15 kg/m^3 and coupons treated to approximately 30 kg/m^3 with ACA are in service at all three test sites. After 96 months in service, CCA-C treated coupons were rated almost the same at both the Shediac Bridge and West Vancouver test sites (94 versus 92.9), indicating that a similar marine borer hazard exists at these two sites. Similar coupons at the Whitehead Island site were rated 99 after 91 months. For the ACA-treated material, all coupons at the 30 kg/m^3 level were rated as sound after approximately 48 months in service at all three sites, but considerably longer exposure times will be required before the comparative performances of this particular material at the various sites can be verified. There are no equivalent retentions of creosote in service at the eastern and western sites for comparison purposes.

To conclude, the results presented here could be critical in supporting the continued use of wood products in the marine environment. The use of creosoted wood by Public Works Canada seems to have been actively discouraged by the Department of Fisheries and Oceans. The data presented here show that waterborne preservatives can provide an effective alternative (provided that the necessary preservative penetration can be achieved). These data should also allow the CSA O80 committee to make the change from gauge to assay retentions with confidence that they will not have a detrimental effect on the performance of the treated wood. They should also be able to specify one retention for both east and west coasts eliminating unnecessary complexity and potential for confusion in the standard. Possibly the most important finding from this study is the excellent performance of CCA at retentions well below those specified by the AWPA standards.

Specifying a lower CCA retention for Canadian waters would have a three-fold effect: it would reduce the potential for loss of preservative to the environment, it would reduce the cost of the treated wood, making treated wood more competitive, and it would make the standard achievable. These moves should help to retain this market niche for wood products.

5.0 Conclusions

1. Based on results of 14 years of exposure, the waterborne preservatives in Pacific coastal waters may be ranked as follows: CCA-C (excellent); ACA and modified ACA (good); ACZA (fair); AZA (poor). This ranking is for a preservative retention range of 28-32 kg/m^3.

2. The following retentions of waterborne preservatives have provided equivalent performance to 348 kg/m^3 of creosote over 14 years exposure in Pacific waters: 15 kg/m^3 CCA-C, 44 kg/m^3 ACA and 43 kg/m^3 modified ACA.

3. At the Shediac Bridge site in New Brunswick CCA-C, ACA and creosote provided good protection at treatment levels at or just below the minimum values specified in the AWPA C18 standard after 8 years in service.

4. At Whitehead Island the marine borers appear to present a less severe hazard to CCA-C and ACA treated material, but a greater hazard to creosote treated samples, than at the Shediac Bridge site.

5. Retention levels specified in the Canadian Standard should not be lower in Atlantic waters than in Pacific waters.

6.0 Acknowlegements

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7.0 Literataure

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Table 1

Comparison of IUFRO and AWPA/ASTM Rating Scales

IUFRO Rating	AWPA/ASTM Rating*	Description
0	100	Sound, no surface deterioration or signs of tunnelling
1	90	Suspicion of tunnelling or slight surface attack
2	70	Moderate surface attack or clearly defined areas of tunnelling, but board generally sound
3	40	Heavy attack with well established areas of tunnelling, but board integrity maintained
4	0	Boards destroyed or missing at time of inspection or virtual complete loss of strength due to borer attack

* AWPA Standard M19-67. Standard Method of Evaluating Wood Preservatives for Marine Service by Means of Small Size Specimens.(Refers to ASTM Standard D2481-81: Standard Test Method for Accelerated Evaluation of Wood Preservatives for Marine Service by Means of Small Size Specimens)

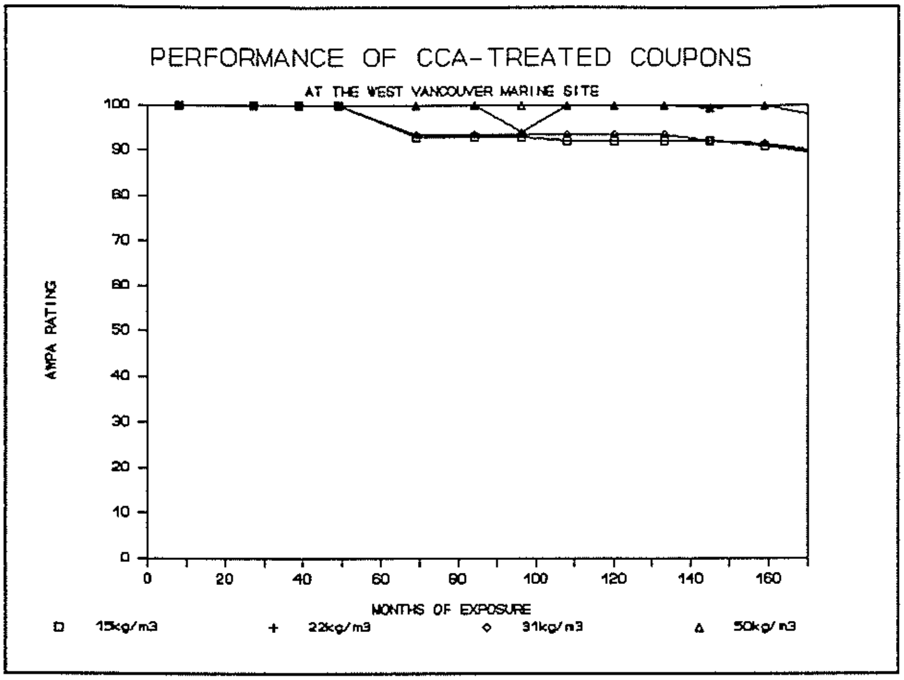


Figure 1

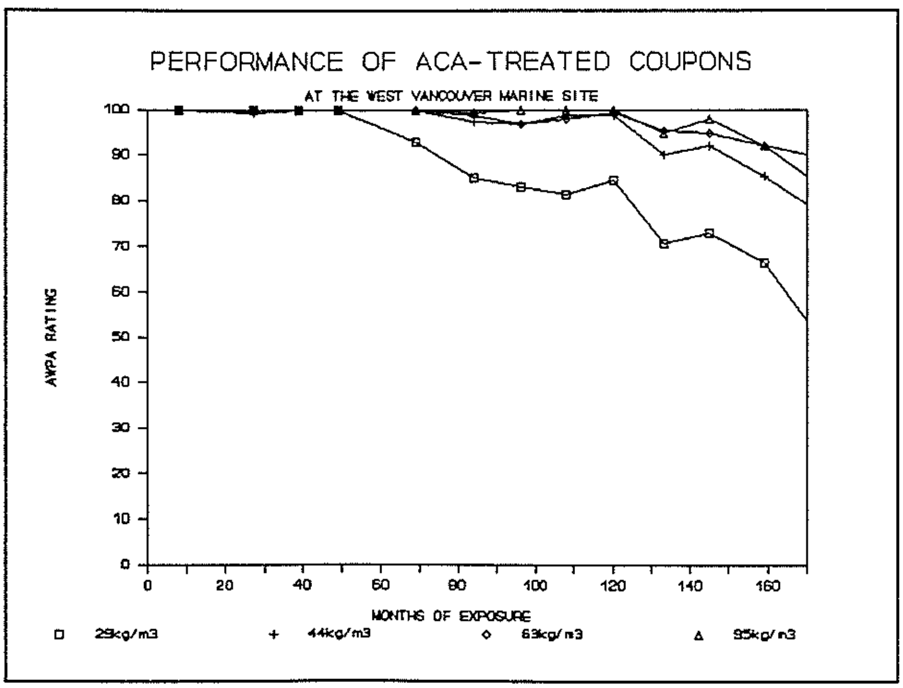
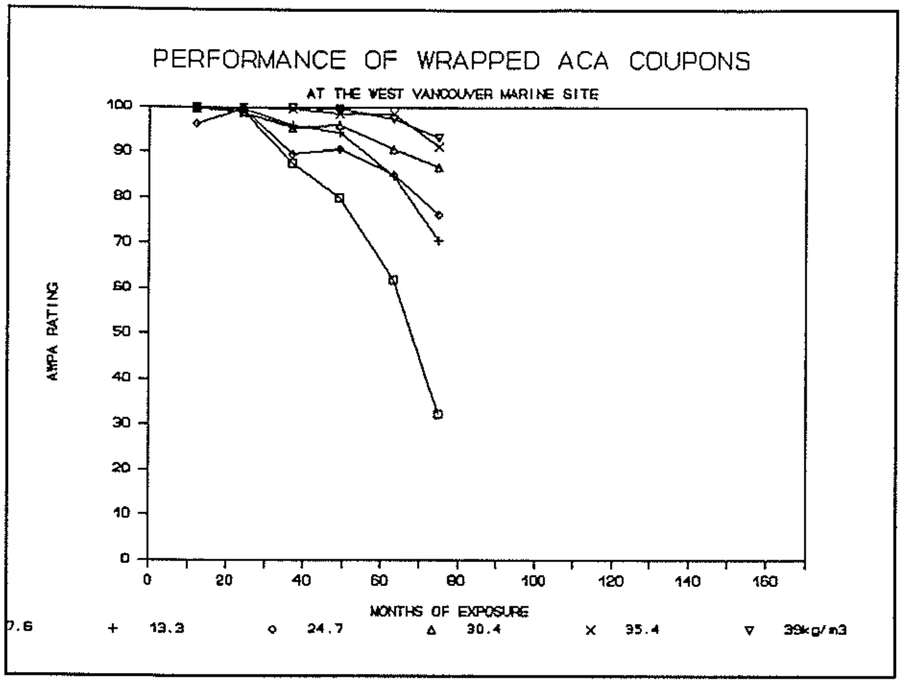


Figure 2



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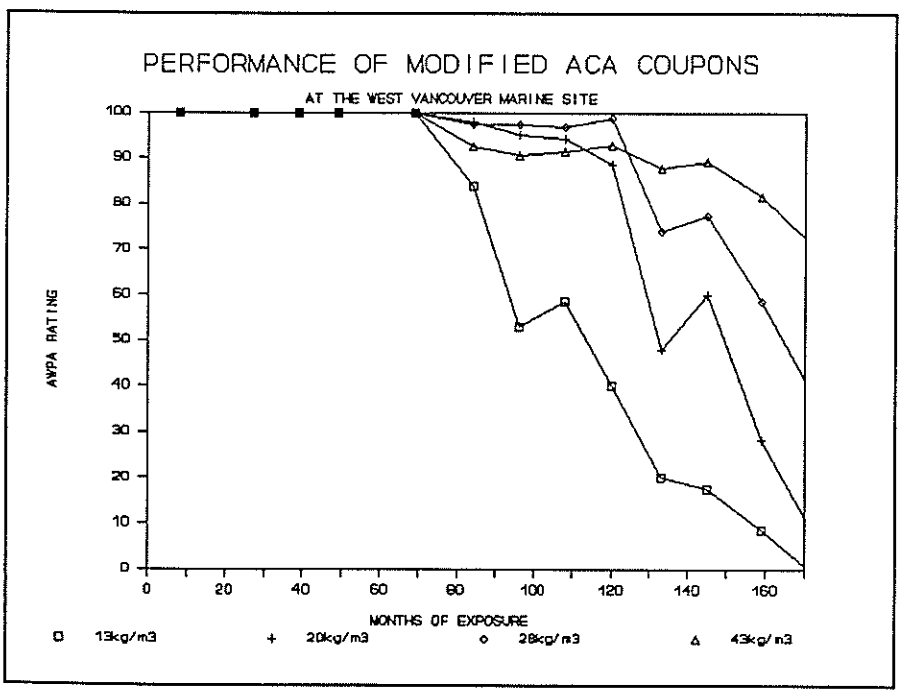

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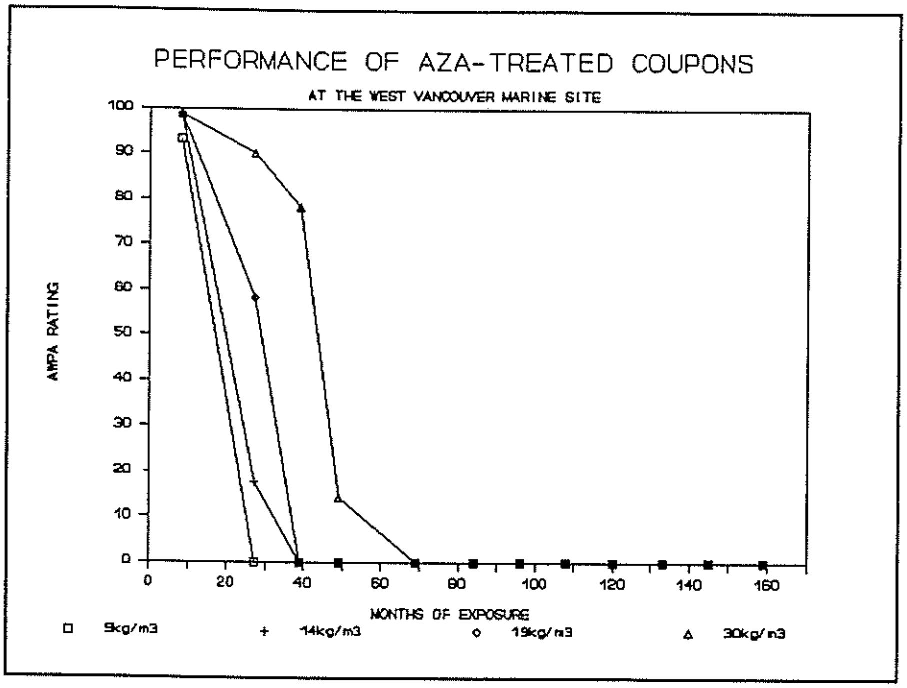

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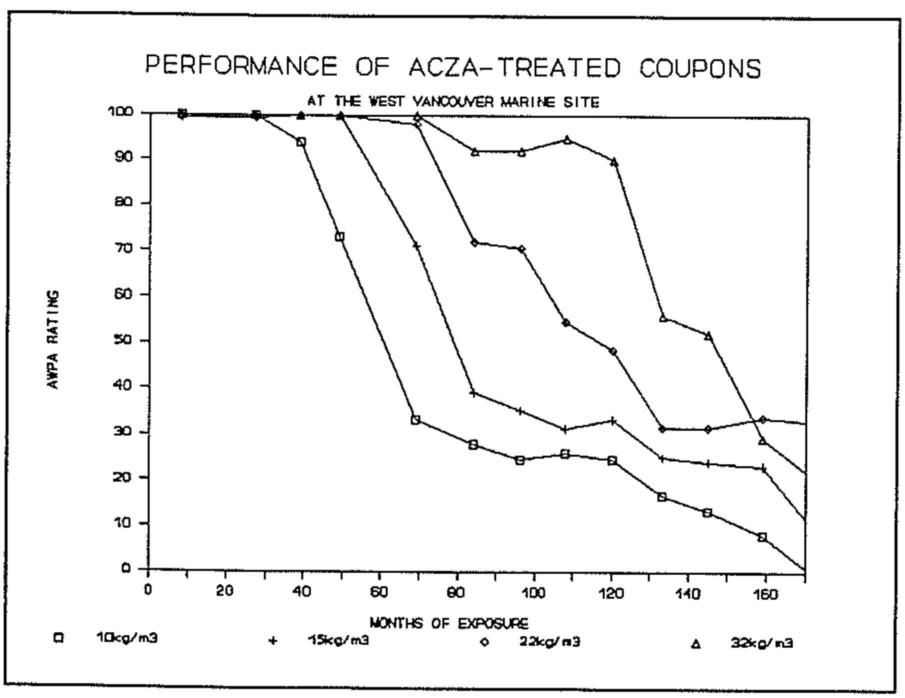

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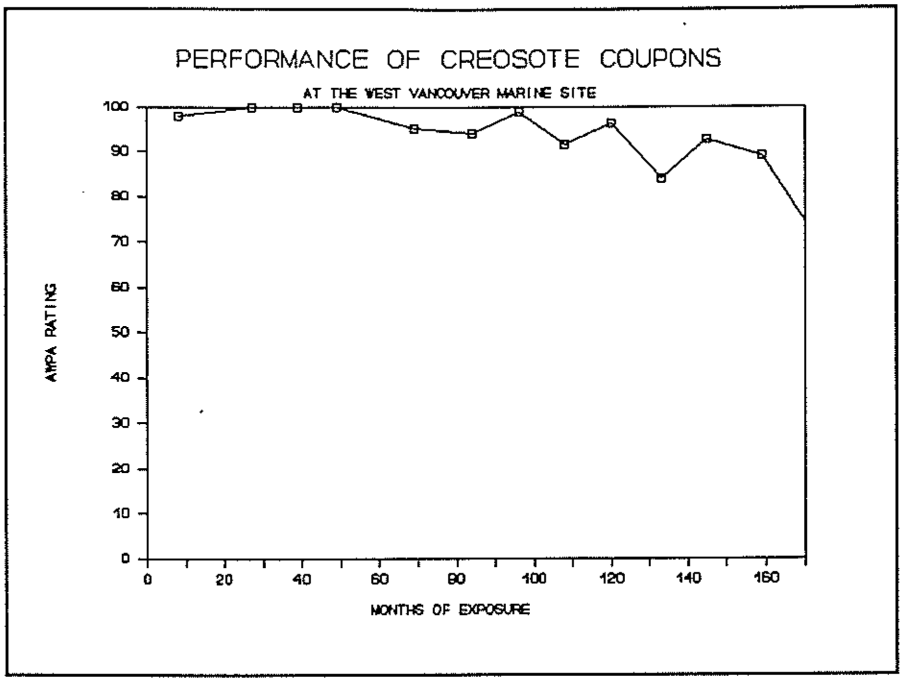

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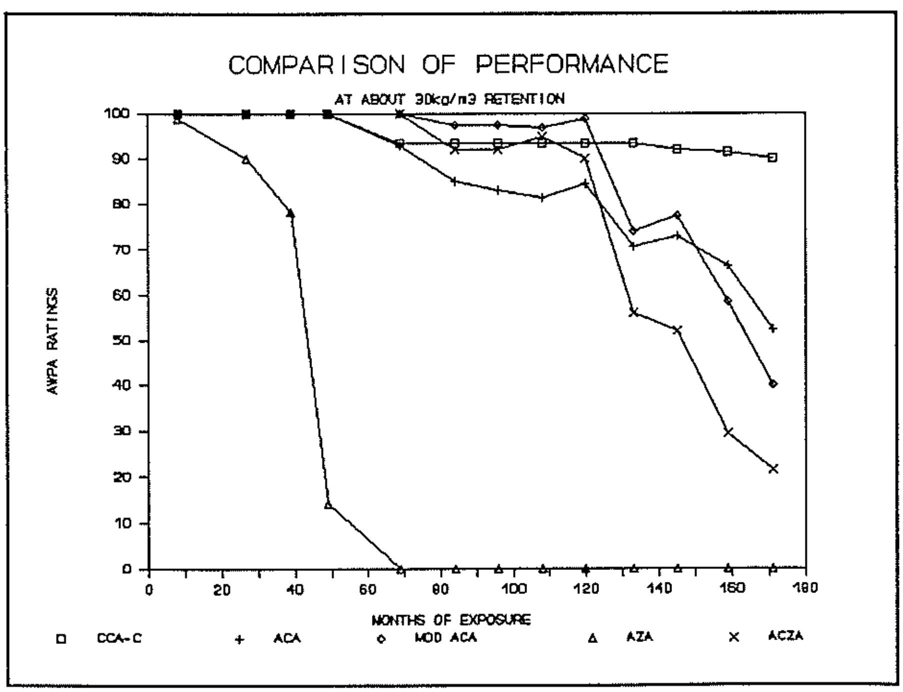

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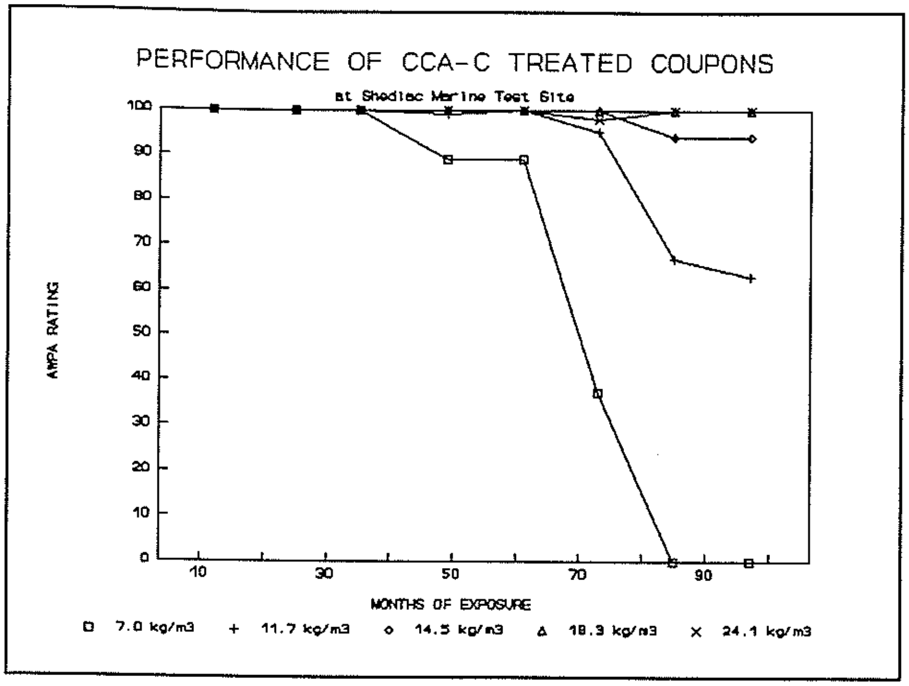

Figure 9

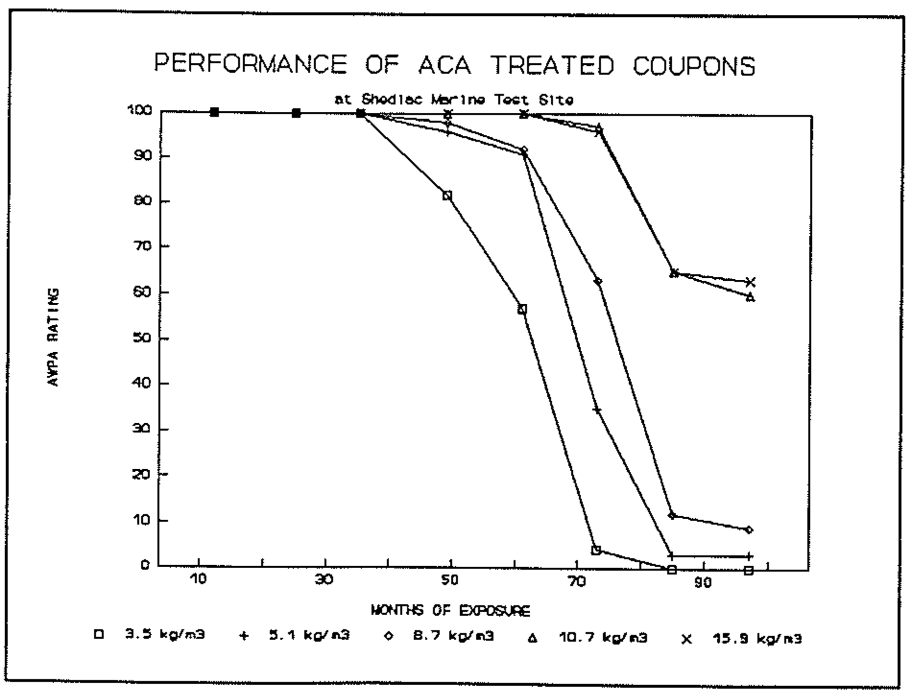

Figure 10

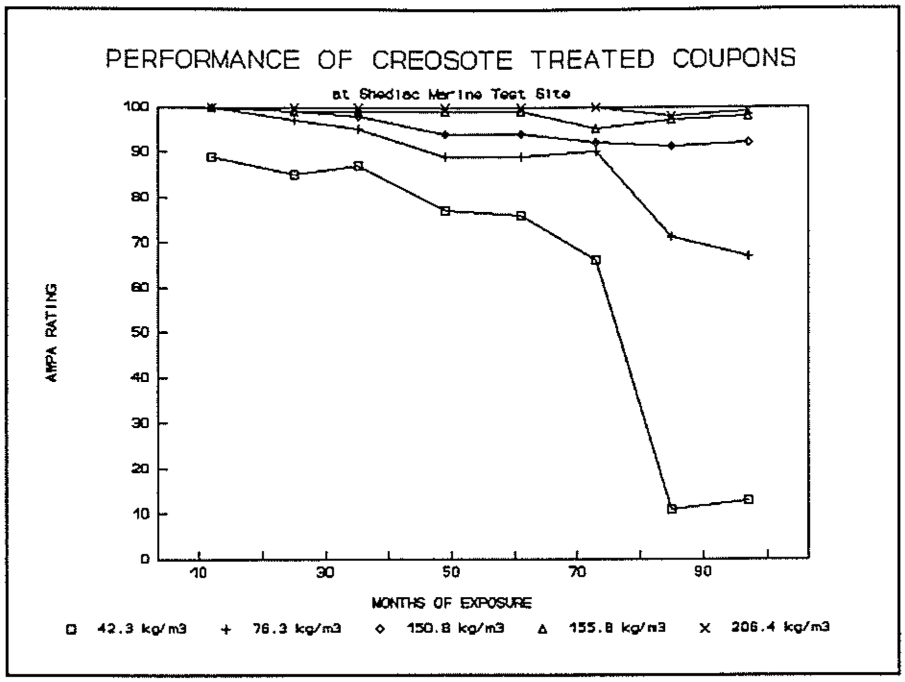

Figure 11

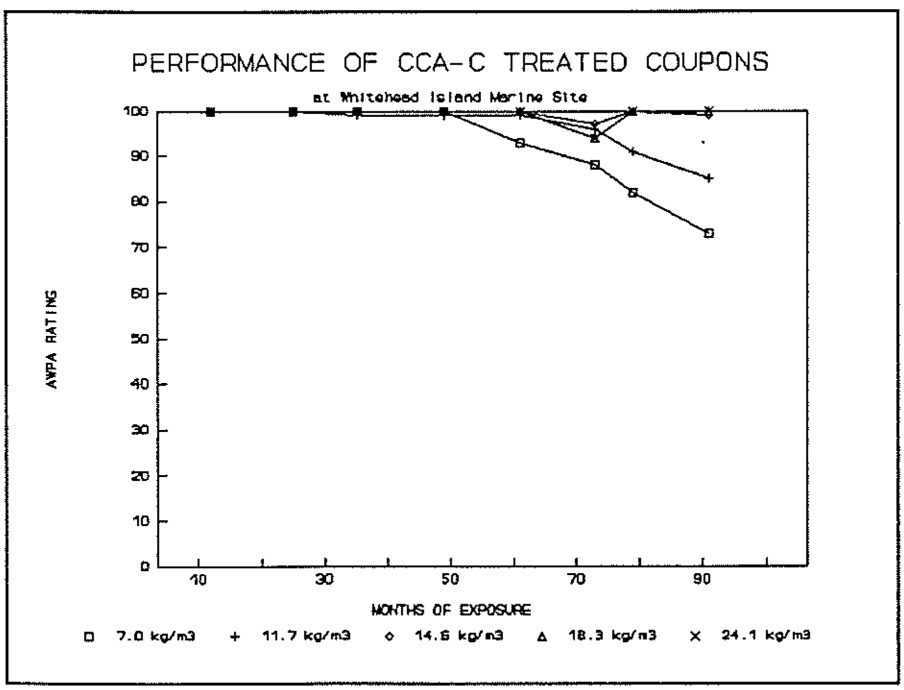

Figure 12

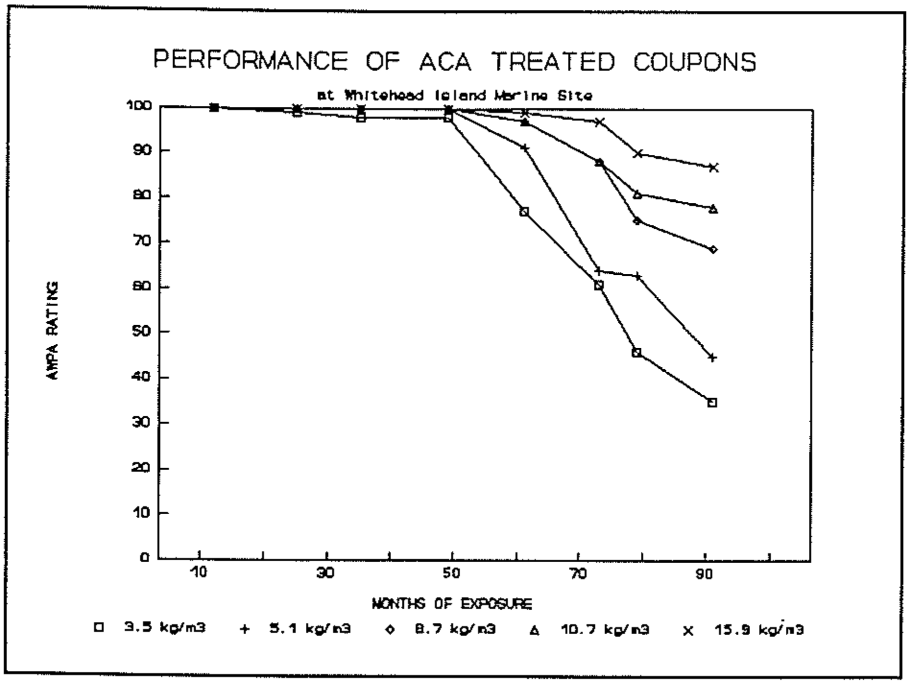

Figure 13

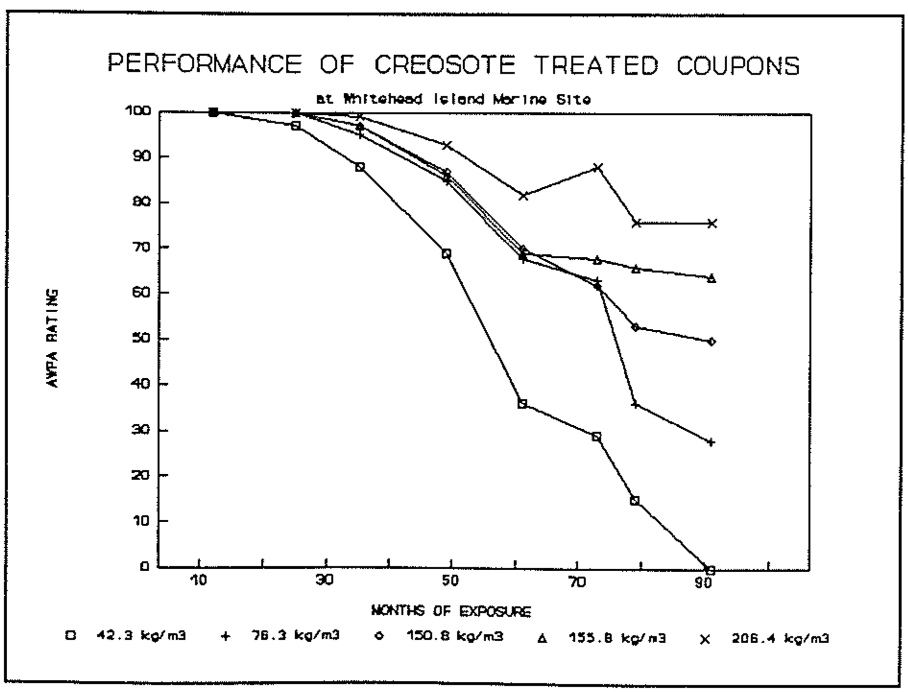

Figure 14