WOOD PRESERVATION AND THE ENVIRONMENT - A CANADIAN PERSPECTIVE

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ABSTRACT

The preservative treatment of wood impacts on the environment in four ways. These are: during the production of treated wood at the treating facility; during the storage of treated wood prior to use; when the pressure treated wood is placed in service; and finally, when the treated product reaches the end of its useful life and must be disposed. By reviewing current and past Canadian wood preserving practices, the impact of environmental concern on future directions for the wood preserving industry is identified. "Information gaps" are identified, which must be filled if the general public's perception of wood preservation as being beneficial to society is to be maintained.

KEYWORDS: Wood preservatives, leaching, CCA, pentacholorphenol, creosote, poles, acid rain, environment.

BACKGROUND

Wood preservation was introduced into Canada in 1906 when Canadian Pacific Railways imported creosote-treated railway ties for installation in a line at Virden, Manitoba. Construction of a treating plant in Manitoba for the production of ties quickly followed in 1911, and until the end of the second world war, this preservative dominated the industry being used for ties, piling, decking, poles, wooden paving, etc. During the late 1940's, pentachlorophenol was introduced on a commercial scale and rapidly gained a dominant position as the preservative of choice for utility poles. By 1970 these two preservatives retained the greater part of the treated wood market although some inorganic arsenical chemicals such as Fluor-Chrome-Arsenate-Phenol (FCAP) had also been used.

The introduction of fixed, multicomponent preservatives such as chromated-copper-arsenate (CCA) and ammoniacal copper arsenate (ACA) in the 1960's, and their general acceptance during the 1970's, heralded the beginning of a change in the preservative use pattern in Canada. A major impetus for the acceptance of the waterborne preservatives was their adoption by the Canadian Standard Association (CSA) as the only preservatives allowed for use in the Preserved Wood Foundation System (PWF). Thus, by the end of the 1970's, CCA in particular, had developed a substantial market share for the treatment of sawn dimensional lumber, and plywood, but in most other markets, pentachlorophenol or creosote still dominated.

The last decade has seen a quite remarkable change in the use-pattern of the four preservatives. ACA has almost disappeared from use in Canada, the reasons for which are unclear. It may be associated with leaching of arsenic from the original formulation which was based upon a copper to arsenic ratio of 1:1 (expressed on an oxide basis). Alternatively, the appearance of ACA-treated wood which is markedly 'harsher' and less 'uniform' than that of CCA-treated wood, may have rendered it less acceptable than CCA for the markets which have come to dominate the industry today. The introduction and acceptance of CCA-treated dimensional lumber for the "Do-It-Yourself" (D.I.Y.) market has shown almost "explosive" growth both in Canada and the U.S. Recent data from the American Wood Preservers Association (table 1) shows that in 1987, the volume of CCA-treated lumber (9 million m^3) accounted for 75 % of the 11.9 million m^3 of CCA-treated wood, or 55 % of all treated wood produced. Almost 97% of the sawnwood was treated with CCA.

Unfortunately comparable data is not available in Canada. Never the less Statistics Canada data has shown that the value of treated wood produced in Canada has grown from $150.2 million in 1983 to $250 million in 1986 (the latest data available). It is worth noting, that during the same period the value added to the products produced only increased from ca. $65 million to almost $74 million. Reasons for this disparity include, gradually increasing material costs (lumber and chemicals) which have eroded to some extent the profit margin, and the reduction in the number of poles produced as utilities reduced inventory. The latter is particularly important as poles remain the single most valuable commodity treated, and the profit margin on lumber for the D.I.Y. market will be much smaller.

WOOD PRESERVATION AND ITS ENVIRONMENTAL IMPACT.

a) At the treating plant.

When assessing the environmental impact of wood preservation, consideration of the trends in treated wood production is useful in two ways. Firstly, it provides a direct indication of the growth of individual preservative use, and secondly it highlights changes in product-preservative combinations being placed in service. For example, the rapid growth in the use of treated wood has principally benefited the CCA-industrial sector. Most of these plants are less than twenty years old, are generally equipped with modern storage facilities, (including tank farms to collect spillage), are computer controlled with alarms to alert the operator when problems arise, and often use fixed solution transfer lines to ensure minimum worker exposure during transfer of chemical at time of delivery by tanker or railcar. The use of roofed structures to protect the treating facility, and provide covered storage minimizes problems associated with rainwater, small amounts of which are easily utilized during make up of the treating solution.

This situation with waterborne preservation treating plants may be contrasted with most of the creosote and oilborne facilities which generally are older, have less sophisticated operational controls, and where plant operators must frequently must pay close attention to prevent dripping of preservative solution from the treated product during storage in the yard. The use of Boultonizing as a conditioning process has been practiced in Canada, and requires the capability to remove phenols from water prior to discharge. Worker exposure during the preparation of the treating solution *may* also be greater than in CCA-treating plants. For example, it is traditional for pentachlorophenol to be shipped in drums or bags in solid form as flakes, or pellets. This must then be unloaded and transferred (often manually) to be dissolved in oil. Disposal of the empty drums must also be considered.

It is possible to upgrade oilborne facilities so that potential for worker exposure and ground contamination are no greater than those at a CCA treating plant. However, given the trends shown in table 1, this is unlikely to occur, as the market share for these oilborne systems in clearly diminishing, with no reason to suggest that this trend will alter. Indeed it is likely to accelerate. The reason for this, is the increasing acceptance of CCA for the treatment of utility poles. In 1955 creosote and pentachlorophenol dominated the pole market, (table 2). In 1970 CCA and ACA - treated poles began to become accepted, and by 1980 almost 0.2 million cubic metres of CCA/ACA-treated poles were produced. However, even in 1987 the volume of poles treated with arsenical preservatives (0.4 million m^3) remained considerably less than that impregnated with pentachlorophenol (1.2 million m^3). This pattern illustrated by the AWPA data, mirrors the trends in Canada, where in Western Canada, CCA treatment has only become accepted for poles during the past 1-2 years. However, in the summer of 1990, B.C. Hydro placed a moratorium on the purchase of pentacholorphenol treated poles and will now purchase CCA-treated poles instead. In Eastern Canada, two of the larger utility companies, Ontario Hydro and Quebec Hydro, still accept only a limited quantity of CCA-treated poles, although this year each will take approximately 10 to 15% for evaluation. Other utilities in Alberta and the Maritimes are evaluating copper naphthenate as an alternative treatment to pentacholorphenol. Climbability remains a key issue preventing a more general acceptance in Eastern Canada, where pine poles dominate the industry.

Reviewing these changing trends in preservative use, it is clear that potential for both worker exposure to preservative and ground contamination are greater with the oilborne treatments. However, the differences in potential for ground contamination at either the treating plant or during product storage may not be so readily identified. The reasons for this include the observation that the volume of oilborne treated products is decreasing, whereas that of the CCA is clearly increasing. In addition, economic forces have lead to utility companies severely reducing their inventory in storage, as was traditionally practiced, so that the risk of ground contamination by PCP at the treating plant site, is also reduced. Conversely the CCA-treated lumber market was designed to minimize storage of the product. In addition one of the major products, the lumber and plywood for the PWF market, must be kiln dried prior to shipment from the plant, which should ensuring fixation of the chemical. Even with such a process, care must be taken to ensure that the conditions in the kiln or fixation chamber are appropriate to fix the chemical. If the wet bulb temperature is set at too low a level, so that the surface equilibrium moisture content falls below

10 percent, unfixed chromium can occur on the surface of the treated lumber. Similarly, *if fixation of the product is achieved by conventional storage, then it must be recognised that under the normal autumn or winter temperatures, complete fixation may take several weeks* (Avramidis and Ruddick, 1989).

Never the less, it is only recently that the need for post treatment fixation of CCA has become considered an integral part of the treating process and until it becomes mandatory in all CCA treating plants the potential for ground contamination in the storage area will exist. Given the production volumes of this product, this observation should cause concern to the industry and measures should be taken to implement post-treatment procedures voluntarily.

The recently released "Recommendations for the Design and Operation of Wood Preservation Facilities" provide a good framework for responding to many issues related to prevention of environmental impact at the treating plant, although some updating relating to the post-treatment fixation of CCA-treated wood is desirable. How much chemical has entered the environment, particularly at old creosote and PCP treating plants, is impossible to estimate. Clearly, a strategy needs to be developed to identify the magnitude of this problem, and also for its solution. Given the cost of such an undertaking, this may require the development of Federal and Provincial Funding Initiatives, similar to those initiated in the U.S.

One area which has attracted considerable attention in British Columbia, is the question of "water run-off" from storage yards of sawmills. The primary concern is the leaching of chemicals from lumber treated with antistain chemical, by the action of rain. Since many of the sawmills are located adjacent to waterways, there is concern over possible contamination of the water, many of which are migratory routes for salmon. Two methods of overcoming the problem that have been suggested, are to provide roofed storage for all lumber in storage at sawmills or to use kiln drying. However, such measures are not likely to be cost competitive with chemical treatment. Research is now in progress to identify alternative chemicals to those now in use, which would not only protect the wood from fungal deterioration, but would be rapidly fixed to the wood surface.

b) Loss of chemical from products in service.

A second major area where there can be potential interaction between wood preservation and the environment, is when the product is placed in service. Once in service and exposed to biological and physical stresses, preservatives may be subject to volatilization into the air or leaching into the surrounding soil or water.

It has long been known that oilborne preservatives are not fixed to the wood, and are subject to movement due to gravitational forces and evaporation of the carrier solvent. Thus it has been proposed that creosote or pentachlorophenol migrate down utility poles and into the surrounding ground. Research on jack pine and red pine poles (Ruddick et. al. 1988 and Ruddick and Lum, 1989) has suggested that pentachlorophenol-treated pine poles lose over 100 kg/m^3 of oil, from the outer 20 mm to the environment, during thirty five years of service. Similarly, the amount of pentachlorophenol is lowered during exposure from almost 30 kg/m^3 in the outer 10 mm in red pine poles to less than 1 kg/m^3 after thirty years (Figure 1). Losses at greater depths from the pole surface are lower, but still significant.

After only ca. 15 years of service, pentachlorophenol profiles in poles removed from service did not show any significant trend in preservative content from the top of the pole to the ground line, but were markedly lower than those in freshly treated poles. This would suggest that any gravitational effect on the pentachlorophenol and oil must be completed during the first 15 years of service or that such effects are not large. The ground line retention in all assay zones was greater than that above the ground. This could be explained in older poles by the application of groundline remedial treatments. In poles which have only been in service a few years, this is more likely associated with the practice of ground-line incising of poles to enhance the preservative content in the part of the pole at greatest risk from decay. While leaching into the ground probably occurs, this recent data suggests that depletion of pentachlorophenol from the pole surface is very important and may be a dominant factor for the above ground portion of the pole.

When considering the impact of these observations on the preservative interaction with the environment, the future for preservatives such as creosote or pentachlorophenol in oil, does not look promising. The reason for this is that the *uncontrolled loss* of relatively large amounts of chemical into the environment is going to be unacceptable, no matter how innocuous the chemical is claimed to be.

The initial reaction with respect to waterborne preservatives such as CCA and ACA isthat they would appear to be under less pressure with regard to the question of leaching. However, here too, concern has been expressed about the depletion of even small amounts of unfixed chromium, copper or arsenic. The introduction of post-treatment fixation processes will eliminate the concern over the leaching of chromium and will minimize losses of coppper and arsenic. . Studies conducted on leaching of CCA from children's playground equipment have shown that the amounts leached are small (Henningsson and Carlson, 1984), and movement in all but sandy soils is very limited due to interaction with the soil components. Consequently, the contribution to the soil chemical levels is difficult to distinguish from background concentrations.

More recently, concern has been expressed about the behaviour of CCA-treated wood when subjected to acid rain environments. Canadian studies reported recently are misleading due to inappropriate test procedures. The use of citric acid, a known copper scavenger, produced severe losses of copper from the treated wood, which is hardly surprising. The results are not in agreement with field observations which showed that after *several decades* in service in southern Ontario, (a region of Canada where acid rain is considered to be a problem) CCA-treated poles retained almost all of their original preservative (table 3), showing only small losses of arsenic and copper, (Jonsson, Nilsson, and

Ruddick, 1989). Clearly, care is needed when attempting to accelerate natural phenomena in the laboratory. These observations are consistent with laboratory studies undertaken by Willeitner and Illner (1986) which indicated no influence of solution pH down to 4.5, on the leaching of chemicals from chromated-copper-borate. After 14 days of fixation in the laboratory at room temperature less than 5 ppm of copper or chromium were measure. It is also worth noting, that the natural pH of softwoods ranges from 3 to 6.

It is known that the action of acids on wood proceeds rapidly initially, during which the hydrolytic scission of the beta-glycosidic linkage is focussed on the amorphous regions of the cell wall. When this disappears the hydrolysis slows markedly. Recently it has been reported by Cooper (1989) that when CCA-treated wood samples were exposed to limited volumes of unbuffered acidic solution the pH of the solution rapidly increased to approximately 6, indicating that the wood has a capacity for changing its microclimate. This observation may invalidate previous leaching studies on unbuffered solutions.

Other research (Henry and Jeroski, 1967) has shown that some formulations of CCA can lose significant quantities of chemical. They suggested that the ratio of arsenic (as As_2O_5) should not be more than 66 percent of the chromium content (as CrO_3), in order to prevent leaching. Based upon this information, one can predict that CCA-type B (which contains more arsenic than chromium), will lose arsenic to the environment. Similarly, CCA-type A would appear to lose chromium when exposed to leaching conditions. While more research is needed on the influence of formulation of CCA, on performance, leachability, fixation mechanism and factors effecting both its rate and path, the question remains as to whether the industry should move voluntarily to eliminate the type A and B formulations from the standards,and identify only the best formulation with respect to minimum leaching?.

A similar comment can be made with respect to ACA, which has been shown to lose significant amounts of arsenic (Rak, 1976; and Ruddick and Minchin, 1986). More balanced formulations containing a higher copper content are now used in the U.S. Should the formulations approved in the standards be modified to eliminate the use of the old formulation which contained equal amounts of copper and arsenic (expressed on an oxide basis)?.

c) Disposal of treated waste.

Perhaps one of the most important areas of change has been in the disposal of treated wood waste. This may be divided into two sub-topics. In the first the focus is on the disposal of waste generated when treated wood products are placed in service. Traditionally this has not been particularly important, since the two products with large volume patterns, namely railway ties and poles or piling, are usually machined to final length, and preframed with appropriate holes, notches etc., so that machining of the treated wood on-site is minimal. The pattern use of CCA and ACA-treated lumber and plywood for the PWF system and CCA-treated lumber for "Do-It-Yourself" project is, however quite the reverse. Here, almost all of the product is sold for adaptation by the end-user for the particular job at hand, and much will be cut to the required length, or bored, both of which will produce waste material. Individual home owners are unlikely to generate sufficiently large volumes of treated wood, that disposal with conventional garbage is a concern. However, the accumulative effect of the large volume being disposed could eventually produce problems, and given the willingness of the general public to consider selective disposal systems it may be possible to develop a "blue box" for treated wood-waste. Such a system would clearly be beneficial for large volume users of CCA-treated sawn wood, for example in a condominium complex, where the volume of treated wood being disposed is concentrated in one locality. This approach has further merit when one considers recent knowledge of how slow even the biodegradation of paper is, in landfill sites.

Perhaps greater concern is being expressed over the disposal of treated material removed from service. Here the changes in the use pattern are valuable in identifying the problems likely to be encountered. Creosote has a long history of use, but one of the principal products, railway ties has a relatively short life, 15 to 30 years dependant upon the traffic conditions. Thus much of the old material has already been disposed. Changing trends have resulted in more concrete ties being used and future tie removals are likely to continue falling from the current estimated levels of slightly more than 3 million ties annually. The creosote content of removed ties has been suggested to be about 55 kg/m^3, for red oak, so that considerable quantities of creosote are available at the time of disposal. General methods of disposal include incineration, burial, and reuse as landscape material. Clearly all three have potential to impact on the environment.

Pentachlorophenol has been used for the last forty years to protect poles. Based on an anticipated minimum life of thirty five years, it is obvious that the problem of the disposal of pentachlorophenol-treated wood is now looming as a major concern in Canada. Recent research (Ruddick, 1989) has suggested that pentachlorophenol-treated poles in Canada lose most of the pentachlorophenol during the thirty to forty years of service, so that in the outer 10 and 20 mm approximately 1 kg remains. Remedial ground line treatment may result in a slightly higher retention found in this region in the outer 30 mm of the removed poles. The analysis of these poles also showed that a class 3, 9.5m long jack pine pole could contain 160 g of pentachlorophenol after 40 years of service, whereas a similar red pine pole after 30 years contains considerably more chemical, ca. 2.25 kg (Figure 2). Although this difference could be accounted for mainly by the differences in preservative penetration in the two species, surface retentions were also higher in the red pine poles.

Pentachlorophenol-treated ties are used by some railway companies, although their method of disposal is not clear. The potential for confusion of the pentachlorophenol and creosote-treated ties presumably exists, and some ties may end up as landscape material. At the present time, the concern (or fear) of the general public over dioxins has resulted in the unwillingness of communities to allow incineration of pentachlorophenol-treated waste in their area. As more concerns are expressed about the problems associated with landfill sites, this avenue is also likely to be closed. Some progress has been made with the encapsulation of the chemical in concrete, with one method recently being granted the status of Best Available Technology for dealing with First Third Wastes by the Environmental Agency in the U.S. Research on alternative strategies both chemical and biological is also being avidly pursued in various countries.

Even CCA-treated wood is not free of this problem. Granted the problem is unlikely to loom large with respect to the disposal of wood removed from service, for some time. The disposal of waste generated at the treating plants in Canada is still not resolved, although good housekeeping practices tend to minimize it. Eventually however, all the wood being place into service, will one day be removed/replaced, if only because of architectural considerations. How will it be disposed?.

Equally interesting, is the question of what service life is desired in a treated product?. Which is more acceptable, a treated product which can last 50 years but which is not easily disposed at the end of its life, or one which lasts only 20 years, but which can be incinerated without production of harmful products?. Even within the domain of existing preservatives, questions of chemical content need to be addressed. Could reduction in the levels of preservative retention be accomplished with an acceptable reduction in the product service life?.

This question of the disposal of treated waste, is I believe a key to the continued well being of the industry. **I would propose that serious consideration be given to the concept of "closing the loop", ie. removal of the chemical from the treated product and the reuse of this chemical in some way.** The wood fibre would also be available for possible reuse. The concept of combining a non-renewable resource (chemical) with the renewable resource (the wood) in a way in which they do not impact negatively on the environment (through leaching, or evaporation), to produce a product which at the end of its useful life is removed to recover and reuse the chemical, and reuse or recylce the wood, is a powerful one, (Figure 3). Such a strategy I believe is the only effective way of responding to the concerns of environmental groups, in that it keeps the chemicals where they should be, in use, and not left to build up in our waterways, land or air. When viewed in this way, the problem of dealing with waste treated wood becomes an industrial opportunity. The demonstration by the industry that it cares over the long term availability of the chemicals and the maximum value of the wood fibre resource, will help maintain and in some cases restore confidence in the value of wood preservation as a major benefactor in conserving our resource.

It is worth remembering that of all structural building materials, few can undergo true recycling - that is regeneration of the components at the molecular level, to reproduce the basaic material, just as it was before. True, this is also possible for a few other materials, like glass and steel. However, wood is the only material for which this regeneration (or recylcling) is possible without a vast input of man-made energy, and which can provide at the same time not only pleasure and beauty, but also a home for wildlife. What is more, it is the only basic building material that we can actually increase the available volume. (This can be achieved through careful replanting and management of our forests.) **For wood is alive and the limitations that we see only reflect our lack of vision.**

CONCLUSION

The impact of wood preservatives on the environment is of critical importance, and must be adequately addressed. Concerns by the general public with respect to contamination of the environment, whether it be at the treating plant or during disposal of the product at the end of its useful life, need to be responded to, and eliminated. Uncontrolled losses of chemical to the environment will no longer be tolerated. A more comprehensive data base on current and future preservatives needs to be identified which would include such aspects as environmental fate, leaching, etc.

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TABLE 1

VOLUME OF TREATED WOOD PRODUCED IN THE U.S.A.*

Year	Creosote	Pentachlorophenol	CCA/ACA	Total
	...............million cubic meters..............			
1955	5.7	0.8	-	7.0
1960	4.0	1.4	-	6.1
1970	4.5	2.0	0.5	7.4
1980	4.0	1.75	3.3	9.4
1987	2.8	1.4	11.9	16.3

* Micklewright (1989)

TABLE 2

VOLUME OF POLES TREATED WITH EACH PRESERVATIVE.*

Year	Creosote	Pentachlorophenol	CCA/ACA
	..........million cubic meters............		
1955	1.6	0.5	-
1960	1.2	0.9	-
1970	0.9	1.2	0.05
1980	0.4	1.2	0.2
1987	0.5	1.2	0.4

* Micklewright (1989)

TABLE 3

SUMMARISED CCA RETENTIONS FOR JACK PINE POLES DURING SERVICE.

Age Year	Section	Retention CrO_3	Retention CuO	Retention As_2O_5
		....	kg/m^3	....
1.4	A	6.28	3.17	7.26
9.5	A	6.25	2.67	6.12
37.2	A	6.19	2.39	2.52
1.4	B	3.85	2.77	6.08
9.5	B	2.90	2.10	4.32
37.2	B	2.51	1.45	1.54
1.4	C	3.25	2.43	5.41
9.5	C	2.51	2.23	4.84
37.2	C	1.90	1.10	1.20
		....	Percent	....
1.4	A	37.0	19.2	43.9
9.5	A	42.4	17.5	40.0
37.2	A	55.2	21.8	23.1
1.4	B	29.9	21.8	48.2
9.5	B	31.3	23.2	45.5
37.2	B	46.0	26.3	27.8
1.4	C	29.1	22.2	48.7
9.5	C	26.6	23.3	50.2
37.2	C	43.4	27.0	29.6

NOTE: Data for 1.4 and 9.5 average years are for CCA type C while that for 37.2 average years is for CCA type A.

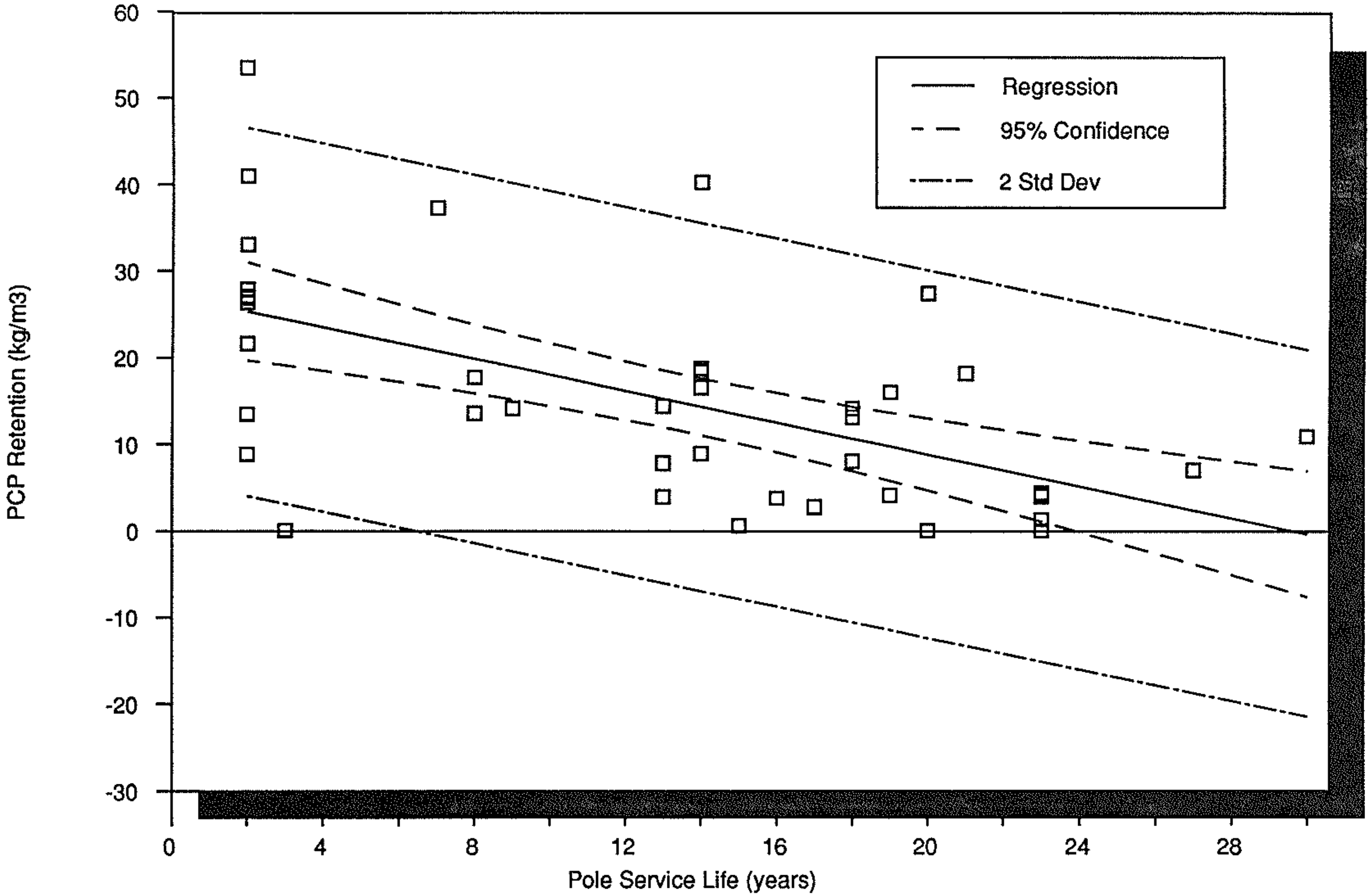

Figure 1. Red Pine Retentions at 0-10 mm

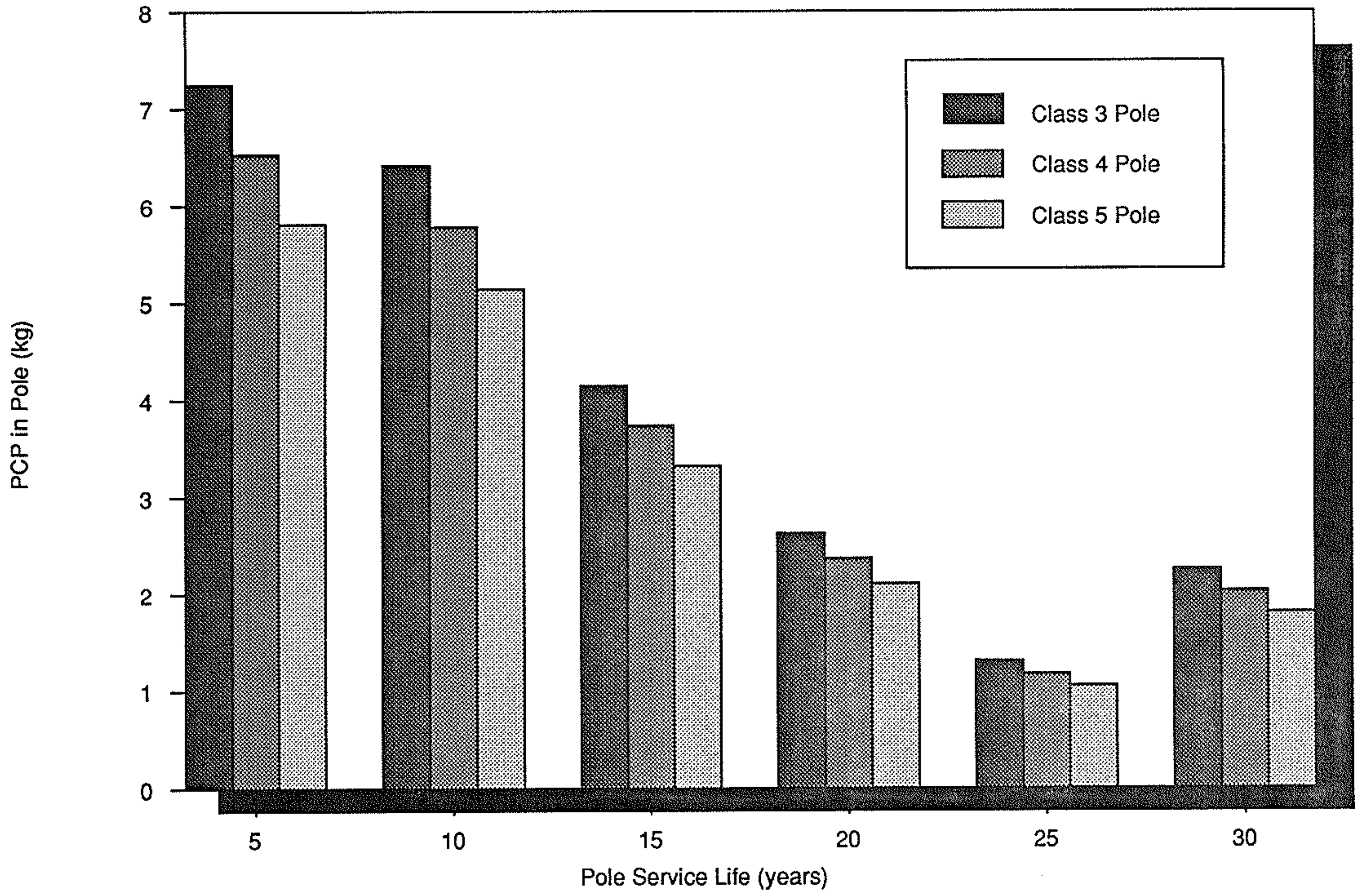

Figure 2. Amount of PCP in 9.5 m
Red Pine Poles

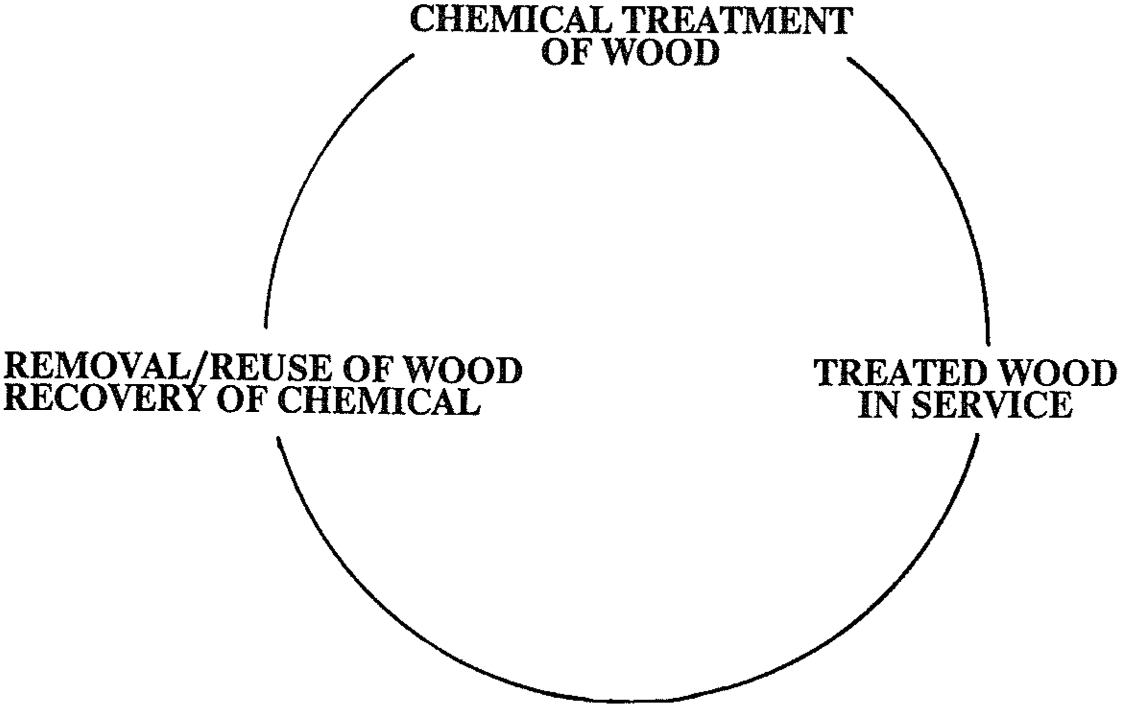

Figure 3. Schematic diagram showing how chemical and wood are combined to provide a beneficial product, which when it reaches the end of its useful life is removed from service and the chemical recovered for reuse while the wood is either reused or returned to the environment.