FEASIBILITY OF RECYCLING SPENT CCA TREATED WOOD IN WOOD/ CEMENT COMPOSITES

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Summary

Large volumes of CCA treated wood, mainly residential construction, are expected to be removed from service in the next few decades. Wood/cement composites have potential as products that could use recycled spent CCA treated wood in their manufacture. CCA treated wood is more compatible with Portland cement than untreated wood which could result in products with improved physical and mechanical properties and better resistance to biological deterioration. The leaching characteristics of chromated copper arsenate (CCA) treated wood particles and treated wood-cement composites were compared using a modified AWPA E11-87 procedure. CCA treated wood particles in a wood-cement composite had arsenic leaching losses virtually eliminated. Copper leaching was greatly reduced relative to losses of equivalent amounts of treated wood in particle form, while chromium leaching rates were not consistently affected by cement encapsulation. The amount of component leached increased with decreased particle size for both cement encapsulated and un-encapsulated particles. Exposure of cut ends of the wood cement composite to the leaching medium did not have a consistent effect on component losses. Follow up leaching tests over an extended period of 12 weeks confirmed the high degree of stabilization of the arsenic and copper components of the treated wood encapsulated in wood cement composites.

1. Introduction

Chromated copper arsenate (CCA) has been a commercial wood preservative treatment for more than 50 years, but it has been only in the past 20 years that its usage has grown dramatically (Cooper and Ung 1989, Stephens *et al* 1996). As a result, the quantities of "spent" or out-of-service CCA treated wood generated each year is relatively low at this time, but it is anticipated that as an equilibrium is established between the amounts of treated wood installed and the amounts removed that significant levels of CCA treated wood will be taken out of service within the next few decades. Of this wood, a high proportion will be residential construction from decks, fences and retaining walls. Estimates of the volumes of different products that may become available each year in Canada (Stephens *et al* 1996) are shown in Figure 1. At this time, viable options for dealing with spent CCA wood are:

REUSE

Damaged poles, posts and piling have some reuse potential for retaining walls and other landscaping timbers and for re-manufactured products such as lumber and timbers. A consortium of treated wood treaters and users and a cement kiln operator are investigating the feasibility of re-sawing poles (all treatments) and using the slabs, sawdust and other waste as fuel in a cement kiln (Millette and Auger, 1997). However, the potential for reuse of CCA treated residential construction wastes is limited, because of the difficulties in collecting and transporting this material, the relatively small size of individual components and the fact that it is contaminated with nails and other fasteners and finishes.

LANDFILLING

At this time, the leaching characteristics of spent CCA treated wood, as defined by the "Leachate extraction Procedure" in Canada and the "Toxicity Characteristic Leaching Procedure" in the USA allow disposal of the wood in landfills. However, individual municipalities may restrict landfilling of this material because of the bulkiness of the wood and perceptions about potential environmental impacts.

INCINERATION

Cement kilns can tolerate some copper, chromium and arsenate in the clinker produced in the lime roasting kilns so there is a potential to recover energy from some spent CCA treated wood in these facilities as discussed above.

RECYCLING IN COMPOSITES

While not yet commercially viable, several investigators have investigated the feasibility of using spent CCA treated wood in wood composite products such as particle board and flake board (e.g., Plackett *et al*, 1995). The treated wood does not create significant problems in bonding the particles and the treated wood does impart additional decay and insect resistance.

There is a need to investigate other potential options for recycling of spent CCA treated wood in a way that takes advantage of the properties of the material, such as residual decay resistance and the physical and mechanical properties of the material.

One potential product is wood/cement composites. The world wide consumption of wood cement composites is huge in recognition of improved weight and insulating properties relative to concrete and better decay, insect and fire resistance compared to wood products. In 1988, world use of these products was 1.1 million m^3 compared to, for example, 1.5 million m^3 for flake board in the USA in 1992 (Felton 1997). Most of this usage is outside of North America, but there is increasing demand here for roofing products, sound barriers and siding products that are made from wood and cement.

In an earlier study (Schmidt *et al* 1994) it was shown that wood treated with CCA-C or with chromic acid and "fixed" to reduce all chromium to the trivalent state had a greater compatibility with Portland cement than untreated wood (Figures 2-4). This resulted in composites with significantly higher bending and compression strengths compared to conventional wood-cement composites (Figures 5 and 6). This observation opens the possibility of recycling waste CCA treated wood removed from service in wood-cement composites for such exterior products as highway sound barriers, simulated clay roof tiles and wall cladding.

However, a concern with such applications is that the comminuted treated wood might have a greater tendency to leach copper chromium and arsenic contaminants both in service and at the point of ultimate disposal of the material. Hsu (1994) incorporated CCA treated wood that had been in service for several years into a wood-cement panel. Samples exposed to water leaching for 14 days released 1 - 3 µg As, 1 - 2 µg Cu and 0.25 - 0.4 µg Cr per gram of wood cement composite. These losses are not large, but it is difficult to compare these losses with those from treated wood itself. It is well known that inorganic toxic wastes can be encapsulated in cement matrices to reduce their leachate toxicities sufficient to render them non-toxic wastes (e.g.,Cocke 1990, Cote *et al* 1990, Shively *et al* 1986, Zamorani *et al* 1988). Thus, the effects of the cement matrix on leaching of preservatives incorporated in wood-cement composites warrants study. In this paper, the effect of particle size and exposure of wood particles by cutting are evaluated for a wood-cement composite containing chromated copper arsenate treated particles.

2. Methodology

Initial study

A single red pine (*Pinus resinosa* Ait.) pole section was used in the initial study. The pole had been treated with 2.0 % CCA-C and allowed to weather out-of-doors for two years. The treated sapwood was split from the section and ground in a Wiley mill to produce particles of three sizes: coarse - passed 8 mm screen but retained on 6 mm screen; medium - passed 2.8 mm screen but retained on 1 mm screen; fine - passed 1 mm screen. Random samples of each particle size was ground to pass 20 mesh per inch (8 mesh per cm) screen and compressed into a pellet for X-ray fluorescence analysis (ASOMA Instruments Inc.). The moisture contents of all particle types were determined by oven-drying.

Wood cement composites were prepared by mixing each particle type with water and Portland cement in the ratio, 50 parts dry wood to 100 parts dry cement to 160 parts water, including the wood moisture. The water and wood were mixed and allowed to stand for 1 hour, then the Portland cement was added and mixed.

Samples for leaching tests were prepared by pouring the wood-cement mixture into rectangular forms of dimensions 25 mm X 25 mm X 37.5 mm or 25 X 25 X 90 mm. The samples were allowed to set in the moulds for 7 days, then removed and allowed to cure at high humidity and 21°C for 21 days. The latter samples were sawn to the 25 X 25 X 37.5 mm dimensions to provide samples with cut ends to determine the effect of exposing particles to the leaching medium. The samples were tested for CCA leaching using a modified AWPA E11-87 (1996) test procedure. Non-standard block dimensions of 25 X 25 X 37.5 mm were used instead of the specified 19 mm cubes to accommodate the large particle sizes in the coarse particle composites. Equivalent masses of loose fine, medium and coarse particles were tested for leaching characteristics to compare with the cement encapsulated particles. Similar amounts of CCA treated wood in block form were also leached for comparison.

For each test with the wood-cement composites, six blocks were vacuum treated with 300 ml distilled water then stirred in the water for 6 hours. A sample of water was collected for analysis and the leach water replaced with 300 ml of fresh water. This procedure was repeated after 24, 48, 96, 144, 192, 240, 288 and 336 hours. The loose wood particle samples and treated blocks were exposed to the same leaching conditions. The water samples collected after each leaching period for each sample type were analysed for copper, chromium and arsenic by ion coupled plasma spectroscopy (ICP). The accumulated elemental losses were determined by summing the ppm values for the different water exchanges; when leachate concentrations were below the detection limits for the elements (0.01 ppm for Cr and Cu and 0.03 ppm for As), the contaminant level was assumed to be one half of the detection limit. The total μg of each element leached was determined as accumulated ppm X 300 ml. The percentage of total CCA components leached were estimated from the leachate analyses and the initial CCA-C retentions of the wood samples.

Follow up study

We were concerned that the preliminary positive results obtained were not representative of longer term exposure. The study described here was designed to follow the leaching of CCA components over a much longer period. Treated wood from a fresh treated section of a CCA treated red pine pole was ground to medium mesh size (1 - 6 mm) and mixed with Portland Cement (Wood/cement/water = 50/100/160) and cast into cubic moulds.

When the composites cubes had cured, they were placed in water and the leaching of CCA components determined after 2 weeks (following the AWPA E11-87 procedure). Water collected during the 9 water change steps was pooled for analysis. For comparison, equal amounts of free wood particles and of solid wood blocks were also leached in the same amounts of water.

The leachates were analysed over the two week initial leach period and the percent of total copper, chromium and arsenic leached from the different samples compared. The blocks were placed in fresh leach water and the leachate analysed and replaced weekly for an additional 4 weeks. The samples were then soaked for an additional 6 weeks and the leachate analysed as above (total of 12 weeks leaching).

3. Results and Discussion

Initial study

The sapwood samples had a high average CCA retention of 18.0 kg/m^3. This corresponds to CCA component concentrations (dry wood basis) of 2.077 % CrO_3, 0.873 % CuO and 1.552

% As_2O_5 or 1.080 % Cr, 0.697 % Cu and 1.002 % As elements.

The amount of chromium leached was not consistently or appreciably affected by the cement matrix (Figure 7). Leaching appeared to be lower for the coarse particles in the cement but slightly higher for fine and medium particles in the wood-cement samples . Zamorani *et al* (1988) reported that trivalent chromium, the form found in properly fixed CCA treated wood, leaches from a cement matrix in relation to the solubility of $Cr(OH)_3$ formed in the high pH cement environment. $Cr(OH)_3$ is considered to be one of the main equilibrium components in CCA treated wood after fixation (Dahlgren 1974), and it is possible that other chromium species are converted to this compound in the alkaline environment. The better stabilization of chromium in the coarse particle composite is probably due to physical retardation of loss by the cement encapsulation rather than to chemical reactions between the cement and the dissolved chromium. Whether encapsulated or not, the chromium leaching losses are relatively minor, accounting for less than 0.5 % of the total chromium in the samples.

Copper was much more effectively stabilized by the Portland cement compared to the chromium (Figure 8). Copper leaching losses were reduced by about 95 % in all cases. The efficient stabilization of cationic metals results from formation of low solubility hydrolysis products in the high pH environment in the cement matrix (Cote *et al* 1990). This may also increase the cation exchange capacity of the wood itself (Cooper 1991) and promote amphoteric metal precipitation and complex sorption reactions in the cement (Cote *et al* 1990). Leaching losses were lowest for the wood-cement composite with the coarsest particles.

The immobilization of arsenic was almost complete (Figure 9), with elemental arsenic losses from the particles reduced by more than 99 % for all wood-cement samples. Again, the losses were least from the composites formed with the coarse particles. This excellent stabilization of the anionic arsenic is somewhat unusual since the cement matrix is also anionic (Cocke 1990). Cement stabilization of anionic wastes, as assessed by acidic leaching, is generally less efficient than for cationic metals (Cote *et al* 1990). Our results also conflict with those found by Hsu (1994) who found higher losses of arsenic compared to copper from wood cement boards containing waste CCA treated wood. The highly efficient arsenic stabilization observed here may result from direct formation of low solubility complexes with metal components of the Portland cement (Ca, Al, Si).

There was no appreciable or consistent effect of cutting the wood-cement samples on the amounts of contaminants released (Figures 7 to 9).

The higher leach resistance of the composites made with coarse particles most likely results from better encapsulation of the fewer larger particles and lower porosity and degree of pore connection which affect diffusion of contaminants out of the wood-cement matrix. This is supported by generally increased water absorptions (14 day soak) with decreased particle size. As expected, the finer particles exposed without encapsulation had greater relative losses of chromium and copper than the coarser samples. This results from the higher surface area to volume ratios of the more highly comminuted samples. However, this expected trend was not observed for arsenic.

Follow up study

In all cases, the CCA component losses were greatest after the initial 2 week period and leaching rates were greatly reduced over subsequent leaching periods. The results confirm that encapsulation in Portland cement reduced the leaching losses of all components. Copper losses were less than 5 % of those from free particles or wood blocks. Chromium losses were reduced by about 50 % and arsenic leaching was reduced to very low levels (less than 1 % of free particles or cubes - Figures 10 to 12). The relatively minor effect on chromium leaching was confirmed, suggesting that the effect is more related to chemical reaction of the leached copper and arsenic with the Portland cement than to encapsulation. Sawdust did not leach appreciably more than blocks.

4. Conclusions

Wood/cement composites offer promise for the recycling of spent CCA treated wood because of the improved compatibility between CCA treated wood and Portland cement and the reduction of copper and arsenic leaching potential from the treated wood. The rate of leaching of chromated copper arsenate (CCA) from treated wood particles was greatly reduced in a treated wood-cement composite compared to losses seen in the unencapsulated particles. Chromium leaching was not reduced significantly, but copper leaching rates were reduced by more than 90 % and arsenic leaching was virtually eliminated (99 % reduction). The amount of component leached increased with decreased particle size in both cement encapsulated and loose particles. Exposure of cut ends of the wood cement composite to the leaching medium did not consistently affect Cr, Cu and As losses from the wood-cement samples.

5. Literature cited

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Figure 1: Estimated Annual production of CCA/ACA treated Products in Canada (Stephens et al 1996).

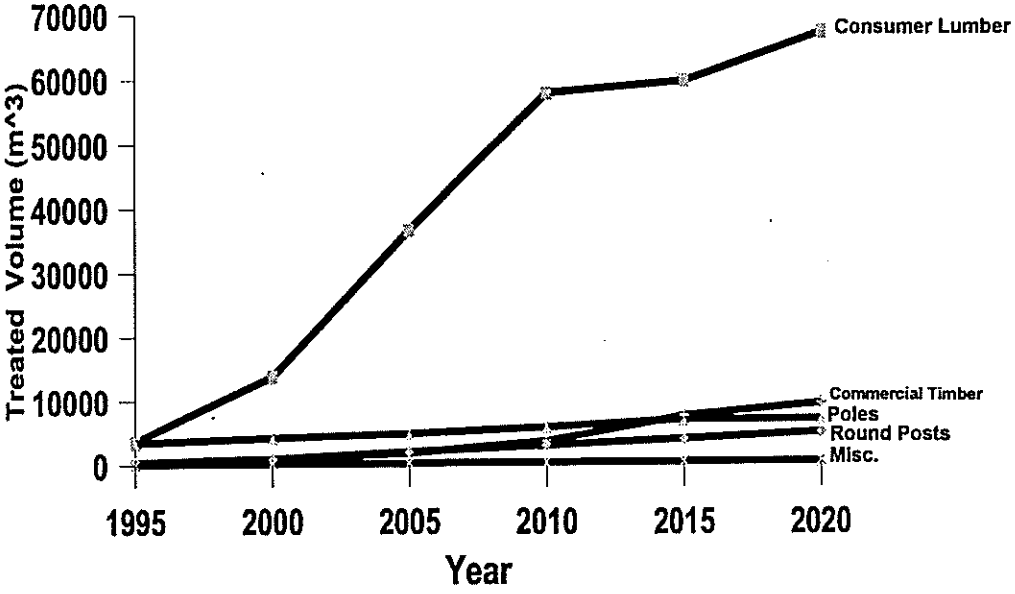

Figure 2: COMPATIBILITY - WOOD/CEMENT RED PINE (Schmidt et al 1994).

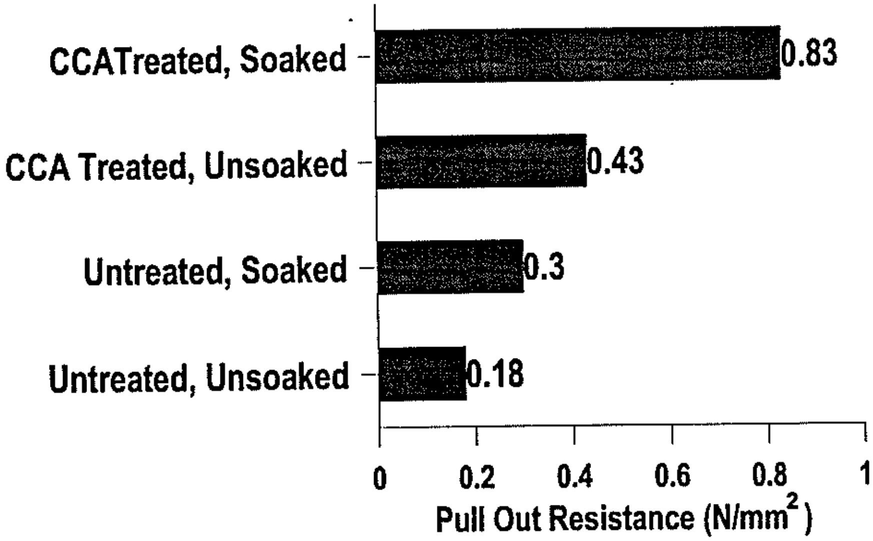

**Figure 3: COMPATIBILITY - WOOD/CEMENT
JACK PINE (Schmidt et al 1994).**

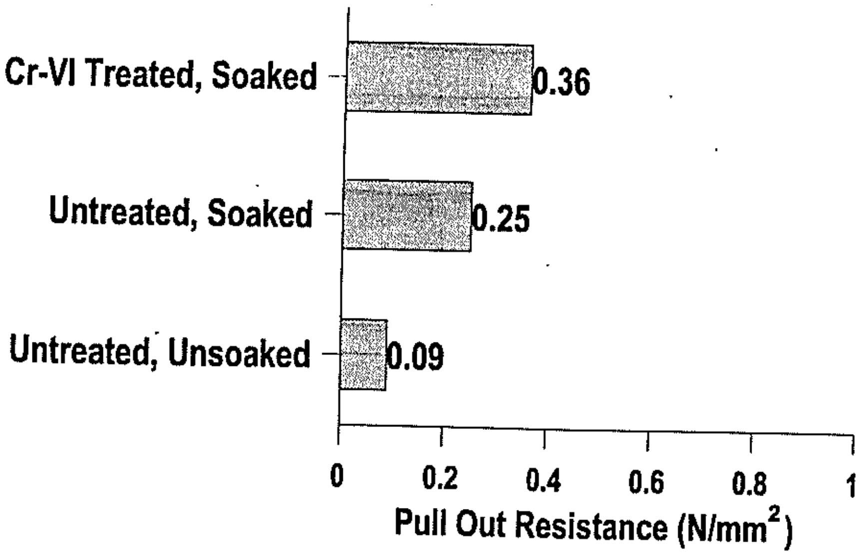

**Figure 4: COMPATIBILITY - WOOD/CEMENT
LODGEPOLE PINE (Schmidt et al 1994).**

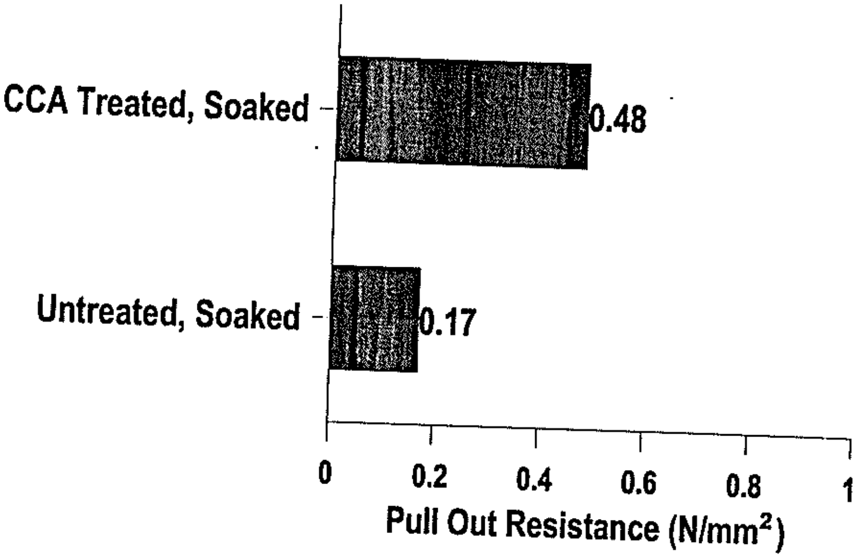

Figure 5: FLEXURAL TOUGHNESS (N/mm^2) STRENGTH, RED PINE- CEMENT: WOOD RATIO, 2: 1 (Schmidt et al 1994).

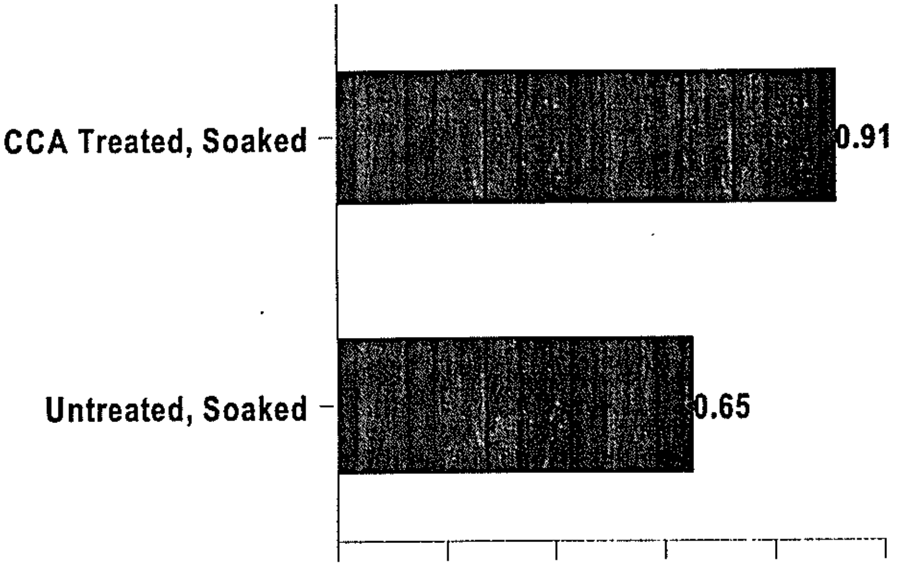

Figure 6: COMPRESSION (N/mm^2) STRENGTH, JACK PINE- CrO3 TREATED (Schmidt et al 1994).

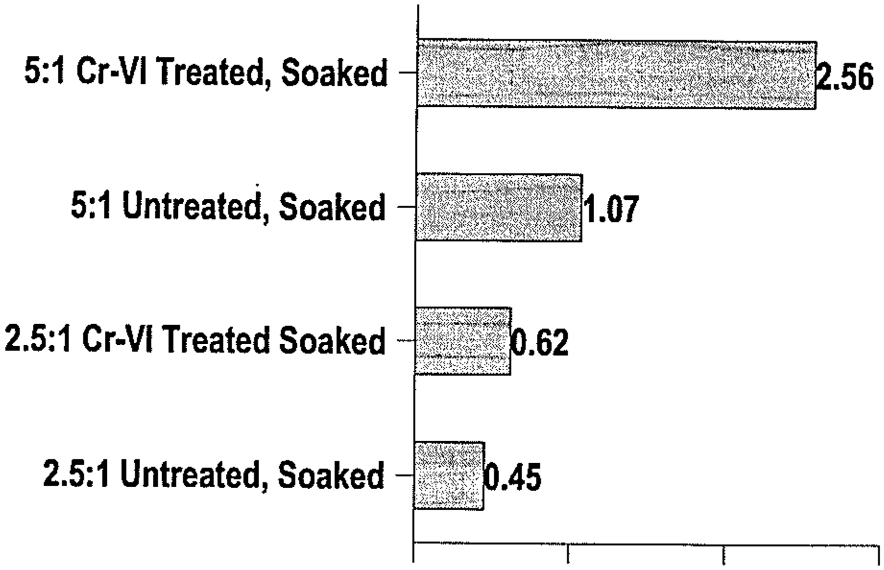

Figure 7: Effect of particle size & cement encapsulation on CCA components leaching from wood.

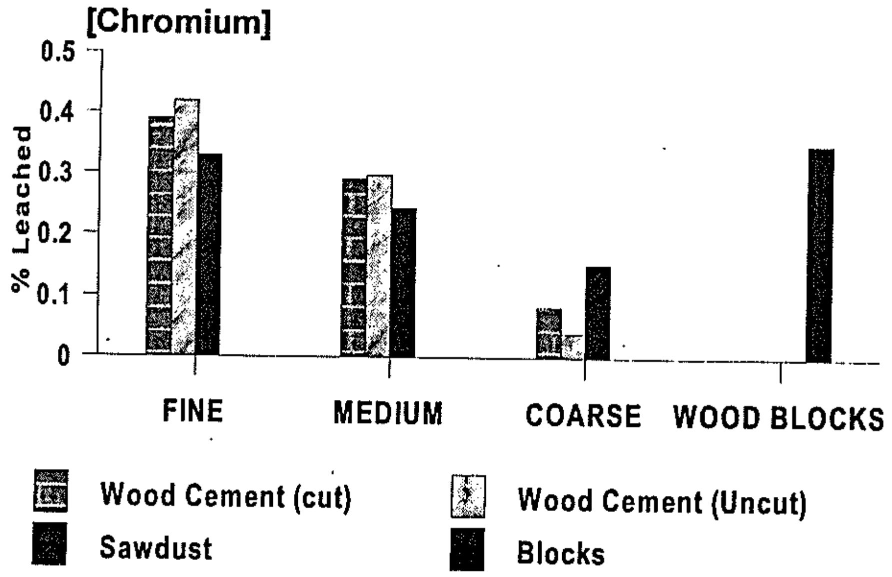

Figure 8: Effect of particle size & cement encapsulation on CCA components leaching from wood.

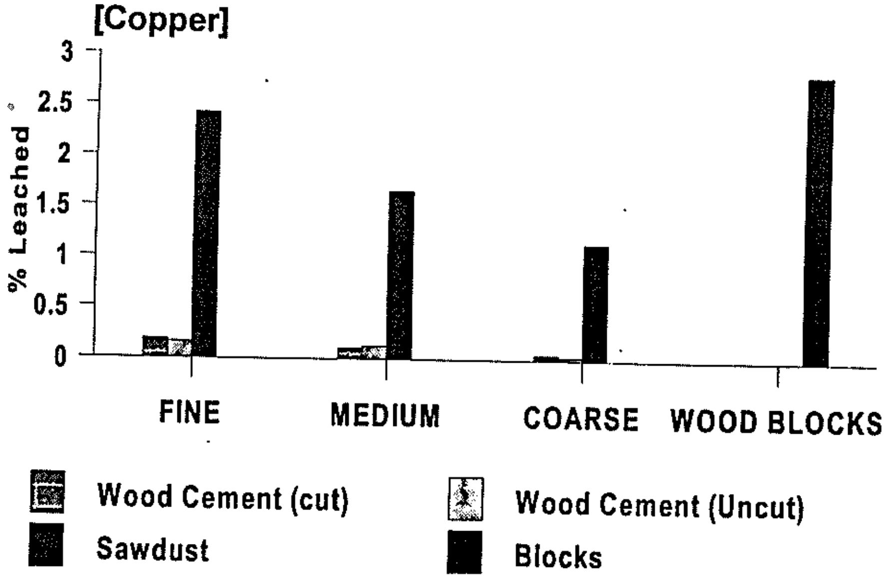

Figure 9: Effect of particle size & cement encapsulation on CCA components leaching from wood.

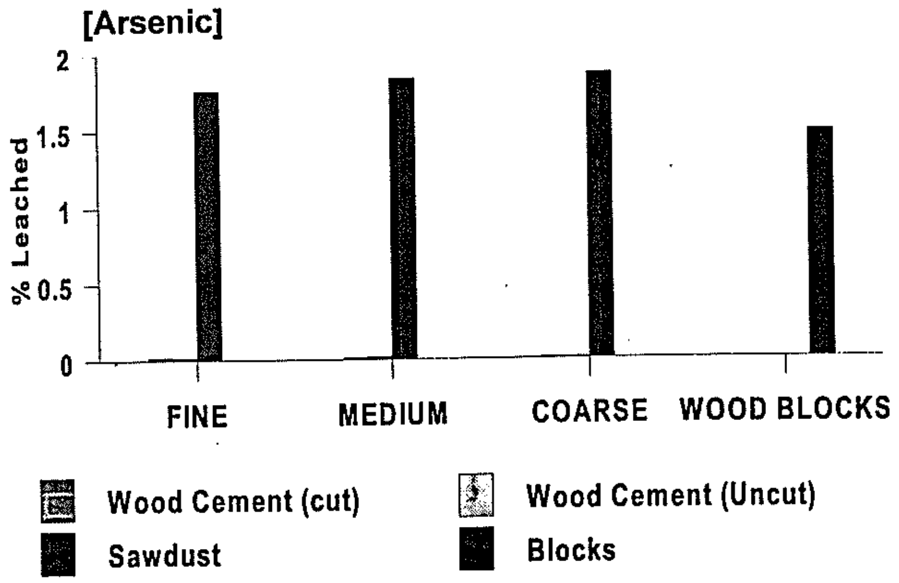

Figure 10: Leaching of Cr components over a 12 weeks period.

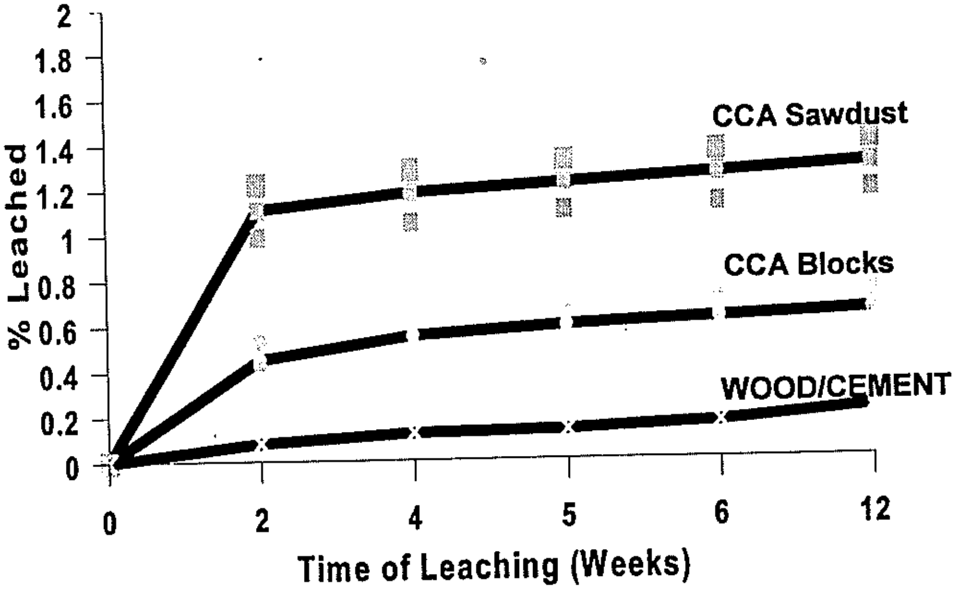

Figure 11: Leaching of Cu components over a 12 weeks period.

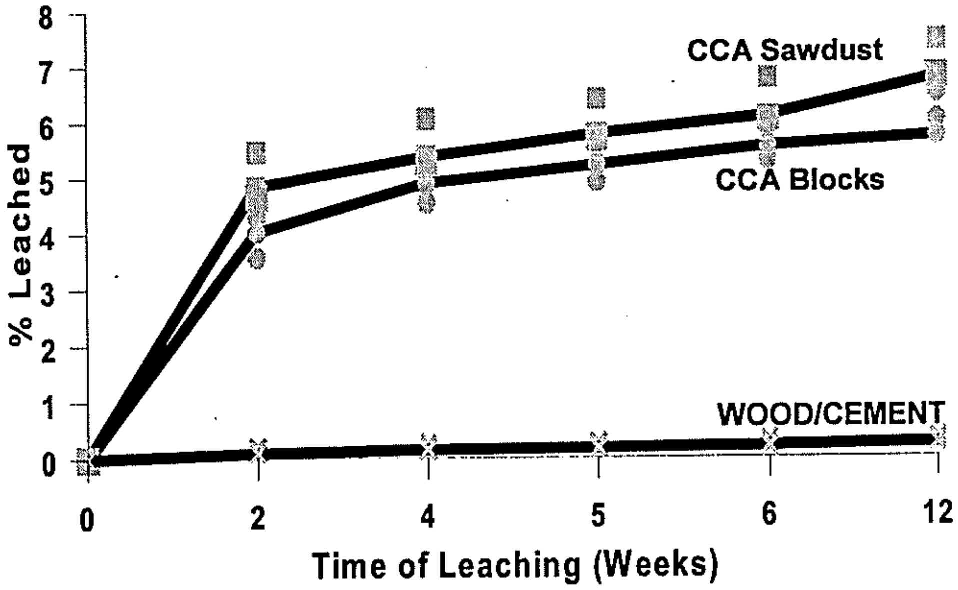

Figure 12. Leaching of As components over a 12 week period.