

RESIDUES OF ARSENIC, CHROMIUM AND COPPER ON AND  
NEAR OUTDOOR STRUCTURES BUILT OF WOOD TREATED  
WITH "CCA" TYPE PRESERVATIVES

D. Riedel<sup>1</sup>, J. Harrison<sup>1</sup>, D. Galarneau<sup>1</sup>,  
D.C. Gregoire<sup>2</sup>, N. Bertrand<sup>2</sup>,

<sup>1</sup>Bureau of Chemical Hazards,  
Health and Welfare Canada,  
Ottawa, Canada, K1A 0L2

<sup>2</sup>Mineral Resources Division,  
Geological Survey of Canada,  
Ottawa, Canada, K1A 0E8

### Introduction

Lumber which has been pressure-treated with water-borne "CCA-type" preservatives containing a combination of salts of arsenic (As), chromium (Cr) and copper (Cu) is a very durable and increasingly popular material for wooden outdoor structures such as fences, decks, playground equipment and also wooden foundations for dwellings. In the mid-1980's in the U.S.A., nearly 600 pressure-treating plants produced 285 million cu. feet per year of such lumber (Micklewright, 1988); in Canada, about 5000 tonnes of 50% preservative concentrate are being used annually to impregnate lumber to obtain retentions of 4 to 12.8 kg of preservative per cubic meter (Konasewich and Henning, 1988). In spite of the huge volumes of these chemicals and of the treated lumber being used, the published literature contains very little information about the extent to which the wood preservative chemicals migrate out of the treated wood, or about the nature and extent of the dislodgeable residues of As, Cr, and Cu which might be present on the surface of structures built of preserved wood. This is of concern because trivalent As and hexavalent Cr are carcinogens, and Cu salts are phytotoxic (IARC, 1980; NRCC, 1978). The data available on the leaching potential of CCA components from pressure-treated wood exposed to outdoor conditions are in part contradictory. Cserjesi (1976) found considerable leaching from experimental cedar shingle roofs exposed under Canadian use conditions in an area of high rainfall. Several groups of investigators have shown that the extent and rate of leaching of As, Cr, or Cu from treated wood is influenced by the composition and acidity of the treating solution, the drying conditions of the wood after treatment, and the composition of the treated wood (Hager, 1969; Fahlstrom et al., 1967; Woolson and Gjovik, 1981). Recent unpublished laboratory studies (McCurdy, 1986) indicate that the composition and pH of aqueous extraction media also affect the leaching process. These observations are of interest to the present study, but the variables identified in them were not investigated by us, although they may well have affected our results. Our aim was to simply provide some preliminary results which would indicate whether the problem of dislodgeable surface and soil residues on and near wooden outdoor structures built of pressure-treated wood needed to be studied in greater detail, and to make some preliminary recommendations for reducing environmental and user exposure from the As, Cr, and Cu residues associated with such structures.

## Sampling and Materials

A study was undertaken in eastern Ontario to determine levels of arsenic, chromium and copper on and near 10 outdoor structures built up to 10 years previously of wood which had been treated with "CCA" type preservatives.

Two type of samples were collected: wood surface wipes and sand and soil samples. The wood surface wipes were collected by dampening a 4" x 4" -8 ply gauze (code 70637, Curity sponge) with 3 mL of distilled water and wiping a 1 meter long wood surface twice (folding the gauze after the first pass) for a total of 2 meter/wipe. For shorter surfaces (i.e. ladder steps/bars) surfaces were wiped 4 times for a total of 2 meters (again folding the gauze after each pass). A total of 4 surface samples were collected for each structure at locations that would come into frequent contact with the hands on clothes of users. For ease of comparison, similar areas were chosen at each playground whenever possible (i.e. right hand rail of slide, monkey bar, hand rail at top of ladder or slide). Control wipe pads were only dampened with 3 mL of distilled water.

Sand samples (= 100-150 grams/sample, wet weight) were taken with a stainless steel spoon, and stored in plastic sampling bags (Nasco Whirl-Pak, 4 oz.). Four sand samples were collected at each playground plus one control soil sample 10 meters away from any wooden structure. Care was taken again to collect samples at similar locations at each playground next to playground wooden structures, usually one at the bottom of slide, next to support post; one at bottom of support post holding main structure, and two underneath wooden platform or structure approximately 1 meter away from posts.

Surgical gloves were used during sampling to avoid any sample contamination by skin contact. All samples were stored at 4°C until analysis was performed.

Weather conditions on the day chosen for sample collection were cloudy, approximately 1-5°C all day. Condition of the structure (i.e. painted, new or old) were noted and a sketch of each structure was drawn; these were supplemented by photographs.

Gauze pads (wipe samples) were placed in a 50 mL plastic centrifuge tube and were equilibrated at room temperature with 20 mL of 1 M nitric acid for a period of 48 hours. The tubes were centrifuged and the sample solution decanted into a covered storage container. Sample solution remaining in the swab was squeezed out using a glass rod.

Gravel and soil samples were dried in an oven at 80°C for three hours. Ten grams of sample material were placed in a 50 mL plastic centrifuge tube and treated in the same manner as gauze pads.

A Perkin-Elmer Sciex Elan Model 250 was used for the determination of arsenic in sample solutions. External calibration was used for obtaining analytical response curves and for calculating results.

Arsenic is a monoisotopic element with an atomic mass of 75 and is subject to an interference arising from  $^{40}\text{Ar}^{35}\text{Cl}$  molecular ion. This species is formed in the Ar plasma gas, and from any Cl derived from chloride species found in the sample material. For this reason, nitric acid rather than hydrochloric acid was used for leaching As from the sample materials. Correction for any naturally occurring chloride can be made by

monitoring the corresponding molecular ion formed at mass 77 from chlorine's second stable isotope (abundance: 24.7%), namely  $^{40}\text{Ar}^{35}\text{Cl}$ . By applying the suitable correction factor based on the relative abundance of  $^{35}\text{Cl}$  to  $^{37}\text{Cl}$  (3.13), correction was made for any molecular ion interference arising from the presence of Cl in the sample. Blank solutions containing 1 M nitric acid are run with the samples and any As present was subtracted from the As intensities obtained from sample solutions.

Copper and Chromium concentrations were also determined for the sample solutions in order to ascertain the source of the arsenic and hence the possible nature of the preservative as being a copper or chromium arsenate.

## Results

### 1. Wipe samples

The results of this preliminary study are shown in Tables 1 to 4.

For practical purposes, our wipe samples can be taken as representing the amount of transferable As, Cr or Cu from 0.05 m<sup>2</sup> of well weathered CCA-treated softwood. It can be seen from Table 1 that most of the wipe samples contained several tens of micrograms (millionths of a gram,  $\mu\text{g}$ ) of As. Only two wipe samples (from playground "H") contained more than 100  $\mu\text{g}$  As. Table 4 shows that the amounts of Cr in the wipe samples were roughly similar to the amounts of As. However, Table 3 shows that the levels of Cu tended to be higher than those of either As or Cr. This could mean either that the preservatives used to treat the wood contained a greater proportion of Cu than of As or of Cr, or that the Cu residues become dislodgeable in a pattern different from that of the As and Cr residues. As the exact type of CCA used for preserving the wood is not known, no inferences can be drawn about the proportions of As, Cr and Cu originally present in the wood. The mean As values for wipe samples from the 10 playgrounds ranged from 4.8  $\mu\text{g}$  to 149.3  $\mu\text{g}$  (thus showing an about 30-fold variance); the corresponding mean Cr values ranged from 5.0  $\mu\text{g}$  to 132.3  $\mu\text{g}$  (an about 26-fold variance). The mean Cu values for the wipe samples ranged from 4.2  $\mu\text{g}$  to 555.8  $\mu\text{g}$  (an about 132-fold variance). A comparison of the age of the structures with the mean As, Cr and Cu values for the wipe samples, or with the As levels in the sand samples, showed no readily apparent correlation, either for bare wood, or for structures which had been stained or painted (Figs. 1 and 2).

### 2. Soil and sand samples

Only arsenic determinations were carried out for the sand and soil samples. The results for the As determinations are shown in Table 2, and are expressed in milligrams (thousandths of a gram, mg) per kg of dry sand or soil (equivalent to "parts per million", ppm). The "background" values in the control soil samples taken at a distance of 10 m from the wooden structures were with one exception (0.37 ppm) below 0.3 ppm. However, most of the sand samples taken below and near the structures contained from about two to ten times as much As as did the control soil samples taken at the same playgrounds. The mean As values for the sand samples from the 10 playgrounds ranged from 0.190 to 7.043 ppm, i.e. from below background to about 20 times the background level. The highest level of As in sand (125 and 102 ppm, mean 113 ppm) was found in one spot at playground structure "C" (Table 2), next to a large support post. The other sand samples from that structure ranged from 6 to 27 ppm.

This last very high level therefore was a "hot spot", and was not representative of the playground as a whole. In this case, a second portion of the sample in question was analyzed to confirm the first analytical result.

Background levels of As, Cr and Cu in the soil samples were all less than 1 ppm (100 to 371 ppb); the sand samples taken below the structures contained from 32 to 9573 (mean 2963.9) ppb of As. The surface wipe samples, which had been collected from a total surface of about 0.1 M<sup>2</sup> of treated wood, contained from 0.5 to 322 (mean 42.9) µg of Cr, and 1.2 to 254 (mean 27.8) µg of Cr, and 1.0 to 914 (mean 193.6) µg of Cu.

### Discussion

With the exception of one sand sample, the amounts of As, Cr and Cu detected in our surface wipe samples and in our sand samples were not very high. The background levels of As in the control soil samples were all less than 0.5 mg/kg (= ppm) (0.1 to 0.371 ppm); the sand samples taken below the structures contained from 0.032 to 9.573 ppm (mean 2.964) ppm of nitric acid-extractable As. The low background levels of As in the soil and in some of the sand samples indicate that the higher As levels found in many of the sand samples taken near the support beams of the structures were due to As from the CCA-treated wood.

The wipe samples, most of which had been collected from wood surfaces measuring 0.05 m<sup>2</sup>, contained from 0.5 to 322 (mean 42.9) µg of extractable As, 1.2 to 254 (mean 27.8) µg of extractable Cr, and from 1.0 to 914 (mean 193.6) µg of extractable Cu. The maximum values thus represent about 6.4 mg As, about 5 mg of Cr, and about 18.2 mg of Cu per m<sup>2</sup> of the weathered CCA-treated wood; the mean values would respectively represent about 0.86 mg As, about 0.56 mg Cr, and about 2.88 mg Cu per m<sup>2</sup>.

It is noteworthy that we found some "background" As in the surgical cotton gauze used to obtain the wipe samples. This As may in part be ascribable to the past use of As-based pesticides in cotton fields, and in part to natural residues of As in the soil in which the cotton was grown (Albert and Paden, 1931).

Most of the published studies on As, Cr and Cu residues associated with CCA-treated wood deal with "retention values" for the wood preservative chemicals, i.e. the amount of the chemicals retained in treated wood after outdoor exposure of various durations. We were not able to determine with which type and with what amounts of CCA the wood in the structures had been treated, and therefore have no information on either the original retention levels or the original As:Cr:Cu ratios. However, wood samples from the structures will be taken and analyzed in the next stage of the study in order to determine the residual retention values in the pieces of wood from which the wipe samples were taken.

Several earlier studies by other investigators have examined removable As surface residues on CCA-treated wood through the use of wipe samples. Arsenault (1975) conducted a study in which twelve samples of CCA-treated plywood were wiped with a laboratory paper tissue or with cellulose sponges. These wipes yielded on the

average 0.244 mg As per square foot; 80 % of the samples showed less than 0.5 mg As per square foot (no maximum value was cited). Additionally, dry and wet bare hands (of adults) were rubbed on 2 samples each of either 2-week old or 2-year old wet or dry CCA-treated plywood. This yielded 0.0005 to 0.024 mg As per square foot of wood with dry hand wipes, and 0.071 to 0.529 mg As per square foot when the hands were wet. The mean for wet hand wipes of dry wood was 0.294 mg per square foot, or 32  $\mu\text{g}$  per 100  $\text{cm}^2$  (3.2 mg per  $\text{m}^2$ ) (Arsenault, 1975). This is about one-half of the average amount of As recovered per wipe in our study with wet gauze wipes. The results obtained by Arsenault (1975) and by us thus indicate that several mg of As may be transferred to wet hands or to wet cotton fabric when these come into contact with CCA-treated wood.

The As residue levels in the wipe samples collected during our study can also be compared to surface residues recovered from CCA-treated wood in studies whose authors used other sampling techniques. Woolson and Gjovik (1981) determined the amounts of As and Cr dislodgeable from CCA-treated wood by rinsing the surface of the treated wood first with distilled water, and then with dilute hydrochloric acid (HCl) at pH 4. They found that the rinse water from five unweathered CCA-treated wood samples contained total removable As residues of up to 213  $\mu\text{g}/100 \text{cm}^2$ , with average values of 29 to 144  $\mu\text{g}/100 \text{cm}^2$ . The total As residues in rinse water from 7 weathered CCA-treated samples averaged 40.2  $\mu\text{g}/100 \text{cm}^2$ , with a range of 4.1 to 106.9  $\mu\text{g}/100 \text{cm}^2$ . These average values are again comparable to the average amounts of As found in the wipe samples collected during our study. In the study of Woolson and Gjovik (1981), the HCl rinse removed additional As residues. That observation is in agreement with the results of laboratory leaching studies with CCA-treated wood carried out by McCurdy (1986) and by Warner and Solomon (1990), who used acidified aqueous media to measure As residues extractable from CCA-treated wood.

Saur et al. (1983) used a vacuum technique to collect As residues from the surface of CCA-treated lumber, and from foundations, decks, walks, walls, benches, bridges and other structures built of such lumber in the eastern and midwestern United States. Outdoor lumber structures yielded from 0.01 to 12.7 mg "respirable" As/ $\text{m}^2$ , but most of their samples were below 3 mg As/ $\text{m}^2$ , and 17 of 26 samples were below 1 mg As/ $\text{m}^2$ .

Klemmer et al. (1975) studied the As content of house dusts in Hawaii, where As-based pesticides and wood preservatives are widely used. In that study, elevated levels of As were found in homes of employees of wood treatment or pest control firms. No comparable studies were available from other regions in North America or elsewhere.

Like the results of the other studies discussed above, the results of the present study confirm that CCA-treated wood in outdoor structures releases measurable amounts of As, Cr and Cu, and that further studies should be carried out to better define the nature and extent of the dislodgeable and leachable residues of As, Cr and Cu. There are several obvious factors which could have influenced our results. These include the age and wear of the structures, the coatings in the form of stains or paints, the amount and the acidity of the precipitation, and the physical and chemical composition of the residues in the samples prior to extraction.

Variables such as the effect of paint coats present on some structures, the differences in preservative retention by different species of wood, the extent and frequency with which the sand below the structures had been replenished, and the slope of the ground at the sites may partially obscure some of the potential

relationships between proximity to the treated wood and As levels in the sand. These therefore need to be investigated in the future. It is also desirable to determine the physical and chemical form of the As, Cu and Cr residues being released from such wood, in order to better understand their significance as environmental contaminants and as potential health hazards. One author (Dunbar, 1962) concluded that the leaching rate of As, Cr and Cu from CCA-treated lumber used in British water cooling towers was "zero". He pointed out that there would be a great leaching potential in such a use setting. However, the original CCA content of the wood in the study of Dunbar (1962) was unknown, and the water cascading over the treated lumber was mostly alkaline (Dunbar, 1962). It is conceivable that in eastern Canada, which receives much acid precipitation, As, Cr and Cu are leached more readily out of CCA-treated wood. Moreover, when CCA-treated wood dries after being exposed to acid precipitation, some of the components of the acid precipitation might combine with As, Cr or Cu to form a coating of minerals such as carbonates or sulfates.

The levels of As, Cr and Cu found in the wipe samples of the present study indicate that outdoor structures built of CCA-treated wood have surface residues of As, Cr and Cu which could lead to some user exposure. The elevated levels of As in sand samples taken close to the treated wood indicate that there is some leaching of the preservative components from the CCA in the wood. In order to protect the environment as well as the users of such structures, it seems therefore advisable to seal the surface of the wood with a protective coating able to withstand the use and climatic conditions affecting the structures. Those parts of the structures subject to a high degree of abrasion should perhaps be built of a different material, or should be covered with protective mats made of a slip-resistant material. The CCA-rich surface layers of the wood would then be protected from abrasion, and the user exposure to As, Cr and Cu, as well as environmental contamination would be reduced.

The ultimate aim of most studies on CCA residues in the living and working environment is to determine the magnitude of the possible hazards resulting from those residues. The attention in such studies has usually been focused on As, because it is a well-known poison, and because many occupational and accidental poisonings due to As have been reported in the literature. When considering our own results and the findings of other investigators discussed above, one has to take into account that trace amounts of As, Cr and Cu are a normal component of many foods (Arnold, 1988; Hamilton and Wetterhahn, 1988; NRCC, 1978; Sarkar, 1988; Vahter and Lind, 1986), and that the intake of additional trace amounts of these elements resulting e.g. from occasional skin contact with preserved wood may not constitute a health hazard.

The microgram amounts of As, Cu and Cr wiped by us from the surface of weathered CCA-treated wood on play structures are trace amounts, and as such do not appear to be alarming. However, our results as well as the results of the wipe study of Arsenault (1975) which were discussed above, indicate that several milligrams of As might be transferred to the wet hands or the wet clothing of people coming into repeated contact with CCA-treated wood. An Australian study conducted on freshly treated pine wood concluded that in most cases the dislodgeable surface residues of As probably present only a small health hazard to children (Johanson and Dale, 1973). However, neither that study nor our own is really reassuring, as the results cannot be used to determine the level of As exposure of children who use play structures built of CCA-treated wood, or of workers who come into daily occupational contact with CCA-treated wood.



The implications of the results of our analyses of the sand samples for human health are also difficult to guess. The relatively low levels of As (0.2 - 3 ppm) found in most of our sand samples are comparable to the arsenic levels reportedly found in table salt and sea salt, or in some household detergents (NRCC, 1978). To put this into proper perspective, one must also take into account that the daily As intake from table salt would be very low, because people do not consume large amounts of salt. A recently published study indicates that it would be unlikely for a child to eat more than 6 grams of soil per day (Davis et al., 1990). At the highest As concentrations in the sand samples examined in the present study (113 ppm), one gram of sand would contain about 0.11 mg of nitric acid-extractable As. It is not certain that all of the ingested As residues in such sand would be absorbed into the body if that sand were to be eaten. Thus based on the study of Davis et al. (1990), if 6 grams of the most highly contaminated sand were ingested, the amount of ingested arsenic would not be more than about 0.66 mg. Also, under experimental conditions, most of the inorganic arsenic absorbed in small doses is apparently metabolized and excreted by humans and thus does not accumulate in the body (Tam et al., 1979).

Many sources of food contain arsenic, and it is found in all human tissues and body fluids (NRCC, 1978; Subramanian, 1988). Values cited by NRCC (1978) for the daily dietary As intake by [adult] humans in North America and Europe range from 0.07 to 60 mg; the figure cited for Canadians is 0.03 mg. However, there are no data or valid exposure models available which could be used to calculate the amount of As which would be absorbed dermally by children using the structures studied by us, or by workers handling CCA-treated wood.

Less information is available on dermal As exposure and on As absorption through the skin, than there is on dietary exposure. However, some of the published exposure estimates for percutaneous As uptake from contact with CCA-treated wood appear to be unrealistically low. Thus, Woolson and Gjovik (1981) arrived at a figure of 0.0008  $\mu\text{g}$  As for a single contact of an adult hand with the surface of CCA-treated plywood. However, in their study this applies to extractable arsenite only and not to total As, and it is also based on the assumption that only 0.01 % of the amount of As present on the skin would be absorbed. Actual experimental data are apparently not available to estimate the efficiency or extent of percutaneous As absorption from contact with treated wood. We hope to generate such data during the planned next phase of our present investigation. Saur et al. (1983) refer to the results of an occupational exposure study on workers at a plant in the U.S.A. where prefabricated houses were built of wood treated with arsenical preservatives, but the report on this study is unpublished, and thus was not available.

At present there is not enough scientific information on the safety of CCA-treated wood. It would therefore be prudent to take into account that inorganic arsenic and chromium are poisonous and carcinogenic when absorbed in excessive amounts, and that while small amounts may be harmless, it would be best to avoid any unnecessary exposure to arsenic or to chromium which could decrease our margin of safety for their ill effects. This is particularly true for their most toxic inorganic forms, namely arsenic III and chromium VI. It thus seems advisable to try to determine and to reduce the amounts of As III and Cr VI residues given off by structures built of CCA-treated wood, and to avoid the use of, and contact with CCA-treated wood in situations where a high degree of environmental contamination and human exposure to the preservative chemicals may occur. Some experts on occupational health state that since arsenic is a human carcinogen, the aim must be to keep exposure as close to background levels as possible (Raffle et al., 1987). The same concern would apply to our children.

Summary

The results did not indicate clear correlations between the age of the structures and the levels of As, Cr or Cu. Variables such as the effect of paint coats on some structures, the differences in preservative retention by different species of wood, the extent and frequency with which the sand below the structures had been replenished, and the slope of the ground at the sites may partially obscure such a relationship, and needs to be investigated in the future. The levels of As, Cr and Cu in the wipe samples indicate that the treated wood has dislodgeable surface residues which could lead to some user exposure and to leaching of the preservative components from the wood. In order to protect the environment as well as the users of such structures, it might therefore be advisable to seal the surface of the wood with a protective coating able to withstand the use and climatic conditions affecting the structures.

Re  
Al  
ce  
Al  
ef  
Pr  
Ba  
tr  
B  
W  
Si  
38  
B  
p  
C  
P  
C  
el  
S  
C  
w  
C  
P  
C  
P  
E  
P  
k  
E  
C  
F  
I  
C  
2  
I  
C  
C



## References

- Albert, W.B. and Paden, W.R. (1931). Calcium arsenate and unproductiveness in certain soils. *Science*. 73:622.
- Arsenault, R.D. (1975). CCA-treated wood foundations. A study of permanence, effectiveness, durability, and environmental considerations. *Proc. American Wood Preservers' Assoc.* 71:126-149.
- Bayley, C.H. and Rose, G.R.F. (1960). Metal-organic complexes formed during the treatment of wood with metal salts. *Nature*. 184:313-314.
- B.C. Research, Occupational Health Group. (1987). Industrial hygiene survey of a wood preserving operation using CCA. Wood Products Manufacturing Sector Subcommittee, Forest Industry Industrial Health Research Program, Vancouver, B.C., 38 pp.
- Behrbohm, P. (1957). [Allergic contact eczema through chromium-containing wood preservatives] (In German). *Berufsdermatosen*. 5:271-283.
- Canadian Institute of Treated Wood (Undated). Waterborne wood preservatives. 4 pp. Canadian Institute of Treated Wood, Ottawa, K1P 5E7.
- Canadian Standards Association. (1990). CAN/CSA Z 614-M90. A guideline on children's playspaces and equipment. A National Standard of Canada. Canadian Standards Association, Rexdale (Toronto), Ontario.
- Coggins, C.R. and Hiscocks, P. (1979). Chromium on the surface of CCA-treated wood. *Internat. J. Wood Preservation*. 1:69-74.
- Conradie, W.E. and Pizzi, A. (1987). Progressive heat-inactivation of CCA biological performance. *Proc. American Wood Preservers' Assoc.* 83:1-17.
- Cserjesi, A.J. (1976). Permanence of preservatives in treated experimental shake roofs. *Forest Products Journal*. 26(12):34-39.
- Dahlgren, S.-E. (1975). Kinetics and mechanism of fixation of Cu-Cr-As wood preservatives. Part V. Effect of wood species and preservative composition on the leaching during storage. *Holzforschung*. 29:84-95.
- Dahlgren, S.-E., and Hartford, W.H. (1972a). Kinetics and mechanism of fixation of Cu-Cr-As wood preservatives. Part I. pH behaviour and general aspects on fixation. *Holzforschung*. 26:62-69.
- Dahlgren, S.-E., and Hartford, W.H. (1972b). Kinetics and mechanism of fixation of Cu-Cr-As wood preservatives. Part II. Fixation of Boliden K 33. *Holzforschung*. 26:105-113.
- Dahlgren, S.-E., and Hartford, W.H. (1972c). Kinetics and mechanism of fixation of Cu-Cr-As wood preservatives. Part III. Fixation of Tanalith C and comparison of different wood preservatives. *Holzforschung*. 26:142-149.

- Davis, S.C., Waller, P., Buschbom, R.T., Ballou, J., and White, P. (1990). Quantitative estimates of soil ingestion in normal children between the ages of 2 and 7 years: population-based estimates using aluminum, silicon, and titanium as soil tracer elements. *Archives of environmental Health*. 45:88-94.
- Dunbar, J. (1962). The fixation of water-borne preservatives in cooling tower timber. *Record of the 1962 Annual Convention of the British Wood Preserving Association*. 25-53.
- Eadie, J. and Wallace, E.M. (1962). Some observations on the fixation of copper and arsenic in *Pinus sylvestris* sapwood. *J. Institute of Wood Science*. 10:56-65.
- Ermusch, N., Kalninsch, A. and Andersome, I. (1980). [The influence of the chromium component in water-soluble wood preservatives on the fixation in wood.] (In German). *Holz als Roh- und Werkstoff*. 38:175-180.
- Fahlstrom G.B., Gunning P.E., and Carlson J.A. (1967). A study on the influence of composition on leachability. *Forest Products Journal*. 17(7):17-21.
- Gilchrist, R. (1989). Under pressure. *Canadian Workshop*. June Issue, pp. 43-44.
- Goulden, F, Kennaway, E. L., and Urquhart, M. E. (1952). Arsenic in the suspended matter of town air. *British J. Cancer*. 6:1-7.
- Greaves, H. and Levy, J.F. (1978). Penetration and distribution of copper-chrome-arsenic preservative in selected wood species. 1. Influence of gross anatomy on penetration, as determined by X-ray microanalysis. *Holzforschung*. 32:200-208.
- Haeger, B. (1969). Leaching tests on copper-chromium-arsenic preservatives. *Forest Products Journal*. 19(10):21-26.
- Henry, W.T. and Jeroski, E.B. (1967). Relationship of arsenic concentration to the leachability of chromated copper arsenate formulations. *Proc. American Wood Preservers' Association*. 63:187-192.
- Jagels, R. (1985). Health hazards of natural and introduced chemical components of boatbuilding woods. *American Journal of Industrial Medicine*. 8:241-251.
- Johanson, R. and Dale, F.A. (1973). Arsenic on the surface of round pine treated with Cu-Cr-As preservative. *Holzforschung*. 27:187-189.
- Jonas, G.-Z. (1956). [The influence of various factors on the reduction of potassium bichromate in wood.] (In German). *Holz als Roh- und Werkstoff*. 14:403-407.
- Jonas, G.-Z. (1957). [Leaching and fixation of U- and UA-preservative salts in wood.] (In German). *Holz als Roh- und Werkstoff*. 15:418-423.
- Klemmer, H.W., Leitis, E., and Pfenninger, K. (1975). Arsenic content of house dusts in Hawaii. *Bulletin of Environmental Contamination and Toxicology*. 14:449-452.
- Klich, B. (1988). Pressure-treated wood must be treated with respect. *The Medical Post*. 20 Sept., p.32

Konasewich D.E. and Henning F.A. (1988). Chromated copper arsenate (CCA) wood preservation facilities. Environment Canada Report EPS 2/WP/4 (1988). Environmental Protection Publications, Conservation and Protection, Environment Canada, Ottawa, Ontario, K1A 0H3. xi + 81 pp.

Mason, J.O. (1989). Toxicological profile for arsenic. Agency for Toxic Substances and Disease Registry, U.S. Public Health Service, Department of Health and Human Services, Atlanta, Ga., 30333, 125 pp.

McCurdy R.F. (1986). Memorandum. Arsenic, chromium and copper: Treated wood. Unpublished Report (1986). Environmental Laboratory, Victoria General Hospital, Halifax, Nova Scotia. (Personal Communication from G. Lawson, Playworks Recreational Equipment Ltd., Kentville, Nova Scotia).

Micklewright J.T. (1988). Wood preservation statistics, 1986. *Proc. American Wood Preservers' Assoc.* 84:343-352.

National Research Council of Canada (NRCC). (1978). Effects of arsenic in the Canadian environment. Publication No. 15391, Associate Committee on Scientific Criteria for Environmental Quality, NRCC, Ottawa, Ontario. 349 pp.

Pepin, R. (1990). Mistreated wood. *Protect Yourself*. June 1990 issue, pp. 36-43.

Raffle, P.A.B., Lee, W.R., McCallum, R.I., and Murray, R. (Eds.). (1987). Arsenic. pp. 259-263 in: *Hunter's Disease of Occupations*. Little, Brown and Company, Boston and Toronto.

Sarkar, B. (1988). Copper. pp. 265-276 in: Seiler, H.G., Sigel, H. and Sigel, A. (Eds.) *Handbook on Toxicity of Inorganic Compounds*. Marcel Dekker, Inc., New York and Basel.

Saur, J.M., Walcheski, P.J., and Gjovik, L.R. (1983). The level of respirable arsenic on the surface of treated wood in service. *Proc. American Wood Preservers' Assoc.* 79:66-67.

Subramanian, S.K. (1988). Arsenic. pp. 573-587 in: McKenzie, H.A. and Smythe, L.E. (Eds.): *Quantitative trace analysis of biological materials*. Elsevier Science Publishers B.V., Biomedical Division.

Tam, G.K.H., Charbonneau, S.M., Bryce, F., Pomroy, C., and Sandi, E. (1979). Metabolism of inorganic arsenic (74 As) in humans following oral ingestion. *Toxicology and Applied Pharmacology*. 50:319-322.

Vahter, M. and Lind, B. (1986). Concentrations of arsenic in urine of the general population in Sweden. *The Science of the Total Environment*. 54:1-12.

Warner, J.E. and Solomon, K. R. (1990). Acidity as a factor in leaching of copper, chromium and arsenic from CCA-treated dimension lumber. *Environmental Toxicology and Chemistry*. 9:1331-1337.

Woolson E.A. and Gjovik L.R. (1981). The valence state of arsenic on treated wood. *Proc. American Wood Preservers' Assoc.* 77:15-22.

TABLE 1

RESULTS OF ARSENIC ANALYSIS OF COTTON WIPES ( $\mu\text{g/wipe}$ )

<u>SAMPLE #</u>	<u>PLAYGROUND IDENTIFICATION LETTER</u>									
	A	B	C	D	E	F	G	H	I	J
1	19.6	71.1	41.6	20.7	29.1	22.2	20.5	78.4	0.5	1.8
2	30.4	75.0	70.2 <sup>1a</sup>	39.7	23.3	26.4	0.9	322.0	1.7	2.0
3	20.8	40.6	87.7 <sup>2a</sup>	48.3	30.2	35.7	8.0	155.0	5.4	28.5
4	53.5	84.7	26.9	29.2	18.0	36.5	24.2	41.9	11.7	38.7
MEAN	31.1	67.9	64.0	34.5	25.2	30.2	13.4	149.3	4.8	17.3
$\pm$ SD	15.7	19.1	25.7	12.1	5.7	7.0	10.8	124.4	5.0	18.8

TABLE 2

RESULTS OF ANALYSIS OF SAND AND SOIL SAMPLES FOR ARSENIC CONTENT

PLAYGROUND IDENTIFICATION LETTER

<u>SAMPLE #</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>	<u>G</u>	<u>H</u>	<u>I</u>	<u>J</u>
	As content in mg/kg dry weight (ppm)									
5	0.269 <sup>3,5</sup>	1.392	7.404	0.058 <sup>3</sup>	0.300	0.364	1.667	2.791	1.665	7.189
6	9.573	1.188	7.430	0.335	0.421	0.722	0.796	5.664	3.637	2.054
7	4.193	4.507	113.5 <sup>4,5</sup>	0.131	0.505	3.913	3.083	3.990	1.319	6.577
8	5.470	2.562	6.295	0.370	0.303	1.805	0.730	9.227	1.180	4.612
MEAN	3.955	2.412	7.043	0.190	0.382	1.701 <sup>6</sup>	1.569	5.368	1.950	5.108
SD	3.908	1.522	0.648 (n=3)	0.153	0.099	1.596	1.096	2.863	1.143	2.314
CONTROL	0.194	0.224	0.371	0.100	0.211	0.179	0.249	0.228	0.200	0.275

**TABLE 3**  
**RESULTS OF COPPER ANALYSIS OF COTTON WIPES ( $\mu\text{g}/\text{wipe}$ )**

<u>SAMPLE #</u>	<u>PLAYGROUND IDENTIFICATION LETTER</u>									
	A	B	C	D	E	F	G	H	I	J
1	108.0	46.5	308	185	180	127	596	485	1.7	1.0
2	121.0	78.4	141	143	293	68.3	355	914	2.3	4.6
3	85.0	51.9	529	377	332	63.1	364	42.1	4.8	14.9
4	97.0	89.9	165	177	177	44.9	908	4.7	8.1	51.7
MEAN	102.8	66.7	285.8	220.5	245.5	75.8	555.8	361.5	4.2	18.1
$\pm$ SD	15.4	20.8	178.1	105.9	79.0	35.6	260.0	428.1	2.9	23.2

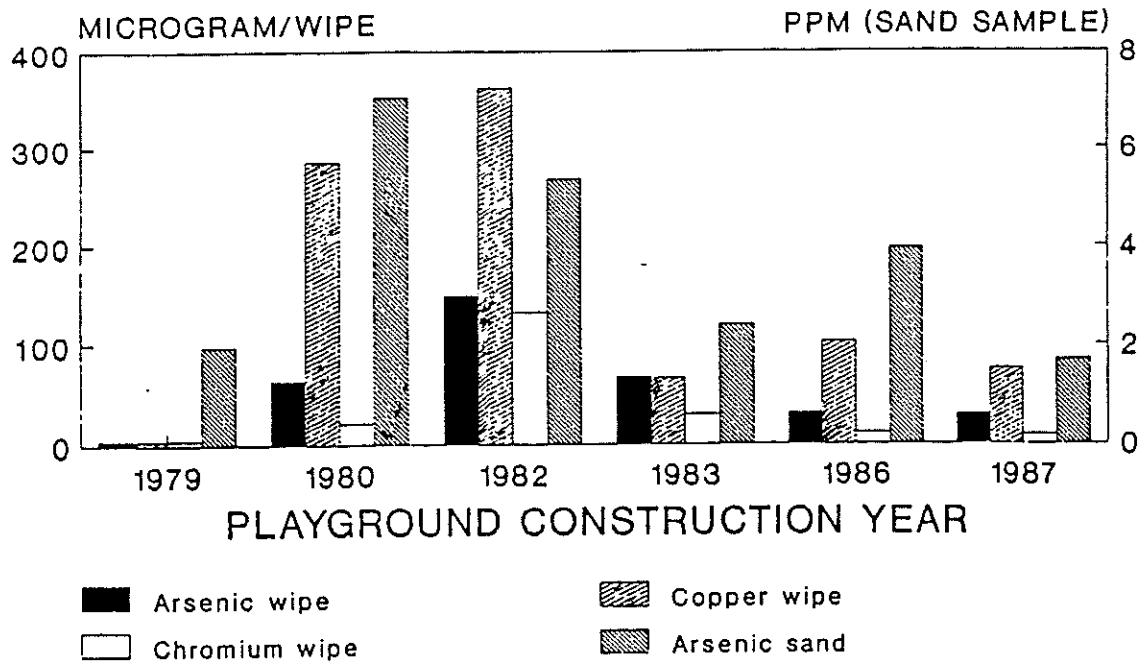
**TABLE 4**  
**RESULTS OF CHROMIUM ANALYSIS OF COTTON WIPES ( $\mu\text{g}/\text{wipe}$ )**

<u>SAMPLE #</u>	<u>PLAYGROUND IDENTIFICATION LETTER</u>									
	A	B	C	D	E	F	G	H	I	J
1	7.4	30.1	18.5	6.8	15.0	6.9	30.1	91.7	1.2	2.6
2	13.7	34.4	22.8	14.3	10.5	10.2	39.1	254	2.0	5.1
3	7.9	19.8	31.4	16.5	9.5	11.1	9.1	143	4.7	43.5
4	16.2	35.9	10.7	16.6	5.6	8.0	24.6	40.5	12.2	27.8
MEAN	11.3	30.1	20.9	13.6	10.2	9.1	25.7	132.3	5.0	19.8
$\pm$ SD	4.3	7.3	8.6	4.6	3.9	1.9	12.6	91.3	5.0	19.5



# ARSENIC/COPPER/CHROMIUM

## Wipe and sand samples/age of playground

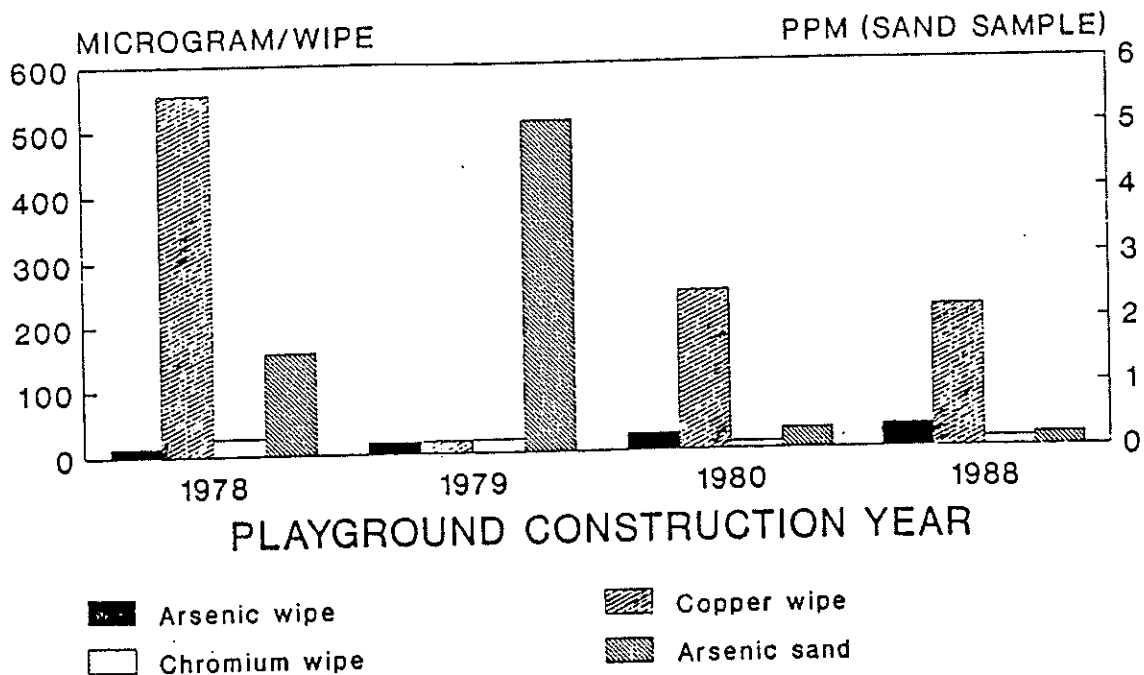


Structures not stained or painted

Figure 1

# ARSENIC/COPPER/CHROMIUM

## Wipe and sand samples/age of playground



Structures painted or stained

Figure 2