RESIDUE CHEMISTRY SCIENCE CHAPTER

EXECUTIVE SUMMARY

Chromated Copper Arsenicals(CCA) are registered for use as wood preservatives. Historically, the Agency has not considered wood preservative uses as food uses. Therefore, there have been no dietary exposure considerations for the registered use of arsenicals when used as wood preservatives and no pesticide tolerances have been required for food commodities as a result of residues that could be incurred as a result of these uses.

However, this does not prevent contact between residues from wood treated with wood preservatives and food commodities. The Agency is aware that purchasers of CCA-treated wood have frequently used CCA-treated wood in and around sites where food is grown. These uses could include, but are not limited to the use of CCA-treated wood; to outline home fruit and vegetable gardens; as stakes in gardens to support vine crops such as berries or grapes; in container box gardening; and in the construction of greenhouse planter boxes. Wood preservatives that are present in treated wood that is used for theses purposes could migrate from treated wood to soil and be taken up from soil by food commodities.

At the present time, the Agency and the wood treatment industry rely on printed information and on tags affixed to treated wood to discourage the use of CCA-treated wood around food commodities. The wood treatment industry has also agreed to voluntarily cancel the use of chromated copper arsenicals used to treat most wood, including dimensional lumber, after December 2003.

As part of the CCA residue chemistry chapter, the Agency will include a discussion of residues that could result in dietary exposure to arsenic and chromium from the use of CCA-treated wood in home gardens. These home garden uses of CCA-treated wood are considered the most likely uses that would contribute arsenic residues to the human diet.

This chapter will not include a discussion of CCA residues that could result in the diet from other uses of CCA-treated wood such as: in the construction of fruit and vegetable packing crates; truck bodies; or underwater fish-farming structures. These exposure sources are expected to largely disappear with the voluntary cancellation of the use of CCA to treat dimensional lumber.

This document addresses the levels of arsenic in food from the use of CCA-treated wood in situations where food is grown; i.e. specifically when used as landscaping wood in/around home gardens. There are little residue data available for arsenic concentrations in food reflecting the use of CCA-treated wood used in raising fruits and vegetables in gardens outlined with wood, in containers, in greenhouses, or used as garden stakes. Likewise, there are very little residue data for chromium residues in food commodities grown in the vicinity of CCA-treated wood.

The majority of residue data that are available in the literature and from researchers' studies do not reflect typical situations for the use of treated landscape wood used to outline home gardens. The available arsenic residue data generally reflect the following scenarios: plants grown in pots

with soil that has been fortified with arsenic; plants grown in pots with CCA-treated stakes or wood blocks; or plants grown in soil fortified with sawdust from CCA-treated wood. The data do tend to show that small amounts of arsenic, above background level, result in food grown near CCA-treated wood. The data are not adequate to quantitate arsenic and chromium levels under typical uses in which the bed would be outlined with CCA-treated wood. The data indicate that arsenic levels in plants appear to depend on various factors including the type of plant, the plant part, soil properties, and distance that the food plant is grown from the CCA-treated wood. Additionally, the residue data for both arsenic and chromium reflect total arsenic levels in the plants and do not differentiate between organic and inorganic arsenic and do not determine the oxidation state of the two elements.

Considering the above, it can be stated that on a fresh weight basis, the total arsenic level in edible plant parts from plants grown near CCA-treated wood is generally less than 0.3 ppm. Higher arsenic levels occur in the roots and fibrous parts of the plants(e.g. up to 1.8 ppm in bean leaves and stems).

The limited residue data available which reflect chromium levels in food commodities grown in the vicinity of CCA-treated wood appear to show little difference in the levels of endogenous chromium levels in the food plants and any added chromium residues from the CCA-treated wood. However, the data are very limited for purposes of drawing any conclusions.

DIETARY EXPOSURE CHAPTER

1. Background

Chromated copper arsenate (CCA)-treated wood is commonly used by consumers to outline vegetable gardens and construct raised-bed gardens. The use of CCA-treated wood has been popular because of its long life expectancy due to its ability to resist rot, even in soil. CCA-treated wood is manufactured by forcing CCA into the cells of the wood under high pressure. Even though a vacuum carries the CCA deep into the cells of the wood, studies have shown that arsenic and chromium from the CCA-treated wood may migrate to the soil. Once in the soil, arsenic and chromium may then be taken up by edible plants. Thus, the presence of arsenic and chromium residue in edible plants from CCA-treated timber would be considered additives to the naturally-occurring arsenic and chromium already present in food. Currently, there are no registered food uses for CCA. Few studies have been specifically conducted on the uptake of arsenic and chromium from CCA-treated wood by edible plants and the studies that are available show conflicting results. However, the majority of the studies, including the most recently conducted, show that very small amounts of arsenic from CCA-treated wood are taken up into the edible parts of plants grown in the vicinity of CCA-treated wood. The amount of arsenic taken up by plants depends on a variety of factors such as the type of plant, part of plant (i.e. root vs. above ground), distance from the CCA-treated wood, and the soil properties.

2. Results of CCA-Treated Wood Studies

Alamgir (date unknown), Stilwell (2001), Arch Wood Protection (1991), and Levi (1974) conducted experiments to study the uptake of arsenic and/or chromium in edible plants using CCA-treated lumber as the source of CCA. The Alamgir experiment consisted of growing plants in pots of sandy loam and loamy sand soil in which the soil was obtained from raised bed gardens at least ten years old and constructed with CCA-treated wood; the Arch Wood Protection (1991) experiment consisted of growing plants directly in raised bed gardens constructed with Wolmanized and Extra Wolmanized brand CCA-treated wood; the Stilwell (2001) experiment consisted of growing plants in pots of soil with CCA-treated blocks of wood; and the Levi (1974) experiment consisted of growing grapes near wooden stakes treated with CCA. All of the experiments, except Levi's, showed small increases in the level of arsenic at varying degrees in some or all of the plants as compared to the control samples. Plants were analyzed for chromium only in the studies conducted by Stilwell and Arch Wood Protection. In these studies, the concentration of chromium in the treated plants did not vary significantly from the concentration of chromium detected in the control plants.

In the Alamgir study, arsenic was detected in edible parts of carrots, spinach, beans, and buckwheat grown in pots containing soils that had been taken at distances of 0 to 1 inch away from the edge of CCA-treated boards of vegetable gardens. Residue levels were 3 to 123 times higher on a fresh weight basis than control samples (plants grown in soil obtained from 45 to 50 inches away from the edge of CCA-treated boards of vegetable gardens). Overall, on a fresh weight basis, concentrations of arsenic in the edible parts of the treated plants ranged from 0.022 ± 0.003 to 0.305 ± 0.067 parts per million (ppm) and from 0.358 ± 0.048 to 2.950 ± 0.809 ppm (on a dry weight basis) and the concentration of arsenic in the control plants ranged from less than

0.001 to 0.033 ± 0.007 ppm (less than 0.006 to 0.307 ± 0.044 ppm on a dry weight basis). For both the sandy loam and loamy sand experiments, the highest concentration of arsenic was detected in the carrot peel. The results of Alamgir's study are shown in Table 1.

In the Stilwell (2001) study, romaine lettuce, grown in pots with CCA-treated boards for 3 to 5 weeks, showed concentrations of arsenic between 0.06 and 0.1 ppm on a fresh weight basis and 0.8 and 1.7 ppm on a dry weight basis; whereas control samples exhibited concentrations of arsenic less than 0.01 ppm on a fresh weight basis and less than 0.2 ppm on a dry weight basis.

The study performed by Arch Wood Protection examined arsenic concentrations in carrots, okra, peppers, cucumbers, and tomatoes. As compared to control samples, the concentrations of arsenic in carrots were approximately three times higher for both Wolmanized and Extra Wolmanized wood (2.9 and 2.2 ppm versus less than 0.8 ppm on a dry weight basis, respectively). For okra, arsenic was not detected in the control or Wolmanized wood experiment, but was detected in the Extra Wolmanized wood experiment at a concentration of 1.5 ppm. Similarly, arsenic concentrations were less than 0.8 ppm in the control tomato plants, but reached concentrations of 0.5 ppm in the Wolmanized wood sample and 3.7 ppm in the Extra Wolmanized wood sample. For the pepper and cucumber plants, there was no significant difference between the arsenic levels detected in the plants grown in the CCA-treated garden beds versus the untreated garden beds. Additionally, there were no significant differences in the concentration of chromium detected in the plants grown in the CCA-treated garden beds versus the untreated garden beds. The results of the Arch Wood Protection Study are presented in Table 2.

The arsenic levels in the Arch study are reported only on a dry weight basis. There are no information provided as to the moisture content of the commodities. The arsenic levels for these commodities would likely be about 10 - 15% of the dry weight basis, or about 0.3 ppm on a wet basis.

3. Factors Controlling Uptake of CCA by Edible Plants

a. Type and Part of Plant

As already demonstrated in the Arch Wood Protection and Alamgir studies, the type of plant is a predominate factor in determining the amount of arsenic taken up by a plant. Additionally, metals typically tend to concentrate in roots of plants, especially in the fibrous parts, with limited movement to the edible portions above ground. However, leafy green vegetables such as lettuce, spinach, and mustard greens have also been shown to accumulate higher concentrations of metals. As such, leafy green vegetables and plants such as carrots, turnips, and potatoes tend to take up more elements from CCA (Stehouwer, 2001). In Arch Wood Protection's study, the highest concentration of arsenic was detected in the carrot (2.9 ppm on a dry weight basis), as compared to the okra, pepper, cucumber, and tomato plant. Similarly, the highest concentration of arsenic in the Alamgir study was detected in the carrot peel (0.305 ppm on a fresh weight basis and 2.95 ppm on a dry weight basis), as compared to carrots with peel, carrots without peel, spinach, bean pods, and buckwheat. Typically, metals remain on the surface of skin and can be removed by peeling (Lively, 1998).

In a study conducted by Woolson (1973), green beans, lima beans, spinach, cabbage,

tomatoes, and radishes were grown in soil to which sodium arsenate was added at a level which would reduce plant growth by 50%. This application rate was most likely an exaggerated rate and the arsenic levels in the plants would be expected to be high. In this experiment, the highest concentration of arsenic was exhibited in the radish at a concentration of approximately 8 ppm on a fresh weight basis (76 ppm on a dry weight basis), followed by spinach at a concentration of approximately 1 ppm (10 ppm on a dry weight basis). Woolson did not study the effects of chromium on the plants.

Speir (1992) conducted a study in which beets, lettuce, and clover were grown in soil to which CCA-treated sawdust was added at 10% (v/v) volume. In this study, the plant tops (above ground portions) and roots were analyzed separately for both arsenic and chromium. Speir found that arsenic and chromium did not accumulate in the tops of the plants at high levels, but did concentrate in the fibrous roots. For example, arsenic accumulated in the aboveground edible parts of lettuce at concentrations between 6 ppm and 9 ppm for all experiments (control and treated), but accumulated in the lettuce roots grown in the CCA amended soil at a concentration of around 150 ppm compared to less than 10 ppm in the controls. Arsenic levels are reported on a dry basis.

b. Soil Properties

Another factor determining the amount of arsenic and chromium taken up by plants is the properties of the soil. In particular, studies have shown that uptake by plants is higher when plants are grown in soil with a low pH. Arsenic, and especially chromium, are more soluble and mobile in soils at a lower pH. Additionally, the amounts of arsenic and chromium leached from wood to the soil will increase as the pH decreases, thus providing a greater amount of CCA available for uptake in plants. In Speir's study, plants were grown in CCA amended soil with a pH of 5 and a pH of 7. In general, the concentration of arsenic and chromium was greater in the plants grown in the soils with a pH of 5 than a pH of 7. Additionally, in the Alamgir study, the higher concentrations of arsenic detected in the plants grown in the loamy sand soil as compared to the sandy loam soil may have been attributed to the lower pH in the loamy sand soil, as well as a higher organic matter content and slightly higher concentrations of arsenic in the loamy sand soil.

c. Distance from CCA-Treated Wood

The distance of the plants from the CCA-treated wood may also determine the amount of CCA which will be taken up by the plants. In general, the concentration of arsenic in soil will decrease as the distance from the CCA-treated wood increases. For example, in the Alamgir study, the arsenic concentrations in the soil collected from 0 to 1 inch from the treated wood were significantly higher than soil collected from 45 to 50 inches from the treated wood. The analysis of the plants grown in soil from these distances also showed higher concentrations of arsenic in the plants grown in soil from 0 to 1 inch from the edge of the wood. According to DeGroot (1979), the soil adjacent to CCA-treated posts, which had been in the ground for 30 years, showed increases in arsenic and chromium within 6 inches from the posts, but no changes further away. As such, it appears that the CCA elements which do leach from CCA-treated wood do not migrate far from the wood.

d. Valence State of Arsenic

The valence state and form of arsenic determines the level of toxicity in plants and humans. In general, inorganic arsenic is more toxic than organic arsenic. The oxidation state of arsenic was not determined in the studies reviewed. Of the total levels of arsenic detected in the plants, much of the arsenic would be in the organic form (Lively, 1998).

4. Dietary Risk from CCA-Treated Wood

In general, the studies reviewed conclude that most edible plants grown in gardens constructed with CCA-treated wood tend to have a slightly higher concentration of arsenic in the plant tissue as compared to control samples. For the most part, however, the concentrations of arsenic in the plants are below 0.3 ppm on a wet basis. In the studies reviewed, the maximum concentration of arsenic detected in plants grown near CCA-treated lumber was 2.9 ppm on a dry weight basis. The amount of arsenic taken up by plants may decrease with increased distance from the edge of the treated wood and may be higher in root crops (i.e., carrots and beets). Limited data are available on the uptake of chromium by plants from CCA-treated wood. However, the data available suggest that plants grown in gardens constructed with CCA-treated wood show no greater concentration of chromium in the plant tissue than plants grown elsewhere.

Table 1: Concentrations of Arsenic Detected in Plants Grown in Soils Near CCA Treated Wood, As Determined in the Alamgir, F, D. Allen, and C. Rosen Study

Crop	Soil Type	Distance From Treated Wood (inch)	Arsenic Concentration (part per billion)	
			Fresh Weight Basis	Dry Weight Basis
Carrots (without peel)	Loamy Sand	0 - 1	27 ± 4	186 ± 32
	Loamy Sand	45 -50	9 ± 2	55 ± 7
	Sandy Loam	0 - 1	43 ± 8	283 ± 45
	Sandy Loam	45 -50	5 ± 2	30 ± 10
Carrot Peel	Loamy Sand	0 - 1	165 ± 15	1,633 ± 169
	Loamy Sand	45 -50	33 ± 7	307 ± 44
	Sandy Loam	0 - 1	305 ± 67	2,950 ± 809
	Sandy Loam	45 -50	19 ± 3	165 ± 50
Carrots (with peel)	Loamy Sand	0 - 1	51 ± 3	378 ± 29
	Loamy Sand	45 -50	14 ± 2	92 ± 13
	Sandy Loam	0 - 1	85 ± 12	608 ± 70
	Sandy Loam	45 -50	8 ± 3	49 ± 10
Spinach	Loamy Sand	0 - 1	22 ± 3	358 ± 48
	Loamy Sand	45 -50	5 ±0.4	72 ± 8
	Sandy Loam	0 - 1	92 ± 9	1,475 ±96
	Sandy Loam	45 -50	5 ± 0.5	65 ± 9
Beans	Loamy Sand	0 - 1	38 ± 21	318 ± 184
	Loamy Sand	45 -50	<1 ± 1	<9 ± 7
	Sandy Loam	0 - 1	40 ± 23	360 ± 204
	Sandy Loam	45 -50	<1 ± 0.3	<6 ± 2
Beans Leaves and Stems	Loamy Sand	0 - 1	1,150 ± 73	6,831 ± 922
	Loamy Sand	45 -50	113 ± 12	682 ± 85
	Sandy Loam	0 - 1	1846 ± 130	10,894 ± 1,575
	Sandy Loam	45 -50	15 ± 6	105 ± 47
Buckwheat	Loamy Sand	0 - 1	59 ± 15	565 ± 146
	Loamy Sand	45 -50	7 ± 0.3	54 ± 4
	Sandy Loam	0 - 1	229 ± 86	1,966 ± 663
	Sandy Loam	45 -50	4 ± 2	37 ± 13

Table 2: Concentrations of Arsenic and Chromium Detected in Plants Grown in Soils Near CCA Treated Wood, As Determined in the Arch Wood Protection Study

Vegetable Analysis, Dry Basis, mg/kg (ppm)				
Vegetable	Untreated Wood	Wolmanized Wood	Extra Wolmanized Wood	Store Purchase
Arsenic				
Carrot	<0.8	2.2	2.9	2.7
Okra	<0.8	<0.8	1.5	--
Pepper	<0.8	0.5	<0.8	--
Cucumber	0.5	<0.9	<0.5	--
Tomato	<0.8	0.5	2.1	3.7
Chromium				
Carrot	3.5	1.5	1.9	1.3
Okra	1.2	1.1	0.2	--
Pepper	0.5	0.9	0.9	--
Cucumber	1.9	1.2	0.5	--
Tomato	1.1	0.4	3.5	0.6

LITERATURE SUMMARIES

Alamgir, F., D. Allen, and C. Rosen, date unknown

This study assesses the safety of using CCA-treated wood vegetable garden beds by evaluating the distribution of arsenic in the soil and the uptake of arsenic in carrot, spinach, bean, and buckwheat plants. The uptake of arsenic in plants was studied by growing the plants in pots with sandy loam and loamy sand soil in which the soil was obtained from raised bed gardens at least 10 years old and constructed with CCA-treated wood. With respect to the distribution of arsenic in the soil, the study authors concluded the concentration of arsenic in the soil is higher closer to the wood (39.7 to 49.9 ppm at 0 to 1 inch from the wood) and decreases further away from the wood (<3.1 to 10.4 ppm at 45 to 50 inches from wood). With respect to the uptake of arsenic in the plants, the plants grown in soil collected from 0 to 1 inch away from the treated wood exhibited concentrations of arsenic significantly higher than the plants grown in soils collected from 45 to 50 inches away from the treated wood (control samples). The levels of arsenic detected in the edible portions of the plants were at or below 0.3 ppm2.6 ppm on a fresh weight basis. Of the edible plant parts, carrot peel exhibited the highest concentration of arsenic in both the sandy loam and loamy sand soils (0.305 and 0.165 ppm on a fresh weight basis, respectively). It is unlikely that plants would be grown in pots filled with soil taken from within 1 inch of treated wood. The exception would be for plants grown in container gardening. Arsenic levels would also tend to be higher in container gardening because the plant root system are confined to the container and not spread into surrounding soil as would be the case for plants grown in a garden.

Arch Wood Protection, 1992

This is an excerpt from a study conducted to assess the uptake of chromium, copper, and arsenic in vegetables grown in raised bed gardens constructed with Wolmanized and Extra Wolmanized brand CCA-treated lumber. The vegetables studied were carrots, okra, peppers, cucumbers, and tomatoes. The concentration of copper, chromium, and arsenic in the vegetables grown in the raised bed gardens constructed with Wolmanized and Extra Wolmanized CCA-treated lumber were compared to concentrations detected in the vegetables grown in raised bed gardens constructed with untreated lumber, and concentrations in store bought vegetables. Concentrations of chromium and copper detected in the vegetables grown in the treated beds were very similar to the concentrations detected in vegetables grown in the control (untreated) beds, and the store purchased vegetables. Arsenic was detected in the carrots and tomatoes grown in the treated beds at concentrations slightly higher than the carrots and tomatoes grown in the control beds. However, the concentrations of arsenic in the store purchased vegetables were similar to the concentrations in the vegetables grown in the treated beds.

Levi, M.P., D. Huisingh, W.B. Nesbitt, 1974.

This is an excerpt from a study in which grapes were analyzed for copper, chromium, and arsenic at 1, 2, and 3 years after planting the grapes three inches from Southern pine posts which were treated with chrome-arsenate or flour-chrome-arsenate-dinitrophenol. Chromium and arsenic were not detected in the grapes at concentrations above the limit of detection (0.2 and 0.05 ppm, respectively). Thus, the study concluded that there is no evidence for the uptake of wood preservative components into leaf tissue, stem tissue, or fruit of plants grown adjacent to treated posts.

Lively, R., 1998

This article presents information to help gardeners decide if pressure-treated wood belongs in the garden. Specifically, the article provides data from a variety of sources on leaching of arsenic from CCA-treated wood into the soil and the uptake of arsenic in vegetables. The article also provides information on alternative preservatives which can be used to treat wood.

Speir, T.W., J.A. August, and C.W. Feltham, 1992

To access the feasibility of using CCA sawdust as a soil amendment, beetroot, white clover, and cos lettuce were grown in soil to which CCA sawdust was added at a 10% (v/v) level. After the addition of the CCA sawdust, the arsenic and chromium contents of the soil increased by 63 mg/kg and136 mg/kg, respectively. As compared to the control samples, very little arsenic and chromium were taken up to the plant tops and beetroot bulbs; however, large amounts were taken up in the fibrous roots of the plants. Additionally, the uptake of arsenic and chromium in the roots and plant tops was generally higher at a pH of 5 than a pH of 7. The study authors concluded that the uptake of arsenic and chromium by the edible portions of the plants are low, and probably would be minimal at a normal garden pH; however, uptake of arsenic and chromium by fibrous roots is a concern. The study authors stress that this study only evaluated three plant species and a wider range of edible plants should be studied. The use of sawdust from CCA-

treated wood is not a recommended practice. However, this practice could result in arsenic levels above background levels in plants.

Stehouwer, R., 2001

This fact sheet, prepared by Pennsylvania State University, College of Agricultural Science, Agricultural Research and Cooperative Extension, explains the method for treating wood, examines the risks from gardening with treated lumber, and makes recommendations for reducing any possible risks. Specifically, the fact sheet provides information on the effects of arsenic, chromium, and copper on plant and human health, the properties of these elements in soil and plants, and scientific evidence for the leaching of these elements from treated wood and uptake into plants.

Stilwell, D., 2001

Stilwell conducted experiments using romaine lettuce and mustard greens grown in Pro Mix (50% Peat Moss, 25% Perlite, 25% Vermiculite, and lime to pH 5.6) and sandy loam soil to which CCA treated blocks of wood, CCA liquid spikes, or CCA powder was added. The plants were allowed to grow for 3 to 5 weeks in pots and were then analyzed for copper, chromium, and arsenic by atomic spectroscopy. The results show that small, but measurable, increases of arsenic were detected in the lettuce grown with CCA sawdust and CCA treated blocks of wood. The amount of arsenic detected in the mustard plants, which were only grown in pots of soil treated with liquid CCA, was about 8 times greater than the amount detected in the romaine lettuce grown under the same conditions. In most cases, the arsenic level in the plant tissue increased as the concentration of arsenic in the soil increased. However, in some cases, the arsenic level in the plant tissue reached a plateau or saturated region. The form of arsenic found was not known. In this report, Stilwell also summarizes the results of experiments conducted by other researchers on the leaching of CCA from CCA-treated wood to soil and the subsequent uptake of CCA in plants.

This study is intended to show that arsenic added to soil can result in an increase in plant arsenic concentrations. The plant arsenic levels in the study are undoubtedly higher than would have occurred if the plants had been grown in untreated soil.

Woolson, E.A. , 1973

This study analyzed the phytotoxic response and crop uptake of arsenate by six different vegetable crops on three soils with different physical and chemical characteristics. The soils were treated with 500 ppm of arsenic as sodium arsenate. The results showed that the phytotoxicity of arsenic residues was highest on Lakeland loamy sand and lowest on Hagerstown silty clay loam. Correlations between available arsenic and plant dry weight indicated that green beans were most sensitive to arsenic. Following green beans, the crop sensitivity to arsenic in declining order was lima beans, spinach, radish, tomato, and cabbage. When considering the edible plant parts, radish (a root crop) had the highest arsenic content at the level which growth was reduced by 50% (GR_{50}) by the addition of sodium arsenate to the soil. Spinach had the next highest arsenic content at the GR_{50} level. The arsenic concentrations in the radish and spinach plants at the GR_{50} level were approximately 8 ppm and 1 ppm on a fresh weight basis, respectively, and 76 ppm and 10 ppm on a dry weight basis, respectively. The soil at the GR_{50} level for radish contained about

19 ppm of available arsenic from a treatment of 50 ppm to the Hagerstown soil and 100 ppm to the other two soils. Correlation coefficients between the arsenic and the edible part of the plant were much lower than when the whole plant was considered, expect for radish, spinach, and lima beans.

LITERATURE REFERENCES

Alamgir, F., D. Allen, and C. Rosen. No Date Available. Arsenic Availability from CCA Treated Lumber and Uptake by Plants. Department of Soil, Weather, and Climate. University of Minnesota. www.preservedwood.com/safety/research_rosen.html

Arch Wood Protection. 1992. Raised Bed Garden Study. www.wolmanizedwood.com/raisedbed.html

DeGroot, R.C., T.W. Popham, L.R. Gjovik, and T. Forehand. 1979. Distribution Gradients of Arsenic, Copper and Chromium around Preservative-Treated Wooden Stakes. J. Environ. Qual. 8(1):39-41.

Lively, R. 1998. Does Pressure-Treated Belong in Your Garden? Kitchen Garden. 15:55-59.

Speir, T.W., J.A. August, and C.W. Feltham. 1992. Assessment of the Feasibility of Using CCA (Copper, Chromium, and Arsenic) - Treated and Boric Acid - Treated Sawdust as Soil Amendments. Plant and Soil. 142:235-248.

Stehouwer, R. 2001. Environmental Soil Issues - Garden Use of Treated Lumber. Penn State College of Agriculture Science Research.

Stilwell, D.E. 2001. Uptake of Arsenic by Plants Grown Near CCA Preserved Wood. Department of Analytical Chemistry. The Connecticut Agricultural Experiment Station. Unpublished.

Woolson, E.A. 1973. Arsenic Phytotoxicity and Uptake in Six Vegetable Crops. Weed Science. 21(6):524-527.

Levi, M.P., D. Huisingh, W.B. Nesbitt. 1974. Uptake by Grape Plants of Preservatives from Pressure-Treated Posts Not Detected. www.wolmanizedwood.com/levi.html