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Public Health Risk Assessment of CCA-Products

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Chromium - Copper - Arsenic products CCA-preserved wood

Public Health Risk Assessment

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1. Introduction

Chromium (C) - Copper (C) - Arsenic (A) preparations are widely used as preservative agents for timber products. In the Netherlands, these timber products are for example used for fences in gardens, wooden building constructions, and in outdoor playing structures. For the prolongation of the admittance of a number of CCA-products, the National Institute of Public Health and the Environment was requested to prepare a toxicological evaluation of the ingredients of CCA-products followed by a risk assessment with respect to public health. Toxicological consequences of occupational exposure will not be addressed in this report.

A toxicological evaluation of chromium trioxide, copper oxide, and arsenic pentoxide was prepared recently (see ref. 1). The toxicological data and endpoints as presented in this report will be used for the present risk assessment unless otherwise indicated. Because solid estimates of the toxicological limit values are not always present for each route of exposure, for some conditions a scientifically based quantitative estimation of the risk involved cannot be determined. In these conditions, a brief qualitative estimate of the expected risk will be provided. For such conditions, it should be emphasised that such estimates are indicative solely, and one should be careful to draw any 'hard' conclusions in these cases.

In 1995, the RIVM already published an evaluation of the public health effects of CCA-products (see ref. 2) for the Ministry of Public Health, Welfare, and Sports (VWS). Essentially, the present evaluation will be based primarily on this report of Janssen et al. (2) supplemented with new data and insights where possible or relevant.

The present report consists of 8 chapters: 1) Introduction, 2) Production and use of CCA-products, 3) Toxicological endpoints for Chromium, Copper, and Arsenic, 4) Possible routes of exposure and exposure levels, 5) Risk Assessment, 6) RIVM Evaluation and Conclusions, 7) Main Uncertainties in the Calculations, and 8) References

2. Production and Use of CCA-products

2.1 Type and Composition of the Products

CCA-Products are used as wood preservatives against the damaging actions of fungi and insects. The active ingredients of these products are chromium-compounds (dichromates or chromic acid), copper compounds (copper sulfate or copper (II) oxide), and arsenic compounds (mainly arsenic pentoxide). Copper and arsenic are responsible for the fungicidal and insecticidal actions whereas chromium primarily functions as a fixative agent. Over the years, mainly mixtures on the basis of oxide formulations have been used.

Several types of CCA-products are available on the (inter)national market. In West-Europe mainly two types have been used which are characterised by the relative amounts of the active ingredients.

CCA Type B	35% CrO ₃ , 45% As ₂ O ₅ , 20% CuO	1 : 1.28 : 0.57	Cr - As - Cu
CCA Type C	52% CrO ₃ , 29% As ₂ O ₅ , 19% CuO	1 : 0.56 : 0.37	Cr - As - Cu

As can be concluded from the above data, primarily the ratio of chromium over arsenic determines the type of CCA-product. The proportional composition of the various commercial products can be a little different as compared to the above composition. For wood impregnation, CCA-products are commonly used as aqueous solutions of 1-5% (w/v).

Depending on the type of wood and the type of usage of the wood, the dosages of CCA-salts are varying from 3 to 16 kg CCA/m³ wood (in most products about 4-7 kg/m³).

2.1.2 Treatment of Wood

Treatment of wood with CCA-products in the Netherlands, is almost exclusively performed by vacuum-pressure impregnation. The vacuum is used to subtract the residual water from the wood. Impregnation is performed under slight overpressure (± 800 kPa). After the pressure-treatment, the wood is removed from the treatment chamber (after termination of the pressure-treatment a short rest period may be incorporated) while it is still wet. For an effective preservation, the metals react with wood sugars (lignin) to form highly insoluble precipitates which results in a fixation of the metals within the wood (3). This can be performed by a 'natural' process or by an artificially accelerated fixation process. The 'natural' method involves only the storage of the treated wood for a few weeks in the open air (with or without roof-protection). The artificial method is performed directly after the pressure treatment and involves either steam-fixation or storage in a climate-chamber. The latter process is essentially identical to the 'natural' process in which the wood is stored at an elevated temperature (e.g. 35°C) solely to accelerate the process of fixation. Steam-fixation ('Hifix') is a rather fast process at a high temperature (e.g. 70°C) in which local differences in the proportions of the ingredients can occur (4). In addition, the surface of the treated wood is 'washed' using the Hifix process.

Because of the chemical reactions occurring in the wood, hexavalent chromium is converted to trivalent chromium. Depending on the accuracy of the fixation process, the type of wood used and the relative proportions of chromium, arsenic, and copper, the efficiency of fixation may be hampered resulting in residual amounts of Cr(VI) in the wood or on the surface of the wood. For example, in a Swedish study (5) the residual amount of Cr(VI) in commercially available wood varied from 12 to 22% of the total amount of chromium (see section 4.1.1).

As mentioned above also the relative proportions of chromium, arsenic, and copper are of importance for the effectiveness of fixation. It is known that the amount of leaching of the metals from wood treated with CCA-type C is considerably less compared to treatment with CCA-type B (2,4). Therefore, most impregnation companies in the Netherlands use type C CCA-products (32).

3. Toxicological Endpoints and Limit-Values

In this chapter a condensed presentation of the most relative toxicological endpoints and limit-values will be given for each compound separately. The information in the following paragraphs is based on the RIVM-CSR-advisory report no. 05318A00 (ref. 1). For chromium, the values for chromium (III) and chromium (VI) will be presented separately. In this report no discussion on the toxicological limit-values is included. A detailed description and discussion of the toxicological endpoints and their evaluation was recently presented in ref. 1.

3.1 Chromium

3.1.1 Chromium VI

Absorption

Inhalation:

Cr(VI) is rapidly taken up from the lungs and transferred to other tissues. Absorption is positively correlated to the water-solubility of the Cr(VI)-compound.

Oral:

Hexavalent chromium is absorbed more than Cr(III). In humans, absorption values ranging from 1.1 to 17.5% of the ingested dose have been observed. Mean absorption values are about 5-6% of the dose. A value of 6% will be used to calculate the absorbed dose after oral intakes.

Dermal:

For CrO₃ (which is the Cr(VI)-compound in CCA-products) it can be concluded that absorption through the skin is significant (at least at high doses) since oral and dermal LD₅₀ values are nearly identical. Reported quantitative absorption values for various Cr(VI)-compounds are highly variable and fractional data range from <1% - 4% of the administered dose. This indicates that for most Cr(VI)-compounds, dermal absorption is rather low, with the possible exception of CrO₃. The value of 4% will be used to calculate the dermal uptake of Cr(VI) in this evaluation.

Metabolism, Distribution, Excretion

Systemically available Cr(VI) will be converted to Cr(III) within the gastrointestinal tract, the blood and the liver. Although this reducing capacity is high, it is still unclear whether Cr(VI) is completely converted to Cr(III) (see ref. 1, for a detailed discussion on this subject). Cr(VI) is physiologically present as the chromate-ion (CrO₄⁻) which is easily transported into all cells of the body. The main route of excretion for systemically available chromium is excretion via the urine. (see ref. 1).

Irritation and Sensitisation

Cr(VI)-compounds are considered to be irritative and corrosive to the skin, the eyes, and the airways. Cr(VI)-compounds are also able to induce a sensitisation response after skin contact and inhalation.

Short / Long-term Toxicity

Inhalatory Route:

All Cr(VI)-compounds are classified as known human carcinogens by inhalation. In addition, Cr(VI) is a potent genotoxic substance. Based on various epidemiological studies the WHO proposed a general unit risk (i.e. the risk for lung cancer at a life-time exposure to 1 µg/m³) of 4 x 10⁻². Based on this UR, the RIVM calculated a life-time risk of 1 x 10⁻⁶ at a life-time exposure to 0.025 ng Cr(VI)/m³ (28) which was adopted in the recent evaluation on CCA-components (1).

For non-carcinogenic effects, A NOAEL of 1 µg Cr(tot)/m³ has been observed in workers for nasal mucosa irritation and ulceration and a decrease in lung function parameters (see ref. 1). Based on this value, the ATSDR calculated an MRL¹ of 0.02 µg Cr(VI)/m³ for intermittent occupational exposure (28).

¹ MRL = Minimal Risk Level.

In the Netherlands MAC-values have been established at $60 \mu\text{g}/\text{m}^3$ (as inhalable dust) for soluble Cr(III) compounds (TWA-8h) and $50 \mu\text{g}/\text{m}^3$ (as inhalable dust) for Cr(VI) compounds (TWA-8h) (6).

Oral Route:

Only limited adequate information is available. Cr(VI) is converted for an extensive amount to Cr(III) inside the gastro-intestinal tract. However, it must be remarked that the available evidence to support a threshold-concept for oral Cr(VI) exposure is at present considered to be insufficient to abrogate the non-threshold concept for oral Cr(VI) exposure (for evaluation see ref. 1). Because Cr(VI) is a potent genotoxic substance, a carcinogenic risk after oral exposure cannot be excluded.

Although the SMRs² of various forms of non-pulmonary cancer have been presented (7), a unit risk cannot be derived from these values because of the lack of appropriate exposure data.

For non-carcinogenic effects the EPA determined a long-term RfD³ of $5 \mu\text{g Cr(VI)}/\text{kg bw}/\text{day}$ based on a less than life-time toxicity study in rats (NOAEL was $2.5 \text{ mg}/\text{kg bw}/\text{day}$). This value will be used for risk assessment in this evaluation.

Dermal Route:

The most documented and relevant effects after dermal exposure are irritation and sensitisation. For sensitisation, a 10% allergic response level in sensitised individuals has been determined at $0.089 \mu\text{g}/\text{cm}^2$. Because the prevalence of Cr-induced contact dermatitis in the overall population is lower than 1%, the limit value of $0.089 \mu\text{g}/\text{cm}^2$ is considered to protect 99.9% of the overall population (28). This limit value was adopted in the recent evaluation on CCA-components (see ref. 1). Concentrations needed to induce sensitisation are substantially higher (for solutions 1750 to 7000 mg/l)(1).

3.1.2 Chromium (III)

Absorption

Inhalation:

Quantitative data for absorption of Cr(III)-compounds are limited. It was estimated that 5-30% of an inhaled dose was absorbed or cleared from the lungs.

Oral:

The absorption of inorganic trivalent chromium after ingestion is very low. Mean absorption values of 1-2% are reported for inorganic Cr(III). The value of 2% will be used to calculate the absorbed dose after oral intakes in this evaluation.

Dermal:

No data are available with respect to dermal absorption values of Cr(III). However, it is generally accepted that dermal absorption of Cr(III) is substantially less than observed for Cr(VI). A default value of 1% will be used in this evaluation to calculate dermal uptake of Cr(III).

Metabolism, Distribution, Excretion

Absorbed Cr(III) is transported almost exclusively in the blood plasma because biological membranes are relatively impermeable to Cr(III). Cr(III) is an essential micro-nutrient to mammals. The minimum daily requirements are estimated at 2 - 8 μg per day for adults. Recommended daily dietary intakes are 50 - 200 $\mu\text{g Cr(III)}/\text{day}$ (28). For other aspects of chromium metabolism, see Cr(VI).

Irritation and Sensitisation

Cr(III) is considered to be non-irritative to the (intact) skin. Although Cr(III) is able to induce allergic contact dermatitis or to induce a sensitisation response in Cr(VI)-sensitised individuals (cross reactivity), the levels of Cr(III) required for these effects are considerably higher than for Cr(VI). Using Cr(VI)-sensitised individuals the 10%-response level for allergic contact dermatitis was $> 33 \mu\text{g Cr(III)}/\text{cm}^2$ (highest dose tested)(see ref. 1). The value of $33 \mu\text{g}/\text{cm}^2$ will be used for risk assessment in this evaluation.

² SMR = Standard Mortality Ratio.

³ RfD = Reference dose. The RfD is equivalent to the ADI (acceptable daily intake).

Short / Long-term Toxicity

Inhalatory Route:

Cr(III)-compounds are not considered to be genotoxic or carcinogenic. In the criteria document for chromium an inhalatory limit-value for Cr(III) has not been established (11) which was adopted in the recent evaluation of CCA-components (1).

A route-to-route extrapolation based on the oral limit-value yields an inhalatory limit value of 20 $\mu\text{g}/\text{m}^3$. However, because of the low reliability of this value, it may be used only for indicative purposes (see ref. 2).

In the Netherlands MAC-values have been determined of 60 $\mu\text{g}/\text{m}^3$ (as inhalable dust) for soluble Cr(III) compounds (TWA-8h) and 50 $\mu\text{g}/\text{m}^3$ (as inhalable dust) for Cr(VI) compounds (TWA-8h) (6).

Oral Route:

Cr(III) is an essential element for mammals. Minimal daily requirements are estimated to be 0.03 - 0.13 $\mu\text{g}/\text{kg}$ bw/day. In long-term studies with rats, NOAEL's of 1210 and 2.5 mg Cr(III)/kg bw/day have been observed. Based on the lowest NOAEL, Vermeire et al. (8) calculated a temporary TDI of 5 μg Cr(III)/kg bw/day. However, it should be remarked that the dose level of 2.5 mg Cr(III)/kg bw/day was the highest dose tested in the study involved (28). The EPA determined an oral RfD of 1000 $\mu\text{g}/\text{kg}$ bw/day for Cr(III) based on the absence of effects in a chronic rat feeding study using a highest dose of 1460 mg/kg bw/day. The limit-value of 1000 $\mu\text{g}/\text{kg}$ bw/day, which correlates to the low toxicity of Cr(III) compounds, will be used for risk assessment in this evaluation.

Dermal Route:

The available information is extremely limited. For dermal sensitisation, cross-reactivity between Cr(VI) and Cr(III) may occur (see above).

3.2 Copper

Because Cu^+ can be converted to Cu^{2+} in-vivo (and vice versa), toxicological limit-values will be presented for copper in general without specification of the chemical speciation (see refs. 1,9).

Absorption

Inhalation:

No adequate quantitative data are available for the determination of copper absorption during inhalatory exposure. It has been reported that about 20% of the inhaled copper is absorbed (this value is indicative only).

Oral:

Copper is an essential trace element for all living organisms. Mammals possess a homeostatic regulatory mechanism for controlling the uptake of copper from the gastrointestinal tract. Mean absorption values range from 25-70% of the ingested dose.

Dermal:

Dermal absorption is known to occur although it may be low. Only a single animal study reported a fractional absorption value for dermal absorption which amounts to 3% of the applied dose.

Metabolism, Distribution, Excretion

Absorbed copper is transported to the liver. Within the liver (the homeostatic control organ for copper) copper is either retained bound to thionein-like proteins, excreted to the bile, or bound to ceruloplasmin and excreted to the circulation. The total copper content of the human body is about 50-150 mg. Daily requirements for adults are about 1-3 mg.

Copper is almost exclusively excreted via the bile into the faeces. Faecal excretion accounts for more than 90% of total copper excretion. Urinary excretion is only a minor route.

Irritation and Sensitisation

Copper is considered to be irritating to the eyes and the airways. There are no indications for skin irritation after dermal contact with copper. Although the prevalence is very low, copper may induce sensitisation due to dermal contact in humans.

Short / Long-term Toxicity

Inhalatory Route:

In humans, copper fumes and mists may induce so-called "Metal Fume Fever". In the recent evaluation of CCA-components no inhalatory limit-value has been established (see ref. 1). In occupational studies, Metal Fume Fever has been observed at levels of $100 \mu\text{g}/\text{m}^3$. Based on this information, Calabrese and Kenyon (10) calculated a highly provisional limit-value of $20 \mu\text{g}/\text{m}^3$. This provisional limit-value will be used for risk assessment in the present evaluation although it is noted that this value can be used for indicative purposes only. In the Netherlands MAC-values have been determined for copper fumes ($200 \mu\text{g}/\text{m}^3$) and copper dust ($1000 \mu\text{g}/\text{m}^3$) (6).

Oral Route:

Information on intoxication after oral exposure is limited. In general no adequate chronic toxicity studies are available. Reliable NOAELs were identified only in subchronic animal studies: 5-7 mg for rats, 3 mg for pigs, 8 mg for dogs, and 44 mg for mice (all expressed in mg Cu/kg bw/day) (see ref. 1). In the criteria document for copper (11) it was concluded that, based on copper levels in food and drinking water, the daily dietary intake of humans will not easily exceed 10 mg, corresponding to 0.17 mg Cu/kg bw/day. This value has been recommended as a safe level of dietary intake (29) and was recently adopted in the evaluation on CCA-components (see ref. 1). The limit value of $170 \mu\text{g}/\text{kg}$ bw/day will be used risk assessment in the present evaluation.

Dermal Route:

A dermal limit value for copper is not available (see ref. 1).

3.3 Arsenic

Because As^{3+} can be converted to As^{5+} in-vivo (and vice versa), the limit-values will be presented for total arsenic without specification of the chemical speciation (see for details ref. 1).

Absorption

Inhalation:

The absorption of inhaled arsenic is correlated to the water-solubility of the compound. Inhaled arsenic is first deposited in the lung after which nearly all deposited arsenic is absorbed. Both deposition as well as absorption values varied from 30-60%.

Oral:

Absorption values of water-soluble inorganic As-compounds are 80-90% of the ingested dose in humans and 80-100% in experimental animals. For less water-soluble compounds, the absorption is lower. For inorganic arsenic, a value of 95% is used for risk assessment in the present evaluation.

Dermal:

Dermal absorption of As-compounds is usually considered to be sufficiently slow that this route is unlikely to be of health concern. No quantitative data were available in ref. 1. A recent publication of Wester et al. (12) reported dermal absorption values in-vivo of about 4% in both animals and humans. The value of 4% will be used for risk assessment in the present evaluation.

Metabolism, Distribution, Excretion

Absorbed arsenic is rapidly distributed throughout the whole body. While trivalent arsenic tends to accumulate in tissues, pentavalent arsenic is more rapidly excreted. Arsenic can be metabolised by two processes (independent of exposure route): 1) reduction/oxidation reactions ($\text{As}^{3+} \leftrightarrow \text{As}^{5+}$); 2)

methylation of As^{3+} in the liver to monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA). Since methylation is an enzymatic process, this methylation capacity can become saturated. Excretion of As occurs mainly via the kidneys. In humans the proportions of metabolic products in urine are usually 40-60% DMA, 20-25% As^{3+} and As^{5+} , and 15-25% MMA (see ref. 1)

Irritation and Sensitisation

Trivalent arsenic is considered to be irritative to the skin, the eyes, and the airways. For pentavalent arsenic no data are available. Since interconversion of As^{3+} and As^{5+} is possible, pentavalent arsenic is considered to possess identical irritative properties. Occupational exposure to As^{3+} has been shown to induce sensitisation due to skin contact (see ref. 1).

Short / Long-term Toxicity

Arsenic was considered to be a human carcinogen after oral exposure (skin-tumours) as well as inhalatory exposure (pulmonary tumours). Arsenic induces chromosome aberrations in mammalian cells. Mechanistic studies indicate that As inhibits specific enzymes associated with DNA replication or DNA-repair systems. It is assumed that for this mechanism of action, a threshold concentration exists. Therefore, limit values for the oral and inhalatory route have been established (29).

Inhalatory Route:

Inhalatory exposure to arsenic is associated with irritation of the mucosa of the nose, the larynx, and the bronchi, as well as conjunctivitis and dermatitis. Other effects included slight effects on the cardiovascular system and neuropathology. Marginal effects were observed at $50 \mu\text{g}/\text{m}^3$. In the RIVM criteria document on arsenic it was concluded that an occupational exposure of $5 \mu\text{g}/\text{m}^3$ would not result in toxic effects. Using a safety-factor of 10, this NOAEL provided the basis for a limit-value of $0.5 \mu\text{g}/\text{m}^3$ for the general population (29) which was adopted in the recent evaluation of CCA-components (1). The value of $0.5 \mu\text{g}/\text{m}^3$ will be used for risk assessment.

In the Netherlands MAC values have been determined for the combined exposure to various As-compounds ($50 \mu\text{g}/\text{m}^3$ TWA-8h) and soluble As-compounds ($25 \mu\text{g}/\text{m}^3$ TWA-8h). For short term exposures (15 min) these values are 100 and $50 \mu\text{g}/\text{m}^3$ respectively (6).

Oral Route:

The most critical effects after prolonged oral exposure to arsenic were hyperpigmentation and hyperkeratosis of the skin. NOAELs for these effects ranged from 0.4 to $3 \mu\text{g}/\text{kg}$ bw. In the RIVM criteria document on arsenic the weekly limit of $15 \mu\text{g}/\text{kg}$ bw/week originally determined by the JECFA was adopted (see ref 1). The value of $15 \mu\text{g}/\text{kg}$ bw/week was used for risk assessment in the present evaluation.

Dermal Route:

Because of the lack of appropriate data, a toxicological limit-value for dermal exposure is not available (see ref. 1).

4. Possible Routes of Exposure & Exposure Levels

In this section the available data with respect to exposure of humans to CCA-products will be presented. As remarked before, occupational exposure will not be addressed in this report. However, some data which have been obtained for occupational settings may be adopted also for non-occupational exposure (e.g. inhalation data).

Exposition of humans to CCA-products during the 'use' of CCA-treated wood can occur via various routes:

- ◆ Direct dermal contact (e.g. handling of CCA-treated wood during 'do-it-yourself' jobs; contact with CCA-treated wooden playing structures or garden furniture).
- ◆ Indirect dermal contact (e.g. children playing in/on soil contaminated with CCA-ingredient due to leaching from CCA-treated wood).
- ◆ Oral exposure (e.g. hand-to-mouth transfer in young children, ingestion of contaminated soil by children, ingestion of food crops grown in the vicinity of CCA-treated materials).
- ◆ Inhalation of CCA-treated wood-dust (e.g. during sawing and joinery of CCA-treated wood)
- ◆ Exposition due to leaching to surface- or groundwater (e.g. during swimming in contaminated water, migration into drinking water, contamination of aquatic consumption products (fish, shellfish etc.)).
- ◆ Inhalatory exposure due to burning of CCA-treated wood.

Exposure by direct evaporation of the CCA-ingredients is considered unimportant because of the low volatility of the active ingredients involved. Dust from indoor construction timber may possibly be an additional route of exposure but is not considered to be of quantitative importance (see also ref. 2).

Exposure Calculations: Methodological Approach and Assumptions

In general, the available data with respect to the above listed exposure routes are limited. Nevertheless all available exposure data will be presented below and the presentation is given for each route of exposure separately as much as possible.

The approach used was aimed at obtaining a realistic or mean exposure scenario and a so-called 'worst case' or maximal exposure scenario. For several parameters variability in exposure conditions are likely to occur. For those factors for which a reliable range of values was available, both a realistic or mean value as well as a worst case or maximal value were calculated or estimated. These factors include the amount of dislodgeable residue on wood surfaces, contribution of Cr(VI) to total chromium, increases in Cr, Cu, and As in sand/soil due to leaching of CCA-components, the time spent on CCA-treated playing structures, soil ingestion rate, and wood dust levels after wood processing.

For other parameters only one fixed value has been used for the calculations because one or more of the following arguments:

1. The level of variability in the factor is considered to be significantly low as compared to other factors. Therefore, the use of a mean and maximal value would contribute little to the final exposure calculations (palmar surface area of children).
2. Only a mean value for the factor is considered relevant because the risk assessment is based on a mean individual (adult or child) (palmar surface area, body weights for children and adults, hand-to-mouth transfer, inhalation rate).
3. The (scientific) information available on the (variability of the) factor involved is limited to such an extent that it is only considered acceptable to establish a single best guess value for the factor

to be used (dermal transfer factor, hand-to-mouth transfer, soil adherence, contribution of CCA-components in airborne wood dust).

For the factors with a fixed value, the values selected will be addressed in the separate sections below associated with the appropriate references.

Using realistic or mean values for all factors involved, a realistic or mean exposure scenario was calculated. In addition, a maximal or worst case scenario was calculated using the maximal or worst case values for each factor involved. Furthermore, to illustrate the range of values that may occur for some exposure conditions, also 'mean-max' or 'max-mean' calculations were included in the tables (e.g. for the combination of dislodgeable residue of total chromium and the contribution of Cr(VI)). Using such calculations, it can be shown to what extent limit values may be exceeded.

4.1 Dermal Exposure: Direct Contact with CCA-treated Wood

4.1.1 Dislodgeable residues of Chromium

As has been pointed out in chapter 3, the chemical speciation of chromium is of pivotal importance with respect to toxic effects. Unfortunately, most studies reporting levels of dislodgeable residues on CCA-treated wood only determined total chromium. In these cases, the amount of Cr(VI) is not known. Recently, some studies on the speciation of Cr(VI) in CCA-treated wood have been reported (see below). In the following section, first the data on total dislodgeable residues will be presented followed by a discussion on the relative proportions of Cr(VI) in the total dislodgeable chromium. In table 4.1, the available data are listed.

From the data listed in table 4.1, it can be concluded that the amount of dislodgeable Cr-residue is clearly reduced during the first period after CCA-treatment. In fact, Coggins & Hiscocks (14) claimed that the time-dependent change in residue concentrations in their study was similar to data previously reported. The studies they referred to, reported residue levels about 10 times as low as reported by Coggins & Hiscocks. In addition, the results of Arsenault (13), Health Canada (15), and the RIVM (16) also reported residue levels of about a factor 10 lower. Therefore, the data of Coggins & Hiscocks most likely overestimate the true Cr-residue on CCA-treated wood; possibly because of the sampling technique used (30 seconds swabbing). Some studies have even reported higher levels of dislodgeable residue but in these cases unrealistic sampling methods (e.g. washing and scrubbing of the wood) have been applied. Such values are not considered relevant for the present evaluation.

The data of Health Canada and the RIVM are considered the most reliable, ranging from as low as 0.00012 to as high as 0.658 $\mu\text{g}/\text{cm}^2$ for installed playing structures and commercial timber. Considering all individual measurements from these two reports, an arithmetic mean value of $0.119 \pm 0.137 \mu\text{g}/\text{cm}^2$ can be calculated. This mean value is considered to represent a realistic exposure scenario whereas the value of 0.658 is considered to represent a 'worst case' scenario.

In references 13, 14, and 15 the chemical speciation of the dislodgeable Cr was not determined. Coggins & Hiscocks performed, however, experiments with CCA-treated wood blocks and measured the proportion of Cr(VI) of total Cr (details of method not available). At 0, 7, 25, and 50 hour after impregnation, the percentages of Cr(VI) were 90, 70, 20, 5% respectively (estimated from graphic illustrations). At 150 h after treatment, Cr(VI) was virtually absent (based on graphic illustrations). Nygren & Nilsson (5) investigated the fraction of Cr(VI) compared to total chromium in wood dust from commercially available CCA-treated wood and observed that Cr(VI) contributed 0 - 22 % to the total chromium content indicating incomplete fixation. However, in dust filtered from the air during processing of CCA-treated timber for the production of furniture, the same investigators failed to detect any Cr(VI). It was claimed that this type of wood was strictly selected on quality

(well-dried wood without any visible residues) in contrast to the various types of commercial timber which are of varying quality.

Table 4.1 Data on the amount of dislodgeable chromium (total chromium) from the surface of CCA-impregnated wood

Reference	Amount of total dislodgeable Cr ($\mu\text{g}/\text{cm}^2$)	Sampling method	CCA-type	Remarks
Arsenault 1977 (13)	0.489	wet hand		Mean value
Coggins & Hiscocks (14)	14.5 - 17.0	wet glass-wool 30 sec. swabbing	Celcure A	Sampled directly after CCA-treatment at various temperatures 5-30 °C
"	2.5 - 4.0	"	Celcure A	Sampled 4 days after CCA-treatment
"	2.7 - 4.5	"	Celcure A	Sampled 3 weeks after CCA-treatment
Health Canada 1993 (15)	0.090 - 0.628	wet gauze pad	?	Sampled directly after construction of playing structures with commercial CCA-treated wood
"	0.078 - 0.314	"	?	Sampled 2 months after installation of playing structures
"	0.126 - 0.140	"	?	Sampled 1 year after installation of playing structures
Van Bruggen 1997 (16) RIVM/IEM	0.165-0.211	wet cotton-wool	?	Directly sampled after CCA-treatment
"	0.133 / 0.325	"	?	Sampled 2 weeks after CCA-treatment and stored indoors/outdoors
"	0.189 / 0.109	"	?	Sampled 6 weeks after CCA-treatment and stored indoors/outdoors
"	0.106- 0.658	"	?	Commercial timbers sampled after a 3 week fixation period
"	0.00012 - 0.102	"	?	Outdoor playing tools sampled within 1 year after installation

In the studies of the RIVM (16) it was shown that directly after impregnation about 75% of total chromium was present as Cr(VI) on the surface of CCA-treated wood. This value was reduced to 8.3 and 1.9% after 2 and 6 weeks respectively for CCA-treated wood stored indoors. For wood stored outdoors, this value was 0.4% at both time points. However, in the dislodgeable residues of commercially available timber sampled about 3 weeks after impregnation (a period in which fixation is expected to be complete), 11 to 33% of total chromium was Cr(VI) (minimum detected level: $0.0082 \mu\text{g Cr(VI)}/\text{cm}^2$; maximum detected level: $0.197 \mu\text{g Cr(VI)}/\text{cm}^2$). In samples from wooden playing structures outdoors installed for less than a year, 0.5 - 7.7% of total chromium was Cr(VI). In the latter samples, absolute levels of Cr(VI) ranged from $0.02 \text{ ng Cr(VI)}/\text{cm}^2$ to $59 \text{ ng Cr(VI)}/\text{cm}^2$. Recently, Cruz et al. (17) investigated the chemical speciation of chromium in CCA-treated building timbers and found Cr(VI) to contribute 1.2 to 1.4 % of total chromium (southern yellow pine, treated with CCA-C, N=4).

When wood is impregnated and steam-fixed according to the most proper methods, no Cr(VI) was detected within the wood during wash-experiments (W.J. Homan, SHR, pers. comm.).

These observations indicate that the fraction of total dislodgeable chromium present as Cr(VI) is highly variable. Factors of importance may be the time of sampling after treatment, the type of wood, the type of CCA-product used, frequency of use and contact, wear and tear, sampling method, the type of surface of the wood under investigation, and - most importantly - the quality of the impregnation process. At present it is unclear to what extent CCA-treated wood of poor quality (i.e. wood with high surface residues) is present on the Dutch market.

Because of these uncertainties a value of 30% Cr(VI) is considered to represent a worst case exposure scenario whereas a value of 3% Cr(VI) is considered to represent a mean or realistic exposure scenario. This implicates that the mean Cr(VI) residue will be $0.03 \times 0.119 = 0.0036 \mu\text{g}/\text{cm}^2$ whereas the maximal Cr(VI) residue will be $0.3 \times 0.658 = 0.197 \mu\text{g}/\text{cm}^2$ (worst case).

4.1.2 Dislodgeable residues of Copper

Values for dislodgeable residues of copper from CCA-treated wood were only available from Health Canada (15) which are presented in table 4.2. For dislodgeable copper residues no data were available to illustrate a decrease of the dislodgeable residues during the days or weeks directly after CCA-impregnation such as observed for chromium.

Table 4.2 Data on the amount of dislodgeable copper from the surface of CCA-impregnated wood.

Reference	Amount of dislodgeable Cu ($\mu\text{g}/\text{cm}^2$)	Sampling method	CCA-type	Remarks
Health Canada 1993 (15)	0.014 - 0.204	wet gauze pad	?	Sampled directly after construction of playing structures with commercial CCA-treated wood
"	0.020 - 0.078	"	?	Sampled 2 months after installation of playing structures
"	0.043 - 0.049	"	?	Sampled 1 year after installation of playing structures

Based on these individual data of Health Canada (15) an arithmetic mean value of $0.088 \pm 0.100 \mu\text{g}/\text{cm}^2$ can be calculated. This mean value is considered to represent a realistic exposure scenario whereas $0.204 \mu\text{g}/\text{cm}^2$ is used for a 'worst case' scenario.

4.1.3 Dislodgeable residues of Arsenic

Several reports have determined the amount of dislodgeable arsenic residues on the surface of CCA-impregnated wood. However, none of these studies investigated the chemical speciation of this arsenic residue.

For dislodgeable As-residues, no data were available to illustrate a decrease of the dislodgeable residues during the days or weeks directly after CCA-impregnation such as observed for chromium. Most of the data in table 4.3 are within the same order of magnitude. As observed also for chromium, arsenic surface residues vary from undetectable levels to $0.688 \mu\text{g}/\text{cm}^2$ in a commercial piece of CCA-treated wood. Because the individual data were not available from all studies reported

in table 4.3, a reliable mean value cannot be calculated. Based on the reported ranges, the present reviewers estimate that a mean value of $0.200 \mu\text{g}/\text{cm}^2$ may serve as a realistic exposure scenario whereas the level of $0.688 \mu\text{g}/\text{cm}^2$ may be used for a 'worst case' assessment.

Table 4.3 Data on the amount of dislodgeable Arsenic from the surface of CCA-impregnated wood.

Reference	Amount of dislodgeable As ($\mu\text{g}/\text{cm}^2$)	Sampling method	CCA-type	Remarks
Koppers Comp. 1978 (18)	0.0005-0.025	dry hand	?	Multiplex
"	0.126-0.568	wet hand	?	Multiplex
Arsenault 1977 (13)	0.320	wet hand	?	
U.S. CPSC 1990 (19)	0.688	nylon wipe a)	?	southern pine wood from local market, unfinished piece of wood, sanded only
"	0.219	"	?	sanded only
"	0.321	"	?	core cut, cored stained
"	< 0.062	"		5 of 7 pieces of commercial wood did not yield detectable As residues
Health Canada 1993 (15)	0.060 - 0.420	wet gauze pad	?	Sampled directly after construction of playing structures with commercial CCA-treated wood
"	0.052 - 0.220	"		Sampled 2 months after installation of playing structures
"	0.084 - 0.147	"		Sampled 1 year after installation of playing structures

a) It was shown that the nylon wipe method yielded a similar amount of dislodgeable residue as wiping with leather chamois (animal skin).

4.1.4 Dermal Exposure to Dislodgeable Residues

In a previous health risk assessment paper of the RIVM on CCA-treated wood (see ref. 2), dermal exposures were estimated by assuming that the skin surface will be fully loaded with residue at the first time of contact. At repeated contact, the amount of residue taken up by the skin surface would be equal to the amount of residue released by the skin surface, i.e. an equilibrium will exist between the skin surface and the wood surface. In a second-opinion report, it was debated whether this assumption would hold true and a concept of concentrating up to a factor of 40 was suggested (20).

In recent years investigations on the transfer of dislodgeable residues to the skin were performed and reported. In such studies dermal transfer coefficients are calculated to quantify the transfer of dislodgeable residue on a specific contact surface to the skin. The concentration of the substance involved is measured with dermal dosimeters under controlled activities after a specific period of time to yield dermal deposition values (in $\mu\text{g}/\text{hour}$). These dosimeter concentrations are then divided by the level of measured dislodgeable residues ($\mu\text{g}/\text{cm}^2$) for the surface area under investigation. Such transfer coefficients (expressed as cm^2 skin contact/hour) may be quite variable for different types of substances, contact surface areas, and activities. All values reported below were obtained from occupational exposures or standardised exercise in adults. For chlorothalonil a total body transfer coefficient of $450 \text{ cm}^2/\text{h}$ was reported in tomato harvesters (21). A transfer coefficient of

4500 cm²/h was reported for the transfer from leaves to hands using four different pesticides (22). Transfer coefficients of 1200, 2400, and 4550 cm²/h were reported for a skin area of the hands and the forearms using the pesticides abamectin, dodemorph, and bupirimate respectively (23). When considering the hand surface area only these values may be reduced roughly by about a factor 2, resulting in estimated transfer coefficients for the hands of 600, 1200, and 2275 cm²/hour. It must be emphasised again that all these values refer to adults and need to be corrected for children. The Canadian PMRA has calculated a transfer coefficient of 1040 cm²/hour for the hands only. This value was based on an adult exposure study and corrections for children surface areas and was stated to be conservative (C. Campbell, pers. comm.). The EPA suggests a default dermal transfer coefficient of 10,000 cm²/h for the whole body surface area (42). Considering that the hands will contribute about 6-7% of the body surface area, this value corresponds to a transfer coefficient of 600-700 for hands. Based on this range of data, the present reviewers estimate that a transfer coefficient of 1000 cm²/hour for children hands may provide an acceptable value for a realistic exposure scenario (see for a discussion of this estimation chapter 7).

The dermal exposure (loading) due to direct contact with dislodgeable residues is then calculated according to the following equation:

$$\text{Dermal Exposure} = \frac{\text{Dislodgeable residue } (\mu\text{g}/\text{cm}^2) \times \text{Transfer Coefficient } (\text{cm}^2/\text{h})}{\text{Palmar Surface Area } (\text{cm}^2)} \times \text{Contact time } (\text{h})$$

In table 4.4, the calculated dermal exposure values are presented using the following assumptions and values:

- ◆ The transfer coefficient for the hands of a child at about 5 years of age is 1000 cm²/hour
- ◆ Palmar surface area for a child at 5 years of age is 65 cm² (see ref. 19).
- ◆ Contact time with CCA-treated structures is 0.33 or 0.42 h/day (see section 4.4)
- ◆ The contribution of Cr(VI) to total chromium is 3% or 30%.

Table 4.4 Dermal exposure (μg/cm²) over one day to chromium, copper, and arsenic due to direct contact with CCA-treated wood in children of about 5 years.

	Dermal Exposure in μg/cm ²			
	Using a Mean Dislodgeable residue		Using a Maximal Dislodgeable residue	
	0.33 h/day	0.42 h/day	0.33 h/day	0.42 h/day
Chromium total	0.604	0.769	3.341	4.25
Cr (VI) 3%	0.018	0.023	0.102	0.127
30%	0.181	0.230	1.002	1.275
Copper	0.447	0.568	1.035	1.318
Arsenic	1.015	1.292	3.493	4.446

4.2 Dermal Exposure: Indirect Contact by Contaminated Soil

Although chromium, copper, and arsenic will form insoluble substances which are expected to be fixed within the wood, a certain amount of these metals is known to leach from the wood into the environment. Leaching from the wood is highly dependent on several types of factors, e.g. temperature, moisture, rainfall, placement of the wood (in or above the ground), pH, type of wood, type of CCA used, and the quality of the fixation process. With respect to these modifying factors, two general comments can be formulated. First, it has been shown that leaching of Cr, As, and Cu from CCA-treated wood was significantly enhanced when the pH of the water in contact with the

wood was lowered (2, 24). Second, leaching from pine-wood (NL: grenen) is generally higher as compared to deal-wood (NL: vuren) (2, 25).

Because the available data on the various modifying factors are limited or involve only a single observation per factor, it is not considered adequate to subdivide the exposure conditions for all such factors. Therefore, all available data on leaching will be considered to estimate a realistic and a 'worst case' exposure level.

In a similar way as described for dislodgeable residues, all leaching studies indicate that the leaching-flux of each metal (expressed in mg/m^2 wood \times day) is highest during the first period after CCA-treatment or installation and gradually decreases over time (see ref. 25). For total chromium and copper these values may become very low or virtually zero, whereas arsenic leaching may continue at significant amounts for a prolonged period of time.

In the following sections on soil concentrations of chromium, copper, and arsenic the 'mean' and 'worst case' soil levels to be used for risk assessment will refer to estimated or measured *increases* in soil concentrations. Because of the high variability in various types of soil in the Netherlands, the increase in the exposure due to contaminated soil is considered to be the most relevant. At the stage of risk assessment, background levels will be taken into account.

4.2.1 Chromium Concentrations in Soil

After an initial period of about 60 days after installation (in which leaching may be substantial), leaching of chromium from CCA-treated wood is found to be very low and in various cases virtually zero. Henningson and Carlsson (26) measured the amounts of chromium, copper, and arsenic in the soil directly nearby CCA-treated playing structures and in soil at 0.5m distance from the playing structures (tools were installed for 2-4 years). Samples of 12 different locations indicated that Cr-levels in the sand directly near the timber were only marginally increased compared to samples at 0.5m distance (6.0 vs. 5.2 mg/kg sand) indicating that leaching of Cr from CCA-treated is very low. Based on laboratory leaching experiments with CCA-treated wood, Buchanan (24) reported that chromium levels in soil did not increase compared to control samples after simulation of a one year acid rain precipitate (Cr levels were 9-11 mg/kg soil for sand and loam; 19 mg/kg soil for clay). In a small-size study in the Netherlands, a slightly elevated Cr-level in the soil under CCA-treated playing structures was observed in one sample but not in a second sample from another location (location 1: 8.0 mg/kg soil, location 2: 11.5 mg/kg soil; control samples 8.0 and 9.0 mg/kg soil respectively) (27).

In a report of Health Canada (15), "soil" (not specified) and sand concentrations nearby newly constructed CCA-treated playing structures were determined 1, 2, and 12 months after installation of the wooden objects. For structures placed on sand, the mean concentrations of chromium were 29.9 mg Cr/kg sand after 1 month and 15.5 mg Cr/kg sand after 2 months. For structures placed on soil, the concentrations were 36.6 mg Cr/kg soil after 1 month and 34.7 mg Cr/kg soil after 2 months. After 1 year, chromium concentrations in sand were 15 mg/kg for sand and 80.0 mg/kg for soil. The highest value measured was 165 mg/kg in soil. All values of Health Canada were corrected for background values determined before placement of the objects. Thus, these values refer to increases in soil concentrations. These data indicate that a significant amount of chromium may diffuse into the soil (unfortunately the CCA-type and impregnation process used not specified) although it should be noted that these mean values were high primarily due to the fact that very high concentrations were measured directly at the base of vertical posts. For example, the mean value of 80 mg/kg for soil 1 year after installation comprises three values directly measured at the base of vertical posts (i.e. 18.5, 135.0 and 165.0 mg/kg soil) whereas a measurement at about 25 cm distance revealed 2.55 mg/kg soil. The high concentrations measured directly at the base of vertical posts represent a very specific and probably highly local condition and these levels are not considered to be relevant for a mean exposure scenario. However, these values will be used to select a worst case exposure scenario.

In soil, Cr(VI) is rapidly reduced to Cr(III) by organic substances. Cr(III) is bound to clay-particles and organic substances and may form complexes with various types of ligands. The amount

of bound Cr(III) in the soil is dependent on the composition of the soil, the pH of the soil, and the presence of other metals and ions (e.g. phosphates, sulfates, arsenates). The reduction of Cr(VI) is less in poor sandy type of soils but in such conditions the wash out of chromium is higher. Therefore, it is most likely that chromium contents of the soil represent Cr(III).

In the Netherlands, background soil levels of chromium are highly variable: 0 - 100 mg/kg in polder areas, 20-130 mg/kg for clay, and up to about 400 mg/kg for sediments from harbours (28).

When considering soil ingestion as a relevant route of exposure (e.g. for children on playing grounds), the present reviewers estimate that a mean increase of 5 mg Cr/kg soil may be used for a realistic exposure scenario whereas 165 mg Cr/kg soil may be used for a 'worst case' scenario. These values are established by considering all measurements presented in the paragraph above and are considered to represent conditions in soil types other than sand and for a period of about 1 year after installation of the wooden structures.

4.2.2 Copper Concentrations in Soil

Leaching of copper from CCA-treated wood is generally low after the initial period. However, some studies have reported data on copper levels nearby CCA-treated structures. Henningson and Carlsson (26) observed slightly elevated copper levels in sand directly near CCA-treated timber as compared to soil samples 0.5m from the treated timber (11.9 vs. 9.3 mg/kg sand), i.e. an increase of about 2.6 mg/kg. In a small-size study in the Netherlands (27), copper levels in the soil directly below CCA-treated playing tools were about 2 mg/kg soil higher compared to control samples, the highest value being 12.0 mg/kg soil (most likely being sand).

In a report of Health Canada (15), "soil" (not specified) and sand concentrations nearby CCA-treated playing structures were determined 1, 2, and 12 months after installation of the playing structures. For structures placed on sand, the mean concentrations of copper were 295 mg Cu/kg sand after 1 month and 164 mg Cu/kg sand after 2 months. For structures placed on soil, the mean concentrations were 492 mg Cu/kg soil after 1 month and 381 mg Cu/kg soil respectively. After 1 year, copper concentrations in sand were 126 mg/kg for sand and 786 mg/kg for soil. The highest value measured were 747 mg/kg for soil and 1650 mg/kg for sand. All values of Health Canada were corrected for background values determined before placement of the objects. Thus, these values refer to increases in soil concentrations. These data indicate that a significant amount of copper may diffuse into the soil (unfortunately the CCA-type and impregnation process used were not specified) although it should be noted that these mean values were high due to the fact that very high concentrations were measured directly at the base of vertical posts. For example, the mean value of 786 mg/kg for soil 1 year after installation comprises of three values directly measured at the base of vertical posts (i.e. 88.6, 1400 and 1650 mg/kg soil) whereas a measurement at about 25 cm distance revealed 4.3 mg/kg soil. The high concentrations measured directly at the base of vertical posts represent a very specific and probably highly local condition and these levels are not considered to be relevant for a mean exposure scenario. However, these values will be used to select a worst case exposure scenario.

In the Netherlands, soil concentrations of copper range from 0.8 to 27 mg/kg for sand and 2 - 67 mg/kg for other types of soil. In sediment from harbours, values range from 76 - 235 mg/kg soil.

When considering soil ingestion as a relevant route of exposure (e.g. for children on playing grounds), the present reviewers estimate that a mean increase of 4.5 mg Cu/kg soil may be used for a realistic exposure scenario whereas 747 mg Cu/kg sand and 1650 mg/kg soil may be used for a 'worst case' scenario. These values are established by considering all measurements presented in the paragraph above and are considered to represent conditions for a period of 1 year after installation of the wooden structures.

4.2.3 Arsenic Concentrations in Soil

In various studies, it has been shown that arsenic may be the predominant component leaching from CCA-treated wood (see refs 2,25). Henningson and Carlsson (26), measured elevated As levels

in soil nearby CCA-treated playing structures as compared to soil samples at 0.5m from the structure (6.0 vs. 0.8 mg/kg soil for sand play-boxes; 4.7 vs. 0.6 mg/kg soil for other CCA-treated playing structures), i.e. an increase of about 5 mg/kg. In a report of Health Canada (15), soil and sand concentrations nearby CCA-treated playing structures were determined 1, 2, and 12 months after installation of the wooden tools. For structures placed on sand, the mean concentrations were 32.8 mg As/kg sand after 1 month and 28.6 mg As/kg sand after 2 months. For structures placed on soil, the mean concentrations were 51 mg As/kg soil after 1 month and 32.2 mg As/kg soil after 2 months respectively. After 1 year, arsenic concentrations were 29.5 mg/kg for sand and 91.2 mg/kg for soil. All values of Health Canada were corrected for background values determined before placement of the objects, and thus refer to increases in soil concentrations. These data indicate that a significant amount of arsenic may diffuse into the soil (unfortunately the CCA-type and impregnation process used were not specified) although it should be noted that these mean values were high due to the fact that very high concentrations were measured directly at the base of vertical posts. For example, mean value of 91.2 mg/kg for soil 1 year after installation comprises of three values directly measured at the base of vertical posts (i.e. 53.4, 145 and 165.0 mg/kg soil) whereas a measurement at about 25 cm distance revealed 1.55 mg/kg soil. The high concentrations measured directly at the base of vertical posts represent a very specific and probably highly local condition and these levels are not considered to be relevant for a mean exposure scenario. However, these values will be used to select a worst case exposure scenario.

In the Netherlands, soil concentrations of arsenic are mostly below 10 mg/kg for sand whereas in clay or polder areas levels are normally between 10 and 20 mg/kg soil (29).

When considering soil ingestion as a relevant route of exposure (e.g. for children on playing grounds), the present reviewers estimate that a mean increase of 15 mg As/kg soil may be used for a realistic exposure scenario whereas 165 mg Cr/kg soil may be used for a 'worst case' scenario. These values are established by considering all measurements presented in the paragraph above and are considered to represent conditions in soil types other than sand and for a period of 1 year after installation of the wooden structures.

4.2.4 Dermal Exposure to Soil

For an estimation of the dermal exposure by direct contact with contaminated soil, values for soil adhesion to the skin are needed. It is assumed that only the hands will be in direct contact with the soil. In a report of the U.S. CPCS it was calculated that the amount of soil on the hands of children was 1.47 mg/cm² for boys and 0.82 mg/cm² for girls. In a report of the EPA (30), possible soil adherence values from 0.2 to 1.5 mg/cm² were reported. Recently Finley et al. (33) evaluated a number of studies on soil adherence and concluded that neither particle size, nor soil type influences adherence to a degree that warrants evaluation in quantitative risk assessment. In addition, no significant evidence was found to assume soil adherence in children to be different from adults. Based on distribution calculations, Finley et al. suggested an arithmetic mean value for soil adherence of 0.52 mg/cm² (33). Because this value was derived from data underlying a range of different studies, the value of 0.52 mg/cm² will be adopted in the present evaluation.

In the table 4.5, the estimated dermal exposure data due to direct contact with contaminated soil are presented based on the following values and assumptions.

- ◆ Mean soil adherence value is 0.52 mg/cm²

- ◆ Mean increases in soil levels for chromium, copper, and arsenic are 5, 4.5, and 15 mg/kg soil respectively.
- ◆ Maximal increases in soil levels for chromium, copper, and arsenic are 165, 1650, and 165 mg/kg soil respectively.
- ◆ All chromium, copper, and arsenic present in the soil may become bioavailable *
- ◆ Dermal exposure involves only the palmar surface area.
- ◆ Palmar surface area for a 5 yr old child is 65 cm² (see ref. 19).

* Bioavailability from soil is presumably lower than 100%. E.g. for arsenic bioavailability values for soil have been reported from 3 to 24% (31).

Table 4.5 Dermal exposure (µg/cm²) to chromium, copper, arsenic due to contact of children of 5 years with contaminated soil nearby CCA-treated structures.

	Mean increase in soil concentration		Maximal increase in soil concentration	
	dermal exposure µg/cm ²	Total dermal exposure (µg)	dermal exposure µg/cm ²	Total dermal exposure (µg)
Chromium - total	0.0026	0.169	0.086	5.59
Copper	0.0023	0.149	0.858	55.77
Arsenic	0.0078	0.507	0.086	5.59

4.3 Dermal Exposure: Swimming in Contaminated Water

Various studies have investigated the leaching of CCA-components from treated wood when placed in contact with water. Studies considered relevant for this route of exposure have been summarised either in ref. 2 or in ref. 25 and for details on the studies these reports should be consulted. Based on the leaching study by Berbee (1989), Janssen et al. (2) reported that for all three metals an initial increase in the surface water would occur during the first two months after placement of a wooden structure of CCA-treated timber in a 'standard' water (canal)⁴. For arsenic the concentrations are roughly estimated to range from 60 to 300 µg/l, for total chromium 0 - 50 µg/l, and for copper 30 - 250 µg/l. After these first months, leaching of chromium and copper is markedly reduced which will result in a rapid reduction of chromium and copper levels to background levels. The leaching of arsenic is lower but may remain significant for a prolonged period of time. It was estimated that after 240 days, As levels may still be as high as 60 µg/l (roughly estimated) (see ref. 2).

In a recent RIVM-report (25), the increase in metal concentrations was calculated for a standard work in a standard canal (see footnote 4). The results which are based on several sets of leaching data, are presented below. In addition to the estimations from Janssen et al. It was calculated that initial arsenic concentrations may be as high as 773 µg/l whereas the arsenic concentrations after 1 year may be as high as 151 µg/l.

Table 4.6 Concentrations of copper, chromium, and arsenic in a standard canal (expressed in µg/l) after installation of a standard work of CCA-treated timber. Both the range and the mean values are given (Source: ref. 25).

⁴ The RIZA has selected a number of standard waters or canals. The largest canal (model A), used in the present calculations, has the following characteristics. Length 1000m; width 20m; depth 1m; volume 20000 m³; flow 0.02 m³/s; length of CCA-treated work 1000 m; height of CCA-treated work 1m; surface of CCA-treated work 2000m² (work is installed on both sides of the canal) (see ref. 25).

	maximum		at 28 days		at 1 year	
	deal	pine	deal	pine	deal	pine
Copper	43-247 93.3 ± 103	82-189 128 ± 48.7	5-39 19.6 ± 14.8	49-78 59.5 ± 12.6	0.74-4.98 3.17 ± 1.92	9.82-27.5 10 ± 3.7
Chromium	0.91-22.4 8.09 ± 9.99	17.4-41.4 26.0 ± 11.2	0.34-3.46 1.41 ± 1.47	2.63-25.1 12.4 ± 11.1	0.028-0.425 0.18 ± 0.17	0.32-10.5 5.03 ± 5.38
Arsenic	8.78-151 63.5 ± 71.1	33.6-773 235 ± 264	5.33-83.3 36.8 ± 37.4	22.4-420 179 ± 187	2.23-30.4 13.6 ± 13.3	10.8-151 72.2 ± 68.3

During swimming, some amount of water may be ingested which may contribute to oral intakes of CCA-components. Assuming a daily intake of 2 l (worst case) contaminated water due to leaching of CCA-treated timber, calculations (not shown) revealed that such a substantial amount of water intake would contribute less than 5% to the total oral dose as calculated for children. Therefore, the contribution of water ingestion during swimming was considered to be negligible.

4.4 Oral Exposure: Soil Ingestion and Hand-to-Mouth Transfer

Direct ingestion CCA-products or CCA-treated wood is not a relevant route of exposure since CCA-products are only used in a limited number of registered companies in which the use of CCA-products is strictly regulated (32). Ingestion of CCA-products or CCA-treated wood by individuals within the general population is highly unlikely to occur.

A possible route of oral exposure occurs in workers (and people performing 'do-it-yourself' jobs) in the wood-processing industry. When dust from CCA-treated wood is inhaled (e.g. during sawing or cutting the wood), some fraction of the deposited CCA-dust will be cleared from the lungs by microciliary mechanisms and eventually ingested. Such a mechanism has been observed also for chromium particles (see ref. 1). A quantification of this oral route is addressed in the inhalation section, i.e. 4.5.

A specific route of oral exposure may occur in children when they come in contact with CCA-treated playing structures and / or CCA-contaminated soil. Since young children do show some extent of hand-to-mouth transfer (HTM, i.e. licking-off dirt from their hands/fingers) or distinct mouthing behaviour this route of exposure may be relevant for young children (up to about 5-6 years of age).

4.4.1 Soil Ingestion

Estimates or indirect measurements (by use of chemical markers) of the amount of soil ingestion by children have been performed by various investigators. Based on three reports, in which various literature sources were evaluated, a mean and a 'worst case' assumption will be determined (see refs. 19,33, 34, 35, 36, 37, 38).

In the Netherlands, soil ingestion values were evaluated e.g. in studies on pesticide usage in the flowering business (39). Based on various literature sources, it was concluded that ingestion of 100-200 mg soil per day by HTM-transfer would provide a good estimate for young children. As 'worst case' these authors assumed a maximal daily intake of 1000 mg soil (39).

In a report of the U.S. CPSC (19) 6 studies on soil ingestion by children published between 1985 and 1989 were evaluated. Using primarily the data generated by Calabrese in 1989 (40), a mean soil ingestion was reported of 218 ± 1286 mg/day. The large standard deviation led to the suggestion that the mean value was high due to extreme outliers (19,40) and that the median value of 30 mg/day would be more appropriate. The latter value has been used by the U.S. CPSC for their risk assessment for children aged 2-5 yrs. Soil ingestion of children ≥ 6 yrs of age was considered negligible.

Table 4.7 Reported values for soil ingestion by children and adults in the literature.

	Age Range (years)	Tracers used ^a	Mean soil ingestion (mg/day) ^a	'Worst case' soil ingestion (mg/day) ^a
Binder et al. 1986 (38)	1 - 3	Al, Si, Ti	108-184	386-578
Clausing et al. 1987 (36)	2 - 4	Al, Ti, acid insol. residue	129 (air) 232 (Al)	979
Calabrese et al. 1989 (35)	1 - 4	Al, Si, Ti, Mn, Ba, V, Ba	153-575	223-780
CML report 1989 (39)		none	100-200	1000
CSOIL RIVM 1993 (41)	'child'	-	150	-
Davis et al. 1990 (37)	2 - 7	Al, Si, Ti	39 - 82	905
Calabrese et al. 1990 (34)	adults	Al, Si, Ti, Mn, Ba, V, Y, Zr	5 - 77	2183
Finley et al. 1994 (33)	1 - 4	Zr	16 (50%-ile)	110 (95%-ile)

a) All tracers used in the original study are indicated. However, only results based on the tracers Al, Si, Y, or Zr are presented for soil ingestion rates because the other tracers yield unreliable values.

With respect to the data in table 4.7, it should be noted that the data of Binder et al., Clausing et al., and Calabrese et al (1989) as well as the default value of 150 µg used in the RIVM model CSOIL, were not corrected for dietary intakes of the tracers. In the studies of Davis et al. and Calabrese et al. (1990), the data were corrected for dietary intake resulting in lower estimates for soil ingestion rates. Taking these arguments into account, the present reviewers will adopt a mean soil ingestion rate of 100 mg/day for a realistic exposure scenario. When we assume a 'worst case' value of 1000 mg/day, the distribution calculations of Finley et al. (33) indicate that this value may include about 97-98% of the children in the general population.

Soil ingestion will occur only when children will spend time playing outdoors. In the Exposure Factors Handbook of the EPA (42) it is claimed that the 90-percentile of time spent outdoors is 210 min/day for children up to 4 years of age. For older children this time is slightly increased. In some Canadian and American questionnaire studies the times spent outdoors ranged from 60 min to 300 min per day (43,44,45), the highest values obtained during the weekends. Based on this range of values, a default value of 240 min/day is used in the present evaluation for the total time spent outdoors. The questionnaire-studies referred above (43,44,45) reported playing times in parks and playgrounds of about 60 min/day for children of 2 - 5 years (45), 30 - 150 min/day for children in a 'pre-school' age (43), 87 - 108 min/day for children of 6 -11 years (45), and 64 - 119 min/day for children 9 - 11 years (44). When it is assumed that children in playgrounds or parks spend 25% of their time on the CCA-structures and 25% of their time in contact with the soil around these structures, it can be roughly estimated from that the mean time of 'CCA-contaminated-soil-contact' will be about 20-25 min/day. Considering a total time spent outdoors of 240 min, this implicates that about 10% of the total daily soil ingestion may occur from 'CCA-contaminated-soil' in the vicinity of CCA-treated playing structures.

In table 4.8, the daily oral doses for children of 2-5 years of age due to ingestion of CCA-contaminated soil are calculated using the following values and assumptions.

- ◆ Mean increases in soil concentrations are 5, 4.5, and 15 mg/kg soil for chromium, copper, and arsenic respectively.
- ◆ Maximal increases in soil concentrations are 165, 747 (sand) and 1650 (soil), and 165 mg/kg soil for chromium, copper, and arsenic respectively.
- ◆ Soil ingestion rates are 100 and 1000 mg/day for a mean and worst case scenario respectively.
- ◆ The mean body weight for children of 2-5 years of age is 16.7 kg (see ref. 19,42).
- ◆ All chromium, copper, and arsenic in soil becomes bioavailable (see ref. 31).

Table 4.8 Estimated daily oral doses in children of 2-5 years due to ingestion of CCA-contaminated soil.

	Increase in soil concentration (mg/kg)	Daily oral dose (in µg/kg bw/day)	
		Mean Exposure Soil ingestion of 100 mg/day	Worst Case Exposure Soil Ingestion 1000 mg/day
Chromium (total)	5.0	0.003	0.030
	165	0.099	0.988
Copper (sand) (soil)	4.5	0.003	0.027
	747	0.447	4.473
	1650	0.998	9.880
Arsenic	15	0.009	0.090
	165	0.099	0.988

It must be emphasised, however, that in the table above the assumption has been made that all chromium, copper, and arsenic in the soil may become bioavailable within the gastrointestinal tract. This assumption is highly conservative. It is known that chromium, copper and arsenic are bound to specific substances within the soil which highly reduces the bioavailability of the compounds. For arsenic bioavailability data for ingested soil have been reported to range from 3 to 24% (31). However, no quantitative estimates of the bioavailability of chromium and copper are available for soil. In addition, the bioavailability will be quite different for different types of soil.

4.4.2 Hand-to-Mouth Transfer

HTM-transfer is known to be age-dependent; being more pronounced in younger children. A small percentage of children may show extreme mouthing behaviour ("Pica-behaviour") (19,39). This specific group of children was not considered in the present evaluation.

In a study of the U.S. CPSC (19) HTM-behaviour was evaluated from several literature sources on soil ingestion of children. It was calculated that the 'handload' of boys would amount to 1.47 mg soil/cm² palmar surface whereas for girls this value amounts to 0.82 mg soil/cm² palmar surface (the surface hand areas involved were 48, 65, and 115 cm² for children of age 2, 5, and 12 years respectively). For example, based on a mean daily soil ingestion of 218 mg, these data show for e.g. a 2 yr-old boy, a HTM-transfer of 3.07 'handloads' per day ($[218 \text{ mg} / 1.47 \text{ mg/cm}^2] / 48 \text{ cm}^2 = 3.07$). Based on a median daily soil ingestion of 30 mg, a similar calculation yields 0.42 handloads per day for a 2 yr-old boy. As discussed in section 4.4.1 the original authors of these studies suggested that the mean soil ingestion values were overestimated due to a number of very high outliers implicating that the median value would be more appropriate. This arguments have been adopted by the U.S. CPSC (19). Using these median values the U.S. CPSC estimated the daily oral dose by HTM-transfer. For example, a 2-yr old boy playing on CCA-treated tools resulted in an As-residue on the hand of 100 µg/cm² (assumption). Total amount on the hands would then be 100 µg/cm² x 48 cm² = 4800 µg per 'handload'. Since this boy would ingest a median of 0.42 'handloads' per day, the daily

oral dose by HTM-transfer would then amount to 2016 µg/day. In accordance with the U.S. CPSC, in the present evaluation only median ‘handload’ values will be used to calculate oral exposure due to HTM-transfer.

Table 4.9 Reported values for estimated Hand-to-Mouth behaviour (source: U.S. CPSC (19)).

age (yrs)	palmar area (cm ²)	Handloads per day: Boys			Handloads per day: Girls		
		median	mean	90%-ile	median	mean	90%-ile
2	48	0.42	3.07	3.77	0.76	5.59	6.87
5	65	0.31	2.27	2.79	0.56	4.11	5.06
12	115	0.18	1.29	1.59	0.31	2.32	2.85

Another characterisation of HTM-transfer has been adopted by the U.S. EPA. It was reported that HTM-transfer activity would amount to 0.026 events/min (= 1.56 events/h) for children aged < 5 years (42). This value is multiplied by the surface areas for the palmar areas, a mean playing-time on CCA-treated structures of 20-25 min/day (based on the questionnaire-studies referred to above see refs. 43,44,45), and the dislodgeable residues to yield a daily oral dose by HTM-behaviour.

In table 4.10, the estimated oral doses due to HTM-behaviour of dislodgeable residues on the hand are presented. Both estimates by the ‘handload-method’ and the ‘EPA-method’ have been used for calculations, because the available information is too limited to discard one of the two methods. For the calculations in the table the following assumptions and values have been used:

- ◆ Mean dislodgeable residues for chromium, copper, and arsenic are 0.119, 0.088, and 0.200 µg/cm² respectively (see section 4.1)
- ◆ Maximal dislodgeable residues for chromium copper and arsenic are 0.658, 0.204, and 0.688 µg/cm² respectively (see section 4.1).
- ◆ Dermal exposure values are obtained from table 4.4
- ◆ 50% of the dermal residue may be licked-off.
- ◆ Mean body weight is 19.7 kg for a 5 yr old (see refs. 19,33)
- ◆ Mean palmar surface is 65 cm² for a 5 yr old (see ref. 19)
- ◆ Median handload values are obtained from table 4.9
- ◆ HTM-transfer factor: 1.56 events/h (‘EPA-method’)
- ◆ Time playing on CCA-structures: 25 min/day = 0.42 h/day
- ◆ Contribution of Cr (VI) to the total chromium residue is 3% or 30% (worst case)

Using the ‘handload-method’ the daily oral dose is calculated according to the following equation:

$$\text{Oral Dose } (\mu\text{g/kg bw/day}) = \frac{\text{Residue on hand } (\mu\text{g/cm}^2) \times \text{palmar surface area } (\text{cm}^2) \times \text{handload } (\text{day}^{-1}) \times 0.5}{\text{Body Weight } (\text{kg})}$$

Using the ‘EPA-method’ the daily oral dose is calculated according to the following equation:

$$\text{Oral Dose } (\mu\text{g/kg bw/day}) = \frac{\text{Residue hand } (\mu\text{g/cm}^2) \times \text{palmar surface area } (\text{cm}^2) \times \text{events } (\text{hr/day}) \times \text{contact time } (\text{hr}) \times 0.5}{\text{Body Weight } (\text{kg})}$$

Table 4.10 Estimated daily oral doses due to HTM-transfer of dislodgeable residues in a child of 5 years.

	Daily oral dose (µg/kg bw/day)
--	--------------------------------

	Median Handload		EPA-Method
	Boys	Girls	combined sexes
Chromium - total			
mean residue	0.39	0.71	0.83
maximal residue	2.17	3.93	4.59
Chromium (VI)			
mean residue-Cr(VI) 3%	0.012	0.021	0.025
max. residue-Cr(VI) 3%	0.065	0.12	0.14
mean residue-Cr(VI) 30%	0.12	0.21	0.25
max. residue-Cr(VI) 30%	0.65	1.18	1.38
Copper			
mean residue	0.29	0.52	0.61
maximal residue	0.67	1.22	1.42
Arsenic			
mean residue	0.66	1.19	1.40
maximal residue	2.27	4.12	4.81

4.5 Inhalation Exposure: Dust from CCA-treated Wood

Exposure to CCA-ingredients by inhalation will occur where CCA-treated wood is reshaped or processed (e.g. sawing, cutting, drilling, and sanding). The potential inhaled dose is calculated from:

$$\text{Wood dust level } (\mu\text{g}/\text{m}^3) \times \text{CCA fraction in dust} \times \text{inhalation rate } (\text{m}^3/\text{h}^{-1}) \times \text{contact duration (h)}$$

Dose =

body weight (kg)

This dose is expressed in $\mu\text{g}/\text{kg}$ bw/day. The dose calculated in this way represents the rate of entry, but only the respirable fraction will reach the lung. The remaining non-respirable fraction will be swallowed and will enter the gastrointestinal tract. Thus, the potential inhaled dose is separated into an oral and an inhalatory part by means of the respirable fraction f .

$$\text{Dose} = \text{inhalatory dose} + \text{oral dose} = f \times \text{Dose} + (1-f) \times \text{Dose}$$

The parameters used can be quantified as follows.

Dust concentration.

All reported measurements refer to indoor occupational situations. We will assume that the upper limit of occupational measurements is representative for residential exposures to dust during working with CCA-treated wood in a non-occupational setting (e.g. during do-it-yourself jobs). Indoor dust concentrations during processing of wood reach upper limits of $38.3 \text{ mg}/\text{m}^3$ (13) $45 \text{ mg}/\text{m}^3$ (46) and $49 \text{ mg}/\text{m}^3$ (47), with a single value of about $150 \text{ mg}/\text{m}^3$ (46). Modal values are typically around $2 \text{ mg}/\text{m}^3$ (13,46,48) or lower (5). For a worst case evaluation, a value of $45 \text{ mg}/\text{m}^3$ will be taken here to represent dust concentrations. For a realistic scenario a median value of $2 \text{ mg}/\text{m}^3$ for several types of wood processing activities may be used.

For outdoor wood processing activities (relevant for many 'do-it-yourself' jobs) no adequate data were available. Unpublished data (T. Gordon, pers. comm., ref. 47) showed mean dust levels for outdoor activities below $1 \text{ mg}/\text{m}^3$.

CCA concentration in dust.

Measurements of CCA fractions in wood are presented by Arsenault (13) and Rapp et al., (46). Arsenault (13) reports 0.26% chromium, 0.14% copper and 0.19% arsenic in CCA treated multiplex. Rapp et al. (46) report concentrations of chromium, copper and boron in wood and wood dust treated with Chromium-Copper-Boron preservatives as used in various industries. The 75 percentile for chromium was at maximum 20 ppm, that of copper at maximum 120 ppm (estimated from graphic illustrations). These values are lower than those of Arsenault, and therefore we will use the Arsenault values for a worst case evaluation. Because of the limited amount of data available, mean concentrations for CCA-ingredients in wood dust are not used.

Jensen and Olsen (49) directly measured concentrations of arsenic in air. They found air levels of 2.8 to 5.5 $\mu\text{g As/m}^3$ in the breathing zone during the production of garden fences. During production of weekend cottages and new houses, the upper limit is 2.9 $\mu\text{g As/m}^3$. Rapp et al. (46) report air level distributions of chromium(VI) and copper in wood processing businesses, being 1 $\mu\text{g/m}^3$ and 10 $\mu\text{g/m}^3$ respectively (75 percentile of highest activity). Unpublished data of Gordon (47) showed airborne concentrations of 3 - 5 $\mu\text{g/m}^3$ for chromium, 2 - 3 $\mu\text{g/m}^3$ for copper, and 5 - 8 $\mu\text{g/m}^3$ for arsenic at *outdoor* working sites. For *indoor* wood processing activities such as sanding of CCA-treated timber airborne concentrations of 137 - 576 $\mu\text{g/m}^3$ for chromium, 92 - 242 $\mu\text{g/m}^3$ for copper, and 140 - 571 $\mu\text{g/m}^3$ were measured using personal samplers (47). Indoor sawing operations revealed lower airborne concentrations (47). These preliminary data indicate that indoor wood processing activities involving CCA-treated timber may at least occasionally result in extremely high airborne concentrations of chromium, copper, and arsenic.

Inhalation rate.

The inhalation rate is used at a default value of 20 m^3/day which is equivalent to 0.833 m^3/hr (50).

Contact duration.

Occupational exposure will not be addressed in this evaluation. For non-occupational exposure, e.g. during do-it-yourself jobs, no data are available to quantify the duration of wood processing. As a worst case estimate, it is assumed that there are 8 hours of exposure per day for 2 weeks per year. Averaged per year, this amounts to 0.31 hour per day.

Respirable fraction f.

Arsenault (1977) reports that 6% of the dust was smaller than 10 μm . All particles below 10 μm are assumed to be respirable, while none of the larger particles are assumed to be respirable. The respirable fraction is set to 0.06. From this it follows that 94% of the dust does not reach the lungs but will be disposed in the upper airways (e.g. nose, buccal cavity).

In the table 4.11, the oral and inhalatory dose levels as a consequence of the inhalation of wood dust are presented using the following values and assumptions:

- ◆ Worst case wood dust level is 45 mg/m^3
- ◆ Realistic mean wood dust level is 2 mg/m^3
- ◆ Yearly average time exposed is 0.31 h/day
- ◆ Inhalation rate is 0.833 m^3/hr
- ◆ Concentrations of total chromium, copper, and arsenic are 0.26%, 0.14%, and 0.19% respectively
- ◆ The respirable fraction is 6%
- ◆ Adult body weight is 70 kg
- ◆ The contribution of Cr(VI) in the wood dust is 30% (worst case).

Table 4.11 Exposure of adults to CCA-ingredients due to the inhalation of CCA-treated wood dust during the processing of wood.

	Averaged dose per year ($\mu\text{g/kg bw/day}$)		Single Exposure ($\mu\text{g/m}^3$)	
	Max. wood dust	Mean wood dust	Max. wood dust	Mean wood dust

	level of 45 mg/m ³	level of 2 mg/m ³	level of 45 mg/m ³	level of 2 mg/m ³
<i>ORAL ROUTE</i>				
Chromium total	0.406	0.018		
Chromium (VI)	0.122	0.005		
Copper	0.219	0.010		
Arsenic	0.297	0.013		
<i>INHALATORY ROUTE</i>				
Chromium total	0.026	0.001	117	5.2
Chromium (VI)	0.008	0.0003	35	1.6
Copper	0.014	0.0006	63	2.8
Arsenic	0.019	0.0008	86	3.8

From the worst case single exposure data in table 4.11 it can be calculated that the average daily exposure concentration during the periods of wood processing is $117 \times (8/24) = 39 \mu\text{g}/\text{m}^3$ for total chromium (worst case). Similar calculations for Cr(VI) (=30% of Cr-total), Cu, and As reveal levels of 11.6, 21, and $28.6 \mu\text{g}/\text{m}^3$ respectively using a worst case dust level of $45 \text{ mg}/\text{m}^3$.

When these exposure conditions are expressed as average values over a period of 1 year, the maximal exposure concentration is $117 \mu\text{g}/\text{m}^3 \times (8/24) \times (14/365) = 1.50 \mu\text{g}/\text{m}^3$ for total chromium. Similar calculations for Cr(VI) (=30% of Cr-total), Cu, and As reveal levels of 0.45, 0.81, and $1.10 \mu\text{g}/\text{m}^3$ respectively using a worst case dust level of $45 \text{ mg}/\text{m}^3$.

4.6 Inhalation Exposure: Burning of CCA-treated Wood

Quantitative data on the possible indoor air concentrations on chromium, copper, and arsenic due to burning of CCA-treated timber in fire-places are lacking. However, a report has been published on the health effects observed within a family of 8 individuals who used CCA-treated timber as fuel for their fire-place (51). All family-members displayed symptoms of eye irritation, dermatitis (especially young children playing on the floor), bronchitis, headache, nosebleeds, alopecia, and diarrhoea (51). Arsenic concentrations in hair and finger-nails were extremely high indicating marked arsenic exposure (51).

In a (rather dated) report of Dobbs et al. (52) several reports and experiments on the burning of CCA-treated wood have been discussed. It appears that arsenic is the predominant component to be volatilised during combustion of preserved wood. Depending on the extent of impregnation, the amount of supplied air, and the combustion temperature, it was estimated that the percentage of emitted arsenic may range from 20 to 90% of the total arsenic content in the wood. In the evolved gases, the arsenic concentration may range from $53 \text{ mg As}/\text{m}^3$ air (for 20% volatilisation from wood treated with $4 \text{ kg CCA}/\text{m}^3$ wood) up to $960 \text{ mg As}/\text{m}^3$ air (for 90% volatilisation from wood treated with $20 \text{ kg CCA}/\text{m}^3$ wood). Although the reliability of these values cannot be determined, these estimations indicate that during combustion of CCA-treated wood, substantial amounts of arsenic may be present in the emitted gases.

For chromium and copper, less data were presented by Dobbs et al. but the available evidence indicates that the amount of emitted copper may be considered negligible. For emitted chromium, values of 0 - 13% of the total chromium content in the wood have been reported (52).

Because between 1.5 - 5% of the original wood mass was recovered after combustion and maximally 90% As would be volatilised (for Cr and Cu even less), the concentration of these metals in the remaining ash or fly ash will be expected to be very high. Indeed, Polandt et al. (53) reported high levels. In fly ash: $32.4 \text{ g As}/\text{kg}$, $37.4 \text{ g Cr-tot}/\text{kg}$, $43.3 \text{ g Cu}/\text{kg}$; in the remaining ash: $5.6 \text{ g As}/\text{kg}$, $81.9 \text{ g Cr-tot}/\text{kg}$, $87.7 \text{ g Cu}/\text{kg}$ (53). It was observed that a substantial amount of the chromium present in ash and fly ash was present as highly soluble Cr(VI) (52,53) which renders the ash potentially toxic.

Dobbs et al. suggested that burning of CCA-treated wood would not produce problems when considered as a total environmental burden. However, burning of CCA-treated wood may give rise to local or occasional problems as in the case of bonfires and indoor combustion of CCA-treated wood in furnaces, fireplaces or boilers (52). However, no quantitative exposure data were available for such conditions. In addition, it is not known to what extent burning of CCA-treated wood occurs in the

Netherlands. Nevertheless, the case-report cited above indicates that burning of CCA-treated wood may give rise locally to serious toxicological problems (51).

5. Risk Assessment

5.1 Direct and Indirect Dermal Contact

Direct dermal contact is considered to represent conditions in which CCA-treated wood is directly handled. This occurs during 'do-it-yourself' jobs by adults and during playing on CCA-treated wooden structures by children. Indirect dermal contact is considered to represent conditions in which the active ingredients of CCA-treated wood have leached into the soil or into surface water.

For direct dermal contact with CCA-treated wood the dermal exposure to chromium, copper, and arsenic was calculated based on a mean dermal transfer coefficient of 1000 cm²/hour for the palmar surface area of children about 5 years of age. This value is roughly estimated based on a limited range of dermal transfer coefficients reported in recent years for adults.

5.1.1 Chromium

Exposure data for dislodgeable residues on CCA-treated wood have been presented in section 4.1.4, indirect exposure data to CCA-contaminated soil have been presented in section 4.2.1, while indirect dermal exposure data to surface water have been presented in section 4.3.

The mean dislodgeable residue for total chromium was calculated to be 0.119 µg/cm² whereas a worst case value of 0.658 µg/cm² was selected. The contribution of Cr(VI) to total chromium was selected to be 3% for a realistic scenario and 30% for a worst case scenario. This implicates that the mean dislodgeable residue yields a value of $0.03 \times 0.119 = 0.0036$ µg Cr(VI)/cm² whereas the maximal residue assumption yields a value of $0.3 \times 0.658 = 0.197$ µg Cr(VI)/cm².

Using a dermal transfer coefficient of 1000 cm²/hr, the total dermal dose was calculated for a playing-time 0.33 and 0.42 h/day in contact with CCA-treated timber. These calculations yield a dermal exposure to 0.604 and 0.769 µg total chromium/cm² for a mean dislodgeable residue on the wood and a dermal exposure to 3.341 and 4.250 µg total chromium for a maximal dislodgeable residue on the wood. When Cr(VI) contributes 3% to total chromium, the dermal doses will be 0.023 and 0.127 µg Cr(VI)/cm² for mean and maximal dislodgeable residue on the wood respectively (for a contact time of 0.42 h/day). In a worst case condition of 30% Cr(VI), dermal doses may be as high as 0.230 and 1.275 µg Cr(VI)/cm² respectively (for a contact time of 0.42h/day).

For dermal contact with contaminated soil, total chromium exposure may amount to 0.0026 µg/cm² for a realistic exposure scenario and 0.086 µg/cm² for a maximal or worst case scenario. These values are quantitatively of minor importance when compared to the dermal exposure due to direct contact with CCA-treated wood. In addition, it is considered that the amount of Cr(VI) in (Dutch) soils is negligible and that all chromium will be present in the trivalent state.

For total chromium, the maximal total dermal dose is therefore $4.250 + 0.086 = 4.336$ µg/cm². Assuming all chromium is Cr(III) these exposure values do not provide a risk for dermal effects since the threshold response level for allergic contact dermatitis for Cr(III) was considered to be > 33 µg/cm².

For Cr(VI), the dermal dose during a mean or realistic exposure condition (0.023 µg/cm²) is below the threshold value of 0.089 µg/cm². However, when maximal dislodgeable residues are present on the wood and/or the contribution of Cr(VI) is at a worst case level (30%), dermal dose levels are estimated to range from 0.102 to 1.275 µg Cr(VI)/cm² (see table 4.4). These values are all higher than the limit value of 0.089 µg Cr(VI)/cm² indicating a risk for the occurrence of allergic contact dermatitis in sensitised individuals.

Remarks on Direct Dermal Contact to Chromium

- ◆ As has been discussed in chapter 3, the 10%-response threshold dose is considered to protect 99.9% of the general population because the incidence of chromium-induced allergic contact dermatitis is considered to be < 1% in the general population and the level of 0.089 $\mu\text{g}/\text{cm}^2$ results in a significant response only in 10% of these sensitised individuals (see chapter 3).
- ◆ The dermal exposure values have been calculated for children using a dermal transfer factor and a playing time of 0.42 h/day. For adults handling CCA-treated timber during 'do-it-yourself-jobs', the type of activity may be substantially more intensive resulting in higher values for the dermal transfer factor and contact time and, therefore, higher dermal exposures to Cr(VI).
- ◆ The worst case assumption of a 30% contribution of Cr(VI) to total dislodgeable chromium is based on a measurement on commercial timber of unknown quality sampled directly after the required fixation period. This indicates that such a piece of timber may be available on the commercial market and may be used for 'do-it-yourself' jobs. As can be concluded from the exposure data in section 4.1.1. dislodgeable residue values tend to decrease after some period of time especially in wood installed outdoors. Measurements of the RIVM showed a maximal dislodgeable residue of 0.59 ng Cr(VI)/ cm^2 on installed playing structures in the Netherlands (16). According to the calculations in section 4.1.4, this would result in a dermal exposure value of 3.8 ng Cr(VI)/ cm^2 skin which is about 20-25 times below the dermal threshold value of 0.089 $\mu\text{g}/\text{cm}^2$.

Swimming in contaminated water presents a specific form of dermal exposure to CCA-ingredients. Based on leaching studies it was roughly estimated that total chromium levels in surface water in the vicinity of CCA-treated wooden waterworks may range from 0-50 $\mu\text{g}/\text{l}$ (2). Peak levels of total chromium calculated for a standard canal would be maximally 41 $\mu\text{g}/\text{l}$ (25). Even when all chromium would be present as Cr(VI), these values are far below the lowest threshold value reported for allergic contact dermatitis for dissolved Cr(VI)-solutions, i.e. 800 $\mu\text{g}/\text{l}$.

In conclusion, a risk for Cr(VI)-induced allergic contact dermatitis may exist when relative freshly produced CCA-treated timber of poor quality (i.e. high residue of Cr(VI)) is directly handled or processed. It is expected that this risk decreases to negligible levels after a period of several months, especially when the wood is installed or stored outdoors since the amount of dislodgeable residue is markedly decreased over time.

5.1.2 Copper

Although copper-induced allergic contact dermatitis is known to occur in humans, its prevalence is very low and a dose-response-relationship or a threshold response level have not been established. Other direct effects of copper on the skin have not been reported.

Dermal exposure to copper from direct contact CCA-treated wood is estimated to be 0.447 - 0.568 $\mu\text{g}/\text{cm}^2$ for a mean dislodgeable residue of 0.088 $\mu\text{g}/\text{cm}^2$ and 1.035 - 1.318 $\mu\text{g}/\text{cm}^2$ for a maximal dislodgeable residue of 0.204 $\mu\text{g}/\text{cm}^2$.

Dermal contact with contaminated soil nearby CCA-treated wooden structures may result in an exposure of 0.0023 $\mu\text{g}/\text{cm}^2$ for a mean exposure scenario and 0.858 $\mu\text{g}/\text{cm}^2$ for a worst case scenario. Swimming in contaminated water due to leaching of CCA-treated wood may involve maximal peak concentrations of copper of 30 - 250 $\mu\text{g}/\text{l}$.

Using the maximal dermal exposure values for dislodgeable residues (1.318 $\mu\text{g}/\text{cm}^2$) and for soil contact (0.858 $\mu\text{g}/\text{cm}^2$) it can be calculated that this will result in a total dermal dose of $[1.318 + 0.858 \mu\text{g}/\text{cm}^2] \times 65 \text{ cm}^2 = 141 \mu\text{g}$ for a child playing on CCA-treated structures. Considering a body weight for young children of 16.7 (see section 4.4.1) and a 100% absorption of the dermal dose, this will result in a dose of 8.47 $\mu\text{g}/\text{kg}$ bw/day which is far below the limit value (oral TDI is 170 $\mu\text{g}/\text{kg}$ bw/day).

5.1.3 Arsenic

Arsenic is known to be irritating to the skin but no reliable toxicological data are available with respect to dermal exposure to arsenic compounds from which a dermal limit value could be derived.

Direct dermal contact with CCA-treated wood is estimated to result in a dermal dose of 1.015 - 1.292 $\mu\text{g As/cm}^2$ for a mean dislodgeable residue of 0.200 $\mu\text{g/cm}^2$ on the wood and 3.493 - 4.446 $\mu\text{g As/cm}^2$ for a maximal dislodgeable residue of 0.688 $\mu\text{g/cm}^2$ on the wood.

Additional exposure due to contaminated soil may be maximally 0.086 $\mu\text{g/cm}^2$ assuming that all As in the soil will be bioavailable. Swimming in contaminated water due to leaching of CCA-treated wood may involve peak concentrations of arsenic as high as 773 $\mu\text{g/l}$ during the first weeks and 151 $\mu\text{g/l}$ one year after installation of the wood.

Because of the limited knowledge on dermal exposure to arsenic, it is not known whether these calculated exposure values are able to induce irritation effects. Systemic consequences of these dermal exposure scenarios are further addressed in section 5.4.

5.2 Oral Route

Oral exposure to CCA-products may occur via indirect routes. For example, precipitated particles of inhaled CCA-treated wood dust will be partly cleared from the airways through mucociliary mechanisms in which these particles eventually are moved to the buccal cavity and swallowed. In section 4.5, this route of exposure has been quantified for an adult worker performing 'do-it-yourself' wood processing activities for 2 weeks per year and 8 hours per day. Although there are no data available on which the time spend on 'do-it-yourself' activities could be based, an assumption of 2 weeks - 8 h/day working with CCA-treated timber appears to be a rather conservative assumption which will include nearly all non-occupational exposure scenario's.

For children in contact with CCA-treated structures, e.g. on playgrounds, two routes for oral exposure to CCA-ingredients are possible. First, children are known to ingest a particular amount of soil when playing outdoors. When this involves soil which is contaminated due to leaching of chromium, copper, and arsenic from CCA-treated wood, soil ingestion may provide an additional exposure to CCA-ingredients. Second, due to HTM-transfer a certain amount of dislodgeable residue from treated wood may be ingested by licking of the palmar surface.

In section 4.4.1., the mean and maximal daily oral exposure to CCA-ingredients due to soil ingestion was calculated.

In section 4.4.2, the HTM-transfer was quantified for a 5 year old child using two different methods for estimating the amount of HTM-behaviour. It should be noted that calculations of the daily oral dose due to HTM-behaviour were largely similar for both methods. Because the 'EPA-method' yields slightly higher values, in the following risk assessment only the data generated with the EPA-method are used.

5.2.1. Chromium

For Cr(III), the oral limit value of the U.S. EPA of 1000 $\mu\text{g/kg bw/day}$ will be used for risk assessment. For Cr(VI) the oral limit value of the U.S. EPA of 5 $\mu\text{g/kg bw/day}$ will be used for the risk assessment of non-carcinogenic toxic effects. Due to the absence of adequate data, a quantification of the carcinogenic risk after oral exposure to Cr(VI) cannot be established.

The maximal oral dose of adults (due to ingestion of wood dust after inhalatory exposure) working with CCA-treated timber (2 weeks/year; 8h/day) was estimated to be 0.406 $\mu\text{g/kg bw/day}$ for total chromium and 0.122 $\mu\text{g/kg bw/day}$ for Cr(VI) using a worst case wood dust level of 45 mg/m^3 and a maximal contribution of 30% for Cr(VI). These dose levels are clearly below the toxicological limit values for oral exposure (1000 $\mu\text{g/kg bw/day}$ for Cr(III) and 5 $\mu\text{g/kg bw/day}$ for Cr(VI).

For children playing on CCA-treated playing structures, the maximal daily dose for total chromium due to soil ingestion for children 2-5 yrs of age amounts to 0.988 µg/kg bw/day (see section 4.4.1). Since the amount of Cr(VI) in (Dutch) soils is considered to be negligible (28), this oral exposure is considered to represent Cr(III) only. It should be noted that a 100% bioavailability is assumed for chromium in the soil which is highly conservative.

Based on the EPA-method for quantifying the HTM-transfer after direct contact with CCA-treated wood, it was calculated that the maximal oral dose due to HTM-transfer is 4.59 µg/kg bw/day for total chromium. This corresponds to 1.38 µg Cr(VI)/kg bw/day and 3.21 µg Cr(III)/kg bw/day (using a contribution of 30% Cr(VI)).

For Cr(III), the maximal total oral dose would then amount to $0.988 + 3.21 = 4.198$ µg/kg bw/day. This value is clearly below the oral limit value of 1000 µg/kg bw/day.

For Cr(VI) the maximal oral dose of 1.38 µg Cr(VI)/kg bw/day is about 3-4 times below the oral limit value for non-carcinogenic effects, i.e. 5 µg/kg bw/day.

It should be noted that there is no limit-value for carcinogenic effects after oral exposure to Cr(VI) (see chapter 3).

5.2.2. Copper

For copper an oral limit value of 170 µg/kg bw/day was determined by the RIVM.

The oral dose of adults (due to ingestion of wood dust) working with CCA-treated timber (2 weeks/year; 8h/day) was estimated to be 0.219 µg/kg bw/day for copper using a worst case wood dust level of 45 mg/m³. This exposure is far below the oral limit value of 170 µg/kg bw/day.

For children playing on CCA-treated playing structures, the oral dose of copper due to the ingestion of contaminated soil, is calculated to be maximally 9.88 µg/kg bw/day (using a the highest increase in soil concentration measured directly near CCA-treated timber (1650 mg/kg) and a worst case soil ingestion rate of 1000 mg/day). Due to HTM-transfer after direct dermal contact with CCA-treated wood, the oral dose may be maximally 1.42 µg/kg bw/day. The maximal total oral dose of $9.88 + 1.42 = 11.30$ µg/kg bw/day is about 16 times below the recommended limit value of 170 µg/kg bw/day.

5.3.3. Arsenic

The oral limit value for arsenic is 15 µg/kg bw/week (see ref. 1).

The oral dose of adults (due to ingestion of wood dust) working with CCA-treated timber (2 weeks/year; 8h/day) was estimated to be 0.297 µg/kg bw/day using a worst case wood dust level of 45 mg/m³. When we assume that wood processing activities are performed during a single united period of 7 days (worst case) this would result in a weekly dose of 2.08 µg/kg bw/week. This value is below the oral limit value of 15 µg/kg bw/week.

For children playing on CCA-treated playing structures, the mean oral exposure to arsenic due to ingestion of contaminated soil was calculated to be 0.009 µg/kg bw/day for a 5-yr old when assuming a mean increase in soil concentration of 15 mg/kg and a mean soil ingestion of 100 mg/day. When a maximal increase in soil arsenic level of 165 mg/kg is used, the oral dose is 0.099 µg/kg bw/day. For a worst case soil ingestion rate of 1000 mg/day the daily oral doses become 0.090 and 0.988 µg/kg bw/day for a mean and maximal increase in arsenic soil concentration respectively. When we assume that children will play on CCA-treated playing structures for 4 days per week (19), the daily doses due to soil ingestion correspond to weekly doses of 0.036 (mean soil ingestion/mean soil level), 0.396 (mean soil ingestion/maximal soil level), 0.360 (maximal soil ingestion/mean soil level), and 3.952 µg/kg bw/week (maximal soil ingestion/maximal soil level).

Oral exposure due to HTM-transfer of dislodgeable residues was calculated to be 1.40 and 4.81 $\mu\text{g}/\text{kg bw}/\text{day}$ (EPA-method) for a mean and maximal dislodgeable residue on CCA-treated wood respectively. Again assuming that children play 4 days per week on CCA-treated playing structures, these doses correspond to weekly doses of 4.60 and 19.24 $\mu\text{g}/\text{kg bw}/\text{week}$.

For a mean exposure scenario, the total oral exposure will be $4.60 + 0.036 = 4.636 \mu\text{g}/\text{kg bw}/\text{week}$. For a mean dislodgeable residue and a maximal soil ingestion, the total oral dose will be $4.60 + 3.952 = 8.552 \mu\text{g}/\text{kg bw}/\text{week}$. These values are about 2-3 times below the oral limit value of 15 $\mu\text{g}/\text{kg bw}/\text{week}$. However, when maximal dislodgeable residues are present on CCA-treated wood, the oral exposure level slightly exceeds the oral limit value (19.24 vs. 15 $\mu\text{g}/\text{kg bw}/\text{week}$). When soil ingestion is added, the maximal total oral dose will be $19.24 + 3.952 = 23.2 \mu\text{g}/\text{kg bw}/\text{week}$ which is above the oral limit value of 15 $\mu\text{g}/\text{kg bw}/\text{day}$.

Remarks on Oral Exposure to CCA-derived Arsenic

- ◆ From the available data it can be concluded that the health risk due to oral exposure to CCA-derived arsenic is mainly caused by hand-to-mouth transfer of dislodgeable residues. Ingestion of contaminated soil contributes quantitatively little to the total oral exposure.
- ◆ The level of dislodgeable residue is, similar to chromium, extremely variable and ranges from undetectable levels to the highest level measured 0.688 $\mu\text{g}/\text{cm}^2$. Although less marked than for chromium, the dislodgeable residue of arsenic on CCA-treated playing structures decreases over time when the CCA-treated wood is installed outdoors (highest level measured on playing structures 1 year after installation is 0.147 $\mu\text{g}/\text{cm}^2$)(15).
- ◆ It should be noted that hand-to-mouth behaviour decreases markedly with increasing age and is considered to be a relevant route of exposure only for children up to an age of about 5-6 years. When the time spend on CCA-treated structures on playing grounds is lower for younger children of age 2-4 years, the amount of dislodgeable residue on the hands is proportionally reduced because the time of contact is considered to determine the dermal loading of dislodgeable residue.

5.3 Inhalatory Route

Inhalatory exposure to CCA-components as a consequence of burning of CCA-treated wood (outdoor bonfires, indoor furnaces or fireplaces) may provide a toxicological hazard. The remaining ash and the fly ash contain high concentrations of chromium, copper, and arsenic and should be considered as potentially toxic. The extent to which CCA-treated timber is burned by the general public is not known but is expected to be low.

Inhalatory exposure to wood dust during processing of CCA-treated timber (e.g. during 'do-it-yourself' jobs) was separated in an respirable fraction and a non-respirable fraction which is deposited on the epithelium of the nose, the mouth, and the buccal cavity. The latter fraction is eventually ingested and has been evaluated in section 5.2. In the following sections, only the actual inhalatory exposure (i.e. the respirable fraction) will be addressed.

The health risks due to the inhalation of CCA-treated wood dust can be evaluated using two different approaches. First, the acute health risks can be assessed in case of a single exposure. The calculated exposure values will be compared to NOAEL or limit values for short-term effects (when such values are available) and will be compared to the Dutch MAC-values. Second, the long-term health risks can be assessed by comparing the calculated average daily dose (over 1 year) with the long-term limit values.

5.3.1 Chromium

Using a worst case wood dust level of 45 mg/m^3 it was calculated that a single exposure would result in a airborne level total chromium level of $117 \text{ }\mu\text{g/m}^3$ and a Cr(VI) level of $35 \text{ }\mu\text{g/m}^3$ (assuming 30% Cr(VI). It should be noted that values up to $500 \text{ }\mu\text{g/m}^3$ have been measured occasionally (respirable fraction not known, 47). Daily average exposures during wood processing are $39 \text{ }\mu\text{g/m}^3$ for total chromium and $11.6 \text{ }\mu\text{g/m}^3$ for Cr(VI) for a worst case exposure scenario.

The single exposure value for total chromium is above the MAC-value of $60 \text{ }\mu\text{g/m}^3$ for inhalable dust of soluble Cr(III) compounds. However, two remarks should be made. First, it is presently unknown whether all chromium present in wood dust may become bioavailable. Second, since the MAC-value is based on *inhalable dust* ($< 10 \text{ }\mu\text{m}$) only the respirable fraction of the wood dust (=6%) should be considered. This fraction accounts for $0.06 \times 117 = 7.02 \text{ }\mu\text{g/m}^3$, which is clearly below the MAC-value. The level of $35 \text{ }\mu\text{g/m}^3$ for Cr(VI) is below the MAC-value of $50 \text{ }\mu\text{g/m}^3$ for Cr(VI).

When expressed as the average daily concentration over one year, the concentrations of total chromium and Cr(VI) are 1.50 and $0.45 \text{ }\mu\text{g/m}^3$ respectively using a worst case wood dust level of 45 mg/m^3 and a contribution of 30% Cr(VI) to total chromium. For Cr(VI) this value is above the acceptable risk level for carcinogenicity of 0.025 ng/m^3 ($1:10^6$). For a mean exposure level at a wood dust level of 2 mg/m^2 the average daily exposure will be $0.067 \text{ }\mu\text{g/m}^3$ which is also above the acceptable risk level for carcinogenicity of 0.025 ng/m^3 . Even when a mean Cr(VI) contribution of only 3% is assumed, the exposure level will be $0.006 \text{ }\mu\text{g/m}^3$ which is still above the acceptable risk level of 0.025 ng/m^3 .

Other relevant toxicological effects during inhalation of chromium are nasal mucosal irritation and ulceration, bronchial irritation, and a decreased lung function. In humans, a NOAEL of $1 \text{ }\mu\text{g Cr(VI)/m}^3$ has been identified for these effects. This level is exceeded during periods of wood processing during worst case conditions since the daily average concentrations was calculated to be $11.6 \text{ }\mu\text{g/m}^3$. For a mean exposure scenario, the daily average exposure concentration is $1.6 \times (8/24) = 0.53 \text{ }\mu\text{g/m}^3$ which is below the NOAEL for irritation and lung function effects.

Remarks on Inhalatory Exposure to Cr(VI)

- ◆ The calculated exposure scenarios are based on *indoor* measurements. *Outdoor* wood processing activities will result in lower exposure conditions (47).
- ◆ The contribution of Cr(VI) in the wood dust may be highly variable indicating a large variability in the possible exposure to Cr(VI).
- ◆ It is presently unknown to what extend the Cr(VI) present in/on the wood dust may become bioavailable upon inhalation.
- ◆ The acceptable risk level of 0.025 ng/m^3 has been determined for a life-long exposure while the exposure to CCA-treated wood dust is not expected to occur life-long. Nevertheless, peak exposure levels to airborne chromium may be substantial.

5.3.2 Copper

Using a worst case wood dust level of 45 mg/m^3 it was calculated that a single exposure would result in a copper level of $63 \text{ }\mu\text{g/m}^3$ while the daily average concentration is $21 \text{ }\mu\text{g/m}^3$. This value is clearly below the MAC-value for copper dust of $1000 \text{ }\mu\text{g/m}^3$.

Expressed on a yearly average basis, the exposure levels are estimated to be $0.81 \text{ }\mu\text{g copper/m}^3$. This value is below the provisional limit value of $20 \text{ }\mu\text{g/m}^3$ based on 'metal fume fever' effects.

5.3.3 Arsenic

Using a worst case wood dust level of 45 mg/m^3 it was calculated that a single exposure would result in an arsenic level of $86 \text{ } \mu\text{g/m}^3$ (worst case). The associated daily average exposure concentration is $28.6 \text{ } \mu\text{g/m}^3$ during periods of wood processing. It should be noted that airborne concentrations for arsenic have been reported up to about $500 \text{ } \mu\text{g/m}^3$ (during sanding of CCA-treated timber, ref. 47). These values are clearly above the MAC-values for combined arsenic compounds ($50 \text{ } \mu\text{g/m}^3$) and soluble arsenic compounds ($25 \text{ } \mu\text{g/m}^3$).

Expressed on a yearly average basis, the maximal exposure levels are calculated to be $1.10 \text{ } \mu\text{g As/m}^3$. This value is slightly above the limit value of $0.5 \text{ } \mu\text{g/m}^3$ for the general population. However, the average exposure concentration of $1.10 \text{ } \mu\text{g/m}^3$ is well below the marginal LOAEL on the most sensitive effect (clinical neuropathy) of $50 \text{ } \mu\text{g/m}^2$ observed in workers (see ref. 1).

Using a mean exposure scenario (wood dust level of 2 mg/m^3), the yearly exposure level would be 0.05 which is 10 times below the chronic limit value of $0.5 \text{ } \mu\text{g/m}^3$.

5.4 Integration of Routes of Exposure

In this section all relevant routes of exposure will be integrated for children in contact with CCA-treated wood in order to obtain a total value for the 'internal' dose after absorption by the various routes. This calculations has not been performed for copper because the exposure of children to CCA-derived copper was shown to be far below the toxicological limit-values for both dermal and oral exposure, separately and combined (see section 5.1 and 5.2). Therefore the following calculations will be performed only for chromium III, chromium VI and arsenic.

- ◆ Inhalation of CCA-treated wood dust is considered not to be a relevant route of exposure only for adults performing 'do-it-yourself-jobs' and therefore no inhalatory exposure is considered for children.
- ◆ Exposure to CCA-components as a consequence of swimming in CCA-contaminated water is not included in the present calculations since the risk of combined exposure to CCA-components on a single day either due to playing on CCA-treated playing structures and swimming in CCA-contaminated water is considered to be negligible (see section 4.3).
- ◆ Because of the large variability in background soil levels, we have chosen to use mean and maximal *increases* in the soil concentration of chromium, copper and arsenic due to the leaching of CCA-treated wood. Oral exposure to CCA-components due to ingestion of contaminated soil includes only the *additional* exposure to CCA-derived chromium and arsenic.

In the table 5.1, calculations are presented which represent a mean exposure scenario (i.e. mean conditions for each factor involved) or maximal exposure scenario (i.e. worst case condition for each factor involved). Calculation have been performed using the following values and assumptions.

- ◆ All chromium and arsenic in soil will be bioavailable, both for the oral and the dermal route.
- ◆ Oral absorption values for Cr(III), Cr(VI), and As are 2%, 6%, and 95% of the dose, respectively.
- ◆ Dermal absorption values for Cr(III), Cr(VI), and As are 1%, 4%, and 4% of the dose, respectively.
- ◆ The calculated systemic doses were compared to the systemic doses corresponding to ingestion of the oral limit values of $1000 \text{ } \mu\text{g/kg bw/day}$ for Cr(III), $5 \text{ } \mu\text{g/kg bw/day}$ for Cr(VI), and $15 \text{ } \mu\text{g/kg bw/week}$ for As using the oral absorption values above.
- ◆ Body weight for child of age 5 years is 19.7 kg
- ◆ Daily dietary intakes (background exposure) include values for food and drinking water (see refs. 28,29). For inorganic total chromium this value is $200 \text{ } \mu\text{g/day}$ for an adult (upper limit)

corresponding to a dose of $(0.02 \times 200)/70 = 0.06 \mu\text{g}/\text{kg bw}/\text{day}$. For inorganic arsenic this value is $58 \mu\text{g}/\text{day}$ for an adult (upper limit) corresponding to a dose of $(0.95 \times 58)/70 = 0.79 \mu\text{g}/\text{kg bw}/\text{day}$.

Table 5.1 The integrated systemic dose (expressed in $\mu\text{g}/\text{kg bw}/\text{day}$) in a child of 5 years.

	Chromium (III)		Chromium (VI)		Arsenic	
	Mean	Max	Mean	Max	Mean	Max
Oral route (soil ingestion) ($\mu\text{g}/\text{day}$)	0.05	16.50	0	0	0.15	16.50
Oral route (HTM-transfer) ($\mu\text{g}/\text{day}$)	16.35	90.42	0.49	27.19	27.58	94.75
Dermal route (soil contact) ($\mu\text{g}/\text{day}$)	0.169	5.59	0	0	0.507	5.59
Dermal route (wood contact) ($\mu\text{g}/\text{day}$)	49.98	276.2	1.49	82.87	84.00	289.00
Total oral ($\mu\text{g}/\text{day}$)	16.40	106.92	0.49	27.19	27.73	111.25
Total dermal ($\mu\text{g}/\text{day}$)	50.15	281.79	1.49	82.87	84.51	294.59
Oral dose absorbed ($\mu\text{g}/\text{day}$)	0.33	2.14	0.029	4.97	26.34	105.68
Dermal dose absorbed ($\mu\text{g}/\text{day}$)	0.50	2.82	0.059	3.31	3.38	11.78
Total dose absorbed without background ($\mu\text{g}/\text{day}$)	0.83	4.96	0.088	8.28	29.72	117.46
Total dose absorbed without background ($\mu\text{g}/\text{kg bw}/\text{day}$)	0.04	0.25	0.004	0.42	1.51	5.96
Total dose absorbed including background ($\mu\text{g}/\text{kg bw}/\text{day}$)	0.10	0.31	0.004	0.42	2.30	6.75
Total absorbed dose corresponding with the oral limit value. ($\mu\text{g}/\text{kg bw}/\text{day}$)	20	20	0.3	0.3	2.04	2.04

Note: Values printed in **bold** indicate conditions in which the corresponding limit value is exceeded.

In table 5.1, the total systemic daily dose have been calculated for children of about 5 years of age. Since individuals will not only be exposed to CCA-derived chromium, copper, and arsenic, the main source of background exposure to these metals, i.e. dietary intake, has been included in the table. In the criteria documents on chromium and arsenic of the RIVM (28,29) daily dietary intakes were reported to range from 50 - 200 $\mu\text{g}/\text{day}$ for total chromium (contribution of Cr(VI) unknown but considered to be negligible in food) and from 15 - 58 $\mu\text{g}/\text{day}$ for inorganic arsenic. These levels correspond to systemic doses of $(0.02 \times 200)/70 = 0.06 \mu\text{g}/\text{kg bw}/\text{day}$ for total chromium (most likely Cr(III)) and $(0.95 \times 58)/70 = 0.79 \mu\text{g}/\text{kg bw}/\text{day}$ for inorganic arsenic.

As can be concluded from the data in table 5.1, the total exposure to Cr(III) is far below the corresponding limit value, even when normal daily intakes (background) are included.

For Cr(VI), the total exposure is clearly below the corresponding limit value for a mean exposure scenario. However, in a worst case scenario, the corresponding limit value may be slightly exceeded (0.42 vs. 0.3 $\mu\text{g}/\text{kg bw}/\text{day}$).

For arsenic, the mean exposure scenario is below the corresponding limit value but this amount is already about 75% of the corresponding limit value. When the background dietary intake is included, the daily dose is slightly higher than the corresponding limit value (2.30 vs. 2.04 $\mu\text{g}/\text{kg bw}/\text{day}$). For a worst case arsenic exposure, the corresponding limit value is clearly exceeded irrespective of the dietary intake (5.96 or 6.75 vs. 2.04 $\mu\text{g}/\text{kg bw}/\text{day}$). Thus, when these 'background' intakes are taken into account, the additional exposure to arsenic in young children due to contact with CCA-treated wood may result in daily arsenic exposure levels above the limit value even under 'mean' exposure conditions.

6. RIVM Evaluatie en Conclusies

Chroom (C) - Koper (C) - Arseen (A) mengsels zijn veel gebruikte middelen voor het conserveren van hout. In dit rapport is een risico evaluatie opgesteld voor de volksgezondheid met betrekking tot de gebruiksfase van met CCA's behandeld hout. De gezondheidsrisico's ten gevolge van de productie van CCA-geïmpregneerd hout en het beroepsmatig gebruik van CCA-geïmpregneerd hout worden in dit rapport dus niet beoordeeld.

Voor de volksgezondheid bestaan er een aantal relevante blootstellingsroutes voor CCA-geïmpregneerd hout. 1) Direct dermaal contact door het vastpakken van CCA-geïmpregneerd hout; 2) Indirect dermaal contact doordat CCA-ingrediënten zijn uitgelooagd naar de bodem of naar het oppervlakte water (bijv. spelen in CCA-verontreinigde bodem en zwemmen in CCA-verontreinigd water); 3) Orale blootstelling ten gevolge van bodemingestie door kinderen, hand-mond overdracht van dermale residuen bij kinderen, en ingestie van houtstof of zaagsel van CCA-geïmpregneerd hout door volwassenen; 4) Inhalatoire blootstelling middels houtstof en/of zaagsel door volwassenen ten gevolge van het verwerken van CCA-geïmpregneerd hout (zagen, schuren etc.); 5) Inhalatoire blootstelling ten gevolge van het verbranden van CCA-geïmpregneerd hout. Voor al deze blootstellingsroutes zijn de blootstellingen aan chroom, koper en arseen zo kwantitatief mogelijk berekend of geschat waarna toetsing heeft plaatsgevonden aan toxicologische limietwaarden zoals die zijn afgeleid in een recente toxicologische evaluatie omtrent CCA-producten (zie referentie 1).

Direct en Indirect Dermaal Contact

Op basis van diverse studies zijn voor chroom (zowel Cr(III) als Cr(VI), koper en arseen) de gehalten aan afveegbaar residu bepaald op CCA-geïmpregneerd hout (voor blank hout zonder vernis, verf of andere coating). Er is zowel een gemiddeld afveegbaar residu als een maximaal afveegbaar residu vastgesteld voor de berekening van een realistisch en een 'worst case' blootstellingsscenario. Middels gebruik van een zogenaamde 'dermale transfer coëfficiënt' is een schatting gemaakt van de dermale belasting op de huid. De berekening is uitgevoerd voor kinderen aangezien de intensiteit van dermaal contact in deze groep het hoogst wordt geacht.

Indirect contact middels het spelen op of in verontreinigde bodem ten gevolge van uitloging van chroom, koper en arseen naar de bodem in de directe nabijheid van CCA-geïmpregneerde speeltoestellen is berekend middels waarden voor dagelijkse bodemingestie, een geschatte maximale speeltijd op en in de nabijheid van CCA-geïmpregneerde speeltoestellen, en de gemiddelde en maximale stijging in bodemgehalten aan chroom, koper en arseen zoals die zijn gemeten in de directe nabijheid van CCA-geïmpregneerde speeltoestellen.

Koper is niet irriterend voor de huid. Derhalve is het niet te verwachten dat de berekende dermale blootstelling aan koper dermale effecten zal veroorzaken.

Hoewel arseen irriterende eigenschappen bezit, is er voor huidirritatie geen ondergrens vastgesteld. Over de mogelijke dermale effecten van de berekende dermale blootstellingen aan arseen kan dus geen uitspraak worden gedaan.

Voor chroom (III) ligt de maximale dermale belasting (berekend als zijnde $4,336 \mu\text{g}/\text{cm}^2$) ver beneden de grenswaarde voor allergische reacties op de huid ($> 33 \mu\text{g}/\text{cm}^2$). Voor chroom (VI) blijft de berekende dermale belasting voor een realistisch blootstellingsscenario ($0,023 \mu\text{g}/\text{cm}^2$) beneden de grenswaarde voor allergische contact dermatitis voor gevoelige individuen ($0,089 \mu\text{g}/\text{cm}^2$) waarbij er dus geen risico is voor allergische contact dermatitis. Voor een 'worst case' scenario (maximaal afveegbaar residu, 30% van total chroom is Cr(VI), maximale speeltijd) zijn dermale belastingen berekend van $0,102$ tot $1,275 \mu\text{g Cr(VI)}/\text{cm}^2$ en wordt derhalve de dermale limietwaarde overschreden. Hierbij moet worden opgemerkt dat deze overschrijding van de grenswaarde $< 1\%$ van de populatie betreft aangezien deze grenswaarde is vastgesteld voor chroom-geïmpregneerde individuen. Indien er sprake is van CCA-geïmpregneerd hout met een lage kwaliteit (d.w.z. met een

hoog afveegbaar residu en een hoge bijdrage van Cr(VI)) bestaat er een risico op allergische reacties op de huid in chroom-gevoelige individuen. Metingen van het RIVM in speeltuinen hebben echter laten zien dat de hoogte van het afveegbaar residu binnen enkele maanden na installatie van de toestellen daalt tot lage waarden terwijl het aandeel van Cr(VI) afneemt tot enkele procenten. Derhalve mag geconcludeerd worden dat het risico voor het optreden van een allergische reactie in de huid tengevolge van dermale blootstelling aan Cr(VI) zeer gering is.

Mensen die zwemmen in water dat is gecontamineerd met chroom, koper en arseen afkomstig van CCA-geïmpregneerd hout dat bijvoorbeeld voor beschoeiing en of steigers is gebruikt, kunnen in de eerste weken na installatie van het hout worden blootgesteld aan piekconcentraties van 50 µg/l voor chroom, 250 µg/l voor koper, en 773 µg/l voor arseen. Na de eerste weken dalen de concentraties van chroom en koper vrij snel tot achtergrondniveaus. De concentratie van arseen kan na een jaar nog ongeveer 150 µg/l bedragen. Voor chroom blijft de maximale concentratie van 50 µg/l ruimschoots onder de limietwaarde voor allergische contact dermatitis voor chroom (VI) (800 µg/l). Koper is niet irriterend voor de huid. Derhalve is het niet te verwachten dat de geschatte concentraties in het water dermale effecten zullen veroorzaken. Hoewel arseen irriterende eigenschappen bezit, is er voor huidirritatie geen ondergrens vastgesteld. Over de mogelijke dermale effecten van de berekende dermale blootstellingen aan arseen tijdens zwemmen kan dus geen uitspraak worden gedaan. Gezien de lage concentraties van CCA-componenten in het water en de snelle daling van de concentraties (m.n. voor chroom en koper) in het water enkele weken na installatie van het hout, wordt het risico van blootstelling aan CCA-componenten tijdens zwemmen als uitermate gering beschouwd.

Orale blootstelling

Volwassen (bijvoorbeeld 'doe-het-zelvers') die worden blootgesteld aan houtstof en/of zaagsel afkomstig van CCA-geïmpregneerd hout zullen een groot gedeelte van deze stof inslikken aangezien veel van deze stofdeeltjes neerslaan op de slijmvliezen van de neus, mond- en keelholte. Berekening van de maximale orale blootstelling via deze route levert waarden van 0,406 µg/kg lg/dag voor chroom(III), 0,122 µg/kg lg/dag voor chroom (VI), 0,219 µg/kg lg/dag voor koper, en 0,297 µg/kg bw/dag voor arseen. Voor geen van deze stoffen wordt de orale toxicologische limietwaarde overschreden. Orale blootstelling aan chroom, koper en arseen via ingestie van houtstof levert derhalve geen risico op voor niet-carcinogene effecten.

Bij kinderen kan orale blootstelling plaatsvinden middels ingestie van verontreinigde bodem en het aflikken van de handen (de zogenaamde hand-naar-mond route). Voor bodemingestie zijn redelijk betrouwbare kwantitatieve gegevens beschikbaar. Voor de kwantitatieve berekening van de hand-mond route zijn twee verschillende methodes gebruikt die ongeveer vergelijkbare blootstellinggegevens opleverden.

De berekende maximale orale blootstellingen in kinderen blijft voor koper (11,3 µg/kg lg/dag) en totaal chroom (4,2 µg/kg lg/dag) ver beneden de orale toxicologische limietwaarden (170 µg/kg lg/dag voor koper en 1000 µg/kg lg/dag voor chroom). Blootstelling aan koper en chroom(III) afkomstig van CCA-geïmpregneerd hout via de orale route levert dus geen gezondheidsrisico op.

Voor Cr(VI) is een maximale orale blootstelling berekend van 1,38 µg/kg lg/dag hetgeen ongeveer 3 tot 4 maal lager is dan de orale grenswaarde van 5 µg/kg lg/dag. Aangezien dit een 'worst-worst-case' blootstelling betreft (maximaal afveegbaar chroom residu, maximaal gehalte aan Cr(VI) van 30%, maximale bodemingestie, 100% biobeschikbaarheid van chroom in de bodem, maximale speeltijd) is het te verwachten dat de orale blootstelling aan Cr(VI) afkomstig van CCA-geïmpregneerd hout ten alle tijde beneden de toxicologische limietwaarde voor niet-carcinogene effecten zal blijven en derhalve geen gezondheidsrisico oplevert.

Voor chroom(VI) kan een carcinogeen risico bij orale blootstelling van zowel volwassen als kinderen niet worden uitgesloten. Een kwantitatieve schatting van het carcinogeen risico kan niet worden

gemaakt omdat er te veel onzekerheden zijn t.a.v. de bijdrage van Cr(VI) in het totaal aanwezige chroom in CCA-geïmpregneerd hout en omdat er voor orale blootstellingen aan Cr(VI) geen betrouwbare 'unit risks' bekend zijn waarmee een carcinogeen risico zou kunnen worden bepaald.

Voor arseen is de orale blootstelling bij een gemiddeld blootstellingsscenario van kinderen spelend op speeltoestellen van CCA-geïmpregneerd hout berekend op 4,7 µg/kg lg/week hetgeen ongeveer 3 keer lager is dan de orale limietwaarde van 15 µg/kg lg/week. Indien er echter sprake van een maximale blootstelling (maximaal afveegbaar residu, maximale bodemingestie, maximale stijging in bodemconcentratie) bedraagt de orale dosis 23,2 µg/kg lg/week (aangenomen is dat kinderen op 4 van de 7 dagen op CCA-geïmpregneerde speeltoestellen spelen) hetgeen boven de orale limietwaarde van 15 µg/kg lg/week ligt. In deze situatie kan een gezondheidsrisico dus niet worden uitgesloten. Het is te verwachten dat bij gebruik van hout met een goede kwaliteit (d.w.z. met een laag gehalte aan afveegbaar arseen residu) de orale blootstelling van kinderen spelend op speeltoestellen van CCA-geïmpregneerd hout dermate laag is dat er geen gezondheidsrisico is.

Inhalatie van CCA-geïmpregneerd Houtstof

Inhalatoire blootstelling aan chroom, koper, en met name arseen is mogelijk bij verbranding van CCA-geïmpregneerd hout in bijv. vreugdevuren of in open haarden. De overblijvende as bevat hoge concentraties aan chroom (ook Cr(VI)), koper en arseen. Dit type blootstelling heeft incidenteel tot ernstige gezondheidsklachten geleid. Een kwantitatieve schatting van deze blootstelling is niet mogelijk en het is niet bekend in hoeverre in Nederland CCA-geïmpregneerd hout door particulieren wordt verbrand.

Inhalatoire blootstelling van volwassenen aan houtstof en/of zaagsel van CCA-geïmpregneerd hout is een zeer relevante blootstelling voor bijvoorbeeld 'doe-het-zelvers'. De beschikbare data ten aanzien van dit type blootstelling zijn echter uiterst beperkt. De berekende blootstellingswaarden en de daaruit voortvloeiende conclusies dienen als voorlopig te worden beschouwd. Echter, deze waarden vervullen wel een signalerende functie om te bepalen of er mogelijk een risico aanwezig is.

Voor chroom (III) en koper duiden de uitgevoerde berekeningen niet op een overschrijding van de inhalatoire limietwaarden na inhalatoire blootstelling aan houtstof afkomstig van CCA-geïmpregneerd hout. Derhalve levert inhalatoire blootstelling van chroom (III) en koper in houtstof geen gezondheidsrisico op.

De maximale concentratie van Cr(VI) in de lucht bij het zagen, schuren of anderszins verwerken van CCA-geïmpregneerd hout blijft beneden de MAC-waarde voor Cr(VI) (35 µg/m³ versus 50 µg/m³). De gemiddelde dagblootstelling tijdens de periode van houtverwerking (uitgaande van een maximale 'doe-het-zelf' tijd van 2 weken per jaar, 8 uur per dag) bedraagt voor Cr(VI) 11,6 µg/m³ (worst case). Deze waarde is hoger dan de waargenomen NOAEL in werknemers van 1 µg/m³ voor irritatie en effecten op longfunctieparameters waardoor dergelijke effecten niet kunnen worden uitgesloten. Indien de maximale Cr(VI) blootstelling gemiddeld over een jaar wordt berekend is de blootstelling aan Cr(VI) 0,45 µg/m³ hetgeen beduidend hoger is dan het niveau waarop er sprake is van een aanvaardbaar carcinogeen risico (0,025 ng/m³ bij levenslange blootstelling; risico 1 : 10⁶). Zelfs bij een gemiddeld blootstellingsscenario (laag stofgehalte, 3% bijdrage Cr(VI)) wordt de waarde voor een acceptabel carcinogeen risico overschreden (6 ng/m³ versus 0,025 ng/m³). Derhalve kan een verhoogd carcinogeen risico ten aanzien inhalatoire blootstelling aan Cr(VI) bevattend houtstof van CCA-geïmpregneerd hout niet worden uitgesloten indien bovenstaande condities worden aangenomen. Aangezien gegevens omtrent de blootstellingscondities van 'doe-het-zelvers' (zowel met betrekking tot blootstellingsduur, stofniveaus, het gehalte aan Cr(VI) in houtstof alsmede het gedrag van Cr(VI) in houtstof (biobeschikbaarheid)) slechts in beperkte mate beschikbaar zijn, wordt een kwantitatieve schatting van het carcinogeen risico bij inhalatoire blootstelling aan CCA-geïmpregneerd houtstof op dit moment niet zinvol geacht. Zie ook hoofdstuk 7.

De maximaal inhalatoire blootstelling aan arseen tijdens het verwerken van CCA-geïmpregneerd hout bedraagt $86 \mu\text{g}/\text{m}^3$ terwijl de gemiddelde dagblootstelling $28,6 \mu\text{g}/\text{m}^3$ bedraagt (worst case). De waarde van $86 \mu\text{g}/\text{m}^3$ ligt boven de MAC-waarde voor totaal arseen ($50 \mu\text{g}/\text{m}^3$). De maximale inhalatoire blootstelling gemiddeld over een jaar (uitgaande van een maximale 'doe-het-zelf' tijd van 2 weken per jaar, 8 uur per dag) bedraagt $1,10 \mu\text{g}/\text{m}^3$ hetgeen een factor 2 boven de chronisch inhalatoire limietwaarde van $0,5 \mu\text{g}/\text{m}^3$ ligt. Echter, deze blootstelling is aanzienlijk lager dan de laagste LOAEL van $50 \mu\text{g}/\text{m}^3$ waargenomen in werknemers gebaseerd op marginale neuropathologische effecten. Voor een realistisch blootstellingsscenario (laag stof gehalte) ligt de jaargemiddelde concentratie een factor 10 onder de inhalatoire limietwaarde ($0,05 \mu\text{g}/\text{m}^3$ versus $0,5 \mu\text{g}/\text{m}^3$). Op basis van deze berekeningen is het niet te verwachten dat er een substantieel gezondheidsrisico bestaat voor arseen ten gevolge van de inademing van houtstof van CCA-geïmpregneerd hout. Over het risico van piekbelastingen boven de MAC-waarde kan op dit moment geen uitspraak worden gedaan.

Integratie van Blootstellingsroutes voor Kinderen

Kinderen die spelen op en in de nabijheid van speeltoestellen geconstrueerd van CCA-geïmpregneerd hout worden blootgesteld aan CCA-ingrediënten via diverse routes (bodemingestie, hand-mond route, direct dermaal contact, dermaal contact met verontreinigde bodem). Gebruik makende van orale (2% voor Cr(III), 6% voor Cr(VI), en 95% voor As) en dermale absorptiewaarden (1% voor Cr(III), 4% voor Cr(VI) en 4% voor As) is de totale dagelijkse systemische belasting berekend. Voor koper zijn deze berekeningen niet uitgevoerd aangezien de limietwaarden niet werden overschreden of benaderd bij dermale en orale blootstelling, zowel afzonderlijk als gecombineerd.

Voor chroom(III) is de totale systemische belasting berekend op maximaal $0,25 \mu\text{g}/\text{kg lg}/\text{dag}$. De orale limietwaarde van $1000 \mu\text{g}/\text{kg lg}/\text{dag}$ correspondeert met een systemische belasting van $0,02 \times 1000 = 20 \mu\text{g}/\text{kg lg}/\text{dag}$. De waarde van $0,25 \mu\text{g}/\text{kg lg}/\text{dag}$ is derhalve een factor 100 lager dan de orale limietwaarde. Derhalve is er geen risico op systemische gezondheidseffecten.

Voor Cr(VI) is de systemische belasting $0,004 \mu\text{g}/\text{kg lg}/\text{dag}$ bij een gemiddeld blootstellingsscenario. De orale limietwaarde correspondeert met een systemische belasting van $0,3 \mu\text{g}/\text{kg lg}/\text{dag}$. In deze situatie is de systemische belasting een factor 75 lager dan de limietwaarde. Echter, indien er voor alle factoren een 'worst case' aanname wordt gemaakt is de totale systemische belasting $0,42 \mu\text{g}/\text{kg lg}/\text{dag}$ hetgeen duidt op een geringe overschrijding van de limietwaarde. In deze worst case situatie kan een eventueel gezondheidsrisico niet geheel worden uitgesloten.

Voor arseen wordt de systemische belasting bij een gemiddeld blootstellingsscenario berekend als zijnde $1,51 \mu\text{g}/\text{kg lg}/\text{dag}$. De orale limietwaarde correspondeert met een systemische belasting van $2,04 \mu\text{g}/\text{kg lg}/\text{dag}$. Bij een 'worst case' blootstelling bedraagt de systemische belasting $5,96 \mu\text{g}/\text{kg lg}/\text{dag}$. In deze worst case situatie wordt de limietwaarde van $2,04 \mu\text{g}/\text{kg lg}/\text{dag}$ met een factor 2,5 overschreden. Het dient te worden opgemerkt dat achtergrondblootstellingen ten gevolge van voedsel en drinkwater niet zijn opgenomen in bovenstaande berekeningen. Op basis van gegevens uit het RIVM-basisdocument voor arseen kan worden afgeleid dat de dagelijkse inname van arseen via voedsel en drinkwater ongeveer $0,7 - 0,8 \mu\text{g}/\text{kg lg}/\text{dag}$ bedraagt. Gelet op deze achtergrondblootstelling kan de orale limietwaarde voor arseen dus ook worden overschreden bij een gemiddeld blootstellingsscenario ($1,51 + 0,8 = 2,3 \mu\text{g}/\text{kg lg}/\text{dag}$) voor kinderen die spelen op speeltoestellen van CCA-geïmpregneerd hout. Dit duidt op een potentieel gezondheidsrisico voor kinderen spelend op CCA-geïmpregneerd houten speeltoestellen.

Ontbrekende gegevens / aanvullend onderzoek

De voornaamste bronnen van onzekerheid in de huidige risicoschatting (zie ook hoofdstuk 7) zijn de 'dermale transfer factor' voor de berekening van dermale blootstelling en de beschikbaarheid van gegevens omtrent de inhalatoire blootstelling aan houtstof van CCA-geïmpregneerd hout.

- De dermale transfer factor is een maat voor de hoeveelheid stof die per tijdseenheid van een bepaald oppervlak wordt overgedragen naar (een deel van) de huid bij uitvoering van een bepaalde activiteit. Deze maat is afhankelijk van het type activiteit, het type contact oppervlak, het oppervlakteresidu en het type stof. Er zijn op dit moment geen gegevens beschikbaar voor de afleiding van een dermale transfer factor voor kinderen spelend op houten speeltoestellen van CCA-geïmpregneerd hout. Transfer data voor de overdracht van chroom en arseen van een houten oppervlak naar de hand zijn derhalve wenselijk voor de risicoschatting van dermale blootstelling aan CCA-producten.
- Er zijn momenteel zeer beperkte gegevens omtrent de inhalatoire blootstelling van 'doe-het-zelvers' aan CCA-geïmpregneerd houtstof. Aanvullende gegevens op de volgende gebieden zijn wenselijk voor een kwantitatieve risicoschatting van de inhalatoire blootstelling aan CCA-geïmpregneerd houtstof.
 - a) Gegevens omtrent de blootstellingsduur van 'doe-het-zelvers'. Hoeveel tijd wordt er door 'doe-het-zelvers' besteed aan het verwerken of het bewerken van CCA-geïmpregneerd hout? Hoeveel tijd wordt er binnenshuis of buitenshuis met hout gewerkt?
 - b) Gegevens omtrent de blootstellingsniveaus van 'doe-het-zelvers'. Wat zijn de stofniveaus bij diverse vormen van bewerken van (CCA-geïmpregneerd) hout (hiervoor kunnen ook gegevens uit de arbeidssituatie worden gebruikt) zowel in binnen- als in de buitenlucht?
 - c) Wat zijn de gehalten aan totaal chroom, chroom (VI), koper en arseen in houtstof van CCA-geïmpregneerd hout?
 - d) Informatie betreffende de biobeschikbaarheid van chroom, koper en arseen bij inademing van CCA-geïmpregneerd houtstof (mate van depositie en absorptie?).

7. Main Sources of Uncertainty in the Calculations

In the present report a comprehensive evaluation of the health risks associated with the 'use' or 'contact' of CCA-treated wood was performed. As described in chapter 4, both mean or realistic and maximal or worst case scenarios have been considered by accurately evaluating the available data and performing a series of detailed calculations. Nevertheless, some values or some calculating procedures possess some degree of uncertainty. Most of this uncertainty is, however, obviated by calculating worst case scenarios. For some factors, e.g. the increases in soil concentrations of chromium, copper, and arsenic due to leaching of CCA-treated wood, an estimation of the mean value could only be established by a best guess because actual mean values could not be calculated. In the sections below, the main sources of uncertainty will be briefly discussed.

Toxicological Limit Values

See reference no. 1 for a discussion on the reliability on the various toxicological limit values

Dislodgeable residues

The database on dislodgeable residues is, although limited in size, considered to be adequate. For both chromium and arsenic, various studies were available which reported dislodgeable residues at similar levels. As was demonstrated by various measurements, the levels of dislodgeable residue for arsenic and chromium, especially Cr(VI), are highly variable. This high variability is a source of uncertainty in the exposure calculations of children in contact with CCA-treated wood. At present it is unclear to what extent CCA-treated wood of poor quality (i.e. wood with high dislodgeable residues) is commercially available on the Dutch market. This may be a point of concern considering the large impact of the level of dislodgeable residue on the exposure to CCA-ingredients in young children. It should be remarked that painting or coating CCA-treated wood (not discussed in the present evaluation) highly reduces the amount of dislodgeable residues (15,19) which may therefore be considered as an effective risk reduction measurement.

Dermal Exposure to Dislodgeable Residues

Dermal exposure to dislodgeable residues has been calculated using a dermal transfer coefficient. This coefficient has been estimated based on a range of values obtained for adults. Dermal transfer coefficients may be variable depending on the type of substance involved, the type of contact surface, and the type and intensity of the activity performed. Because no data were available for playing activities of children, the contact of wood surfaces, or the the transfer of metals such as chromium, copper, and arsenic, the value of 1000 cm²/h as used in the present evaluation represents a best estimate of the true transfer rate. However, since a value of 1000 cm²/h is considered to be in the upper range for dermal transfer coefficients (for children) it is expected that the dermal exposure values calculated by using this transfer coefficient represent realistic exposure scenarios.

Soil Concentrations

Because of the large variability in background soil levels, we have chosen to use mean and maximal *increases* in the soil concentration of chromium, copper and arsenic due to the leaching of CCA-treated wood. It should be noted that leaching is highly dependent on modulating factors such as acidity, rainfall, moisture and others, whereas the eventual concentrations in the soil depends on the characteristics of the soil, the distance from the CCA-treated object, and the time after installation of the wooden structure. Furthermore, it should be recognised that by using the increase in soil concentrations of *CCA-derived* chromium, copper, and arsenic, only the *additional* risk due to soil exposure was addressed.

Hand-to-Mouth Transfer Behaviour

Two different approaches have been used to estimate the hand-to-mouth transfer of young children. As far as we know, these methods have not been (experimentally) validated and therefore

the degree of uncertainty is unknown. However, since both approaches resulted in similar exposure levels, it is considered likely that the present methods provide good estimations of the mean hand-to-mouth transfer rate.

Inhalation of Wood Dust

The quantification of this type of exposure is highly provisional because of various limitations.

1. The amount of data available for wood dust levels during wood processing is very limited.
2. The amount of data available on chromium (especially Cr(VI)), copper, and arsenic in wood dust is extremely limited.
3. The respirable fraction of 6% was based on only one study which reported determinations on particle size.
4. The time spent on the processing of CCA-wood in non-occupational settings is unknown. The present assumption of 2 weeks - 8h/day is considered to represent a worst case scenario.
5. All available data were associated with indoor wood processing in occupational settings (worst case). It is reasonable to assume that non-occupational 'do-it-yourself' jobs are performed largely outdoors which may be associated with substantial lower exposure conditions (see e.g. ref. 47).
6. Because exposure conditions may be highly variable (high exposures on a limited number of days) averaged values should be considered with caution.
7. The bioavailability of chromium, copper, and arsenic from wood dust is not known.

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