Australian Pesticides &
Veterinary Medicines Authority

The Reconsideration of Registrations of Arsenic Timber Treatment Products (CCA and arsenic trioxide) and Their Associated Labels

REVIEW SUMMARY

DRAFT FOR PUBLIC CONSULTATION

December 2003

Australian Pesticides &
Veterinary Medicines Authority

Canberra
Australia

This review report for the arsenic timber treatment products, copper chrome arsenate (CCA) and arsenic trioxide, is published by the Australian Pesticides and Veterinary Medicines Authority. For further information about this review or the Pesticides Review Program, contact:

Manager Pesticides Review
Australian Pesticides and Veterinary Medicines Authority
PO Box E240
KINGSTON ACT 2604
Australia

Telephone: 61 2 6272 3213
Facsimile: 61 2 6272 3218
Email: chemrev@apvma.gov.au
APVMA web site: http://www.apvma.gov.au

FOREWORD

The APVMA is an independent statutory authority with responsibility for the regulation of agricultural and veterinary chemicals in Australia. Its statutory powers are provided in the *Agricultural and Veterinary Chemicals Code Act, 1994* (Agvet Codes).

The APVMA can reconsider the approval of active constituents, the registration of chemical products or the approval of labels for containers of chemical products at any time. This is outlined in Part 2, Division 4 of the Agvet Codes.

The basis for the reconsideration is whether the APVMA is satisfied that continued use of arsenic timber treatments, copper chrome arsenate (CCA) and arsenic trioxide in accordance with the instructions for their use:

- would not be an undue hazard to the safety of people exposed to it during its handling; and
- would not be likely to have an effect that is harmful to human beings; and
- would not be likely have an unintended effect that is harmful to animals, plants or things or to the environment.

A reconsideration may be initiated when new research or evidence has raised concerns about the use or safety of a particular chemical, a product or its label.

The process for reconsideration includes a call for information from a variety of sources, a review of that information and, following public consultation, a decision about the future use of the chemical or product.

In undertaking reviews, the APVMA works in close cooperation with advisory agencies including the Office of Chemical Safety (OCS), the Department of Environment and Heritage (DEH), the National Occupational Health and Safety Commission (NOHSC), and State Departments of Agriculture as well as other expert advisors, as appropriate.

The APVMA has a policy of encouraging openness and transparency in its activities and community involvement in decision-making. The publication of review reports is a part of that process.

The APVMA also makes these reports available to the regulatory agencies of other countries as part of bilateral agreements. Under this program it is proposed that countries receiving these reports will not utilise them for registration purposes unless they are also provided with the raw data from the relevant applicant.

This document *The reconsideration of registrations of arsenic timber treatment products (CCA and arsenic trioxide) and their associated labels* relates to all products containing CCA and arsenic trioxide. The review's findings and recommendations are based on information collected from a variety of sources. The information and technical data required by the APVMA to review the safety of both new and existing chemical products must be derived according to accepted scientific principles, as must the methods of assessment undertaken.

The draft review report containing the APVMA's summary assessments is available from the APVMA website: http://www.apvma.gov.au/chemrev/chemrev.html. The technical reports from its advisory agencies are available from the APVMA directly.

COMMENT FROM THE PUBLIC IS INVITED

The APVMA invites persons and organisations to submit their comments and suggestions on this draft review report directly to the APVMA. Your comments will assist the APVMA in preparing the final report.

The draft review report consists of a Review Summary which outlines the APVMA review process, gives information to the public about how to respond to the review, summarises the technical assessments from the reviewing agencies and outlines the proposed regulatory action to be taken in relation to the continued registration of arsenic timber treatments (CCA and arsenic trioxide). In most cases, the Review Summary will provide sufficient detail to enable informed response to the review.

The Review Summary is available on the APVMA website at http://www.apvma.gov.au/chemrev/chemrev.html. (The full technical assessment reports from DEH and OCS can be obtained upon request to the APVMA.)

PREPARING YOUR COMMENTS FOR SUBMISSION

You may agree or disagree with or comment on as many elements of the report as you wish.

When making your comments:

- clearly identify the issue and clearly state your point of view;
- give reasons for your comments supporting them, if possible, with relevant information and indicate the source of the information you have used;
- suggest to the APVMA any alternative solution you may have for the issue.

Please try to structure your comments in point form referring each point to the relevant section in the Review Summary or the technical reports. This will help the APVMA assemble and analyse all of the comments it receives.

Finally please tell us whether the APVMA can quote your comments in part or in full.

THE CLOSING DATE FOR SUBMISSIONS IS: 29 February 2004

Your comments should be mailed to:

Manager Pesticides Review

APVMA
PO Box E240
KINGSTON ACT 2604

or faxed to: (02) 6272 3218
or emailed to: chemrev@apvma.gov.au

ACRONYMS AND ABBREVIATIONS

ACVM	New Zealand Agricultural Compounds & Veterinary Medicines Group
ADI	Acceptable Daily Intake
ADWG	Australian Drinking Water Guidelines
ai	active ingredient
APVMA	Australian Pesticides and Veterinary Medicines Authority
ARfD	Acute Reference Dose
ATDS	Australia Total Diet Survey
CCA	Copper Chrome Arsenate
Codex	FAO/WHO Codex Alimentarius Commission
DEH	Department of Environment and Heritage (previously Environment Australia)
DMA	dimethylarsinic acid
ERMA	Environmental Risk Management Authority (New Zealand)
FSANZ	Food Standards Australia New Zealand
IARC	International Agency for Research on Cancer
IPCS	International Programme on Chemical Safety
JECFA	Joint Expert Committee on Food Additives
JMPR	Joint FAO/WHO Meeting on Pesticide Residues
LD_{50}	The dose at which 50% of a test population dies
LOAEL	Lowest Observed Adverse Effect Level
LOD	Limit of Detection
LOEL	Lowest Observed Effect Level
LOQ	Limit of analytical Quantitation, also referred to as limit of determination
LOR	Limit of Reporting
MMA	monomethylarsinic acid
MOE	Margin of Exposure
NEDI	National Estimated Dietary Intake
NEPC	National Environmental Protection Council
NESTI	National Estimated Short-Term Intake
NHMRC	National Health and Medical Research Council
NOEL	No Observed Effect Level
NOHSC	National Occupational Health and Safety Commission
OCS	Office of Chemical Safety
OECD	Organisation for Economic Cooperation and Development
OHS	Occupational Health and Safety
PACSC	Pesticide and Agricultural Chemical Standing Committee
PHED	Pesticide Handlers Exposure Database
PMRA	Pest Management Regulatory Agency (Canada)
POEM	Predictive Operator Exposure Model
PPE	Personal Protective Equipment
RTECS	Registry of Toxic Effects of Chemical Substances
TC	Transfer Coefficient
TDI	Tolerable Daily Intake
US CPSC	United States Consumer Product Safety Commission
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation

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EXECUTIVE SUMMARY

Introduction

Arsenic timber treatments, copper chrome arsenate (CCA) and arsenic trioxide, are used to control and prevent damage to timber and timber structures by insects (termites, borers, beetles), wood rot and wood fungus. CCA is generally used on wood intended for outdoor uses, such as telegraph poles, decking and fencing, in landscaping, and in building structures. Timber treated with CCA can also be used in school and community playground equipment. Arsenic trioxide is used in very limited quantities for post-construction control of termites in the home, under carefully-controlled conditions.

In March 2003, the APVMA announced the reconsideration (review) of the registrations of timber treatment products containing arsenic, and the approval of the labels associated with those products. There was new information that indicated that the extent of dislodgeable residues (capable of being transferred from the surface of treated timber through contact) in CCA-treated timber structures were unacceptably high and this had possible public health implications. Other information also raised concerns that environmental contamination may potentially occur near sites where timber is treated with CCA and where timber is disposed of. In March 2003, the APVMA released a document entitled *Arsenic Timber Treatments (CCA and Arsenic Trioxide): Review Scope Document* that detailed the concerns and the scope of the review. The aim of the review was to examine the potential for toxicological effects associated with products containing or treated with arsenic (CCA or arsenic trioxide), the environmental effects from the use and disposal of CCA or arsenic trioxide products, and the adequacy of instructions and warnings on product labels.

In this review, the APVMA, in collaboration with its advisory agencies, has completed the assessment of the data from the registrants, public submissions, scientific literature, archival holdings and reviews by overseas regulatory authorities.

In assessing the data and information, the APVMA consulted widely with the registrants, representatives of the timber industry, relevant state departments, the CSIRO and the community. The APVMA also conferred with the US Environmental Protection Agency. A summary of the review findings and the proposed regulatory actions are presented in this document.

Toxicological Assessment

CCA

CCA, as the name suggests, consists of three active constituents, copper, chromium and arsenic. The arsenic in CCA products primarily protects timber against insects, while copper acts as a fungicide, and chromium fixes these two chemicals in the timber. Although the individual components of CCA are reported to be fixed during the timber treatment process, some release does occur when the treated timber is in service. The public can potentially be exposed to the dislodgeable residues available for transfer to mouth when they come in contact with treated timber equipment or structures.

Copper, chromium and arsenic are present in the natural environment (in air, food, water and soil), albeit at low levels. Therefore, the public is exposed to these chemicals through sources other than timber treated with arsenic.

Toxicological assessment found that copper and chromium in the CCA-treated timber do not present an undue risk to public health. The focus of the toxicological assessment was to determine whether arsenic that may be present in the dislodgeable residues on, or in the topsoil surrounding, CCA-treated timber structures poses an unacceptable risk for public health, particularly for children. Young children, aged 3-5, who normally exhibit appreciable hand-to-mouth behaviour are considered to be the most at-risk group.

The World Health Organisation has set an intake of 2 µg of arsenic per day as the tolerable intake per kilogram of body weight (the tolerable intake is the amount of the chemical which can be ingested daily without any appreciable health risk for a lifetime of exposure). The Food Standards Australia New Zealand set the tolerable intake at 3 µg per day per kilogram of body weight. The Australian worst-case aggregate estimate for the inorganic arsenic intake from natural sources by an average 3 – 5 year old child is 0.5 µg per day per kilogram of body weight. Therefore, the key issue in relation to CCA-treated timber is whether the additional exposure to arsenic that may arise from dislodgeable residues from timber structures can significantly increase the total intake of arsenic. To address this issue, data of acceptable scientific quality is required to answer the following key questions.

a. How much dislodgeable arsenic is present on the surfaces of timber structures treated with CCA?
b. How much arsenic is likely to adhere to children's hands and other parts of the body during the course of play?
c. What fraction of such adhered arsenic will subsequently be transferred to mouth, or absorbed through the skin?

The data available for the review were not sufficient to answer the above questions. While the data from a USA study could be adapted for Australian scenarios to answer questions b and c above, Australian studies are required to estimate the quantities of dislodgeable arsenic on the timber structures treated with CCA (question a) because of possible differences between the US and Australia in plant operation practices and differences in leaching rates under Australian climatic conditions.

Of the several studies available to the review that measured dislodgeable arsenic, the only study that was of sufficient scientific quality and conducted under controlled conditions was based on a small sample in the USA. Other assessed studies, including one from Australia, were limited in scope. While these other studies demonstrated that arsenic is released from CCA-treated timber with a high degree of variability (and in some cases at unacceptably high quantities), they did not address the parameters required to arrive at the quantity of arsenic that a child is likely to ingest or absorb by coming into contact with treated timber.

Neither the overseas data (including the aforementioned USA study), nor the Australian data adequately covered the range of timber products from different manufacturing plants, the age of treated timber structures or the environmental conditions to which treated timber structures might be exposed relevant to Australian conditions.

Since insufficient data are available to resolve key concerns, the APVMA cannot be satisfied that there is no undue risk from the continuing use of products containing CCA to treat timber that is used in the manufacture of equipment and structures with which the public are likely to come into frequent contact. The APVMA proposes that the label instructions for CCA timber treatment products be varied to prohibit the use of products containing arsenic for treating timber that will be used in structures with which members of the public are likely to come into intimate and frequent contact, such as children's play equipment, picnic tables, decking and handrails.

However, there is no evidence to preclude use of arsenic-treated timber products where there is no frequent physical contact, such as telegraph poles, rural fence posts or other structural timbers. Alternative timber protection products that do not contain arsenic and that are effective against the same pests are registered by the APVMA and can be used in applications for which CCA is recommended to be prohibited.

The APVMA has no regulatory authority over existing CCA-treated timber structures. While there is not enough scientific evidence to confirm the safety of ongoing use of CCA to treat timber used in applications such as decks and play equipment, the Authority does not have evidence to conclude that the existing structures are unsafe. The APVMA is liasing closely with the USEPA in relation to the outcome of their extensive assessment of this issue which is anticipated early next year. Results are expected to shed further light on the safety of existing CCA-treated structures.

Arsenic trioxide

Arsenic trioxide is unlikely to be a public health hazard as the application of the products is carried out by licensed pest control operators (PCOs) and the treated timber parts are concealed. The PCOs who are eligible to carry out the application of arsenic trioxide are assessed as competent to Certificate II level of the National Pest Management Industry Competency Standards. Holes are drilled into infested timber or trees and 1 –2 g of the product is applied per infestation. The opening is then covered with a tape. For these reasons, products containing arsenic trioxide are not considered likely to present a public health risk.

Environmental Assessment

CCA

The potential for unintended harmful environmental effects can arise from contamination during the treatment process, leaching of arsenic from treated timber into soils or water, and disposal or burning of discarded timber. Environmental assessment led the APVMA to conclude that product labels do not contain adequate instructions for timber treatment with respect to harmful effects on the environment. From an environmental perspective, the critical issue is that of the competence of persons using the products and the nature of the facilities in which treatment occurs. Both of these factors influence the potential for harm to the environment by significantly influencing the extent to which release to the environment may occur as a consequence of the application process or subsequently from leaching from treated timber over time. These releases can occur both at treatment facilities during application and fixation processes, and also during use of treated timber in various structures. Contamination of soil from leaching of arsenic from in-service treated timber has been found to be largely localised. Nonetheless it is important to minimise such leaching by ensuring correct treatment standards are adhered to.

The environmental assessment concluded that, to minimise the environmental risks, it is necessary that timber treatment is carried out only by those with special skills and knowledge and that the treatment process meets appropriate Australian Standards (ANZEC guidelines (1996) and AS/NZS 2843.1:2000 and AS/NZS 2843.1:2000). APVMA proposes that CCA products be declared as restricted chemical products, and that the label instructions be varied so as to minimise environmental contamination by requiring more stringent controls in the timber treatment process.

No evidence of elevated arsenic uptake was found in studies of vineyard trellis posts and grapevines (fruit, leaf and stem tissues). Another study found no evidence of enhanced arsenic uptake in bananas exposed to CCA treated support posts for four years or to vegetables with treated stakes in pots. In general, leached arsenic is likely to remain in soil close to the treated wood. Plants in vegetable gardens with root systems largely in soil not adjacent to treated timbers are not likely to take up significant amounts of arsenic.

Arsenic trioxide

Treatment of timber with arsenic trioxide products occurs in confined areas where termites are present in structures and nearby trees. Secondary dispersal is likely to be in the vicinity of the treated material, and/or destinations of the treated material during disposal when the structure is modified or removed. The use of arsenic trioxide products in accordance with their respective instructions would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment.

Occupational Health and Safety Assessment

While the review focussed on public health and environmental issues, some of the data submitted was also relevant to occupational health and safety (OH&S). In reviewing this data, it was recognised that further, more specific worker exposure data was required to address the identified concerns for worker safety. The occupations considered at greatest risk from exposure to CCA are (i) timber treatment plant workers and (ii) downstream workers who are involved in machining (sawing/sanding etc) of CCA treated timber products. Insufficient information/data were available to fully characterise risks to Australian timber treatment workers. There were no exposure data available to estimate risks to workers handling CCA treated timber. Neither the Predictive Operator Exposure Model (POEM) nor the Pesticide Handler Exposure Database (PHED) contains appropriate scenarios for use in estimating exposure for these occupational scenarios.

As a result, it is proposed that worker exposure data (dermal and inhalation) be generated for CCA timber preservative products (for both arsenic and chromium). In addition worker exposure data will be required for chromium and arsenic for workers involved in activities representative of a worst-case scenario for machining CCA treated timber products (this should involve handling and machining of freshly treated timber).

Insufficient information/data were available to fully characterise risks from arsenic trioxide to Australian workers. There was no exposure data available to estimate risks to workers applying arsenic trioxide termiticides to timber. Neither the Predictive Operator Exposure Model (POEM) nor the Pesticide Handler Exposure Database (PHED) contains appropriate scenarios for use in estimating worker exposures during timber treatment with arsenic trioxide.

Potential risks exist from repeated exposure to arsenic trioxide, although it is considered that exposures from inhalation or dermal contact are likely to be low, due to the small quantities of dust that are used per treatment. In addition, since these products are used only by pest control operators, it is considered likely that adequate risk mitigation measures (e.g. gloves and respirator) will be employed during the application process. NOHSC do not consider that exposure data is required to further mitigate risks.

Adequacy of Label Instructions

The review identified some significant deficiencies with current label instructions. The labels do not provide adequate instruction on process/procedures including engineering controls. Consequently, it is proposed to vary all labels to include instructions for application, mixing and vacuum/pressure operations, management of freshly treated timber, management of liquids, sludge or waste material containing CCA residues, protection of wildlife, fish crustaceans and the environment, and storage and disposal.

Public Submissions

There were 24 public submissions received from a wide spectrum of the community, including individuals, state and governmental departments, CSIRO, environmental groups, and timber industry groups. The concerns outlined in the submissions varied from potential impacts on human health, possible modes of exposure, potential effects on the environment, the availability of suitable alternatives, and potential impacts on business. These concerns as outlined in the submissions were considered in the review.

Consultation with Stakeholders

For the regulatory measures proposed in this document to be effective, the end-user needs to be aware that CCA-treated timber is not to be used in structures that people can come into frequent contact with. CCA-treated timber is sold nationwide in both wholesale and retail outlets. At present there is no national system that regulates the sale of timber and therefore, there is no mechanism in place to control the destination of the treated timber. The APVMA recognises that, for the proposed regulatory measures to achieve the intended risk mitigation, stakeholders (product registrants, timber treatment plants, building industries, etc) will need to implement effective mechanisms for segregating specified timber products that will satisfy the APVMA. The APVMA has held discussions with some key stakeholders in this regard, and they have indicated that it is possible to put constraints in place so that the proposed regulatory measures can be effective. The APVMA will continue to liaise with key stakeholders on this issue.

Summary of review recommendations

Based on the assessment, it is recommended that:

- CCA timber treatment products be declared Restricted Chemical Products. It is in the public interest to ensure that supply of these products will be restricted to suitably trained persons.
- CCA product labels be varied to recommend that timber treatment facilities be designed and operated to meet appropriate Australian Standards (ANZEC guidelines (1996) and AS/NZS 2843.1:2000 and AS/NZS 2843.1:2000). The APVMA will consult with relevant commonwealth and state agencies with a view to achieving this.
- Product labels be varied such that uses of CCA timber treatment products are not permitted on timber intended for use in structures such as picnic tables, deckings, handrails and children’s play equipment.*
- Product labels be varied to include more detailed instructions for application, mixing and vacuum/pressure operations, management of freshly treated timber, management of liquids, sludge or waste material containing CCA residues, protection of wildlife, fish, crustaceans and the environment, and storage and disposal.
- Registrants be required to generate worker exposure data in relation to risks associated with arsenic and chromium (VI) in CCA.

* Implementation of this recommendation is contingent upon the successful development of effective ways to segregate CCA-treated timber products that should not be used in specified domestic applications.

1. INTRODUCTION

Arsenic timber treatments are used to control and prevent damage to timber and timber structures by insects (termites, borers, beetles), wood rot, wood fungus and general timber decay. Arsenic trioxide is commonly used for post-construction control of termites in the home. Copper chrome arsenate (CCA) is generally used on wood intended for outdoor uses, such as telegraph poles, decking and fencing, in landscaping, and in building structures. Timber treated with CCA can also be used in school and community playground equipment.

Various recent international regulatory actions in relation to CCA and new information that emerged in connection with those regulatory activities raised concerns with the APVMA about the safety of timber treatment products containing arsenic. Due to these concerns, the APVMA announced, in March 2003, the reconsideration (review) of the registrations of timber treatment products containing arsenic, and the approval of the labels associated with those products.

1.1 Regulatory status of arsenic timber treatments in Australia

Registered arsenic timber treatments are used for the control and prevention of damage to timber and timber structures by insects (termites, borers, beetles), wood rot, wood fungus and general timber decay. Treatments such as CCA have been registered in Australia since the 1980s.

There are nine registered products containing CCA and three registered products containing arsenic trioxide (Appendix 1). Formulation types include dusts (for termite treatment), and aqueous concentrates, blending concentrates, liquids, liquid concentrates and pastes (for timber preservatives).

1.2 Reasons for Review of Arsenic Timber Treatments (CCA and arsenic trioxide)

The new information from overseas suggested that the potential for human exposure to arsenic from treated timber may be greater than was previously thought. The information also raised concerns that environmental contamination may occur near sites where timber is treated and where timber is disposed of.

In 2002, the APVMA noted action taken in the US to move away from timber treatments containing arsenic by December 2003, ahead of the completion of the formal assessment of CCA by the USEPA. Since this announcement, various actions have been taken in Europe, Canada and New Zealand, based on claims of potential human health risks associated with CCA. Potential health risks included the suggestion that arsenic might be more carcinogenic than previously recognized, and that arsenic may be present at significant concentrations on CCA-treated timber and in underlying soil.

1.3 Scope of the Review

In March 2003, the APVMA released the document entitled *Arsenic Timber Treatments (CCA and Arsenic Trioxide): Review Scope Document* in which detailed the concerns and the scope of the review. The review was set to examine the potential for toxicological effects associated with products containing or treated with arsenic (CCA or arsenic trioxide), the environmental effects from the use and disposal of CCA or arsenic trioxide products, and the adequacy of instructions and warnings on product labels.

The product registrations and associated label approvals that are to be reconsidered are those listed in Appendix 1.

1.4 Regulatory options

The basis for a reconsideration of the registration and approvals for a chemical is whether the APVMA is satisfied that the requirements prescribed by the Agvet Codes for continued registration and approval are being met. In the case of arsenic timber treatments (CCA and arsenic trioxide), these requirements are that the use of the product in accordance with the instructions for its use would not be likely to have an effect that is harmful to human beings and would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment.

The requirements for product labels are that the label contains adequate instructions. Such instructions include:

- the circumstances in which the product should be used;
- how the product should be used;
- the times when the product should be used;
- the frequency of the use of the product;
- the withholding period after the use of the product;
- the disposal of the product and its container;
- the safe handling of the product.

There can be three possible outcomes to the reconsideration of the registration arsenic timber treatments and their labels. Based on the information reviewed, the APVMA may be:

- satisfied that the products and their labels continue to meet the prescribed requirements for registration and approval and therefore confirms the registrations and approvals.
- satisfied that the conditions to which the registration or approval is currently subject can be varied in such a way that the requirements for continued registration and approval will be complied with and therefore varies the conditions of registration or approval.
- not satisfied that the requirements for continued registration and approval continue to be met and suspends or cancels the registration and/or approval.

1.5 Application/treatment methods

1.5.1 Copper Chrome Arsenate

The general treatment process involves the timber being placed under vacuum to remove air and water from the wood cells. The timber is then pressure treated with the CCA mixture to refill the wood cells with the CCA mixture. The CCA solution is orange, but turns green on fixation to give treated timber its familiar light green colour. It is considered that important reactions in the fixation process occur during the first few hours of treatment, corresponding to the time during and immediately following treatment. The conditions during treatment and fixation (temperature, length of treatment time, pressure, etc.), composition and concentration of the CCA solution, wood characteristics may have an influence on the extent of fixation and subsequent leachability of CCA, as well as the time for fixation to occur and other quality and performance aspects of the treatment (depth of penetration, retention rate of CCA in the wood, depth and uniformity of colour, etc).

1.5.2 Australian Standards pertaining to application and use

CCA is applied to wood in specially designed facilities so application and fixation conditions can be controlled and to minimise and contain release of the product or waste material to the environment.

The Australian/New Zealand Standard™ Timber Preservation Plant Safety Code, Part 1: Plant design (AS/NZS 2843.1:2000) and Part 2: Plant operation (AS/NZS 2843.1:2000) specifies the standards for the safe operation of wood preservation treatment plants using CCA and other preservatives, and for reducing environmental and occupational hazards. The standard refers to and incorporates information from the Australian Guidelines for Copper Chrome Arsenate Timber Preservation Plants (ANZECC, 1996). A further document (AS/NZS 1605:2000) describes methods for sampling and analysing timber preservatives and preservative-treated timber.

Australian or Australian/New Zealand Standards also provide guidance on use for various types of timber. Standards for Specification for Preservative Treatment include Sawn and Round Timber (AS 1604.1:2000), Reconstituted Wood-based Products (AS/NZS 1604.2:2002), Plywood (AS/NZS 1604.3:2002), Laminated Veneer Lumber (AS/NZS 1604.4:2002), and Glued Laminated Timber Products (AS/NZS 1604.5:2002).

Various requirements of the ANZECC Guidelines and the above Standards seek to protect the environment by minimising and containing leakage, spillage and other means of environmental contamination from CCA, and ensuring that spillages, sludge or contaminated material are collected and recycled or treated and disposed of according to regulatory authority requirements.

1.5.3 Past use and current adherence to these standards

CCA was introduced commercially into Australia in 1957. The Australian Environmental Guidelines (1996) were developed jointly by the Australian & New Zealand Environment and Conservation Council (ANZECC) and the Timber Preservers Association of Australia (TPAA), to generate an Australian national standard for the design of new treatment facilities and for the upgrading of existing plants. The document indicates that new plants are expected to comply with these guidelines immediately and existing plants (where presumably there may in some cases be contaminated areas from inadequate plant design and operation in the past) within two years (ie presumably by September 1998). Whether due to inadequacies in plant design or in plant operation, it appears that full compliance with the guidelines/standards cannot yet be replied upon: the submission for this review from NSW EPA notes gaps which were found through audits of a number of NSW timber treatment facilities which included a review of best environmental management practices. A survey by the Timber Preservers Association of Australia produced 28 out of 29 respondents indicating that they treated wood in accordance with the requirements of AS1604 series of Standards, but 3 out of 29 respondents indicated that their plant did not conform to AS2843 or similar specifications.

The NSW EPA submission also notes that the Standards contain most, but not all of the best environmental management practices used within the industry worldwide. Also, current facilities may not have adequate provisions for managing ash and particulate recovery. The Standards do not seem very clear on how the treatment plant yard used for holding CCA-treated timber should be constructed, though the ANZECC Guidelines indicate that impervious treated timber storage areas may need to be provided in cooler areas where fixation times may be extended in winter. Another aspect which could be considered is the use of the chromotropic acid test as an alternative means of assessing fixation to that indicated under AS/NZS 1605-2000.

1.5.4 Application rates

Through the description of various hazard classes and specifications for their use, guidance is provided in the Australian Standards to ensure efficacy while avoiding unnecessarily high rates. Indications of the selection criteria used and typical uses for sawn and round timber are summarised in Table 1, obtained directly from the published standards. It indicates the retention rate and penetration requirements specified for sawn and round timber under the same standards (ie specifically AS 1604.1 – 2000). The same hazard classes, exposure situations, service conditions, biological hazards and retention rates essentially apply to other timber product types and necessary information can simply be adapted for use on product labels, as is the case with the one current product label providing this information. However, typical uses and penetration requirements differ between sawn and round timber and other timber products (ie reconstituted wood-based products, plywood, laminated veneer lumber and glued laminated timber products (AS/NZS 1604.2-1604.5), and the higher hazard classes are not relevant to some timber products. The differences in penetration requirements and complexity of descriptions for these make this information in particular more difficult to add to the label. No current product label carries it.

Table 1. Selection criteria and typical uses for sawn and round timber for Hazard Classes under Australian Standards (AS 1604-2000).

Hazard class	Exposure	Specific service conditions	Biological hazard	Typical uses
H1	Inside, above ground	Completely protected from the weather and well ventilated, and protected from termites	Lyctids	Susceptible framing, flooring, furniture and joinery
H2	Inside, above ground	Protected from wetting, nil leaching	Borers and termites	Framing, flooring and similar, used in dry situations
H3	Outside, above ground	Subject to periodic moderate wetting and leaching	Moderate decay, borers and termites	Weatherboard, fascia, pergolas (above ground), window joinery, framing and decking
H4	Outside, in-ground	Subject to severe wetting and leaching	Severe decay, borers and termites	Fence posts, greenhouses, pergolas (in ground) and landscaping timbers
H5	Outside, in-ground contact with or in fresh water	Subject to extreme wetting and leaching and/or where the critical use requires a higher degree of protection	Very severe decay, borers and termites	Retaining walls, piling, house stumps, building poles, cooling tower fill
H6	Marine waters	Subject to prolonged immersion in sea water	Marine wood borers and decay	Boat hulls, marine piles, jetty cross-bracing, landing steps and similar

1.5.5 Arsenic trioxide

Product labels indicate that formulations of arsenic trioxide for the control of termites may be used both in the interior and exterior of buildings, and outside buildings in logs, stumps, poles or living trees suspected of harbouring termites. Australian Standard 3660-2000 applies to the use of such products. The dust is applied into the termite workings by a hand blower, gaining access by prising a splinter from the surface or drilling holes through which the dust may be gently puffed. The labels stress that only a small amount should be applied, with the indicated rate being 1-2 g per infestation.

In practice, the quantity used in an infestation is somewhat dependent on the level of infestation, and the size of an infestation or the area that needs to be treated may vary widely. An infestation is likely to be located some distance from the main colony/nest, linked by a series of subterranean tunnels, and there may be several other infestations from the same colony. There may also be more than one infestation affecting a structure, eg with termites from another species.

The labels note that excessive use of arsenic trioxide dust could lead to termites sealing off galleries, and that with living trees, care should be taken to avoid contamination of the sapwood. This label adds that after treatment the treated areas should be left undisturbed for 10-20 days, then reopened and areas still occupied by termites retreated, which may need to recur several times before complete control is achieved. Thus, any sealing by the operator that does occur is likely to be temporary, both because holes are simply sealed with tape, and because they are likely to be reopened in any case to inspect the workings for any remaining activity.

Dissemination of the dust throughout the termite galleries and contact with the queen is assisted by the slow (hours to days) toxic action of the poison. The powder adheres to the bodies of worker and soldier termites as they move through parts of the nest reached by the dust, and is then passed from termite to termite by grooming and cannibalism. They note that success depends on using minute quantities (usually ≤2 g per colony) of ultra fine powder propelled by relatively large quantities of air, with minimum disruption of the termite workings. Colony elimination usually takes from 14-28 days.

2. TOXICOLOGY ASSESSMENT SUMMARY

2.1 Introduction

Although the individual components of CCA are reported to be 'fixed' during the timber treatment process, some leaching does occur when the timber is 'in service'. The public can potentially be exposed to the dislodgeable residues when they come in contact with equipment or structures such as children's play equipment, picnic tables, decking and handrails. Copper, chromium and arsenic are present in the natural environment (in air, food, water and soil), albeit at low levels. The public are exposed to these chemicals through sources other than timber treated with CCA. Thus, the key issue is whether the additional exposure to dislodgeable residues arising from CCA-treated timber structures is of concern. The focus of this risk assessment was to consider whether any dislodgeable residues of copper, chromium and arsenic which may be present on treated timber or in the topsoil surrounding such timber structures posed an unacceptable risk for public health, particularly for children.

2.2 Hazard and Risk Assessment

Several reviews of arsenic, chromium and copper have been published by international organisations (IPCS, 1981, 1988, 1998, 2001; ERMA, 2003; UK Environment Agency, 2002a, 2002b; RIVM, 2001; USEPA, 2001a,b,d; US CPSC, 2003a). The OCS has also reviewed arsenic toxicity (DHFS, 1999). The following information is based on these reviews.

2.2.1 Arsenic

Arsenic is a metalloid element with a complex chemistry. Inorganic arsenic occurs in many minerals and is widely distributed in rocks, soils and sediments. It can exist in several oxidation states, the most common being the pentavalent and trivalent forms. In minerals, the highest arsenic concentrations generally occur as the sulphide or oxide, or as the arsenides of copper, lead, silver or gold. The most important commercial compound, arsenic(III) oxide (also known as arsenic trioxide), is produced as a by-product in the smelting of copper and lead ores. A variety of arsenates (AsO_4, pentavalent arsenic) and arsenites (AsO_3, trivalent arsenic) are found in water, soil and food.

Arsenic can undergo an extensive range of chemical reactions to form organic and inorganic compounds. Methylated arsenic compounds, such as di- and trimethylarsines, occur naturally in the environment as a result of biological activity. In water, these may undergo oxidation to methylarsinic acids, for example monomethylarsinic acid (MMA) and dimethylarsinic acid (DMA). However, the biomethylated forms of arsenic produced are subject to bacterial demethylation back to inorganic forms.

Arsenic is released into the general environment from a variety of natural and anthropogenic sources. On a global scale, releases to the air from natural sources such as volcanic eruptions and forest fires, and releases to water from weathering or leaching of arsenic-rich rocks and soils, may be the dominant ones. On a local scale, releases as a result of human activity, such as the burning of coal, the disposal of wastes from industrial activity, or the burning of wood treated with arsenic-containing preservatives, are likely sources.

Bioavailability and metabolism

In humans water-soluble arsenic compounds are well absorbed from the gastrointestinal tract (55%-95%). Absorption of inorganic arsenic in inhaled airborne particles (cigarette smoke, dust and fumes) is estimated to be high (75-90% in humans). Dermal absorption of inorganic arsenic is low (<5%).

In many species arsenic metabolism occurs mainly by (1) reduction reactions of pentavalent to trivalent arsenic, and (2) oxidative methylation reactions in which trivalent forms of arsenic are sequentially methylated (in liver) to form mono-, di- and trimethylated products. Methylation of inorganic arsenic facilitates the excretion of inorganic arsenic from the body, as the end-products mononmethylarsenic acid (MMA) and dimethylarsinic acid (DMA) are readily excreted in urine (IPCS, 2001). In humans and most common laboratory animals, inorganic arsenic is extensively methylated and the metabolites are excreted primarily in the urine. Following ingestion in humans, arsenic has a half-life in whole body of 2-3 days.

Analysis of tissues taken at autopsy from people who were exposed to background levels of arsenic in food and water revealed that arsenic is present in all tissues of the body. Most tissues had about the same concentration level (0.05–0.15 ppm), while levels in hair (0.65 ppm) and nails (0.36 ppm) were somewhat higher (Liebscher & Smith, 1968). This suggests that there is little tendency for arsenic to accumulate preferentially in any internal organs although it is known to occur in keratin-rich tissues (eg. nails and hair).

Levels of arsenic or its metabolites in blood, hair, nails and urine are used as biomarkers of arsenic exposure. Blood arsenic is a useful biomarker only in the case of acute arsenic poisoning or stable chronic high-level exposure. Arsenic is rapidly cleared from blood, and hence it is difficult to measure the chemical forms of arsenic in blood. Arsenic in hair and nails can be indicators of past arsenic exposure, provided care is taken to prevent external arsenic contamination of the samples. Speciated metabolites in urine expressed either as inorganic arsenic or as the sum of metabolites (inorganic arsenic + MMA + DMA) provide the best quantitative estimate of a recently absorbed dose of arsenic (IPCS, 2001).

Ingested organoarsenicals such as MMA, DMA and arsenobetaine are much less extensively metabolised and more rapidly eliminated in urine than inorganic arsenic in animals and humans.

Toxicity

Inorganic arsenic is considerably more toxic than the organoarsenicals. Within these two classes, the trivalent forms are more toxic than the pentavalent forms, at least at high doses. Arsenic is known to affect skin, and respiratory, cardiovascular, immune, genitourinary, reproductive, gastrointestinal and nervous systems.

Laboratory animal studies

Acute poisoning due to inorganic arsenic ingestion can lead to severe toxic effects (including death) within 30-60 min. The most prominent effect is seen on gastrointestinal system (vomiting, intestinal injury with bleeding and diarrhoea), followed by multi-organ failures (IPCS, 1981; 2001). The oral LD_{50} for arsenic trioxide, sodium arsenite and calcium arsenate in mice and rats ranged between 15 and 293 mg (arsenic)/kg bw. Trivalent inorganic arsenic appeared to be more toxic than pentavalent inorganic arsenic. The dermal LD_{50} was >400 mg arsenic/kg bw in rats (IPCS, 2001). Sodium arsenite and sodium arsenate were not allergenic in guineapigs (maximisation test; Wahlberg & Bowman, 1986).

Sodium arsenate added to the drinking water of mice at 0.025 or 2.5 mg/L caused a dose-dependent increase in hepatic toxicity after 4 weeks (Hughes & Thompson, 1996). In rats exposed to sodium arsenate in drinking water (50 µg arsenic/mL), histopathological changes were seen in kidneys (focal changes in the glomerulus and tubules) and liver (swollen hepatocytes near the centrolobular vein). In female dogs fed a diet containing sodium arsenite at 1-8 mg/kg bw/d for up to 6 months, liver enzymes (ALT and AST activity) were elevated at =2 mg/kg bw/d although no histopathological changes were seen in the liver.

Embryofetal developmental effects occurred only at doses that were also toxic to the maternal animals. In these studies the no observed adverse effect levels (NOAEL) for (inorganic) arsenic acid were 0.75 and 7.5 mg/kg bw/d in rabbits and mice, respectively (Nemec *et al.*, 1998). In other studies it has been reported that arsenite was 3-10 fold more toxic than arsenate in mice and hamsters (studies evaluated by IPCS, 2001: Baxley *et al.*, 1981; Willhite, 1981; Hood & Harrison, 1982; Hood & Vedel-Macrander, 1984; Nagymajtenyi *et al.*, 1985; Carpenter, 1987; Domingo *et al.*, 1991; Wlodarczyk *et al.*, 1996; NOAELs or NOELs not reported by the IPCS).

Gene mutation studies in bacteria or in mammalian cells gave either negative results or were found to be very weakly mutagenic. There is now growing evidence to suggest that arsenic acts as a co-mutagen or a promoter for some genotoxic mutagens, such as ultraviolet radiation (US CPSC, 2003d; IPCS, 2001). It also causes chromosomal aberrations *in vitro*, affects methylation and repair of DNA, induces cell proliferation, transforms cells, and promotes tumours. Clastogenic effects are also seen in mice.

Arsenic-induced tumours are generally not observed in whole-of-life bioassays. However, in a recent study in C57B1/6J mice (only females used) given arsenic at 500 µg/L (in drinking water) over 2 years, lung, liver, gastrointestinal and skin tumours were observed (IPCS, 2001).

Lifetime studies of rodents given roxarsone (3-nitro-4-hydroxyphenylarsonic acid, an organic arsenic compound) in their feed at doses up to 1.4 mg/kg bw/d gave no evidence of carcinogenicity in mice or rats, but a slight increase in pancreatic tumours was noted in male mice (NTP, 1989). The incidence of possible precancerous lesions in the livers of rats initiated with diethylnitrosamine was increased by subsequent exposure to DMA, suggesting that this compound could act as a cancer promoter (Johansen *et al*, 1984), at least in animals.

Human data

Humans exposed to high concentrations of inorganic arsenic in their drinking water over long periods of time have an increased incidence of various dermatological lesions and skin cancer, and cardiovascular diseases such as peripheral vascular disease and myocardial damage. There is also evidence for chromosomal damage (clastogenic effects) in humans who have been exposed to high arsenic concentrations in drinking water (IPCS, 2001). The IPCS review reports that even with some negative findings, the overall weight of evidence indicates that arsenic can cause chromosomal damage in different cell types in exposed individuals. These gross changes to the chromosomes usually result in the affected cells not being able to divide and replicate successfully.

There is clear evidence of the carcinogenic potential of ingested inorganic arsenic in humans. Epidemiological studies conducted in Taiwan, Japan and Argentina found that people exposed to high levels of arsenic in drinking water showed increased (and dose-related) risks of skin, lung, bladder, kidney and liver cancers (Chen *et al.*, 1992; Chiou *et al.*, 1995; Hseuh *et al.*, 1995; Tseng *et al.*, 1968; Tseng, 1977; Tsuda *et al.*, 1989, 1995; Hopenhayn-Rich *et al.*, 1996). The studies are reviewed in the IPCS (2001) document on arsenic.

In several epidemiological studies on populations living in areas with elevated levels of arsenic in drinking water, skin lesions (hyperkeratosis; hyper- or depigmentation) were the most sensitive indicator of chronic arsenic toxicity (Borgono & Greiber, 1972; Borgono *et al.*, 1980; Cebrian *et al.*, 1983;, Grantham & Jones, 1977; Huang *et al.*, 1985; Mazumdar *et al.*, 1988; Southwick *et al.*, 1983; Tseng, 1977; Tseng *et al.*, 1968; Valentine *et al.*, 1987; Zaldivar, 1977). The lesions were seen in the dose range of between 10 and 100 µg/kg bw/d. In studies conducted in Taiwan on 17,000 people exposed to arsenic contaminated drinking water (up to 1200 µg arsenic/L) from artesian wells, there was no evidence of skin lesions in people with an estimated mean daily intake of arsenic of 0.8 µg/kg bw/d (Tseng *et al.*, 1968; Tseng, 1977) although in another study (Cebrian *et al*, 1983), the NOAEL for skin lesions was estimated to be somewhat lower (ie. 0.4 µg/kg bw/d; USEPA, 2001c).

Exposure to arsenic (together with other confounding factors such as other undefined water contaminants; poor nutritional status etc.; Lu, 1990) in a region of Taiwan that formerly had high levels of arsenic in drinking water has been reported to damage the vascular system, as demonstrated by the occurrence of "blackfoot disease" (progressive loss of circulation in the hands and feet, which may eventually lead to necrosis and gangrene) (Tseng, 1977). The lowest observed adverse effect level (LOAEL) for the Tseng study was 17 µg/kg bw/d. Mortality rates from diabetes mellitus were also found to be higher in the blackfoot disease endemic area (IPCS, 2001).

Neurological effects (including tingling, numbness and peripheral neuropathy) have also been reported to be associated with elevated levels of arsenic in drinking water. Evidence of hepatic damage (enlarged liver, elevated levels of liver enzymes and portal tract fibrosis) has been reported after exposure of arsenic by the oral route, with LOAELs in the range of 20-100 µg/kg bw/d (ATSDR, 2000).

Occupational exposure to arsenic, primarily by inhalation, is causally associated with lung cancer. Increased risks have been observed at cumulative exposure levels ≥ 0.75 (mg/m^3)· year (e.g. 15 years of exposure to a workroom air concentration of 50 µg/m^3). Tobacco smoking has been investigated in two of the three main smelter cohorts and was not found to be the cause of the increased lung cancer risk attributed to arsenic (IPCS, 2001).

Mechanism of carcinogenicity

A number of *in vitro* studies suggest that arsenic can act to promote or enhance carcinogenicity of other agents by effects such as oxidative DNA damage, altered DNA methylation and gene expression, inhibition of enzymes involved in cellular energy production, DNA repair, and other stress-response pathways, altered function of the glucocorticoid receptor, and other effects concerning signal transduction, cell-cycle control, differentiation, cytotoxicity, and apoptosis. Many of these effects could be involved in arsenic-related carcinogenesis, although induction of apoptosis could act to prevent cancer (US CPSC, 2003d). Arsenic-induced apoptosis has been suggested to have an important role in the treatment of acute promyelocytic leukaemia (NRC, 2001).

Health standards

Although exposure to high concentrations of inorganic arsenic results in tumour formation and chromosomal damage (clastogenic effect), the mechanism by which these tumours develop does not appear to involve mutagenesis. Arsenic appears to act on the chromosomes and acts as a tumour promoter rather than as an initiator (Gebel, 2001; Simeonova & Luster, 2000; Wang *et al.*, 2002). Furthermore, the epidemiological evidence from occupational exposure studies indicates that arsenic acts at a later stage in the development of cancer, as noted with the increased risk of lung cancer mortality with increasing age of initial exposure, independent of time after exposure (Brown & Chu, 1983). Hence arsenic appears to behave like a carcinogen which exhibits a threshold effect. This would also be conceptually consistent with the notion that humans have ingested food and water containing arsenic over millennia and so the presence of a threshold seems likely. Nevertheless the mechanism by which tumour formation develops following arsenic exposure has been and still continues to be a source of intensive scientific investigation.

While several epidemiological studies suggest the existence of a threshold effect there is considerable debate regarding the most appropriate dose-response relationship to quantify the cancer risks from arsenic exposure (Beck *et al.,* 1995; Chappell *et al.,* 1997). Studies conducted in Taiwan showed a causal relationship (with dose-dependency) between exposures of high arsenic water content in drinking water and risks of cancers, with a threshold for cancer, especially for skin cancers. Skin cancers appear to be the most sensitive indicator of carcinogenicity of inorganic arsenic in humans, with a threshold of 2.9 µg/kg bw/d. This level, rounded-off to 3 µg/kg bw/d, has been taken to be the provisional maximum tolerable daily intake (PTDI) of arsenic in food (FSANZ, 1999). The tolerable intake is the amount that can be ingested daily without any appreciable health risk for a lifetime exposure. However, the aggregate exposure which includes all other sources apart from food may be high for some children depending on their age, geographical location, housing environment and daily activity.

Based on a number of epidemiological studies the Joint Expert Committee on Food Additives (JECFA) concluded in 1983 that arsenic toxicity (arsenicism) can be associated with water levels containing an upper arsenic concentration of 1 mg/L or greater, and a concentration of 0.1 mg/L may give rise to 'presumptive signs of toxicity'. Assuming a daily water intake of 1.5 L, JECFA concluded that intakes of 1.5 mg/d of inorganic arsenic are likely to result in chronic arsenic toxicity and daily intakes of 0.15 mg (150 µg) may also be toxic in the long term to some individuals. On the basis of available data, JECFA recommended a provisional weekly intake of 15 µg/kg bw (~2 µg/kg bw/d), and recommended further epidemiological studies in populations exposed to elevated levels of inorganic arsenic occurring in drinking water, in order to define more clearly levels of inorganic arsenic which may cause adverse effects. In 1989, JECFA confirmed the provisional maximum tolerable weekly intake (PTWI) of 15 µg/kg bw.

Exposure

Since small children aged 3 to 5 have a high food intake relative to their bodyweight and are the ones most likely to display hand-to-mouth behaviour and ingest soil the following exposure estimates are focussed on this group.

Estimate of daily arsenic intake in children

Using available data, total daily intake (average intake) of arsenic is estimated in the following sections.

Factors and assumptions used in the exposure assessment calculation

Non-playground related exposure

Intake from food

The total intake of arsenic (organic + inorganic) from food by toddlers (2 years of age) in Australia has been estimated to be 0.55-1.3 µg/kg bw/d (0.28-0.83 µg/kg bw/d for boys and girls aged 12 years; FSANZ, 2002). The maximum intake value for toddlers was selected for the risk assessment. The proportion of inorganic arsenic in the total arsenic content in food has been estimated to be up to a maximum of 6% (FSANZ, 1999). Hence the maximum daily intake of inorganic arsenic in children was taken as 1.3 x 6% which is 0.078 µg/kg bw/d.

Intake from water

Water intake in a child aged 3-5 years has been estimated to be 0.87 L/d (USEPA, 1997b). According to the Australian Drinking Water Guidelines (ADWG), the concentration of arsenic in drinking water should not exceed 7 µg/L (NHMRC, 2003). Hence for the purposes of this intake assessment, the maximum arsenic (mostly in the form of inorganic arsenic) intake from in drinking water was estimated to be 0.87 x 7 = 6.09 µg/d/child.

Intake from air

Arsenic concentration in the air is reported to be typically in the range of 0.2-1.5 ng/m^3 in rural areas and 0.5-3 ng/m^3 in urban areas (IPCS, 2001). The USEPA (2002) has estimated that a child's (3-5 years) intake of air is 8.7 m^3/d. These values (arsenic: 3 ng/m^3; air intake: 8.7 m^3/d) were used in the estimating a child's intake of arsenic from the air (3 ng x 8.7 = 26.1 ng = 0.026 µg/d). Systemic absorption from the lungs was assumed to be 100%.

Intake from soil (non-playground)

Oral ingestion

According to Smith *et al.* (2003), the arsenic content of Australian soils ranges between 1 and 50 mg/kg, with a mean value of 5-6 mg/kg. This background concentration range is similar to the values reported for urban and rural soils in Queensland (see below). Based on these values the background soil level of arsenic was taken as 6 mg/kg (or 0.006 µg/mg soil).

The soil ingestion rate was taken to be 100 mg/d/child and the oral bioavailability of arsenic in soil was taken to be 25% (see below under 'Intake of arsenic from contact with soil in playgrounds').

Background arsenic levels in urban and rural soils (Queensland data)

Sample	Arsenic level (mg/kg soil)
Rural soils	<5-40
New suburb	3-31
Old suburb	3-27

Source: Smith *et al*. (2003).

Dermal absorption

The values used for 'Intake of arsenic from contact with soil in playgrounds' (see below) were used for estimating dermal absorption of arsenic from non-playground soil (surface area: 1640 cm^2; soil adherence factor: 0.2 mg/cm^2; bioavailability: 4.5%) except that the soil arsenic concentration was assumed to be 6 mg/kg.

Playground-related exposure

Intake of arsenic from contact with wood

Oral intake

Handload (amount of arsenic on hands): The studies conducted by US Consumer Product Safety Commission (US CPSC, 2003a-k) were chosen as the most appropriate of the available studies for determining the amount of arsenic transferred to a child's hand when playing on wood treated with CCA. The mean value for this parameter was 7.6 μg/handload of arsenic (US CPSC, 2003a, see section 6). This value was used in the exposure calculation.

Hand-to-mouth transfer: The US CPSC (2003a) estimated that an average of 43% of the arsenic residue on children's hands is transferred to their mouths during the day. This transfer to the mouth includes incidental and indirect contact (food, toys, etc.), as well as direct mouthing from the hand (US CPSC, 2003e). A hand-to-mouth transfer factor of 0.43 appropriate was used in the current exposure calculation.

Bioavailability: Studies on bioavailability of arsenic from CCA-treated wood are not considered adequate since only two studies (dogs and pigs) are available, and both were based on urinary excretion of arsenic. In the study in dogs, data were not normalised using data obtained after IV administration of arsenic. Insufficient details were available for the study in pigs. Based on these constraints a conservative value of 100% was assumed for the bioavailability of arsenic from CCA-treated wood.

Frequency of playground use: As suggested by the US CPSC (2003a, j), the frequency of children's contact with CCA-treated playground equipment is assumed to be 156 days per year (3 days a week). It is noted that some risk assessments also take into account the amount of time per day that a child plays on the playground. However, the US CPSC stated that the method used by CPSC staff for estimating the amount of arsenic residue that a child might ingest does not depend on the amount of time per day (hours/d) the child spends on the playground.

Dermal intake

Adherence to skin: The amount of arsenic that adheres to a child's skin is assumed to be similar to that which adheres to the hands (7.6 μg/handload, see above). For a child aged 2-6.5, the mean palm side surface for both hands is 129 cm^2 (Snyder *et al.*, 1997). For an adult, the area of the palm, including fingers, was measured to be 141 cm^2 (thus the palm area of two hands of a child is approximately equivalent to that of one adult palm). Based on this, adherence of arsenic to skin is calculated to be 0.06 $\mu g/cm^2$ (7.6 $\mu g/129\ cm^2$).

The surface area of contact was taken as 1640 cm^2, the area (upper percentile for a 3 year old child: exposed skin surfaces of hands, legs, arms) recommended by the USEPA (2001a).

Bioavailability: The dermal bioavailability of arsenic from CCA-treated wood was <0.01% in monkeys (Wester *et al.*, 2003). For the purposes of a conservative risk assessment, a value of 0.1% was used.

Frequency of playground use: As before (156 days per year).

Intake of arsenic from contact with soil in playgrounds

Oral intake

Amount of arsenic in soil: Studies on soil concentrations of arsenic in playgrounds have not been conducted in Australia. Studies evaluated by the USEPA revealed that mean values of arsenic ranged from 6 to 24 mg/kg soil in 5 studies although one study (Stilwell & Gorny, 1997) reported a high value of 76 mg/kg soil. The overall mean value in all these studies (mean of all means) was 27.2 mg/kg (see USEPA, 2001a in section 7). In a laboratory study simulating weather conditions in Brisbane, the maximum estimated cumulative soil concentration of arsenic (due to leaching from CCA-treated pine deck, after a rainfall of 7300 mm; see Kennedy & Collins, 2001 in section 7) was found to be similar to this value (33.1 mg/kg soil).

Based on the above, in the absence of Australian data on soil content of arsenic in different playgrounds, a value of 30 mg arsenic/kg soil was selected for the risk assessment. The background value (6 mg/kg) was deducted from the playground soil value of 30 mg/kg to calculate the arsenic content in soil (24 mg/kg; 0.024 μg/mg soil) due to leaching of arsenic from CCA-treated wood.

Soil ingestion: The soil ingestion rate of 100 mg/d/child, as recommended by the USEPA (2001a, b), was used.

Bioavailability: Although bioavailability studies on arsenic have been conducted in different species (absolute bioavailability up to 33%), studies conducted in monkeys are considered the most relevant for estimating human exposure. In monkeys, absolute bioavailability was in the range 8-14% (2 studies did not report any value) while the relative bioavailability with respect to that of soluble arsenic was 11-25%. Based on this information, the value chosen for arsenic bioavailability was 25%.

Dermal intake

Surface area of contact: As for the dermal intake of arsenic from contact with wood in playgrounds (i.e. skin area of 1640 cm^2).

Soil adherence factor: The soil adherence factor is the amount of soil which adheres to the skin. The USEPA (Superfund RAG, Part E; Supplemental Guidance for Dermal Risk Assessment, draft 2000; cf: USEPA, 2001a) estimated an activity-specific surface area weighted soil adherence factor for a child (1-6 years old) resident at a day care centre to be 0.2 mg/cm^2, although for a hand contacting commercial potting soil (in lieu of playground soil), the factor is 1.45 mg/cm^2. Another assessment by USEPA (see table below) also estimated a factor of 0.2 mg/cm^2 for children playing in dry (90th percentile) or wet soil (50th percentile). For the current assessment, the value of 0.2 mg/cm^2 was considered appropriate.

Activity specific surface area weighted soil adherence factor

Exposure scenario	**Age (year)**	**Soil Adherence Factor (mg/cm^2)[a]**	
		50th percentile	**90th percentile**
Children playing in dry soil	8-12	0.04	0.2
Children playing in a day care center	1-6.5	0.06	0.2
Children playing in wet soil	8-12	0.2	2.7
Kids-in-mud	9-14	22[b]	123[b]

Source: USEPA Superfund, 2000 (cf. USEPA, 2001a). [a]Weighted adherence factor based on exposure to face, forearms, hands. lower legs and feet. [b]According to the USEPA, these are significant overestimation and will not be used (for risk assessment).

Bioavailability: Based on a study in monkeys (Wester *et al.*, 1993, see section 5), the dermal bioavailability was taken as 4.5%.

Soil concentration in playground: As for the oral intake of arsenic from contact with soil in playgrounds (i.e. 24 mg arsenic/kg soil, after deducting background arsenic value).

Calculation of daily exposure to arsenic in children

Non-playground-related exposure

Arsenic (inorganic) intake	**Factors used**[#]	**Estimated daily intake for a child aged 3 years**
Intake from food	0.078 µg/kg bw/d; bw: 15 kg for a 3-year old child	0.078 x 15 = 1.2 µg
Intake from drinking water	Water intake, 0.87 L/d. arsenic content, up to 7 µg/L	0.87 x 7 = 6.1 µg
Intake from air	Arsenic in air: 0.003 µg/m^3; air intake: 8.7 m^3/d	0.003 x 8.7 = 0.026 µg
Intake from non-playground soil - oral ingestion	Soil content: 0.006 µg arsenic/mg soil; soil ingestion = 100 mg/child; bioavailability = 25%	0.006 x 100 x 25% = 0.15 µg
Intake from soil - dermal	Skin contact area = 1640 cm^2; soil adherence = 0.2 mg/cm^2; soil content of arsenic: 0.006 µg arsenic/mg soil; bioavailability = 4.5%	1640 x 0.2 x 0.006 x 4.5% = 0.09 µg
Total daily arsenic intake = 1.2+6.1+0.026+0.15+0.09 = 7.57 µg/child (0.50 µg/kg bw/d, for a 15 kg child)		

[#]See above for factors used in the calculation.

Playground-related exposure

ARSENIC (INORGANIC) INTAKE	**Factors used**[#]	**ESTIMATED DAILY INTAKE FOR A CHILD AGED 3 YEARS**
Intake from contact with CCA-treated timber in playgrounds		
Arsenic – oral intake	7.6 µg/handload; hand-to mouth transfer: 0.43; bioavailability: 100%; contact days: 156/year	7.6 x 0.43 x 100% x 156/365 = 1.4 µg
Arsenic – dermal intake	0.06 µg arsenic/cm^2 skin area; contact area: 1640 cm^2 (for a 3-year child); bioavailability = 0.1%; contact days: 156/year	0.06 x 1640 x 0.1% x 156/365 = 0.04 µg
Intake from contact with soil in playgrounds (containing CCA-treated timber structures)		
Arsenic – oral ingestion	Soil ingestion = 100 mg/child; 0.024 µg arsenic/mg soil; bioavailability = 25%; contact days: 156/year	100 x 0.024 x 25% x 156/365 = 0.26 µg
ARSENIC – DERMAL INTAKE	Soil adherence to skin = 0.2 mg soil/cm^2; 0.024 µg arsenic/mg soil; skin area of contact = 1640 cm^2; bioavailability = 4.5%; contact days: 156/year	0.2 x 0.024 x 1640 x 4.5% x 156/365 = 0.15 µg
Total: 1.4 + 0.04 + 0.26 + 0.15 = 1.85 µg/child (0.12 µg/kg bw/d, for a 15 kg child)		

BW for a 3-year child: ~15 kg. [#]See above for factors used in the calculation.

Total daily intake of arsenic from all sources

Non-Playground	0.50 µg/kg bw
Playground	0.12 µg/kg bw[#]
Total	0.62 µg/kg bw

The above estimate indicated that the total intake of a child is ~0.6 µg/kg/d. Of this, ~20% intake is from playgrounds. In the estimate, lifetime average daily intake (based on 75 years or 27400 days of living; US CPSC, 2003) will be much lower (~7% of the value, for playground-related exposures only).

Risk to humans from exposure to inorganic arsenic in CCA-treated timber

There are no suitable studies conducted in Australia that could be used to estimate a child's exposure to the components of CCA leached from CCA-treated wood. Available studies (mostly overseas) indicated that CCA residues transferred from a wood surface to a child's hand (on contact) or to a surrogate (such as a polyester wipe) were highly variable. Thus, in exposure studies conducted by the US CPSC that were used in health risk assessments for children, the amount of arsenic picked up by dry polyester wipes varied from 1.6 to 168.5 µg, demonstrating a range of approximately 100-fold. Such a high variability in arsenic transfer was also noted in several other studies.

The estimated aggregate background inorganic arsenic intake for an average 3-5 year old child from air, food, drinking water and soil was approximately 7.57 µg/child/d (or 0.50 µg/kg bw/d for a 15 kg child). For a child playing on or near a CCA-treated timber structure the increase in exposure to arsenic was 0.12 µg/kg bw/d based on average values of dislodgeable arsenic from timber and in soil under timber structures. The combined amount, 0.62 µg/kg bw/d, is below the tolerable daily intake of approximately 2 µg/kg bw/d set by the Joint Food and Agriculture Organisation/World Health Organisation Expert Committee on Food Additives (JECFA) and about 3 µg/kg bw/d set by Food Standards Australia New Zealand (IPCS, 1989; FSANZ, 1999). (The tolerable intake is the amount that can be ingested daily per kilogram of body weight and represents a level of no appreciable health risk for a lifetime exposure.) This combined amount is based on the average handload value obtained from the US CPSC study and therefore does not account for possible high values that might be found in some structures.

Arsenic trioxide

Arsenic trioxide is unlikely to be a public health hazard as the application of the products is carried out by licensed pest control operators (PCOs), and the treated timber parts are concealed. The PCOs who are eligible to carry out the application of arsenic trioxide are assessed as competent to Certificate II level of the National Pest Management Industry Competency Standards. Holes are drilled into infested timber or trees and 1 to 2 g of the product is applied per infestation. The opening is then covered with a tape.

2.2.2 Copper

Natural sources of copper include soil and windblown dust, decaying vegetation, bushfires, volcanoes and water (seawater, surface water, ground water and drinking water). In addition, copper is released into the environment via industrial emissions and mining operations. Copper compounds are used as bactericides, fungicides, insecticides and animal feed additives. Copper compounds are also used in pharmaceuticals and as food additives.

Copper is an essential element in mammals, being incorporated into a large number of enzymes, particularly the oxidoreductases. There is a greater risk of adverse health effects from copper deficiency than from excess copper intake (IPCS 1998). The International Program on Chemical Safety (IPCS) set a lower limit of the acceptable range of oral intake of 0.02 mg/kg bw/d in adults and 0.05 mg/kg bw/d in infants. The upper limit in adults is uncertain, but an estimated range is 2-3 mg/kg bw/d, based on studies of gastrointestinal effects of copper-contaminated drinking water.

Bioavailability

The level of absorption of copper compounds through the gastrointestinal tract is 20-60%, with the remainder excreted via the faeces. Intestinal absorption is influenced by the presence of other metals, such as zinc and iron, dietary proteins, fructose, ascorbic acid and fibre. A recent *in vitro* study suggested that copper may be more bioavailable from wood dust of CCA-treated timber relative to the intact wood (Gordon *et al.,* 2002).

Toxicity

In animals, short-term repeat-dose oral studies with copper compounds found effects on clinical chemistry and haematology parameters and adverse effects on the liver, kidney and lungs. Subchronic and chronic dietary studies indicated effects on the liver and kidney. Laboratory animal studies have provided no indication that copper is carcinogenic. Copper does not appear to affect reproduction. High oral doses of copper reportedly cause fetotoxicity and soft tissue malformations in mice at and above 260 mg/kg bw/d, while lower concentrations had an apparently beneficial effect on development (Lecyk, 1980). Delayed ossification has been reported in rats following *in utero* exposure (Haddad *et al.,* 1991). DNA damage and adducts have been detected in patients with Indian childhood cirrhosis (a discrete clinical and histological entity in which large amounts of copper are deposited in the liver), however, there is little evidence that copper is genotoxic *in vivo*, given that it is mostly protein bound.

Human data

Adverse health effects in humans relate to deficiency as well as excess exposure. Data from human poisoning cases has estimated that the acute lethal dose for adults is 4-400 mg copper^{2+}/kg bw (IPCS, 1998). According to RTECS (2003), the lowest published oral lethal dose of hydrated copper sulphate is 1088 mg/kg bw, while the lowest oral toxic dose is 272 mg/kg bw/d. For anhydrous copper sulphate, lethal oral doses have been reported as 50 and 857 mg/kg bw. In children the lowest toxic oral dose has been reported to be 150 mg/kg bw. Acute oral exposures have resulted in the presence of a metallic taste, epigastric pain, headache, nausea, dizziness, vomiting and diarrhoea, tachycardia, respiratory difficulty, haemolytic anaemia, haematuria, gastrointestinal bleeding, liver and kidney failure and death.

Single and repeated ingestion of drinking water containing high levels of copper compounds has causes gastrointestinal effects. In a double-blinded clinical study, the NOEL for nausea and gastrointestinal symptoms following a single weekly dose of copper sulfate solution for 5 weeks was 4 mg/L, with a LOEL of 6 mg/L (Araya *et al.,* 2001). Other studies have confirmed that vomiting occurs at a concentration of 6 mg/L (Olivares *et al.,* 2001; Poirier *et al.,* 2002). Long term exposure to copper via drinking water also results in gastrointestinal disturbances. Cirrhosis and liver failure occurred in an individual following 2 years of ingesting 30 or 60 mg/d copper as a dietary supplement (O'Donohue *et al.,* 1993). Dermal exposure does not cause systemic toxicity but may induce allergic responses in sensitive individuals.

The IPCS (1998) identified a number of "at risk" groups in the population that may be particularly sensitive to either copper deficiency or overexposure: individuals with genetic conditions such as Menkes disease (a copper deficiency disorder), Wilsons disease (disorder due to excess copper), Indian childhood cirrhosis and idiopathic copper toxicosis; dialysis patients, persons with chronic liver disease, infants and persons with malabsorption syndromes (eg. coeliac disease and cystic fibrosis).

Exposure

The main sources of exposure to copper are via food and drinking water. The IPCS (1998) calculated that the total intake of copper (ie. food plus drinking water) in adults is between 1-2 mg/d, while it may occasionally reach 5 mg/d. Inhalation and dermal exposure to copper are considered to be insignificant, with inhalation exposure of 0.3-2.0 µg/d (IPCS, 1998).

Food

In 1996, the World Health Organisation (WHO) set a tolerable dose for copper of 0.2 mg/kg bw/d (200 µg/kg bw/day), a value that has also been adopted by Australia. The 20th Australian

Total Diet Survey[1] (ATDS) found the highest amounts of copper in almonds, prawns, processed wheat bran, peanut butter, mushrooms, sultanas, breakfast cereal, liver pate and baked beans. It is also widely distributed in a range of plant and animal products. In the majority of foods, copper is found bound to proteins rather than as a free ion. Calculations performed by Food Standards Australia New Zealand (FSANZ) determined that the mean estimated daily dietary exposure to copper was 16 and 14 µg/kg bw/d in adult males and females, respectively. In 12-year old boys and girls it is 21 and 16 µg/kg bw/d, respectively, while in toddlers (2 years) and infants (9 months) it is 40 and 65 µg/kg bw/d, respectively. The intake as a percentage of the tolerable dose for these groups was 8.0%, 7.2%, 11%, 8.2%, 20% and 32%, respectively.

The USA and Canada have set a Recommended Dietary Allowance of 900 µg/d for adults, 340 µg/d for children up to 3-years of age, 440 µg/d for ages 4-8, 700 µg/d for ages 9-13 and 890 µg/d for ages 14-28. The US Academy of Sciences has recommended that all adults should receive a daily intake of 1-3 mg copper to satisfy physiological requirements. Australia does not have a recommended dietary intake (RDI) for copper.

Drinking water

According to the National Health and Medical Research Council (NHMRC), in major Australian reticulated water supplies, total copper concentrations range up to 0.8 mg/L, with typical concentrations of approximately 0.05 mg/L. Based on health considerations, the NHMRC has set a Health Guideline Value for copper in Australian drinking water at 2 mg/L, which is the same as that set by the WHO. However, based on aesthetic considerations, the concentration of copper in drinking water should not exceed 1 mg/L.

Risk to humans from exposure to copper in CCA-treated timber

Based on a consideration of the toxicology profile of copper and the high natural background exposure to copper in food and drinking water, the risk to humans from exposure to copper compounds present in dislodgeable residues from CCA-treated timber is considered to be negligible.

2.2.3 Chromium

In nature, chromium can be found in rocks, soil, animals and plants. Chromium occurs naturally in ores in its trivalent form. Trivalent chromium is an essential element in humans involved in glucose, fat and protein metabolism. CCA products contain hexavalent chromium which is reduced to trivalent chromium by organic compounds once inside wood. However, sawdust from CCA-treated wood has been found to contain some chromium in hexavalent form.

Bioavailability

Gastrointestinal absorption of chromium is relatively poor (0.5-3%), with hexavalent chromium being more readily absorbed than trivalent chromium. This difference is due to the fact that trivalent chromium cannot cross cell membranes. Hexavalent chromium is taken up by an anion transporter and is then reduced intracellularly, via reactive intermediates, to trivalent chromium. Dermal absorption in guinea pigs is 1-4% of the applied dose (Bagdon & Hazen, 1991).

Toxicity

Laboratory animal studies

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[1] http://www.foodstandards.gov.au/_srcfiles/Final_20th_Total_Diet_Survey.pdf

The lethal oral dose of sodium dichromate in rats is 50 mg/kg bw, while the lethal dermal dose in guinea pigs is 335 mg/kg bw (RTECS 1993). Chromic acid has an oral LD_{50} of 52 mg/kg bw in rats and a dermal LD_{50} of 57 mg/kg bw in rabbits (USEPA, 2001d). The dermal LD_{50} for chromium trioxide in rabbits is 30 mg/kg bw (ATSDR, 2000). Hexavalent chromium compounds are corrosive to the eyes and skin of laboratory animals (USEPA, 2001d). Trivalent and hexavalent chromium are skin sensitisers in guinea pigs (Gross *et al.*, 1968; Jansen & Berrens, 1968). Hexavalent chromium is carcinogenic to laboratory animals and is also genotoxic in a number of *in vitro* and *in vivo* assays. There is no evidence that trivalent chromium compounds are carcinogenic or genotoxic. Hexavalent but not trivalent chromium has been found to cause developmental and reproductive effects in rodents.

Human data

Trivalent chromium is an essential element for the potentiation of insulin and the maintenance of normal glucose and fat metabolism.

According to RTECS (1993), the lethal oral dose of sodium dichromate is 50 mg/kg bw. The lowest toxic dose of chromic acid is 100 mg/kg bw, with nausea, vomiting and normocytic anaemia reported (RTECS 2003). Symptoms following acute oral ingestion include vertigo, abdominal pain, gastrointestinal haemorrhage, thirst, vomiting, oliguria, anuria, shock, convulsions, coma and death. Acute dermal exposure can cause systemic toxicity, with symptoms similar to oral exposure.

Hexavalent chromium compounds are strong skin irritants and sensitisers. Contact dermatitis has been reported in chromium workers, and it has been suggested that trivalent chromium-protein complexes are the allergens. Pulmonary irritation and sensitisation has also been reported in workers exposed to hexavalent chromium. Data mainly from chromium workers indicates that acute and chronic exposures via the oral, dermal or inhalational routes can lead to renal and hepatic toxicity (eg. renal tubular necrosis, hepatic necrosis). Low-dose exposure generally causes transient effects and low-level environmental exposures have not resulted in any adverse effects in the human population. Data on the possible reproductive or developmental effects of chromium in humans was not identified.

Occupational exposure to hexavalent chromium has been associated with lung cancer. The International Agency for Research on Cancer (IARC) has classified hexavalent chromium in Group 1, “sufficient evidence of carcinogenicity in humans”, while trivalent chromium is classified in Group 3, “not classifiable – inadequate evidence in humans and animals for carcinogenicity”. The USEPA has classified inhaled hexavalent chromium as a known human carcinogen (Group A), while carcinogenicity via the oral route cannot be determined (Group D).

Exposure

Food

While chromium is found naturally in a variety of commodities, FSANZ has not quantified chromium intake in the 20th ATDS. Although dietary intake of chromium is important for insulin potentiation and maintenance of normal glucose and fat metabolism there is no recommended Australian dietary intake for trivalent chromium.

A 1997 UK total dietary survey [as described in a recent European Commission (EC) evaluation of trivalent chromium[2]] indicated that the highest chromium levels were found in meat products, oils and fats, bread, nuts and cereals. The EC did not set an upper intake level for trivalent chromium as the available human data did not give a clear picture of the dose-response

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[2] http://europa.eu.int/comm/food/fs/sc/scf/out197_en.pdf

relationship. However, the UK Expert Group on Vitamins and Minerals concluded that a total dietary intake of approximately 0.15 mg trivalent chromium/kg bw would not be expected to cause adverse health effects.

The following national dietary intakes of chromium were reported by the EC (2003): Up to 170 µg/d in the UK; between 50-580 µg/d in Sweden; the average intake in Germany is 61 and 84 µg/d for males and females, respectively; the average intake in the US is approximately 30 µg/d (range 3-127 µg/d).

In 2002, the UK Department for Environment, Food and Rural Affairs and the Environment Agency[3] set an oral tolerable daily intake (TDI) for chromium at 3 µg/kg bw/d, with a mean daily intake (MDI) of 13 µg/d (ie. 0.2 µg/kg bw/d for adults and 0.4 µg/kg bw/d for children). A oral tolerable daily soil intake (defined as the difference between the TDI and MDI) was calculated as 2.8 µg/kg bw/d for adults and 2.6 µg/kg bw/d for 6-year old children.

The US Academy of Sciences estimates that the daily dietary intake of chromium by adults is approximately half of the safe/adequate daily intake of 50-200 µg/d. However the US Food and Nutrition Board considered that there was insufficient data to establish an upper limit for trivalent chromium.

Drinking water

In major Australian reticulated water supplies, total chromium concentrations range up to 0.03 mg/L, with typical concentrations being less than 0.005 mg/L. Based on health considerations, the NHMRC has set a Health Guideline Value for chromium in Australian drinking water at 0.05 mg/L. It is recommended that if the concentration of total chromium exceeds this value then a separate analysis for hexavalent chromium should be undertaken.

Risk to humans from exposure to chromium in CCA-treated timber

Although hexavalent chromium compounds are hazardous to human health by virtue of their carcinogenicity potential it has been shown that sawdust from CCA-treated timber contains between 0.3-0.4% of total chromium and less than 2% of the total chromium was present in the hexavalent form (Cruz *et al.*, 1995). Hence the chromium in dislodgeable residues from CCA-treated timber is most likely to be trivalent chromium which is not classifiable with respect to carcinogenicity due to insufficient evidence (IARC). There was no suitable data to quantify the chromium concentration in dislodgeable residues.

2.3 Conclusions

CCA

CCA, as the name suggests, consists of three active constituents, copper, chromium and arsenic. The arsenic in CCA products protects timber against insects, while copper acts as a fungicide, and chromium fixes these two chemicals in the timber. Although the individual components of CCA are reported to be fixed during the timber treatment process, some release does occur when the timber is 'in service'. The public can potentially be exposed to the dislodgeable residues (i.e. capable of being transferred from the surface of treated timber through contact) when they come in contact with treated timber equipment or structures.

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[3] http://www.defra.gov.uk/environment/landliability/pdf/tox4.pdf

Copper, chromium and arsenic are present in the natural environment (in air, food, water and soil), albeit at low levels. Therefore, the public is exposed to these chemicals through sources other than timber treated with arsenic.

Toxicological assessment found that copper and chromium in the CCA-treated timber do not present an undue risk to public health. The focus of the toxicological assessment was to determine whether arsenic that may be present in the dislodgeable residues on, or in the topsoil surrounding, CCA-treated timber structures poses an unacceptable risk for public health, particularly for children. Young children, aged 3-5, who normally exhibit appreciable hand-to-mouth behaviour are considered to be the most at-risk group.

The World Health Organisation has set an intake of 2 µg of arsenic per day as the tolerable intake per kilogram of body weight (the tolerable intake is the amount of the chemical which can be ingested daily without any appreciable health risk for a lifetime of exposure). The Food Standards Australia New Zealand set the tolerable intake at 3 µg per day per kilogram of body weight. The Australian worst-case aggregate estimate for the inorganic arsenic intake from natural sources by an average 3 – 5 year old child is 0.5 µg per day per kilogram of body weight. Therefore, the key issue in relation to CCA-treated timber is whether the additional exposure to arsenic that may arise from dislodgeable residues from timber structures can significantly increase the total intake of arsenic. To address this issue, data of acceptable scientific quality is required to answer the following key questions.

a. How much dislodgeable arsenic is present on the surfaces of timber structures treated with CCA?
b. How much arsenic is likely to adhere to children's hands and other parts of the body during the course of play?
c. What fraction of such adhered arsenic will subsequently be transferred to mouth, or absorbed through the skin?

The data available for the review were not sufficient to answer the above questions. While the data from a USA study could be adapted for Australian scenarios to answer questions b and c above, Australian studies are required to estimate the quantities of dislodgeable arsenic on the timber structures treated with CCA (question a) because of possible differences between the US and Australia in plant operation practices and differences in leaching rates under Australian climatic conditions.

Of the several studies available to the review that measured dislodgeable arsenic, the only study that was of sufficient scientific quality and conducted under controlled conditions was based on a small sample in the USA. Other assessed studies, including one from Australia, were limited in scope. While these other studies demonstrated that arsenic is released from CCA-treated timber with a high degree of variability (and in some cases at unacceptably high quantities), they did not address the parameters required to arrive at the quantity of arsenic that a child is likely to ingest or absorb by coming into contact with treated timber.

Neither the overseas data (including the aforementioned USA study), nor the Australian data adequately covered the range of timber products from different manufacturing plants, the age of treated timber structures or the environmental conditions to which treated timber structures might be exposed relevant to Australian conditions.

Since insufficient data are available to resolve key concerns, the APVMA cannot be satisfied that there is no undue risk from the continuing use of products containing CCA to treat timber that is used in the manufacture of equipment and structures with which the public are likely to come into frequent contact. The APVMA proposes that the label instructions for CCA timber treatment products be varied to prohibit the use of products containing arsenic for treating timber that will be used in structures with which members of the public are likely to come into intimate and frequent contact, such as children's play equipment, picnic tables, decking and handrails.

However, there is no evidence to preclude use of arsenic-treated timber products where there is no frequent physical contact, such as telegraph poles, rural fence posts or other structural timbers. Alternative timber protection products that do not contain arsenic and that are effective against the same pests are registered by the APVMA and can be used in applications for which CCA is recommended to be prohibited.

The APVMA has no regulatory authority over existing CCA-treated timber structures. While there is not enough scientific evidence to confirm the safety of ongoing use of CCA to treat timber used in applications such as decks and play equipment, the Authority does not have evidence to conclude that the existing structures are unsafe. The APVMA is liasing closely with the USEPA in relation to the outcome of their extensive assessment of this issue which is anticipated early next year. Results are expected to shed further light on the safety of existing CCA-treated structures.

Arsenic trioxide

Arsenic trioxide is unlikely to be a public health hazard as the application of the products is carried out by licensed pest control operators (PCOs) and the treated timber parts are concealed. The PCOs who are eligible to carry out the application of arsenic trioxide are assessed as competent to Certificate II level of the National Pest Management Industry Competency Standards. Holes are drilled into infested timber or trees and 1 –2 g of the product is applied per infestation. The opening is then covered with a tape. For these reasons, products containing arsenic trioxide are not considered likely to present a public health risk.

3. ENVIRONMENTAL ASSESSMENT SUMMARY

3.1 Introduction

The scope document for this arsenic timber treatments review outlined environmental concerns regarding timber treatments mainly related to the potential contamination of sites where timber has been treated and where disposal of treated timber occurs. CCA has been extensively used in the past as a timber treatment and there are sites that have potentially been contaminated due to leaks and spills from treatment plants or drips from freshly treated timbers. Other areas for consideration were release of CCA components into the ground as treated timbers were slowly degraded, and possible subsequent mobility to other areas and effects on non-target organisms. The burning of CCA-treated timber was also noted as a particular environmental concern. Environmental risks associated with the use of arsenic trioxide termite treatments were also considered.

3.2 Environmental exposure

3.2.1 Release and method of use

Copper chromium arsenate is applied to wood in special vacuum-pressure treatment facilities. Annual use of CCA in Australia is thought to be ~6500 tonnes, applied at ~90-100 treatment facilities. The treated timber is then transported for wholesale and retail sale, for subsequent assembly of timber structures on site, or for the manufacture of timber products. CCA-treated wood in structures is likely to remain *in situ* for a prolonged period (of the order of 10-50 years), depending on the nature and purpose of the structure. It might then be re-used, recycled or disposed of in various ways. Release of CCA components to the environment may therefore occur as a consequence of manufacture, transport and storage of the CCA product, treatment, transport and storage of the treated wood, and construction, service and disposal of the structure.

Rates of application of CCA to timber are described in terms of minimum retention and penetration requirements in the treated wood under Australian Standards for Specification for Preservative Treatment (AS 1604.1 to 1604.5 for various types of timber product, published in 2000). Australian Standards have also been specified for plant design, plant operation and methods for sampling and analysing timber preservatives and preservative-treated timber (Australian/New Zealand Standard Timber Preservation Plant Safety Code, Parts 1 and 2: AS/NZS 2843.1-2, and AS/NZS 1605, published in 2000). AS/NZS 2843:2000 refers to and incorporates information from the Australian Guidelines for Copper Chrome Arsenate Timber Preservation Plants.

Arsenic trioxide termite dust is applied into the termite workings by gentle puffing with a hand blower. Indicated rates are 1-2 g per infestation. Treatment occurs to widely dispersed, confined areas where termites are present in structures and nearby trees. Hence secondary dispersal is likely to be in the vicinity of the treated material, and/or destinations of the treated material during disposal when the structure is modified or removed.

3.2.2 Evidence of environmental contamination

There are several published reports from overseas of contaminated sites where CCA treatment has occurred or is still occurring, in some cases with demonstrated off-site movement into streams or lakes. These generally refer to treatment plants that are old and have been abandoned or decommissioned. Hence they were likely to have been in use before modern environmental standards were adopted. However, they do indicate the extent to which environmental contamination may occur if suitable facilities and management practices are not in place. There are likely to be many more such published and unpublished reports, presumably including some for treatment sites in Australia. Evidently, there may also be data available regarding leachate from landfill sites containing CCA-treated timber.

The available studies show that soil concentrations of arsenic, copper and chromium may accumulate to high levels in the area of CCA treatment plant facilities, particularly in soil near the impregnation cylinder or concrete pad on which the cylinder stood, and also in areas where wood piles had stood for fixation and drying. Contamination of some areas was also suspected to be due to sources such as aerosol release during the application process, leaching from stored wood, and disposal of contaminated sawdust. UK data indicated high contamination of off-site soil through natural drainage. Maximum measured concentrations of arsenic, copper and chromium in the surface soil at different sites ranged from 513-73,000 ppm, 74-82,000 ppm and 153-37,000 ppm, respectively.

Concentrations of these elements generally fell with increasing soil depth, but soil concentrations were sometimes still clearly elevated below the surface and in one case concentrations rose in the soil B horizon. The rate of decline differed between the elements and was affected by the soil type, consistent with the known behaviour of each element in soil. In more than one case mobility of chromium was clearly evident (to as deep as 50-60 cm), presumably because it reached the soil in the more mobile form of Cr^{VI}. Estimations of arsenic concentrations in the soil solution at one site were ~0.7% (range 0.1-1.6%) of the total arsenic content, whereas copper and chromium present in that soil were less soluble. At the site where arsenic concentrations reached as high as 18,000 ppm in soil, peak observed soil solution concentrations of arsenic, copper and chromium were 80 ppm, 8 ppm and 10 ppm, respectively. In some situations levels of CCA elements declined towards background levels at soil depths well above groundwater and tests of groundwater showed no accumulation. However, the reason for evaluating one site was that arsenic had been detected in an adjacent drinking well.

Mobilisation off site of arsenic, copper and chromium residues from contaminated soil at former treatment plants has been shown to have occurred. In one case, testing with an aquatic moss known to accumulate trace metals indicated some movement of arsenic, copper and chromium to an adjacent river had occurred during a rain event. In another case, sampling of a brook flowing through an old site showed elevated arsenic and copper levels (59 µg/L and 50 µg/L, respectively). Sediment concentrations (0-5 to 10-15 cm depths) of arsenic, copper and chromium were high in a pool formerly used to hold treated logs (306-829 ppm, 167-788 ppm and 81-563 ppm, respectively). Surface sediment concentrations of arsenic in particular were also elevated in the brook (306 ppm), confluence of the brook and a river (66 ppm) and at a sampling point near where the river entered a lake downstream (18 ppm). The latter point was noted as just exceeding the Canadian Environmental Quality guideline for arsenic in freshwater sediments (18 ppm). A US study showed transport of CCA components had occurred to as far as 4 km downstream in a watershed which received surface run-off from a wood preservative facility, in this case with transport of chromium most evident (maximum sediment concentrations nearer the facility were ~70 ppm for arsenic and copper and 140 ppm for chromium).

A study of a suburban lake in the USA indicated that a greater mass of arsenic and copper was input into the lake than was exported in the study year. For arsenic, leaching from CCA-treated timber in docks, decks and bank stabilisation structures directly on and around the lake was likely to have been an important contributor, together with stream inflow, the latter also evidently predominantly carrying arsenic from anthropogenic sources. One source of arsenic in stream flow may have been leaching from treated wood elsewhere within the suburban catchment, but there were inadequate data presented to confirm this. The major source of copper to the lake was road run-off.

Thus, heavy contamination of CCA treatment sites has clearly occurred from past practices. At the sites where data have been evaluated, the heaviest soil contamination was generally confined to areas near likely sources of CCA treatment solution, with leaching of CCA components deeper into the soil reflecting soil characteristics and the extent of contamination, potentially reaching groundwater in some situations. Mobilisation of CCA elements off-site through run-off and/or leaching has also been found, with arsenic accumulating in downstream sediments. No conclusive data are available regarding off-site movement of arsenic leached from wood in service, except for situations where treated wood is directly in contact with, above or adjacent to a waterbody. However, it is likely that a proportion of arsenic or other heavy metals in run-off would accumulate in downstream sediments, particularly where affected waters do not reach the ocean.

3.3 Environmental fate

3.3.1 General fate in soil and water

Arsenic (atomic symbol As) is an element with metalloid properties. Arsenic in soil may be present in the trivalent As^{III} form (arsenite) or the pentavalent As^{V} form (arsenate). In well-drained soils it is normally present in the form of arsenate because of the oxidising conditions likely to be present. However, in reducing conditions (soil saturated with water and poorly oxygenated), it is present largely as arsenite. Arsenite is generally more mobile in soil and more toxic to terrestrial organisms than arsenate. Arsenic may be adsorbed to various soil colloids, most importantly iron oxides/hydroxides (in acidic and alkaline soils). Arsenic may also adsorb to clay, organic matter, aluminium oxides/hydroxides (acidic soils) and carbonates (calcareous soils). Precipitation as relatively insoluble substances may also occur (eg iron arsenate or sulphides of arsenite). Arsenate behaves similarly to phosphate in soils, with phosphate competing to suppress arsenic adsorption. Soil organisms may convert arsenate and arsenite to substances such as methylated arsines, which are volatile and can be lost from the soil to the atmosphere. In natural waters, the dissolved forms of arsenic present include arsenate, arsenite, monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA). Various complex processes may occur in the water column and sediment, including oxidation and reduction, adsorption to clay surfaces, iron oxides, aluminium hydroxides and organic matter, methylation and demethylation, with microbial action important and transport occurring by turbulence and convection.

Compounds of the metal copper usually have a valence of 2+ (II, cupric) under oxidised conditions or 1+ (I, cuprous) under reducing conditions. As a cation, copper can exchange with other cations on clay and organic matter. Most copper deposited onto soil is strongly adsorbed to the upper few centimetres of soil, being especially bound to organic matter, as well as being adsorbed by carbonate minerals and hydrous iron and manganese oxides. Greatest leaching of copper occurs from sandy soils rather than clays and peats, while acidic conditions favour leaching to groundwater. Under some conditions, copper can also be transported bound to soluble organic matter. Processes influencing the fate of copper in aquatic systems include the formation of inorganic and organic complexes, sorption to metal oxides, clays and particulate organic matter, bioaccumulation and exchange between sediment and water.

In natural soils and waters, the metal chromium (Cr) occurs mainly in the trivalent (Cr^{III}, chromous) and hexavalent (Cr^{VI}, chromic) forms. Cr^{III} interacts strongly with negatively charged ions and colloids in soil, and as a result, is relatively immobile. In contrast, Cr^{VI} is generally more soluble, mobile and bioavailable, and also more toxic than Cr^{III}. Cr^{VI} is present as bichromate or chromate (ie as an anion) rather than as a cation in most soil environments. Though some Cr^{VI} can be formed in some soils, in general chromium is present in soil as Cr^{III} unless added as such to the soil.

The active ingredients in CCA treatment solution or wood treated with CCA are not themselves volatile, but arsenic compounds may be volatilised during burning of treated wood, and the formation of volatile compounds is a possible route for arsenic-containing substances in soil. Arsenic trioxide in termite and plywood glueline treatments may also be volatilised if the wood is burnt.

As pH and the content of organic matter, clay and iron oxides, differing redistribution of the elements may occur down the soil profile, owing to differences in their mobility. A low soil redox potential increases the mobility and toxicity of arsenic through reduction of As^{V} to As^{III}. One study showed that the amount of copper and chromium present in soluble or exchangeable form was higher in mineral soils, but fell for chromium particularly in organic soils. Arsenic was present both as As^{V} and As^{III}, but principally as As^{V}. However, As^{V} content was highest in mineral soil, decreasing as the soil organic matter content increased, possibly due to microbial action, as well as chemical actions after the CCA solution was added to the soil.

A lysimeter study in New Zealand with CCA solution added to the soil surface indicated the potential for Cr^{VI} to leach in some soils. Chromium as Cr^{VI} could be leached to groundwater in the event of a large uncontained spillage of a concentrated CCA solution, particularly in soils with low organic matter contents, where leaching occurs soon after spillage, and with high water input conditions. Once present in the subsoil, a slow rate of reduction would be likely to leave Cr^{VI} anions mobile for a considerable period of time. Another New Zealand lysimeter study examined leaching from CCA-treated wood mulch. This study showed the substantial capacity of a soil high in organic matter to adsorb copper, chromium or arsenic leached from CCA treated material. Hence they suggested CCA elements in leachate could be retained in well constructed landfills using clay capping layers.

3.3.2 Leaching of copper, chromium and arsenic from treated wood

3.3.2.1 Methods of assessment

Fixation refers to the process of chromium reduction and related reactions that render the active elements resistant to removal from the wood. Until fixation is almost complete, the copper, arsenic and particularly chromium in the more toxic Cr^{VI} form are much more susceptible to leaching. Various countries therefore recommend or require that fixation be monitored and treated wood not moved from the drip pad until fixation has reached an adequate level, as do the relevant Australian standards.

Fixation can be monitored by various techniques. Evaluation of Cr^{VI} levels is most critical, as complete conversion of Cr^{VI} in the application solution to Cr^{III} in the timber can be considered as indicating fixation is complete, though further changes may continue at a slow rate. Specification of an acceptable level of fixation is not straightforward: eg significant leaching of Cr^{VI} may still occur if a 99% fixation level is used, and the amount of leaching is then directly related to the retention level of CCA in the timber. The standard against which techniques can be compared is determination of Cr^{VI} and total copper, chromium and arsenic concentration in liquid expressed from treated wood by a hydraulic press. Useful techniques for evaluating fixation for process control appear to be determination of Cr^{VI} in leachate from small borings of treated wood by a diphenylcarbazide colorimetric technique (such a technique is described in the Australian standards, with guidance as to what concentration in the tests can be considered to indicate well-fixed timber), and a chromotropic acid spot test on wood borings. The latter gives only a qualitative indication of the presence or absence of Cr^{VI} residues, but the limit of detection of the test has been considered to be adequately sensitive by various investigators. More realistic evaluation of the extent of fixation using the shower test method with minipacks of wood helps overcome sampling and variability problems with methods using borings, but is more expensive and time consuming.

A diverse range of laboratory and field leaching test methods have been used with CCA treated wood to compare the effects of different CCA treatment processes, evaluate influences of soil and climatic conditions, or to predict worst case or realistic losses in use or upon disposal. Several aspects of the way such tests are conducted affect their outcome, eg the surface area to volume ratio of the wood material, duration of the test, composition and replenishment of the leaching solution, nature of exposure to the leaching solution (continuous or intermittent shower or rain, bathed in liquid which is static or shaken), contact with soil, etc. Hence the methods used need to be considered in interpreting test data, and choice of method is important when planning tests. Various standardised test methods have now been described for evaluation of CCA treated wood in practice (American Wood Preservers Association and British Standards Institute methods), prediction of worst case leaching rates for environmental assessment purposes (OECD emission scenario document for wood preservatives) and prediction of worst case leaching rates for environmental regulation or management purposes with waste material (eg the Toxicity Characteristic Leaching Procedure to characterise waste in regard to landfill, or Synthetic Precipitation Leaching Procedure to evaluate material where land application occurs outside landfill situations). Some research has been undertaken towards combining leaching rate data with that from other tests to estimate potential leaching rates in service, but in general, laboratory methods are useful for exploratory, comparative and regulatory purposes rather than realistic prediction.

3.3.2.2 Factors influencing fixation and leaching during treatment

A large number of factors pertaining to the CCA treatment process influence the rate at which fixation occurs, quality of the product produced and subsequent leachability of CCA components. These include:

- The composition of the CCA formulation – there is an optimal range in the relative proportions of chromium to copper and chromium to arsenic present to achieve a satisfactory balance between maximum efficacy together with minimum leachability. Too low a Cr:As ratio results in a higher level of arsenic leaching, as has been evident with the US CCA-B formulation;

- Retention rate of CCA in the treated timber – while the amount of copper, chromium and arsenic present in the wood and potentially available for leaching increases with increasing retention, leachability may be significantly worse with very low retention rates (~1-2 kg/m^3), possibly due to incomplete fixation of arsenic;

- The pH and concentration of the CCA solution used during treatment – this may affect the leachability of the product in service, and there is a correlation between the final pH of the wood after treatment and leachability of copper and arsenic;

- Temperature during treatment and fixation – this greatly affects the rate at which reactions occur, hence particularly where ambient temperatures are low, various higher temperature or steam processes may be used to reduce the time wood needs to be kept under protected conditions or on drip pads, but in most areas of Australia available data suggest that ambient temperatures for much of the year allow fixation to occur within a few weeks (eg at 16-24°C wood temperature, 99% fixation is estimated to take about 9-21 days);

- Factors such as air circulation (hence stacking, steam supply etc), relative humidity and sunlight – these may also affect the uniformity of treatment and fixation and quality of the product (eg colour), eg, it may be necessary with some treatment systems to maintain adequate relative humidity to prevent excessive drying, as this can arrest the fixation process;

- Wood species, wood quality, seasoning and the presence of heartwood vs sapwood – these may affect the performance of CCA treatments in regard to subsequent leachability, may alter process requirements to achieve the desired penetration and retention level and may limit the success of treatment;

Thus CCA treatment appears to be a highly skilled task requiring thorough knowledge and experience if timber is to be appropriately treated to the desired penetration and retention, while maintaining suitable quality and environmental standards. There are choices in the composition of treatment solution and timber to be treated and strategies and application process which affect leachability of CCA components in treated wood in service. Regarding actions which might relate to product registration or product labels, Australian Standard AS-1604 2000 appears to provide a satisfactory ratio of Cr:As to minimise leaching of arsenic, being similar to the US formulation type CCA-C. The lowest retention rates recommended in Australia equate to ~0.9-1.8 and 2.6-5.2 kg/m^3 as CCA oxides, respectively. However, timber treated to the lowest hazard classes (H1 and H2) are intended for inside, above ground use where there is no exposure to wetting, and should therefore not be exposed to leaching during service. Aspects such as the choice of timber to be treated and process conditions would be expected to be strongly influenced by the knowledge and experience of the applicators and nature of the facilities available.

3.3.2.3 Disproportionation, migration and redistribution of CCA components in timber

Disproportionation (higher chromium levels in the surface layer of wood) is a factor which needs to be born in mind when considering the results of measurements of component levels in treated timber. There is evidence of copper and arsenic migration within the wood during a leaching treatment (constant soaking), confirming that CCA components are not completely immobilised in treated wood. There is also evidence that some protective effect may be gained in untreated wood in contact with treated wood, through movement of copper in leachate into the untreated wood. Thus untreated wood in a structure could potentially be contaminated with copper from CCA-treated wood, but the concentrations of copper, chromium or arsenic that might result would presumably be very low relative to treated wood and also very limited in extent.

3.3.2.4 Factors affecting leaching from timber during use

It is reasonable to expect that the amount of rain, irrigation or other sources of water to which treated timber is exposed will affect the leaching rate. The nature of rainfall is also thought to affect leaching rate, eg in one study short heavy showers did not produce as much leaching as the equivalent mm of steady rain, presumably due to a longer wetting period and deeper water penetration with the latter. A greater surface area to volume ratio of the treated timber is likely to increase leaching rate, as shown by numerous laboratory and field trials discussed elsewhere. A number of other site factors may also affect the rate of CCA leaching from timber in use, including:

- water pH (eg acid rain);
- the presence of organic acids such as citrate, acetate or COOH groups in humic acid (organic matter);
- soil pH and buffering capacity;
- inorganic salt in soil, particularly phosphates;
- soil cation exchange capacity;
- surface area of soil particles (amount of clay present, soil texture);
- iron, aluminium and manganese oxide or hydroxide complexes;
- water temperature.

Thus there are situations such as in silage pits where materials other than CCA-treated timber could be used to avoid excessively high component leaching rates, though the example of silage pits pertains more to leaching of copper than arsenic or chromium. Accelerated leaching due to acid rain is unlikely to be a problem in Australia, hence it may be that leaching rates are lower in Australia than areas where acid rain occurs frequently.

3.3.2.5 Effects of water repellent treatments, coatings and cleaning methods on leaching

Water repellent treatments to reduce checking, splitting, warping and twisting of timber such as decking and stains can be pressure incorporated into the wood at the same time CCA is applied. Studies suggest that some factory applied water repellent treatments do reduce leaching of CCA components. However, there were indications of differences between products, effects of rates, reactions between some water repellent formulations and CCA treatment solutions, and inconsistent results possibly associated with the nature of individual rainfall events. Hence further data and experience appear necessary to clarify the impacts of factory applied water repellent treatments on CCA leaching rates.

Various types of surface coatings and stains are commonly applied after construction and studies have shown that these may also reduce CCA leaching, by as much as ~50%. However, such coatings are likely to need relatively frequent replacement to maintain their water repellent effect. In sensitive environments there may be environmental contamination considerations regarding dripping or spillage during application, and surface preparation for recoating may also release particles containing CCA components.

An evaluation of the effect of various deck washing and brightening treatments indicated that products differed in the extent to which they released CCA components according to their active constituents, with high copper extraction by acid formulations and higher chromium extraction by strongly oxidising formulations. In general, the amount of copper and arsenic leached in a single wash was comparable to that from a rainfall event. While not a problem with the other products tested, release of Cr^{VI} by the alkalis and oxidising agents sodium hydroxide, sodium hypochlorite and (presumably sodium) percarbonate was of concern. Hence the authors recommended that products of this type should not be used on CCA-treated wood.

Thus the use of some water repellent treatments incorporated at the time of CCA treatment may have beneficial effects in reducing CCA leaching, but further research is necessary to clarify what treatments work best. Various coatings and stains applied to timber that has already been treated with CCA may in some cases greatly reduce CCA leaching, but need to be reapplied regularly. Washing a deck with various types of cleaning and brightening products is generally likely to be similar to a rain event, except that products containing sodium hydroxide, hypochlorite or percarbonate should not be used as they enhance release of Cr^{VI} from CCA-treated wood.

3.3.3 Field studies of CCA leaching from timber and addition to soil

3.3.3.1 Studies of CCA-treated poles, posts and stakes

Several investigators overseas have evaluated CCA component concentrations in surface soil and different soil depths at points adjacent to and at various distances out from CCA treated stakes, posts or poles, and in two cases, in soil below treated items. In some cases, data available for retention of CCA in the wood was available to indicate the extent of loss from the wood. Some data were also obtained for concentrations in water running off poles and for concentrations in soil water. The results of these studies are summarised below. It should be noted that surface area effects mean that leaching is relatively high for stakes used for test purposes, and that in some environments acid rain may have exacerbated leaching.

Test stakes and posts:

- Leaching from CCA-B treated test stakes (18-28 kg/m^3) standing in soil at a wet site for 2-28 years led to losses of ~30-40% of initial retentions of arsenic and copper, with higher losses from the top and bottom ends of the stakes, but with little loss of chromium evident. Losses of arsenic and copper at a drier site were much less, ~10-30% for arsenic and 10-20% for copper. Differences in retention over time between the sites may also have been due to differences in soil characteristics. Leaching in stakes held horizontally above the ground for 7 years indicated very high loss of arsenic and copper (50% and 80%) from the end grains, and as might be expected, greater loss from the more exposed upper surface than the lower.

- Low loss of chromium from CCA (UK Type II, 6.25-12.5 kg/m^3) treated stakes was also found in another study standing in soil in the field. Soil concentrations of arsenic and copper declined sharply with distance from the stakes, from 132-184 ppm and 35-84 ppm, respectively, 0 cm from the stakes, to 17-42 ppm and 5-8 ppm at 100-200 mm. A high proportion of total arsenic in soil near the stakes was available, but only a small proportion was available at 100-2000 mm.

- One study investigated lateral and vertical distributions of CCA elements in soil beside and below stakes treated with CCA-A (10.6 kg/m^3) or CCA-B (8.8 kg/m^3), inserted 23 cm deep in the soil. Arsenic levels were much higher with the CCA-B formulation despite a slightly lower retention rate. With CCA-B, mean soil concentrations of arsenic with lateral sampling of the surface 15.2 cm declined from 183 ppm adjacent to the stake to 118 ppm at 7.6 cm, 7 ppm at 15.2 cm and 4.9 ppm at 22.3 cm. With sampling directly beneath the stake (ie from ~23 cm below the soil surface), mean concentrations of arsenic declined from 108 ppm in the first 15.2 cm below the tip of the stake, to 21.4 ppm at 15.2-30.5 cm and 1.1 ppm at 30.5-45.7 cm and deeper. Similar patterns occurred with CCA-A, but at lower concentrations (peak 73.2 ppm at the surface adjacent to the stake and 18.9 ppm immediately below the stake). Broadly similar trends also occurred with copper and chromium, except that their mean maximum concentrations were higher with CCA-A than CCA-B (48.3-56.6 ppm at the surface and 47.9-75.8 ppm immediately below the stakes for copper, 22.9-25.1 ppm and 24.2-45.9 ppm for chromium).

- Concentrations of arsenic and copper in soil adjacent to CCA-B treated posts (8-12 kg/m^3) in place in a test site for 47 years fell with increasing depth, but significant leaching downwards in the sandy soil was evident for all three elements. With posts in undisturbed situations, surface concentrations of arsenic, copper and chromium adjacent to the posts declined from 7.2-8.2 ppm, 254-301 ppm and ~0.5 ppm, respectively, compared to 2.9-3.3 ppm, 15.8-25.9 ppm and 0.3-0.9 ppm, respectively at 45-47.5 cm. Concentrations of all three elements fell rapidly with increasing lateral distance from the posts at all depths (0.2-0.8 ppm, 0.3-2.8 ppm and 0.03-0.05 ppm, respectively, over all sampling depths at 30 cm from the posts). Sampling of soil concentrations immediately below posts showed a decline from elevated levels immediately below the posts to background levels by 120 cm below them.

Posts and poles in actual service:

- Measurements of CCA retention in utility poles after removal from 1-50 years service indicated arsenic was leached more that the other components. There was some evidence for relatively greater leaching of copper from the below ground pole surface.

- One study investigated lateral and vertical distributions of CCA elements in soil in the vicinity of utility poles treated with CCA-C (7-33 kg/m^3, in service from 1-13 years). Soil concentrations fell rapidly with increasing distance from the poles, in most cases approaching background levels within 25 cm or even 10 cm from the pole. Maximum concentrations of arsenic, copper and chromium were respectively, 325 ppm, 995 ppm and 280 ppm. In this study, leaching of copper evidently occurred to the greatest extent relative to background levels, with concentrations often exceeding 100 or 150 ppm at ground level near the poles or occasionally at depth (0.5, 1 or 1.5 m) near or 25 cm away from the pole. Arsenic concentrations occasionally exceeded 20 ppm at the ground surface near the poles and occasionally at depth. Contaminant levels increased with age in service and were generally highest in wet organic soils. Measurements of element concentrations in rainwater running down treated poles indicated concentrations of 0.9-7.7 ppm arsenic, 2-16 ppm copper and 0.7-2.5 ppm chromium. Concentrations in rainwater were not related to pole age, leading the authors to suggest that a steady state equilibrium is reached in leaching rate.

- Another study showed a clear decline in arsenic concentration with lateral distance from treated posts and poles, in surface soil at least. Leaching of arsenic from 17 years old CCA-B treated posts was high (soil arsenic concentrations at depths of ~15 and 30 cm at 0-5 cm from the posts = 303-307 ppm and 197-290 ppm, respectively, falling to 22.3-41.9 and 8.5-14.6 ppm at 10-15 cm from the posts). Soil concentrations were much lower in smaller, 17 years old CCA-A treated posts in the same soil (7.0-14.5 ppm), and in 32 year old CCA-A treated poles in a different area (surface concentrations 23.9-109 ppm at 0-5 cm from the poles, falling to 11.5-25.3 ppm 28-33 cm from the poles).

- A study of CCA-B treated utility poles after 2, 4 and 10 years service indicated average losses of arsenic, copper and chromium from various vertical portions of the poles were

22-34%, 11-22% and 3-24%, with greatest losses occurring at ground level. Soil concentrations ranged from ~28-280 ppm (average ~120 ppm) for arsenic (considerably above background levels of ~0.7-3.3 ppm), and ~9-87 ppm for copper and chromium (averages ~79 ppm and 65 ppm), showing high leaching of arsenic from the CCA-B formulation. Chromium leaching was greater than expected, which the author suggested was possibly due to acid rain effects.

- Evaluations of element retention in CCA-C-treated utility poles in service for 1-15 years in wet and dry sites showed that copper and arsenic were leached significantly from the portions of the poles in contact with water in wet sites, whereas chromium leaching did not appear to be affected by location in the pole or by site. Concentrations of arsenic, copper and chromium in soil water collected near 26 poles ranged from 20-1400 µg/L for arsenic, 40-970 µg/L for copper and 10-280 µg/L for chromium.

- In another study, surface soil concentrations in soil adjacent to CCA-treated utility poles averaged 17.0 ppm for arsenic, 63.8 ppm for copper and 71.0 ppm for chromium for poles in place 0-2 years, with a clear trend of declining concentration with depth. However, soil concentrations were quite different for poles in service for 2-5 or 5-10 years (2.7 and 2.6 ppm for arsenic, 19.9 and 27.3 ppm for copper and 14.5 and 71.0 ppm for chromium, respectively), with a less clear trend in concentration with depth. The authors related these differences to the very sandy soil at the site, with poor retention of added chemicals leading to loss of initially high leaching increments to lower depths in the soil.

Thus several studies available of soil metal concentrations in the vicinity of CCA-treated stakes, poles and posts show that arsenic, copper and chromium do leach from the treated wood, but that lateral movement is very limited in dry sites, and unless the water table is very shallow, leaching downwards in the soil is unlikely to carry these elements to groundwater. Data indicated maximum soil concentrations generally occurred at the surface adjacent to the post or pole, consistent with the prime source of soil contamination being leachate from rainfall running down the pole into the soil. Measured concentrations of arsenic, copper and chromium near posts and poles at this point ranged from ~7-325 ppm, ~9-995 ppm and ~0.5-280 ppm, respectively. The highest levels of arsenic were from CCA-B formulations, with the highest concentrations near CCA-A treated poles being 109 ppm. Measurements of CCA retention in wood confirm that over time, a proportion of the arsenic, copper and chromium in the wood is lost through leaching and that some redistribution of these elements may occur in the wood. Measurements of element concentrations in rainwater running down treated poles in one experiment indicated concentrations of 0.9-7.7 ppm arsenic, 2-16 ppm copper and 0.7-2.5 ppm chromium. Measurements of groundwater surrounding poles in wet sites indicated concentrations of 20-1400 µg/L for arsenic, 40-970 µg/L for copper and 10-280 µg/L for chromium. The results indicate a wide spread in peak soil concentration, which could have arisen through various factors associated with the timber (including formulation type, initial retention, age and dimensions) and site (soil characteristics affecting leaching from the wood and mobility in the soil, climate, and potentially acid rain).

3.3.3.2 Studies of structures such as decks, fences, playground equipment and walkways

Several investigators overseas have evaluated CCA component concentrations in surface soil directly under, adjacent to or in the vicinity of various types of structures. All these studies dealt with relatively recent structures that appear to have been treated with formulations similar to the CCA-C type. Background levels were generally assessed from samples obtained a few metres away from areas influenced by treated wood. Mean surface levels of arsenic, copper and chromium in the most exposed areas (directly under or adjacent to CCA-treated surfaces) in investigations of structures such as fences and public decks, walkways and footbridges in various US states were 11.5-79.1 ppm (range 1.6-350 ppm), 6.2-43 ppm (range 1.7-216 ppm) and 8.2-71.1 ppm (range 2.8-199 ppm), respectively. Background levels were <1-3.7 ppm for arsenic, <1-17 ppm for copper and <1-20 ppm for chromium. In two studies, mean arsenic concentrations in exposed areas were ~20 fold higher than mean background levels, while mean copper concentrations were ~4.4-6 fold higher and mean chromium concentrations ~2.2-3.5 fold higher. Mean arsenic concentrations were ~7 fold higher than mean background levels in a third study, where mean copper and chromium concentrations were generally similar to or slightly lower than mean background levels.

Limited data in one study indicated similar to slightly higher arsenic levels below decks compared to 15 cm from the edge of the decks. In the one study examining CCA-treated fences, concentrations of arsenic, copper and chromium 30 cm from the fences were generally lower than directly under the fences. Limited data in a study with eight CCA-treated structures suggested arsenic leached to a slightly greater depth (up to 20 cm) than copper or chromium (up to 7.6 cm). Preliminary results for a study where leachate from miniature decks exposed outdoors in Florida was collected, leachate from a CCA-treated deck contained an average arsenic concentration of 1.4 mg/L (range 0.8-1.8 mg/L). Other studies have shown concentrations in drip water from CCA-treated decks of 1.0-1.7 ppm arsenic, 1.3-1.9 ppm copper and 0.4-0.7 ppm chromium four months after installation, and 0.3-1.7 ppm, 0.2-0.8 ppm and 0.2-0.5 ppm, respectively, after 2 years.

An Australian study evaluated leaching from model deck sections exposed over a 300 day period to a total of ~600 mm natural rainfall in Brisbane. Concentrations of arsenic, copper and chromium in composite leachate samples were ~0.5-1.2 mg/L, 0.4 mg/L and 0.3 mg/L, respectively. Over the test period, losses of the arsenic, copper and chromium initially retained were ~4%, 1% and 1%, respectively. Extrapolation of mathematical models fitted to the data to a similar rainfall rate over a 10 year period gives estimates of cumulative losses of arsenic, copper and chromium of 6947, 451 and 1258 mg/m^2 deck, respectively. If distributed into the surface 15 cm of soil below a treated deck, this could increase soil arsenic concentration by ~33 ppm, a comparable level to that found in the field measurement studies discussed above. In a study of a walkway in a Tasmanian wilderness area, no leaching of arsenic, but some leaching of copper and chromium was detected from CCA treated wood at sample points adjacent to the track compared to samples >2 m away. Limited sampling suggested there was little downward movement of copper or chromium, and a very rapid decline in chromium concentration with lateral distance from the track, to background levels at ~15-30 cm. That leaching of arsenic was not detected when copper and chromium were found to leach is surprising and may indicate that there were inadequacies in sampling or sample extraction procedures.

Evaluations of arsenic concentrations in base material (the surface layer of soil, sand or wood chips) beneath playground equipment indicate localised increases in arsenic and sometimes copper and chromium levels in the playground area, eg in the vicinity of support poles or near the structure of sand boxes. In one study, sites were evaluated on a grid pattern and also near selected support poles. Measured concentrations of arsenic in three playgrounds where it appears clear that CCA-treated wood was present ranged from ~1-66 ppm (site wide means 0.7, 6.4 and 11.7 ppm, background <1-4 ppm). Measured concentrations of copper in the playground areas ranged from ~1-62 (site wide means 1.5, 10.3 and 6.1 ppm), and those of chromium from ~1-61 (site wide means 1.5, 9.5 and 6.3 ppm). In a study of sand near wood in sandboxes or near playground supports, there was a more than five-fold decline in surface concentrations of arsenic (but not copper or chromium) between sand adjacent to the wood and 50 cm away from it. The available data also suggest some downward movement of arsenic to 20 cm near the wood.

Thus studies with miniature decks indicate concentrations in drips or run-off from the decks during rainfall were ~0.3-1.9 mg/L for arsenic, ~0.2-1.9 mg/L for copper , and ~0.2-0.7 mg/L for chromium. Mean arsenic concentrations in soil beneath or adjacent to a range of structures were increased by ~7-20 fold compared to mean background concentrations, to ~12-79 ppm, though individual sample points ranged as high as 350 ppm. Copper and chromium concentrations in soil were increased by up to ~3-6 fold, but one study detected no increases for either element, although arsenic concentrations did increase. Available studies indicate measured arsenic concentrations in surface cover in playground areas of 1-66 ppm, with the higher values localised to areas such as the vicinity of support poles or treated wood surfaces in sand pits.

3.3.4 CCA components on the surface of treated wood

Regarding environmental exposure, it is likely to be residues of CCA components on or near the surface of treated timber that would be most susceptible to leaching at any particular time. Several studies have been conducted of surface dislodgeable residues for the purposes of human health assessment, with the emphasis on arsenic. Overseas studies using techniques where CCA-treated wood was wiped with a moist tissue or pad have indicated mean surface levels of arsenic of 6.3-37 µg/100 cm^2 (range 0.6-122 µg/100 cm^2). A higher mean of 68 µg/cm^2 was cited for a further study for which no details were available. A study where surface residues on treated wood were evaluated by measuring levels removed by wiping with a moist human hand indicated similar levels, with mean arsenic levels of 31.7 µg/100 cm^2 on unwashed surfaces and 11.7 µg/100 cm^2 on surfaces which had been hosed. However, levels were much lower when the surface was wiped with a dry hand (mean 1.1 µg/100 cm^2 for unwashed timber).

An Australian evaluation of residues on playground equipment using a wipe test method indicated comparable levels of arsenic on horizontal wood surfaces (21 and 24 µg/100 cm^2) to those in similar overseas studies, but much higher levels on vertical surfaces (140, 336 and 710 µg/100 cm^2), possibly because the uprights being in soil were treated to a higher hazard class, or because of accumulation through movement in leachate from further up the vertical posts. In this study and the few others where copper and/or chromium have been measured, the levels of these elements were similar in magnitude to the levels of arsenic present on the same surface (overall range 3-630 µg/100 cm^2 for copper and 4-670 µg/100 cm^2 for chromium).

A technique using a test tube brush indicated mean surface arsenic levels of 120 µg/100 cm^2 (range 12-511 µg/100 cm^2) on treated lumber, of which only 0.9-23.5% (0.8-5.9 µg/100 cm^2) was in soluble form. The highest surface levels have been reported in a study where repeated (5 rinses) gentle scrubbing with a soft brush was used: surface levels of arsenic on the round surface of treated wood were 0.75-4.17 mg/100 cm^2 for arsenic, compared to 12.4-26.3 mg/100 cm^2 in the intact end areas of treated posts.

Thus as might be expected, surface residues detected appear to be influenced by the severity of the wiping/washing process. Surface residues may possibly also be influenced by factors such as the CCA retention rate in the wood, lack of previous exposure of the surface, whether the surface was vertical (perhaps influenced to a greater degree by leachate running downwards or a higher retention rate to suit soil contact) or horizontal, and by end grain effects. One study showed that arsenic levels on the surface of a particular piece of treated timber tended to occur at similar levels over time, though highly fluctuating. This approximate steady state could result from a balance between the amount on the surface washed off by rain, countered by an increase in surface preservative caused by diffusional and erosion effects. Such rejuvenation could continue indefinitely, meaning that arsenic residues could remain on the wood surface (and leaching continue) at a similar level for a number of years. Surface dislodgeable levels of CCA components may also be related to leachability under the same conditions, but this does not appear to have been examined.

3.3.5 Leaching from CCA treated wood in garden and agricultural situations and plant uptake from contaminated soil

Leaching of CCA from wooden blocks has been shown to occur more rapidly when they are buried in compost than when buried in soil or stored in water. Preferential extraction of copper occurred, consistent with the presence of organic acids in compost and leading to failure to protect the wood from fungi by the end of the three year study, whereas the other blocks remained protected. When CCA-treated wood was used to construct compost bins, it was found that after one year, compared to compost elsewhere in the bin or in a plastic composter, compost close to the sides of the bin had higher concentrations of arsenic (~39 and 22 ppm at 0-10 and 0-25 mm, compared to ~7-10 ppm elsewhere) and chromium (~18 ppm at 0-10 mm, compared to 6-9 ppm elsewhere). Results for copper were more variable (12-26 ppm, with no clear pattern), yet it is copper that is likely to have leached most (suggested also by analyses of CCA retention in the boards). Studies of established raised garden beds to investigate the use of CCA-treated timber for garden borders indicated very clearly that arsenic leached into the soil, but that concentrations resulting in the soil fell rapidly with distance (12-55 ppm at 0-2.5 cm, 7-18 ppm at 7.5-10 cm, 4-8 ppm at 30.5-33 cm and 3-7 ppm at 152 cm, background levels 3.6-8.8 ppm). Pot trials using soil with high arsenic levels obtained from soil near the garden edges (~40 and 50 ppm) compared to soil collected from ~1.5 m away (~10 and 3 ppm) indicated that some plants in contaminated soil had higher concentrations of arsenic (eg 378-606 ppm in whole carrot roots) than in the uncontaminated soil (49-92 ppm in whole carrot roots).

Arsenate is an analogue of phosphate and may be taken up by plant roots. The extent of uptake of arsenic by plants and its concentration in plant tissue vary with the plant species, the concentration in soil and soil characteristics affecting availability. One study showed increasing concentration of arsenic in carrot roots with progressive increases in arsenic concentration in soil prepared by mixing various ratios of contaminated soil from a former CCA preservation plant with and uncontaminated soil (arsenic <0.1-1.85 ppm in carrot roots from soil containing 6.5-338 ppm). Another study showed correlations between arsenic levels in compost spiked with CCA and those in plant tissue. Plants vary widely in their uptake and tolerance of arsenic. High levels of arsenic may accumulate in tolerant species, eg 1400 ppm arsenic was found in a plant growing in CCA-contaminated soil containing 6900 ppm arsenic.

Testing of wood mulch prepared with the standard Synthetic Precipitation Leaching Procedure (SPLP) indicated mean arsenic levels in leachate of 153 µg/L (maximum 558 µg/L), exceeding regulatory standards to avoid groundwater contamination in Florida. Other research indicated no negative effects on seed germination or yield from sawdust from CCA-treated wood used as a soil amendment. However, various tissues in the plants accumulated relatively high concentrations of arsenic, copper and chromium. Thus, the use of soil amendments or mulches from wood containing CCA is likely to lead to increases in soil arsenic, copper and chromium concentrations and these would be likely to be reflected in higher concentrations in plant tissues.

No evidence of elevated arsenic uptake was found in studies with vineyard trellis posts and grapevines (fruit, leaf and stem tissues), possibly because leaching from the posts affects only soil close to the pole, and because despite the test vines being planted close to the posts, most root ramification presumably occurred in uncontaminated soil. Another study claimed there was no evidence of enhanced arsenic uptake in bananas exposed to CCA treated support posts for four years, nor to vegetables with stakes in pots.

Thus, garden edges or structures containing CCA-treated timber may leach arsenic and other CCA components into soil. In general, leached arsenic is likely to remain in soil or compost close to the wood, however, it may be taken up by plants growing predominantly in the affected soil, resulting in elevated plant levels. Similarly, soil amendments or mulches containing CCA-treated wood residues may leach arsenic and other components into soil, which may then be taken up by plants. Presumably, plants growing in soil close to decks or fences could also take up elevated levels of arsenic, copper or chromium in leachate from treated timber. However, as with garden borders, in most situations the affected zone of soil is likely to be very limited. Studies investigating plants growing near CCA-treated posts have failed to find elevated CCA-component concentrations in plant tissue, possibly because the plant roots grew largely in uncontaminated soil.

3.3.6 Consequences of timber waste production during construction

A study showed that surface area to volume effects lead to much more rapid leaching of CCA components from construction debris such as sawdust, wood shavings and small off-cuts, with the rate of leaching increasing with decreasing particle size. On a construction site the reservoir of CCA contained in such debris is relatively small compared to the wood in the structure, but debris can cause localised contamination of soil or water in the areas it has fallen. The author argued that contamination of a sensitive site by CCA-treated wood debris can be avoided by construction elsewhere or by collection and removal of debris at the time of construction.

3.3.7 Disposal of CCA treated wood and wood waste

Investigators in Florida in particular have expressed concern at the large volume of CCA treated wood already in use and the potential implications of various disposal pathways for the environment, particularly due to the arsenic content. Some investigators have suggested disposal options that need to be avoided or controlled. Particular concerns centre on arsenic and the potential for it to leach from treated wood and reach soil or groundwater, or to reach the atmosphere during combustion of treated wood by volatilisation or in particulate form.

Studies indicate that the amount of arsenic released to air during burning depends on the combustion conditions, but can range from ~10-90% of the arsenic retained in the wood when it is burnt. Furthermore, the ash or char may contain high levels of arsenic, copper and chromium, and possibly also dioxins and furans formed through combustion. Hence uncontrolled burning of treated wood should not occur. Various studies have been conducted and are continuing in efforts to develop combustion or pyrolysis processes that would safely dispose of the wood, preferably while obtaining energy and recovering the arsenic, copper and chromium from the wood. Studies confirm the high leaching rate likely from wood that has been broken up into mulch or pulverised, hence depending on local conditions and legislative requirements there may be a need to direct such waste to lined, rather than unlined landfills. Leaching from mulch prepared from CCA-treated wood has been confirmed to increase soil arsenic levels and potentially also arsenic levels in plants growing in the soil, hence this use too may be inappropriate, depending again on local conditions and legislation.

Many other disposal approaches for CCA-treated timber have been considered by researchers, including manufacture of products such as wood cement composites or particleboard, re-use of timber for the same or new purposes, and extraction of CCA components from pulverised wood by various solvent, biological or other processes. In addition to disposal of treated timber at the end of its service life, similar issues may arise regarding disposal of wood waste (off-cuts, sawdust etc) generated at the treatment plant or subsequently during wood preparation, construction and maintenance. To avoid environmental contamination with vapours, smoke or ash, at no stage should CCA-treated timber be burnt in uncontrolled facilities.

3.4 Environmental effects

Limited data are available for CCA, so results for arsenic have also been considered.

Arsenic acid consumption, either by acute exposure or through the feed is highly toxic to bobwhite quail.

Based on two fish LC50 values, slight toxicity to fish exposed to acute arsenic acid (AsH_30_4) is indicated. The bully and jollytail LC50 and NOEC values cited in Markich et al (2002) indicate slight to practically no toxicity to acute exposure and slight to very slight toxicity through chronic exposure.

Arsenic acid showed moderate toxicity to the mysid shrimp ($1 < LC50 \le 10$ mg/L) and slight toxicity to the water flea ($10 = LC50 \le 100$ mg/L) while the water flea NOEC indicates moderate chronic toxicity (NOEC in the range10 to 100 mg/L). The As^{III} results indicated slight to moderate toxicity to the organisms tested. *Ceriodaphnia dubia* and the amphipod, *Paracalliope fluviatilis*, were the most sensitive aquatic invertebrates tested with respect to As^{V} toxicity with the EC50s respectively, 0.491 and 0.232 mg/L indicating this valence state of arsenic was highly toxic to these organisms (EC50 of 0.1 to 1 mg/L).

Based on 21 day chronic daphnid toxicity results, a CCA leachate study indicated moderate toxicity with respect to arsenic and high toxicity with respect to chromium and copper (NOECs of 10 to 100 and < 10 µg/L, respectively) to the water flea after 21 days exposure. An earlier 21 day study, however, indicated very slight chronic toxicity with NOECs in the order of 10 to 30 mg/L for the three metals. For the mysid, the seven day NOECs after exposure to CCA-C leachate under low salinity conditions were arsenic 115, chromium 4.7 and copper 80 mg/L, while under conditions of high salinity, the NOECs were arsenic <4.2, chromium <3.2 and copper < 22 mg/L.

Incidences of reported mammalian toxicity appear limited, apart from a report on the poisoning of seven cows after ingestion of ash from burnt CCA treated posts. The IPCS report on arsenic poisoning noted cases of arsenic toxicosis in cattle, horses and white-tailed deer.

Soil biological processes were inhibited in pasture soil following contamination with a CCA timber preservative. At 100 mg/kg of copper, chromium and arsenic the processes were reported not to be significantly depressed, whereas at 400 mg/kg, some depression took place while at 800 mg/kg, normal processes were inhibited.

Based on the EC50 values seen, the effects of arsenic may relate more to the species or the test environment rather than solely the valence state (e.g. EC50s of 6.2 for As^{III} and of 26 and 237 mg/kg soil for As^{V} were reported). NOEC and LOEC values point to effects in the hundred mg/kg soil range. The IPCS report notes that phytotoxicity is dependent on the environment and that arsenic phytotoxicity was recorded in the 1930s.

3.5 Risk assessment

3.5.1 Risks to the environment from the CCA application process

There is ample evidence from evaluations of sites where CCA has been used that poor design and operation of CCA application facilities can lead to significant contamination of the environment, both at the treatment site itself and off-site through run-off into soil and water. Consideration of these data together with a risk assessment conducted in the UK indicates that off-site aquatic contamination could potentially reach harmful levels, though assessment of the aquatic toxicity of arsenic, copper and chromium is difficult because of the complex behaviour of these elements in natural waters and sediment. Suitable procedures should therefore be in place to minimise on-site and off-site contamination with CCA as a direct consequence of the application process.

Furthermore, until fixation of the CCA is achieved, the potential rate of leaching is much greater than after fixation has occurred, including the specific risk of leaching of chromium in the more mobile and toxic Cr^{VI} form. Thus in order to minimise environmental contamination associated with the CCA application/fixation process, protective measures need to extend beyond the actual vacuum-pressure process, through drying of the wood until it is drip dry and until fixation can be considered complete. To ensure adequate protective measures are maintained, treated wood should not leave the application site until fixation is satisfactorily complete. It will therefore be necessary to have appropriate means of identifying when this point has been reached.

Various factors may influence the leachability of CCA components from treated timber in service. Hence inappropriate management of the treatment process may also compromise leachability of CCA components from the final product (ie after fixation is complete). It is also important that the whole application/fixation process is correctly managed to achieve the desired retention rate and penetration depth. Hence appropriately designed and maintained equipment and thorough training of operators are essential to avoid inadequacies in the treatment process causing excessive leaching of the product in service. In addition, a possible consequence of treated timber not reaching the minimum retention and penetration requirements for the specified hazard class is that it could fail prematurely in service. This would add unnecessarily to end-of-use disposal volumes.

3.5.2 Risks to the environment from CCA-treated timber in service

It is clear from semi-field and field studies and *in situ* evaluations that arsenic, copper and chromium can be expected to leach from CCA-treated wood in service in all sorts of terrestrial use situations, with and without ground contact. Leachability may vary widely and is affected by a wide range of interacting factors associated with the treated wood itself, the nature of the structure and the environment in which it is located. Data regarding the form in which arsenic is leached are very limited, but suggest that a high proportion of the arsenic leached may be in insoluble or bound forms dislodged from the eroding wood surface, rather than dissolved from the wood. Regardless, various alteration and degradation processes may occur subsequently in the soil.

The rate of leaching declines greatly with the completion of fixation, though reactions of CCA in the wood are known to continue slowly for some months after that point. Accelerated laboratory leaching studies then indicate that over, for example, a five day test, the rate of leaching of each element declines to a very low level. However, leaching occurs much more gradually in wood in service and there are large differences in exposure conditions. Intermittent wetting and drying may “wick” components from the interior towards the surface and exposure to UV radiation may also significantly increase leaching from treated wood. The available data suggest that leaching continues indefinitely for the life of a structure, though it is likely that the initial leaching rate in the first weeks or months in service declines to a more or less steady state. This appears to be the case even in properly treated timber and in the absence of unfavourable conditions such as soil characteristics favouring leaching.

Field studies show that arsenic, copper and chromium leached from treated wood accumulates in soil adjacent to or underneath various types of structures. However, studies with stakes, posts and poles extending for decades show that even with long periods of service, there is very little lateral movement of CCA components from their immediate vicinity. Residues in soil with various types of structure were generally found to accumulate predominantly in the soil area reached by water running down the wood surface of support posts or poles to the ground, or dripping from horizontal surfaces. However, soil concentrations declined with lateral distance from posts and poles, generally to background levels within ~10-50 cm. Soil concentrations also generally declined with depth. Greater leaching within the soil may lead to lower peak concentrations near the surface in coarse textured, low organic matter content soils, as evident in a Florida study. Greater movement in the soil may occur with saturated soils, where the arsenic may be present in the more toxic As^{III} form.

Soil concentrations of arsenic, copper and chromium in the limited areas reached by leachate may rise substantially above the background level in local soils near the structure. They may also rise above the general range in natural background levels in Australian soils (1-20 ppm or 1-50 ppm for arsenic, 0.4-200 or 2-100 for copper and 2-700 or 5-1000 for chromium, based on two different published sources). They may also exceed the National Environment Protection Council (NEPC) Ecologically-based Investigation Levels (EILs) for arsenic (20 ppm), copper (100 ppm) and chromium (400 ppm for Cr^{III}, 1 ppm for Cr^{VI}). However, whether or not the soil concentrations reached could affect soil organisms and plant growth would depend on the bioavailability of the element. Regardless, any harmful effects would be greatly restricted by the limited volume of soil affected. There is evidence that plant uptake from contaminated soil areas could increase concentrations of arsenic in the tissues of some plants, but again the extent to which this can occur is restricted to a limited area of soil.

Various studies indicate that leachate from treated wood may carry arsenic, copper or chromium concentrations which may be toxic to a range of aquatic organisms, depending on the form and bioavailability of each element. However, these elements are likely to be removed by adsorption and other processes as the water passes over or through soil and/or to be adsorbed to organic matter dissolved or suspended in the water. In any case, leachate from CCA-treated structures would be greatly diluted by other run-off before reaching aquatic situations, where it would be further diluted and undergo complex interactions with components in the water and sediment. Hence concentrations of arsenic, copper or chromium in aquatic situations reached by leachate from treated wood in service are unlikely to reach toxic levels. However, arsenic, copper and chromium from all sources (anthropogenic and natural) may gradually accumulate in sediments downstream of urban areas where CCA-treated timber may be used, particularly where outflows are poor.

Thus use of CCA timber treatments will be likely to result in increased levels of copper, chromium and arsenic in the environment beyond local background levels in soil in close proximity to treated wood as a result of leaching during service. Any impact on soil dwelling organisms or plants is likely to be greatly restricted by the limited surface area and volume of soil affected. In terrestrial areas, most contamination is likely to be restricted to soil in the immediate vicinity of the structure, but some arsenic, copper and chromium may ultimately reach aquatic areas, eg via leachate reaching drains without passing through soil. However, toxicity to aquatic organisms is not expected from this due to great dilution and complex interactions with other components in the water and sediment. Nonetheless, action should be taken to ensure that as far as possible, the CCA-treatment is applied properly and fixation is completed before the treated timber is used, so that leaching in service is minimised.

3.5.3 Risks to the environment from disposal of CCA-treated timber and timber waste

A major potential means of disposal of treated wood and treated wood waste is combustion. This could occur on a scale and frequency ranging from burning scrap timber in a domestic fireplace through to routine industrial or domestic waste incineration, or even to use of the wood as fuel to recover the energy contained in it. Combustion may also arise accidentally through bush- or house fires. Studies show that, depending on the combustion conditions, 10-90% of the arsenic present in CCA-treated wood may be lost to air, either as volatilised As_2O_3 or particulate matter. Furthermore, the ash produced contains all the copper, chromium and arsenic that were present in the treated wood before burning, less any loss of arsenic to the atmosphere.

Hence, from an environmental point of view deliberate burning of CCA-treated wood or wood waste should be avoided because there is a risk of contamination of the atmosphere with arsenic during combustion, and of soil and water by contaminated ash. Incineration should only occur in very controlled facilities where release of arsenic to the atmosphere is minimised and the potentially highly toxic ash is processed and disposed of appropriately. In the context of regulatory action available to the APVMA, it is recommended that suitable label instructions be provided to prevent wood waste or other waste containing CCA produced at CCA treatment facilities from being disposed of by incineration.

While residues of CCA components in soil as a consequence of leaching from individual posts *in situ* are likely to be confined to a relatively small volume of soil surrounding the post, more significant soil contamination could ultimately occur below material such as damaged or used posts if they were stored for long periods in large quantities either on the soil surface or buried in soil. Disposal in quantity to land should therefore be undertaken with care, particularly if there is a risk of heavy metals contaminating groundwater.

Studies confirm a much higher leaching rate if such material is broken up into mulch or pulverised. Leaching from mulch prepared from CCA-treated wood has been confirmed to increase soil arsenic levels, as has amendment of soil with sawdust from CCA-treated wood. Increased soil arsenic levels may then lead to increased levels in plants growing in the soil, though heavy cumulative application rates would be needed to raise soil concentrations of available arsenic to levels generally harmful to the growth of plants or soil organisms. Thus caution is also necessary in disposal of waste CCA-treated wood as mulch or as soil amendments.

In the context of regulatory action available to the APVMA, it is recommended that suitable label instructions be provided to prevent wood waste or other waste containing CCA produced at CCA treatment facilities from being disposed of on site and indicate that disposal must meet local or state regulatory requirements.

Research is continuing into developing suitable incineration or pyrolysis techniques that would achieve this and hopefully recover energy as well as a high proportion of the heavy metals in the ash. Many other disposal approaches for CCA-treated wood have been considered, including manufacture of products such as wood cement composites or particleboard, re-use of timber for the same or new purposes, and extraction of CCA components from pulverised wood by various solvent, biological or other processes. These are beyond the scope of this review and have not been reviewed in detail, but are noted for interest in the wider context of disposal of waste from CCA-treated wood.

3.5.4 Risks to the environment from the use of arsenic trioxide timber treatments

Arsenic trioxide dust blown into termite workings is likely to remain largely unchanged within the treated wood. Eventually release may occur in the vicinity of the treated timber, at the final disposal destination and/or during transport of treated timber waste to a disposal site. However, the scale of contamination is likely to be very low (1-2 g per infestation) and the contaminated area limited in extent. If it is assumed that in a worst case 2 g of arsenic trioxide were distributed on a 1 m^2 area, the resulting increase in arsenic concentration if mixed into the surface 15 cm of soil with a bulk density of 1.5 g/cm^3 would be 8.9 ppm (mg arsenic/kg soil). This is within the range in natural background levels in Australian soils and below levels shown to be toxic to soil organisms, but in any case is a very limited area of contamination. Greater dispersal would result in lower soil concentrations. As with CCA treated timber, burning of timber treated with arsenic trioxide termite treatments or plywood with arsenic trioxide glueline treatment could volatilise arsenic trioxide and leave some residues in the ash. However, the scale of use of arsenic trioxide for these purposes is small compared to the overall use of CCA-treated timber.

3.6 Conclusions

CCA

The potential for unintended harmful environmental effects can arise from contamination during the treatment process, leaching of arsenic from treated timber into soils or water, and disposal or burning of discarded timber. Although leaching of arsenic from treated timber has been found to be largely localised, the assessment by the Department of Environment and Heritage led the APVMA to conclude that product labels do not contain adequate instructions with respect to harmful effects on the environment. Further, from an environmental perspective, the critical issue is that of the competence of persons using the products and the nature of the facilities in which treatment occurs. Both of these factors influence the potential for harm to the environment by significantly influencing the extent to which release to the environment may occur as a consequence of the application process or subsequently from leaching from treated timber over time. These releases can occur both at treatment facilities during application and fixation processes, and also during use of treated timber in various structures.

Arsenic trioxide

Treatment of timber with arsenic trioxide products occurs to widely dispersed, confined areas where termites are present in structures and nearby trees. Secondary dispersal is likely to be in the vicinity of the treated material, and/or destinations of the treated material during disposal when the structure is modified or removed. The use of the products in accordance with their respective instructions would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment.

4. OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT

While the review focussed on public health and environmental issues, some of the data submitted was also relevant to occupational health and safety (OH&S). In reviewing this data, it was recognised that further, more specific worker exposure data was required to address the identified concerns for worker safety. The occupations considered at greatest risk from exposure to CCA are (i) timber treatment plant workers and (ii) downstream workers who are involved in machining (sawing/sanding etc) of CCA treated timber products. Insufficient information/data were available to fully characterise risks to Australian timber treatment workers. There were no exposure data available to estimate risks to workers handling CCA treated timber. Neither the Predictive Operator Exposure Model (POEM) nor the Pesticide Handler Exposure Database (PHED) contains appropriate scenarios for use in estimating exposure for these occupational scenarios.

As a result, it is proposed that worker exposure data (dermal and inhalation) be generated for CCA timber preservative products (for both arsenic and chromium). In addition worker exposure data will be required for chromium and arsenic for workers involved in activities representative of a worst-case scenario for machining CCA treated timber products (this should involve handling and machining of freshly treated timber).

Insufficient information/data were available to fully characterise risks from arsenic trioxide to Australian workers. There was no exposure data available to estimate risks to workers applying arsenic trioxide termiticides to timber. Neither the Predictive Operator Exposure Model (POEM) nor the Pesticide Handler Exposure Database (PHED) contains appropriate scenarios for use in estimating worker exposures during timber treatment with arsenic trioxide.

Potential risks exist from repeated exposure to arsenic trioxide, although it is considered that exposures from inhalation or dermal contact are likely to be low, due to the small quantities of dust that are used per treatment. In addition, since these products are used only by pest control operators, it is considered likely that adequate risk mitigation measures (e.g. gloves and respirator) will be employed during the application process. NOHSC do not consider that exposure data is required to further mitigate risks.

5. SUMMARY OF PUBLIC SUBMISSIONS & CONCLUSIONS

There were 24 public submissions received from a wide spectrum of the community. Four submissions were from Governmental or state departments such as the Department of Human services, Victoria, The Department of Primary Industries Victoria, The Environmental protection Authority NSW. These generally included information on what the review should encompass, and potential and reported modes of exposure (such as contaminated smoke from burning of treated timber). Five letters were from individuals, community or environmental groups such as Friends of the Earth, and the Croydon Conservation Society, etc. In general these submissions highlighted their concerns regarding the potential effects on human health and recommended removal of CCA treatments for use on timber.

We received five submissions from timber groups such as New Zealand Timber Preservation Council Incorporated and the Plywood Association of Australasia Ltd. Generally, these submissions maintained that arsenic timber treatments were safe and effective, and recommended that the APVMA take the conclusions of the New Zealand regulator, ERMA into consideration. Three submissions were from research groups such as the Forest Products Laboratory at CSIRO and the Department of Chemical Engineering University of Sydney. Their submissions varied from the safety of CCA treated wood to the effectiveness of dust toxicant in eliminating pests, to advising that a study examining combustion of CCA treated timbers was underway.

Two submissions were from pest control operators or groups, such as the Australian Pest Managers Association, which recommended that arsenic trioxide be retained for use. Three submissions were from consultants – their advice ranged from recommending the discontinuation of arsenic to maintaining that CCA is not a threat to human life. One submission was from a licensed insurance broker who requested that arsenic dust should remain available to control *Mastotermes darwiniensis*. The Australian Building Codes board also expressed interest in the outcome of the review. In addition, one study was submitted that had measured high levels of arsenic underneath CCA-treated decks in Florida.

Both the APVMA and the external agencies (OCS and DEH) have had regard for all the issues raised in the public submissions. It is worth noting that in almost all cases, both the APVMA and the agencies were already considering the concerns that were raised in these submissions.

6. OVERSEAS REGULATORY STATUS

USA: The US EPA is facilitating voluntary phase out of CCA-treated timber for use in domestic situations. It has not recommended the removal of any existing CCA-treated structures. The USEPA has recently conducted a probabilistic risk assessment for children who come into contact with CCA-treated play equipment and decks. This assessment is yet to be finalised. This assessment focuses on arsenic exposure for children from decking and play equipment, and from direct ingestion of soil under and near decks and play equipment. The APVMA is liaising with the USEPA on this matter. It is expected that the probabilistic risk assessment, when finalised, might help clarify the risk from the existing CCA-treated timber structures in the US.

Another study underway is examining the effect of timber coatings as a level of protection from dislodgeable arsenic in existing CCA-treated structures. An interim report is expected in mid 2004 that may provide helpful information.

Canada: The Canadian Pest Management Regulatory Agency (PMRA) is working in collaboration with the US EPA to effect similar actions in Canada. In particular, the PMRA have also granted the voluntary cancellation of almost all residential uses of CCA. Affected products will not be able to be used to treat timber destined for residential use after December 2003.

European Union: The Commission of European Communities, in its directive 2003/02/EC, required member States to stop use by 30 June 2004 of CCA-treated timber in residential constructions where people would be likely to have direct skin contact with the treated wood. This directive does not apply to CCA-treated wood already in use.

New Zealand: The Environmental Risk Management Authority (ERMA) have determined that there was insufficient evidence at this stage to conclude that these products pose an unacceptable risk, but did support a move away from using CCA treated timber on children's playground equipment.

7. REVIEW RECOMMENDATIONS

CCA Timber Treatment Products

The APVMA is satisfied that the relevant particulars or the conditions of registration and approval for CCA timber treatment products and their labels (listed in Appendix 1) can be varied in such a way that the requirements prescribed by the regulations for continued registration and approval will be complied with.

To achieve compliance with requirements for continued registration and approval, the APVMA proposes that:

- CCA timber treatment products be declared Restricted Chemical Products. It is in the public interest to ensure that supply of these products will be restricted to suitably trained persons.
- CCA product labels be varied to recommend that timber treatment facilities be designed and operated to meet appropriate Australian Standards (ANZEC guidelines (1996) and AS/NZS 2843.1:2000 and AS/NZS 2843.1:2000). The APVMA will consult with relevant commonwealth and state agencies with a view to achieving this.
- Product labels be varied such that uses of CCA timber treatment products are not permitted on timber intended for use in structures such as picnic tables, deckings, handrails and children's play equipment.*
- Product labels be varied to include more detailed instructions for application, mixing and vacuum/pressure operations, management of freshly treated timber, management of liquids, sludge or waste material containing CCA residues, protection of wildlife, fish, crustaceans and the environment, and storage and disposal.
- Registrants be required to generate worker exposure data in relation to risks associated with arsenic and chromium (VI) in CCA.

* Implementation of this recommendation is contingent upon the successful development of effective ways to segregate CCA-treated timber products that should not be used in specified domestic applications.

Proposed new label instructions for CCA products relating to treatment plant operations are found in Appendix 2.

Arsenic Trioxide Termite Treatments

The APVMA is satisfied that use of arsenic trioxide products listed in Appendix 1 in accordance with their respective recommendations for their use (label instructions) would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment.

The APVMA is satisfied that labels for each of the arsenic trioxide products listed in Appendix 1 contain adequate instructions to ensure that the use of the product in accordance with their respective instructions would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment.

Products containing arsenic trioxide are applied only by licensed pest control operators. The public are unlikely to be exposed to the *in situ* products. For these reasons, products containing arsenic trioxide are not considered likely to present a public health risk and thus the APVMA is satisfied that use of the products in accordance with their respective recommendations for their use (label instructions) would not be likely to have an effect that is harmful to human beings.

8. AMENDMENTS TO STANDARDS

The poisons schedule for arsenic, chromium and copper, and the existing First Aid Instructions and hazard statements for CCA timber treatment and arsenic trioxide products remain appropriate.

The poisons schedule for arsenic, chromium and copper remain appropriate.

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Appendix 1: Products included in the review

Product Number	Product Name	Registrant	Label Number(s)
CCA timber treatment products			
30691	Tanalith CP Wood Preservative Paste	Koppers Arch Wood Protection (Aust) Pty Limited	Ψ
39884	Tanalith O Type C Oxide Wood Preservative	Koppers Arch Wood Protection (Aust) Pty Limited	Ψ
40092	Impretect CS	Osmose Australia Pty Limited	40092/0698
41482	Impretect CO	Osmose Australia Pty Limited	41482/0698
41680	Sarmix 3 CCA Salts	Osmose Australia Pty Limited	Ψ
41681	Sarmix Oxcell C-680 For Timber Treatment	Osmose Australia Pty Limited	41681/0698
51821	A&C CCA Salt Wood Preservative	A&C Chemicals Pty Ltd	51821/0799
51822	A&C CCA Oxide Wood Preservative	A&C Chemicals Pty Ltd	51822/0899
55939	Timtech C Oxide Wood Preservative	Timtech Chemicals Pty Limited	55939/1002
Arsenic trioxide termite dusts			
48410	Aldi Arsenic Trioxide Termite Dust	Aldi GC Pty Ltd	48410/01 48410/0602 48410/0802
48909	Garrard's Termite Powder Insecticide	Garrards Pty Ltd	48909/01
51234	One Bite Arsenic Trioxide Termite Treatment	Young's Enterprises Pty Ltd	51234/1098

Ψ Labels transitioned from the States and so do not having an approval number

Appendix 2: Label instructions

CCA TIMBER TREATMENT PRODUCTS

These recommended label changes apply to all CCA product labels.

APPLICATION INSTRUCTIONS
Labels for all products must specify application rates (retention levels in treated timber) according to relevant hazard classes described by AS 1604.1—2000. [*Note: the label for product 55939 mostly meets this recommendation and serves as a useful guide. Rates would need to be adjusted according to the level of the active constituents present in each product.*]

MIXING AND VACUUM/PRESSURE OPERATIONS
Mixing and vacuum/pressure treatment operations must be conducted on impervious, sealed and bunded areas with facilities to contain and collect leakage, spills, excess treatment solution, drips and waste materials. Avoid spilling product while mixing. If product is spilled, follow instructions for management of liquids, sludge or waste material containing CCA residues.

MANAGEMENT OF FRESHLY TREATED TIMBER (DURING DRIP DRYING AND THE FIXATION PROCESS)
Freshly treated timber must be placed on drip pads that ensure treatment solution is contained and can be collected for recycling. Treated timber must not be moved from the drip pads for at least 48 h, and not until the timber surface is dry. Treated timber must then be held on site until chromium has become fixed to the wood (an appropriate indication of adequate fixation is that described in AS/NZS 1605:2000 "Methods for sampling and analysing timber preservatives and preservative-treated timber"). Leachate water contaminated by product must not enter natural watercourses or waterbodies or reach groundwater. This could be achieved by storing timber in a sealed, bunded area with provision for storing and processing drainage water. [*Note: the chromotropic acid test may provide a practicable alternative means of determining fixation is satisfactorily complete, but is not yet referred to in the Australian Standards – it is listed as a standard method for the US and Canadian industries].*

MANAGEMENT OF LIQUIDS, SLUDGE OR WASTE MATERIAL CONTAINING CCA RESIDUES
Do NOT allow spilled product or mixed solution to enter drains, streams, rivers or waterways. Cover spilled product or mixed solution with sand (NOT sawdust) and/or a suitable stabilising agent (such as a 90% lime and 10% sodium metabisulfite mixture).

Where practicable, spilt material, washings or other materials containing CCA residues from all stages of the mixing, vacuum/pressure treatment, fixation and drying processes or from other sources on the site should be collected and returned to the treatment process. If not used or re-used directly in the treatment process, all liquids, sludge or other waste containing CCA residues must be recycled to recover the active ingredients, or disposed of off site according to local State Government regulations.

WARNING

Timber waste or sawdust treated with this product should not be burnt as this could produce gases toxic to animals and plants.

PROTECTION OF WILDLIFE, FISH, CRUSTACEANS AND THE ENVIRONMENT
Do NOT contaminate streams, rivers or other waterways with product or mixed solution.

STORAGE AND DISPOSAL
Store the product in a locked, cool, well-ventilated, bunded and roofed room.

Triple or preferably pressure rinse containers before disposal. Add rinsings to the treatment process. Do not dispose of undiluted chemicals on site. If recycling, replace cap and return clean containers to recycler or designated collection point. If not recycling, break, crush, or puncture and bury empty containers in a local authority landfill. Empty containers and product must not be burnt.