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Matters related to the implementation of the Convention: measures to reduce or eliminate releases from unintentional production

Draft guidance on best available techniques and best environmental practices for the production and use of pentachlorophenol listed with specific exemptions under the Stockholm Convention

Note by the Secretariat

As is mentioned in the note by the Secretariat on the Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional Persistent Organic Pollutants and guidelines and guidance on best available techniques and best environmental practices (UNEP/POPS/COP.9/9), the draft guidance on best available techniques and best environmental practices for the production and use of pentachlorophenol listed with specific exemptions under the Stockholm Convention is set out in the annex to the present note. The present note, including its annex, has not been formally edited.

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* UNEP/POPS/COP.9/1.

Annex

Draft guidance on best available techniques and best environmental practices for the production and use of pentachlorophenol listed with specific exemptions under the Stockholm Convention

Draft

January 2019

Disclaimer

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Preface

This document has been developed by the experts on Best Available Techniques (BAT) and Best Environmental Practices (BEP) nominated by Parties and others in accordance with the process for the review and update of the guidelines and guidance on BAT and BEP. It contains most up-to-date information and knowledge as evaluated and integrated in the draft guidance by the BAT and BEP experts. The work on the review and update of the guidelines and guidance on BAT and BEP is implemented in accordance with the terms of reference set out in annex to decision SC-8/6 and thanks to the generous financial support provided by European Union through the European Commission Global Public Goods and Challenges (GPGC) programme. The in-kind contribution and expert input provided by the BAT and BEP group of experts is highly acknowledged. The experts nominated by Parties and others to be consulted in the process for review and update of the guidelines and guidance on BAT and BEP are part of the joint Toolkit and BAT and BEP expert roster (UNEP/POPS/COP.9/INF/13).

Abbreviations and Acronyms

ACAT - Alaska Community Action on Toxics

ACQ – Ammonium Copper Quaternary

ACZA – Ammonium Copper Zinc Arsenate

ATSDR - Agency for Toxic Substances and Disease Registry

AWPA – American Wood Protection Association

BAT – Best Available Techniques

BEP – Best Environmental Practices

BREF – Best Available Techniques Reference Document

CAS - Chemical Abstracts Service

CCA – Chromated Copper Arsenate

CDC - Center for Disease Control and Prevention

CLRTAP Convention on Long Range Transboundary Air Pollution

ECHA – European Chemicals Agency

EMS – Environmental Management System

ESM – Environmental Sound Management

ESWI - Expert Team to Support Waste Implementation Consortium

FRC – Fibreglass Reinforced Composite

GHS – Global Harmonized System of Classification and Labelling of Chemicals

HCB – Hexachlorobenzene

IARC - International Agency for Research on Cancer

IEP - Institute of Environmental Protection

IPEN - International POPs Elimination Network

ISO – International Organization for Standardization

M&M - Monitoring and Maintenance

LDAR - Leak Detection and Repair

Na-PCP – Sodium Pentachlorophenol

PAHs – Polyaromatic Hydrocarbons

PBT – Persistent, Bioaccumulative and Toxic

PCA - Pentachloroanisole

PCDD – Polychlorinated dibenzo dioxins

PCDF – Polychlorinated dibenzo furans

PCP – Pentachlorophenol

PCPL – Pentachlorophenol Laurate

PMRA – The Health Canada Pest Management Regulatory Agency

POPs – Persistent Organic Pollutants

POPRC – Persistent Organic Pollutants Review Committee

REACH - Registration, Evaluation, Authorisation and Restriction of Chemicals

SDS – Safety Data Sheet

SRF - Solid recovered fuel

TEQ – Toxic Equivalent

TRD - Technical Recommendations Document

TSMP - Toxic Substances Management Policy of the Government of Canada

UNECE – United Nations Economic Commission for Europe

UNEP – United Nations Environment Programme

UNIDO – United Nations Industrial Development Organization

USEPA – United States Environmental Protection Agency

WHO - World Health Organization

XRF – X-ray fluorescence

1. Introduction

At its seventh meeting held from 4 to 15 May 2015, the Conference of the Parties to the Stockholm Convention amended Part I of Annex A to the Convention by listing pentachlorophenol (PCP), its salts and esters with specific exemptions for the production and use of PCP for utility poles and cross-arms (decision SC-7/13). The listing covers pentachlorophenol (CAS No. 87-86-5), sodium pentachlorophenate (CAS No. 131-52-2 and 27735-64-4 (as monohydrate)) and pentachlorophenyl laurate (CAS No. 3772-94-9), when considered together with their transformation product pentachloroanisole (CAS No. 1825-21-4).

According to Part VIII of Annex A to the Convention, each Party that has registered for the specific exemption pursuant to Article 4 for the production and use of PCP for utility poles and cross-arms shall take the necessary measures to ensure that utility poles and cross-arms containing PCP can be easily identified by labelling or other means throughout their life cycles. Articles treated with PCP should not be reused for purposes other than those exempted. The Register of Specific Exemptions for PCP is available at http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/PCPRoSE/tabid/5481/Default.aspx (see Table 1 below).

Table 1: Register of specific exemptions for PCP (as of January 2019)

Activity	Specific exemption	Party	Expiry date	Estimated quantity of production / use	Purpose(s) of production / use	Reason for exemption	Remarks
Production	As allowed for the Parties listed in the Register in accordance with the provisions of part VIII of Annex A	Mexico	Not applicable	6800 metric tons per year	*(Informal translation – original received in Spanish)* Production of pentachlorophenol, 99.98% for shipment to the United States of America and 0.02% for sale in the national territory; the specific uses are those expressed in the Conference of the Parties, i.e. for treatment of utility poles and cross-arms.	*(Informal translation – original received in Spanish)* Existence of the company KMG, a production plant in Mexico that delivers the product in solid state to be later sent to the USA for its distribution and sale.	None.
Use	Pentachlorophenol for utility poles and cross-arms in accordance with the provisions of part VIII of Annex A	Mexico	Not applicable	0.02% of 6800 metric tons per year	*(Informal translation – original received in Spanish)* Production of pentachlorophenol, 99.98% for shipment to the United States of America and 0.02% for sale in the national territory; the specific uses are those expressed in the Conference of the Parties, i.e. for treatment of utility poles and cross-arms.	*(Informal translation – original received in Spanish)* Existence of the company KMG, a production plant in Mexico that delivers the product in solid state to be later sent to the USA for its distribution and sale.	None.

1.1. Purpose

This document has been developed to provide guidance to Parties in their actions to prevent and/or reduce releases of PCP, its salts and esters from production and use under specific exemptions under the Stockholm Convention. It compiles publicly available information relevant to best available techniques (BAT) and best environmental practices (BEP) for PCP, its salts and esters within the scope of the Convention. In addition, reference is made to other documents that provide guidance on other aspects than production and use to assist in environmentally sound management for the full life cycle of the chemical. The present document should therefore be considered in conjunction with other relevant guidance material as noted in the specific Chapters/Sections.

1.2. Structure and use of this document

Chapter 1 outlines the purpose and structure of this document. It also includes a brief overview of characteristics and uses of PCP, its salts and esters, the relevant provisions under the Stockholm Convention and a summary of required measures under these provisions. Furthermore, Table 3 summarizes the alternatives that are available for the use of PCP for the specific exemption application. Table 4 provides a comprehensive summary of BAT and BEP for the specific exemption application.

Chapter 2 includes high level BAT and BEP principles for general chemical management.

Chapter 3 provides specific BAT and BEP guidance for the management of PCP in the production and use specified as specific exemption under the Convention, including information on available alternatives for the exempted use.

Chapter 4 addresses brief considerations for the identification of products and articles containing PCP throughout their life cycles in accordance to Part VIII of Annex A to the Convention.

Chapter 5 briefly discusses the environmentally sound management of contaminated sites.

1.3. Pentachlorophenol (PCP), its salts and esters

1.3.1. Chemicals listed in Part VIII of Annex A of the Convention

The following chemicals listed in Annex A of the Stockholm Convention are in the scope of this guidance document (see Table 2 below):

- pentachlorophenol (PCP, CAS No. 87-86-5);
- sodium pentachlorophenate (Na-PCP, CAS No. 131-52-2 and 27735-64-4 (as monohydrate));
- pentachlorophenyl laurate (PCP-L, CAS No. 3772-94-9);
- their transformation product pentachloroanisole (PCA, CAS No. 1825-21-4).

Pure PCP consists of light tan to white, needle-like crystals. Technical grade PCP is typically about 86% pure (IEP 2008, Environment Canada 2013, KMG “KMG Penta Blocks – SDS” https://kmgchemicals.com/wp-content/uploads/Penta-OL-Penta-Block-SDS-Cust.pdf; accessed on 5 December 2018). The formulated product offered by KMG (KMG “KMG Dura-Treat 40 Wood Preserver – SDS” https://kmgchemicals.com/wp-content/uploads/DT40-US-SDS.pdf; accessed on 5 December 2018) has the following composition:

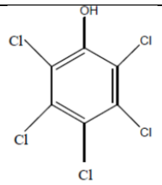
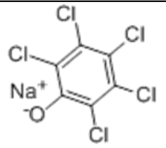
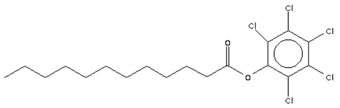
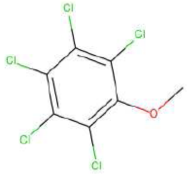
Chemical name	**CAS No.**	**%**
Aliphatic Esters and Aldehydes	Mixture	58.2-61.8
Pentachlorophenol	87-86-5	33.4-35.4
Other Chlorophenols	58-90-2, 4901-51-3, 88-06-2, 95-95-4	3.8-4.2

Composition comments: All concentrations are in percent by weight.

Na-PCP and PCP-L have been available in form of solid blocks, flakes, granulate, powder or as a liquid (UNEP 2013a).

PCA is not used as a commercial chemical or pesticide and is not intentionally released directly into the environment. Therefore, this document does not address PCA, which is a metabolite that may be formed in soil and sediment from the biodegradation of PCP under aerobic conditions by certain microorganisms (UNEP 2013a).

Table 2: Information on the chemical identity of PCP, its salts and esters (Source: UNEP 2013a)

	PCP	**Na-PCP**	**PCP-L**	**PCA**
Molecular formula	C_6HCl_5O and C_6Cl_5OH	C_6Cl_5ONa and C_6Cl_5ONa x H_2O (as monohydrate)	$C_{18}H_{23}Cl_5O_2$	$C_7H_3Cl_5O$
CAS Number	87-86-5	131-52-2 and 27735-64-4 (as monohydrate)	3772-94-9	1825-21-4
Molecular Mass	266.34 g/mol	288.32 g/mol	448.64 g/mol	280.362 g/mol
Structural formulas of the isomers and the main transformation product				
Boiling point	309–310 °C	291 to 533 °C	360 to 494 °C	295 to 322 °C

1.3.2. Characteristics and Risks

PCP and its metabolite PCA are detected in air, water, soil and biota throughout the world, including in remote regions. Biomonitoring information shows similar levels of PCP in humans from remote and more populated areas. Compared to other chlorinated compounds, PCP is one of the most dominant contaminants measured in blood plasma (UNEP 2013a). PCP is hepatotoxic, carcinogenic, immunotoxic, neurotoxic and toxic to the reproduction. In acute toxicity studies in humans, PCP is moderately toxic via the oral, inhalation, and dermal routes. UNEP (2013a) concluded that due to the concentrations of PCP/PCA measured in humans, adverse effects for human health related cannot be excluded. At its ninth meeting, the POPs Review Committee has adopted the risk profile for PCP and its salts and esters, and has concluded that these chemicals are likely, as a result of their long-range environmental transport, to lead to significant adverse human health and environmental effects such that global action is warranted (UNEP 2013a). To provide a complete picture of the characteristics and risks of PCP, its main metabolite as well as the impurities commonly found in PCP, PCP-Na and in PCP-L are considered.

Historically, technical PCP, its salts and esters have been shown to contain a number of impurities, depending on the manufacturing method. Polychlorinated dibenzodioxins (PCDD), polychlorinated dibenzofurans (PCDF), and hexachlorobenzene (HCB) can be unintentionally formed as contaminants in the production process of PCP. The Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional Persistent Organic Pollutants under the Stockholm Convention (UNEP 2013b) and the Guidelines on best available techniques and guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention (UNEP 2007) provide information relevant to the provisions of the Convention with respect to unintentionally produced POPs.

According to UNEP (2013a), concentrations of PCDD/PCDF in PCP technical product decreased after legal measures were taken in the United States and in Europe. In 1987, the U.S. EPA required that no detectable concentrations of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) be present in PCP. It also required that hexachlorodibenzo-p-dioxin (HCDD) concentrations cannot be above 2 ppm on a monthly average and that no single batch exceed 4 ppm (USEPA 2006). Between 1987 and 1999, the total dioxins in PCP technical products dropped 3-6 fold (USEPA 2005). In the European Union, a maximum allowable limit of 4 ppm for total HCDD was originally set in 1992. This limit was further reduced to 2 ppm in 2000 (Commission Directive 1999/51/EC, UNEP 2013a).

In Canada, a review of PCP contaminant data from 2006 and 2013 PCP production indicated that these contaminants have been significantly reduced from the values reported in the 1997/1998 production. In PCP products registered in Canada, the total TEQ for dioxins and furans combined is 555.7 ppb. The total TEQ based on upper measured values is 600.4 ppb. These levels are expected to be reflective of PCP used in the U.S. as well, since they come from the same manufacturing source.

Dioxins, furans and HCB are Track 1 substances under the Government of Canada's Toxic Substances Management Policy (TSMP), which calls for the virtual elimination of those substances. The levels of these substances must be as low as can be achieved by the application of the best available technology from the manufacturing perspective in accordance with Article 5 of the Convention. Additionally, the control measures required for all wood preservation facilities in Canada minimize the release of these contaminants to the environment. The management of levels of contaminants during the risk reduction measures implemented during the treatment and use of treated wood results in reduced environmental releases of these contaminants from the use of PCP as a wood preservative.

Dioxins and furans formed during the PCP manufacturing process can be released during the use and disposal of PCP-treated wood (Lorber et al. 2002, Fries et al. 2002, Lee et al. 2006, Bulle et al. 2010). Dioxins and furans are also a by-product of wood incineration or burning as fuel (treated or untreated). Releases of unintentional POPs from the chemical production of chlorophenols are covered by the provisions of Article 5 and Annex C of the Convention; Parties should have measures in place to control these substances in accordance with the requirements of Article 5 and Annex C (UNEP 2007).

Local PCDD/PCDF point sources on farms such as the historic use of PCP or the burning of PCP treated waste wood in food and feed processing can lead to exceedance of regulatory limit values in food items (UBA 2015, AGES 2017).

1.3.3. Production of PCP, its salts and esters

PCP

PCP has been produced commercially and used as a wood preservative since the 1930s. At the height of its production, global output of PCP was around 90,000 tonnes per year (IEP 2008).. However, by the 1990s, widespread use of PCP was discontinued in most countries (UNEP 2013a).

The US chemical company KMG Chemicals Inc. (https://kmgchemicals.com/our-businesses/wood-treating-chemicals/products/; accessed on 10 January 2019) is reported to be the only producer of PCP for wood preservation in the world (KMG products are offered under the name 'KMG Penta Blocks' – containing 86% PCP; and 'Dura-Treat 40 Wood Preserver' – containing 33.4-35.4% PCP), with a production facility in Matamoros, Mexico (6,600 t/per annum) and a formulation facility in Tuscaloosa, Alabama, USA (7,000 t/per annum) (see UNEP 2014 and information available on the manufacturer's website: https://kmgchemicals.com/our-businesses/wood-treating-chemicals/products; accessed on 10 January 2019). 99.98% of the amount of PCP produced in Mexico is exported for formulation in the United States and 0.02% used within the country. The main share of the PCP use is in North America (UNEP 2013a, 2014, 2017c).

PCP can be produced by several methods (Fedorov 1993, UNEP 2007, IEP 2008, UNEP 2013b):

- Direct chlorination of phenols and hydrolysis of hexachlorobenzene is the most common production method. This is carried out in two steps. First, liquid phenol, chlorophenol, or a polychlorophenol is bubbled with chlorine gas at 30 - 40 °C to produce 2,4,6-trichlorophenol, which is then converted to PCP by further chlorination at progressively higher temperatures in the presence of various catalysts (aluminium, antimony, their chlorides, and others);
- An alkaline hydrolysis of hexachlorobenzene (HCB) in methanol and dihydric alcohols, in water and mixtures of different solvents in an autoclave at 130 - 170 °C;
- Thermolysis of hexachlorocyclohexane (HCH), including a chlorination step and hydrolysis;
- Pyrolysis of waste from lindane production with intermediate production of TCB and HCB (this method was in use until 1981 at the Chapayevsk Chemical Plant of Fertilizers).

A method for reducing contaminants, including PCDD/PCDF, during the synthesis of PCP, is described in Savage and Yu (2010). The method provides a phenol-based starting material and a catalyst, which form the reaction mixture. The chlorine flow is introduced so that it is in contact with the reaction mixture, and the starting material and chlorine are reacted via a temperature-programmed reaction. Because PCDD/PCDF formation occurs mainly in the late stage of the reaction, one conclusion was to stop the reaction at a certain degree of chlorination. The chlorine flow is terminated prior to an end of the temperature-programmed reaction and/or at a point where the yield of pentachlorophenol is less than about 95%. It is unknown whether this technique is in use on a commercial scale.

Na-PCP

UNEP (2014) reports 1,800 t/per annum of Na-PCP manufactured in India and used mainly in producing impregnated wood/particle boards to protect from fungi (Possible producer: http://www.excelind.co.in/Excel_Chemical/products.html#: Listing substance as a “Biocide” to preserve “gum” and “paint”; Possible manufacturers and/or distributors: https://dir.indiamart.com/impcat/sodium-pentachlorophenate.html). This substance is listed in Annex A without specific exemptions. Production and use is thus not allowed under the Convention.

PCP-L

The use of PCP-L is no longer reported and there is no known production of PCP-L (UNEP 2014). This substance is listed in Annex A without specific exemptions. Production and use are thus not allowed under the Convention.

1.3.4. Uses of PCP, its salts and esters

PCP

Only one application is exempted according to Part VIII of Annex A to the Stockholm Convention: the use of PCP as a preservative for utility poles and cross-arms. Industrial wood preservation for treatment of utility poles and cross-arms prevents the wood from biological deterioration (i.e. from wood destroying and/or wood disfiguring organisms such as fungi, insects, termites and marine borers). Such treatments extend the service life of wood utility poles and cross-arms to 20 – 100 years (Mankowski et al. 2002, The North American Wood Pole Council www.woodpoles.org, Wood Preservation Canada www.woodpreservation.ca, accessed on 5 December 2018).

Wood poles and cross-arms must meet several standards to qualify for use. For example, the standards for preservative treating of wood utility poles for the USA are set by the American Wood Protection Association (AWPA; http://www.awpa.com/) and detailed in the AWPA Book of Standards; for Canada by the Canadian Standards Association (CSA; www.csagroup.org) and detailed in CAN/CSA O80 Series-15 – Wood Preservation. All preservatives used for utility poles are approved and regularly reviewed by the U.S. Environmental Protection Agency (EPA) and the Pest Management Regulatory Authority (PMRA) of Health Canada.

Each Party that has registered for the specific exemption pursuant to Article 4 of the Convention is required to take the necessary measures to ensure that utility poles and cross-arms containing PCP can be easily identified by labelling or other means throughout their life cycles. Articles treated with PCP should not be reused for purposes other than those exempted.

Na-PCP

Na-PCP is reported to be used in India, mainly for impregnated wood/particle boards to protect them from fungi in both industrial and domestic settings, and for preservation paint products during storage (ICC 2014a, b). These uses are no longer permitted under the Stockholm Convention.

PCP-L

As for PCP-L, as of 2014 no country had reported its use any longer (UNEP 2014). Uses of PCP-L are not permitted under the Stockholm Convention.

1.4. Consideration of alternatives to PCP

1.4.1. General considerations

The present document includes information on registered/approved alternatives reported to be in use for the application listed as specific exemption for PCP under the Convention. It should be noted that alternative products might not be directly interchangeable and will have specific performance strengths and weaknesses for any given application. Some commonly used commercial chemical alternatives to PCP, namely chromium or arsenic containing substances, and polyaromatic hydrocarbon containing substances (e.g. creosote), exhibit hazardous properties (see information summarized in Table 3 and further details in Chapter 3, Section 3.2.3).

Non-chemical (functional) alternatives to PCP-treated wood poles and cross-arms (such as concrete, steel, fibreglass composite, undergrounding) offer possible options for substitution, but they may have higher manufacture and installation costs.

General guidance for consideration of alternatives to persistent organic pollutants in use under specific exemptions and/or acceptable purposes under the Convention has been developed by the POPs Review Committee (UNEP 2009). Guidance on identifying alternatives for the phase-out of PCP has also been developed and is available in UNEP (2017c). More detailed information on the availability and suitability of the alternatives are available in the source documents used for the development of this guidance. Potential alternatives and their suppliers should be carefully assessed by Parties before being considered as suitable alternatives.

1.4.2. Summary of chemical alternatives

A number of registered/approved wood preservation chemicals exist that either have replaced or have the potential to replace PCP dependent on the specific application. The US EPA (2008) and Environment Canada (2004, 2017) have identified the following key substances that are mass produced as wood preservatives (in addition to PCP):

- Chromated copper arsenate (CCA);
- Creosote-based products;
- Ammonical Copper Zinc Arsenate (ACZA);
- Ammonium Copper Quaternary (ACQ);
- Copper Naphthenate, copper azoles and azoles/permethrin combinations;
- Polymeric betaine, copper and/or boron based products.

Table 3 below summarizes information regarding chemical alternatives to PCP as a wood preservative for utility poles and cross-arms. Further detailed information can be found in Chapter 3, Section 3.2.3.

Table 3: Chemical alternatives to the use of PCP in wood preservation for the exempted application (UNEP 2013a, 2014, 2017c)

Alternative	Chemical description and CAS number(s)	Process description	Hazard information
Chromated copper arsenate (CCA)	Product blend (5:3:2) of chromic acid (CAS No. 1333-82-0), arsenic acid (CAS No. 7778-39-4) and cupric oxide (CAS No. 1317-38-0).	Waterborne preservatives used in pressure treatment process similarly as PCP and creosote, but at lower application temperatures (65°C compared to 100°C).	Contains highly toxic and carcinogenic substances; Environmental and health concerns with its use resulted in being significantly restricted or limited. **GHS Labelling (chromic acid):** - H271: May cause fire or explosion; strong oxidiser; - H301+H311: Toxic if swallowed or in contact with skin: - H330: Fatal if inhaled; - H314: Causes severe skin burns and eye damage; - H317: May cause an allergic skin reaction; - H334: May cause allergy or asthma symptoms or breathing difficulties if inhaled; - H335: May cause respiratory irritation; - H340: May cause genetic defects: - H350: May cause cancer: - H361f: Suspected of damaging fertility; - H372: Causes damage to organs through prolonged or repeated exposure; - H410: Very toxic to aquatic life with long lasting effects. **GHS Labelling (arsenic acid):** - H301: Toxic if swallowed; - H331: Toxic if inhaled; - H350: May cause cancer; - H410: Very toxic to aquatic life with long lasting effects. **GHS Labelling (cupric oxide):** - H302: Harmful if swallowed; - H410: Very toxic to aquatic life with long lasting effects.
Creosote-based products	Produced from the distillation of coal tars. CAS No. 8001-58-9.	Oil-borne preservative that can be used within industrial pressure, immersion or vacuum treatment of wood.	Contains a number of toxic substances including PAHs, phenol, cresols and various POPs. In the EU, creosote was found to meet the PBT criteria. Use limited to industrial applications only. **GHS Labelling:** - H350: May cause cancer.
Copper Naphthenate	Mixture of copper salts and naphthenic acid in petroleum distillates. CAS No. 1338-02-9.	Oil-borne preservative that can be used in the pressure treatment processes similarly as PCP, CCA and creosote.	Data on effects on human health and the environment is limited; Health risks due to occupational exposure are documented. **GHS Labelling:** - H226: Flammable liquid and vapour; - H302: Harmful if swallowed; - H410: Very toxic to aquatic life with long lasting effects.

Ammoniacal Copper Zinc Arsenate (ACZA)	5:3:2 cupric oxide (CAS No. 1317-38-0), zinc oxide (CAS No. 1314-13-2) and arsenic acid (CAS No. 7778-39-4).	Waterborne preservative used in pressure treatment.	Contains arsenic, a carcinogenic substance, and copper oxide, which has high aquatic toxicity. It is listed as a 'restricted use pesticide' for industrial purposes in the US. Health risks due to occupational exposure are documented. **GHS Labelling (cupric oxide):** - H302: Harmful if swallowed; - H410: Very toxic to aquatic life with long lasting effects. **GHS Labelling (zinc oxide):** - H410: Very toxic to aquatic life with long lasting effects. **GHS Labelling (arsenic acid):** - H301: Toxic if swallowed; - H331: Toxic if inhaled; - H350: May cause cancer; - H410: Very toxic to aquatic life with long lasting effects.
Ammonium/ Alkaline Copper Quaternary (ACQ) compounds	Copper oxide (CAS No. 1317-38-0) and quaternary ammonia compounds (many variations).	Waterborne preservative used in pressure treatment processes similarly as PCP, CCA and creosote.	Absence of arsenic or chromium has made it one of the most widely used wood preservatives. **GHS Labelling (cupric oxide):** - H302: Harmful if swallowed; - H410: Very toxic to aquatic life with long lasting effects. **GHS Labelling (quaternary ammonia compounds):** - H302: Harmful if swallowed; - H314: Causes severe skin burns and eye damage; - H400/H410: Very toxic to aquatic life with long lasting effects.
Copper azoles (with Tebuconazole or Propiconazole)	Include copper-amine complex and co-biocides. Tebuconazole (CAS No. 107534-96-3) Propiconazole (CAS No. 60207-90-1)	Waterborne preservative authorised for transmission poles in the EU and US.	In the EU, Tebuconazole is identified as a candidate for substitution that meets the P and T criteria. **GHS Labelling (tebuconazole):** - H302: Harmful if swallowed; - H361d: Suspected of damaging the unborn child; - H410: Very toxic to aquatic life with long lasting effects. **GHS Labelling (propiconazole):** - H302: Harmful if swallowed; - H317: May cause an allergic skin reaction; - H410: Very toxic to aquatic life with long lasting effects.
Copper based preservatives using polymeric betaine and/or boric acid as a co-biocides	Copper oxide (CAS No. 1317-38-0), polymeric betaine (didecyl bis(hydroxyethyl) ammonium borate or didecyl polyoxyethyl ammonium borate – DPAB - CAS No. 214710-34-6) and boric acid (CAS No. 10043-35-3)	Waterborne preservatives used in pressure treatment	Due the fact that polymer betaine fixes to wood and can be degraded in soil and boron is a low toxic substance in the environment the leaching behaviour is defined by leaching of copper. **GHS Labelling (copper oxide):** - H302: Harmful if swallowed; - H410: Very toxic to aquatic life with long lasting effects. **GHS Labelling (DPAB / quats):** - H302: Harmful if swallowed; - H314: Causes severe skin burns and eye damage; - H400/H410: Very toxic to aquatic life with long lasting effects. **GHS Labelling (boric acid):**

			- H360FD: May damage fertility or the unborn child.

1.4.3. Summary of non-chemical (functional) alternatives

A number of functional, non-chemical alternatives to PCP-treated wood poles have been identified:

- Concrete: Use of concrete is widely applied for utility poles that provide a standardized product with high tensile strength and durability; concrete poles are considerably heavier than the equivalent wood poles, which adds to freight and installation costs;
- Steel: Use of steel as an alternative material for utility poles has been investigated in Europe and by some of the utilities in the US; their adoption is limited due to increased financial cost and physical weight of steel poles compared to wood poles equivalents (they are more commonly used at transmission voltages where much higher structures are required than can be catered for by wood poles);
- Fibreglass Reinforced Composite (FRC): Relatively new to market and so have a limited history of use and is a relatively unproven technology in comparison to equivalent steel and concrete poles; they are expensive when compared to wood poles and therefore used in specialist site-specific applications;
- Undergrounding: Burying utility lines is considered an option where aesthetic or weather conditions preclude above-ground power distribution systems. However, geographic and geological conditions also may limit the feasibility of this option in many circumstances.

Initial costs for manufacture and installation of such functional alternatives to PCP-treated wood poles and/or cross-arms are significantly higher than for PCP-treated wood poles. However, several life cycle analyses exist, demonstrating that cost-benefit depends on many factors and that life-time costs along with the health and environmental profile can be either better or worse than treated wood.

Further detailed information on the characteristics of such alternatives, including their costs, can be found in Chapter 3, Section 3.2.3.

1.5. Summary of Best Available Techniques (BAT) and Best Environmental Practices (BEP)

Table 4 below summarizes information on BAT and BEP for the use of PCP and other approved and specified pesticides in the application listed as specific exemption under the Convention (Ireland EPA 2011, IEO-WEI 2011, Norden 2014, Environment Canada 2013, European Commission 2017). Further details are available in Chapter 3, Section 3.2.2; general principles on BAT and BEP are laid out in Chapter 2.

Information on existing BAT and BEP guidance documents that address specific measures applicable to minimize releases from relevant chemical production processes is provided in Section 3.1.

Table 4: Summary of BAT and BEP for the use of PCP and other approved and specified pesticides for wood preservation (Ireland EPA 2011, IEO-WEI 2011, Norden 2014, Environment Canada 2013, European Commission 2017)

Process steps	BAT	BEP*
General	Appropriate plant design and layout: The principle of total containment should be followed during site design and applied to processing plant, wood preservative storage area and the holding area for treated timber. Substitution of harmful / hazardous substances: Periodically assess whether new or alternate products are available which confer a similar level. of durability on treated timber but are less hazardous. Regular inspection and maintenance of plant and equipment: Periodically review the timber treatment process to further optimise and create less waste. Monitoring of emissions / releases. Measures facilitating decommissioning and development of emergency plans incl. practical exercises to test their effectiveness.	Implementation and adherence to an internationally accepted EMS, such as ISO 9001 and ISO 14001. Collection of preservative-treated wood waste for proper recovery or disposal as hazardous waste. Clean uncontaminated rain or surface water shall be diverted away from the plant area. Any waste produced or handled to be managed in an environmentally sound manner.
Delivery, storage and handling of the preservative	Delivery of treatment chemicals or solvents in reusable containers. Cleaning of redundant preservative containers and appropriate waste handling of the cleaning waste.	Deliveries should be made according to written procedure that includes a checklist covering all the safety-critical steps in the delivery process. Proper labelling of containers.
Preparation /Conditioning of wood	Measurement of wood moisture before treatment. Removal of plastic wrap from wood packs prior to treatment. Optimisation of wood charge preparation.	
Preservative application	Use of an efficient preservative application system. Control and optimised consumption of treatment chemicals. Mixing of preservation fluid in closed system.	Proper labelling of preservative tanks and containers. Monitoring & control.
Treatment vessel	Precautionary design features that include: Safety lock for vessel door; Process controls displaying whether liquid is present in the treatment vessel; Process controls prevent the treatment vessel from opening before all preservative solution is removed from the treatment vessel; Catch-lock for the treatment vessel door; Safety pressure-relief valves.	Maintenance and examination: planned written scheme of maintenance. Treatment vessel marking.

Containment	Plant and equipment containment or bund: The treatment plant and its associated loading and / or unloading area and preservative storage tanks, drums or intermediate bulk containers should be located within secondary containment – generally provided by bunding. Bunding should be impervious to the preservative chemicals being used and made of, or sealed with, a substance resistant to the chemicals being used. It must also be strong enough to withstand the hydrostatic pressure when the bund is full of liquid, stresses induced by differential settlement and thermal shrinkage.	Training of personnel to inspect the bund and report on its condition and to observe any leaks or areas requiring remedial action.
Dripping	Sufficient dripping time after treatment (dripping into treatment vessel). Drip test to ensure that wood is 'dry' prior to removal from the contained area. Use of drip trays. Soil/floor sealing, spill and surface run-off collection with reuse. Recirculation of collected drippage and spills of preservatives/treatment chemicals. Re-use of waste water/collected potentially contaminated rainwater and surface run-off and if not possible, treatment of waste water streams. Monitoring of waste water and surface run-off water.	Process modification, timber packing in the vessel and good carriage design which prevents accumulations of preservative will all help to eliminate or minimise post-treatment dripping. Separation of clean, uncontaminated rainwater or surface run-off water. Separation of hazardous and non-hazardous waste at source and separate storage. Reuse, recycling and recovery of wastes.
Post-treatment conditioning and interim storage	Removal of treated wood from working area only after fixation stage (minimum holding time). Post-treatment in proximity to treatment area. Roofing - bulk quantities of dry treated timber be stored under cover or on an impermeable surface to prevent possible contamination of surface and / or groundwater. Collection and treatment of leaching water for open (roof-less) storage of treated wood.	Operational practices to eliminate the spread of contamination via vehicle wheels or footwear are necessary to ensure environmental containment.

*General BEP guidance is provided in Chapter 2.

1.6. Relationship to the Basel Convention

The Basel and Stockholm conventions create a comprehensive life cycle approach to the management of chemicals and hazardous wastes. As stated in Article 6, paragraph 2 (c), of the Stockholm Convention, the Conference of the Parties to the Stockholm Convention shall cooperate closely with the appropriate bodies of the Basel Convention to “work to establish, as appropriate, the concentration levels of the chemicals listed in annexes A, B and C in order to define the low persistent organic pollutant content referred to in paragraph 1 (d) (ii).” This cooperation addresses the provisions referred to in Article 6, paragraph 2, on:

- The levels of destruction and irreversible transformation;
- The methods that are considered to constitute environmentally sound disposal;
- The concentration levels to define low POP content (UNEP 2017a).

Under the Stockholm Convention, POP-containing wastes are, in accordance with Article 6, paragraph 1 (d) (ii), to be disposed of in such a way that the POP content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of POPs or otherwise, they may be disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option, or the POP content is low, taking into account international rules, standards, and guidelines, including those that may be developed pursuant to paragraph 2, as well as relevant global and regional regimes governing the management of hazardous wastes.

A provisional low POP content of 100 mg/kg for pentachlorophenol and its salts and esters in waste was adopted by the Basel Convention at its thirteenth meeting of the Conference of the Parties in May 2017.

Two technical guidelines providing guidance on the environmentally sound management of PCP wastes were adopted by the Basel Convention Conference of the Parties in May 2017:

> "The General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants" (UNEP 2017a); and
>
> "Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with pentachlorophenol and its salts and esters" (UNEP 2017b)

Both documents are available on the Convention´s website at:

http://www.basel.int/Implementation/POPsWastes/TechnicalGuidelines/tabid/5052/Default.aspx.

2. General principles and guidance on BAT and BEP for managing chemicals

2.1. Best Environmental Practices (BEP)

BEP describe the application of the most appropriate combination of chemical management strategies and environmental control measures, including best practices relating to the continuous improvement of environmental, health and safety performance. BEP provide the framework for ensuring the identification, adoption and adherence to management options that play an important role in improving the occupational and environmental performance of a facility.

Key ecological and economic advantages achieved through BEP implementation include protection of workers, the surrounding community and the environment. Specifically, worker and community health, minimizing/optimizing the use of chemicals and auxiliary materials, freshwater and energy, minimizing waste and ecological loading of chemicals from wastewater and off-gassing. Committed senior level company executives are key to making BEP implementation and adherence a success. Well-trained employees are a prerequisite for implementing BEP measures. Limiting factors for improving existing equipment also need to be taken into consideration with the application of BEP, e.g. new equipment has to be rebuilt/modified or installed (for example, automated dosing systems, etc.).

The following Section provides basic information on environmental management systems. Their implementation improves worker safety and environmental performance of the facility.

2.1.1. Environmental management systems

A number of environmental management techniques are determined as BEP. An Environmental Management System (EMS) is a tool that operators can use to address these design, construction, maintenance, operation and decommissioning issues in a systematic, demonstrable way. An EMS includes the organizational structure, responsibilities, practices, procedures, processes and resources for developing, implementing, maintaining, reviewing and monitoring the environmental policy. Environmental Management Systems are most effective and efficient where they form an inherent part of the overall management and operation of an installation. The scope and nature of an EMS will generally be related to the nature, scale and complexity of the facility, and the range of environmental impacts it may have (GTZ 2008, ZDHC 2015).

BEP is to implement and adhere to an EMS that incorporates the following features:

- An analysis that includes the determination of the organisation's context, the identification of the needs and expectations of interested Parties, the identification of characteristics of the installation that are associated with possible risks for the environment (or human health) as well as of the applicable legal requirements relating to the environment;
- Definition and/or development of an environmental policy for implementation led by top management (senior corporate leadership commitment and accountability is regarded as a precondition for a successful application of the EMS);
- Planning and establishing of the necessary procedures (including corrective and preventive actions where needed), to achieve the environmental objectives and avoid environmental risks;
- Implementation of the procedures, paying particular attention to:
    - Organizational structure and responsibility;
    - Provision of the financial and human resources needed;
    - Training, awareness and competence;
    - Communication (internal and external);
    - Employee involvement;
    - Documentation;
    - Efficient operational planning and process control;
    - Maintenance programme;
    - Emergency preparedness and response; and
    - Safeguarding compliance with environmental legislation;
- Performance checks and taking corrective action:
    - Monitoring and measurement;
    - Records Maintenance;
    - Establishing objectives and performance indicators in relation to significant environmental aspects, including safeguarding compliance with applicable legal requirements;
    - Performing independent (where feasible) internal auditing to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained;
    - Evaluation of causes for nonconformities, implementation of corrective actions in response to nonconformities, review of the effectiveness of corrective actions and determination of whether similar nonconformities exist or could potentially occur.

Four additional features are considered as progressive measures; their absence, however, is generally not inconsistent with BEP:

- Examination and validation of the management system and audit procedure by an accredited certification body or an external EMS verifier;
- Preparation and publication of a regular environmental statement describing all the significant environmental aspects of the facility, allowing for year-by-year comparison against environmental objectives and targets as well as with sector benchmarks as appropriate (i.e., continuous improvement plan and annual progress report);
- Consideration of applicable industry-specific standards, when available;

- Implementation and adherence to an internationally accepted EMS, such as ISO 14001 or the Eco Management and Audit Scheme (EMAS).

This last voluntary step could give higher credibility to the EMS, particularly internationally accepted and transparent standards, such as ISO9001 and ISO14001. Non-standardized systems can in principle be equally effective provided that they are properly designed and implemented.

2.1.2. Specific education and training of employees

The following basic training and education opportunities are beneficial for raising awareness for sound chemicals management:

- Establishing and maintaining a management manual and written procedures to control activities with significant environmental impact as well as relevant records;
- Appropriate education of workers concerning handling, storing, using and disposing of chemicals and auxiliaries, especially in case of hazardous substances;
- Fostering employee involvement in good environmental management practices;
- Process- and machinery-specific training to increase the level of environmental awareness;
- Regular maintenance of technical equipment (machines in production as well as abatement and recovery devices such as filters and scrubbers); general maintenance (e.g. pumps, valves, level switches);
- Calibration of equipment for measuring and dispensing chemicals;
- Appropriate disposal systems for chemicals.

2.1.3. Additional considerations

It is also important to consider the following forward looking features of the EMS:

- At the plant (or parts thereof) design stage, consider its environmental impacts throughout its life, which includes construction, maintenance, operation and decommissioning of the unit;
- Give consideration to the development of cleaner technologies;
- Where practicable, conduct sectoral benchmarking on a regular basis, including energy efficiency and energy conservation activities, choice of input materials, emissions to air, discharges to water, water consumption and generation of waste;
- Ensure full details provision for activities carried out on-site, such as:
    - Descriptions of the waste treatment methods and procedures in the place of installation;
    - Diagrams of the main plant items that have some environmental relevance, together with process flow diagrams (schematics);
    - Details on the control system philosophy and how the control system incorporates environmental monitoring information;
    - Details on how protection is provided during abnormal operating conditions such as momentary stoppages, start-ups, and shutdowns;
    - Annual survey of the activities carried out and the waste treated, which contains a quarterly balance sheet of the waste and residue streams, including the auxiliary materials used for each site;
- Have sufficient staff available on duty with the requisite qualifications at all times. All personnel should undergo specific job training and further education, e.g. ensuring the necessary competence and awareness of staff whose work may affect the environmental performance of the installation.

Processes must be designed to state-of-the-art safety and environmental standards as outlined, for example, in the European Union BREFs (http://eippcb.jrc.ec.europa.eu/reference/) and other comparable regulations. Acceptable process design must take into account the potential for side products and wastes, and make provisions for their safe handling or destruction. It must recognize that if the process carries the potential for generation of chemicals listed in Annex C, the four streams being emitted from a facility – air, water, residues and product – also carry that potential. Modern process design takes into account that potential, monitors for and controls emissions and includes operations to reduce or eliminate emission of those materials, commensurate with the requirements of the Convention. Modern safety management includes extensive training for operators and sufficient analytical and control instrumentation so that the facility as a whole operates to responsible standards.

The main demands for modern and safe chemical production can be found, for example, in relevant BREF documents (European Commission 2006, 2016).

The principle of green chemistry to promote the use of alternative synthetic routes and alternative reaction conditions to existing less environmentally friendly processes should be promoted (see for instance European Commission 2006, 2016), i.e. by:

- Improving process designs to maximise the incorporation of all the input materials used into the final product;
- Using substances that possess little or no toxicity to human health and the environment. Substances should be chosen in order to minimise the potential for accidents, releases, explosions and fires;
- Avoiding the use of auxiliary substances (e.g. solvents, separation agents, etc.) wherever possible;
- Minimising energy requirements, in recognition of the associated environmental and economic impacts. Reactions at ambient temperatures and pressures should be preferred;
- Using renewable feedstock rather than depleting, wherever technically and economically practicable;
- Avoiding unnecessary derivatisation (e.g. blocking or protection groups) wherever possible;
- Applying catalytic reagents, which are typically superior to stoichiometric reagents.

2.2. General BAT and BEP measures applicable to handling all chemicals

This Section describes general principles, measures and safety precautions that apply to all types of chemicals and industries handling them (GTZ 2008, ZDHC 2015).

Chemical Knowledge, Storage, Handling, Dosing, Dispensing and Transport

The following principles and/or measures apply:

- When storing, handling, dosing, dispensing, and transporting any chemical, caution should be used, necessary protective measures implemented and proper personal protective equipment worn.
- Before ordering/receiving any chemical review the local language Safety Data Sheet (SDS). If possible, avoid CMR (carcinogenic, mutagenic, reproductive toxin) and PBT (persistent, bioaccumulative and toxic) substances, and substances that can degrade to CMR or PBT substances (see SDS Section 2, 11, and 12).
- In case a complete SDS is not available from one supplier, order the product from an alternative supplier that provides a complete SDS.
- Before handling any chemical, review the SDS carefully.
- Gather information from the supplier on amounts of residual raw materials, by-products and potential degradation products in the product you intend to order.
- A trained representative of the receiving company should authorise and attend the delivery of the product, whether it is to be delivered in bulk quantities or smaller packages and containers.

- Reject leaking or dented containers upon receiving.
- Deliveries should be made according to a written supervision procedure that includes a checklist covering all the safety-critical steps in the delivery process.
- Proper storage according to the instruction of the most up to date safety data sheet (SDS), preferably in Global Harmonization System (GHS) format.
- Proper labelling of containers and equipment; storage in special compartments, containers or locations for toxic and explosive chemicals to avoid leakage and spill.
- Dosing and dispensing without spilling in automated dosing systems.
- All areas where chemicals are delivered, stored, transferred and used should be secure: the site itself should be secure with local measures to ensure security, such as lockable connections to storage tanks or a lockable container storage area.
- The plant and equipment should be regularly inspected and serviced to ensure proper functioning; this includes especially the check of the integrity and/or leak-free status of valves, pumps, pipes, tanks, pressure vessels, drip trays, containment facilities and bunds and the functionality of alarms/warning systems.

Minimization/Optimization of the Chemicals Used

The following principles and/or measures apply:

- Minimize the use of all chemicals and auxiliary materials.
- Measure, mix and dose chemicals carefully to avoid losses.
- Minimize residual, left-over chemicals, by calculating exactly how much is needed for the process step.
- Substitution of overflow rinsing or minimization of water consumption in overflow rinsing by means of optimized process control.
- Reuse of rinsing baths, including final rinsing baths – where possible.
- Reversing of current flows in continuous washing.
- Cleaning and recycling of process water – where possible.

Engineering, Design and Equipment

It is recommended to:

- Use equipment, pipes, valves, etc. that are suited to handle the material (e.g., corrosion resistance) to ensure a long equipment life and to avoid equipment breakdown and leaks.
- Prevent releases to the environment via air, install dust collectors, scrubbers or similar devices.
- Collect all waste and leftover chemicals from all processes and dispose of them in accordance to guidance provided in the product SDS and in compliance with local rules and regulations. In general, the drain is not an appropriate outlet for liquid waste and a community landfill is not an appropriate outlet for solid waste.

Leak and Spill Procedure

It is recommended to:

- Follow instructions according to information provided on the SDS.
- Make such a procedure part of the operator training to enhance preparedness.

- Implement routine monitoring and maintenance (M&M) programme or leak detection and repair (LDAR) programme. Components leak rates should be checked on a regular basis to identify leaking components for repair and future monitoring.
- Over time, it is possible to build up a picture of priority areas and persistent critical components enabling effective targeting of maintenance work and/or improvement in design.

Emissions Reductions and Waste Management

It is recommended to:

- Follow all procedures as outlined above.
- Adhere to waste disposal methods given in the SDS.
- For guidance on sound management of waste, guidance is provided by the Basel Convention (see above).
- Incinerate waste, if required, at an approved facility that operates under BAT conditions.

3. Specific BAT and BEP measures for the production and use of PCP for the specific exemption under the Stockholm Convention

3.1. BAT and BEP for PCP production

As noted in Section 1.3.2., the manufacture of pentachlorophenol may lead to the formation of PCDD/PCDF and other unintentional POPs – all strictly regulated substances. The propensity for PCDD/PCDF formation in the manufacture of chlorophenols has been reported as follows (UNEP 2013b):

Chlorophenols > chlorobenzenes > chlorinated aliphatics > chlorinated inorganics.

Overall, the manufacturer should employ technology to minimize worker exposure and to minimize emissions to the environment which includes water, air and soil.

In a study by UBA (1986), the annual air emission values for PCP resulting from the production of approximately 2000 tonnes of PCP or Na-PCP were estimated to be 18 kg/year and 65 kg/year respectively. According to Registry of Emissions and Transfer of Contaminants of Mexico, the annual air emission value of PCP from production processes at the KMG production plant was of 14 kg PCP/year in 2012 (Mexico 2014). As a result of process design, the quantities of chlorophenolic wastes generated in the chemical production process are reportedly small. Available treatment methods for such waste should prove satisfactory, if they are carefully applied. Gravity separation is the primary treatment method most often used to recover oil and the associated chlorophenol for recycling and treatment. Organisms during secondary treatment degrade roughly 90% of most chlorophenol waste, provided that they are acclimated to the waste, and precautions are taken against shock loadings. As a pre-treatment operation, adsorption on activated carbon can be performed to remove chlorophenols from the waste-streams. The final disposal of the concentrate and the adsorbent should take place in accordance with the Basel Convention Technical Guidelines (UNEP 2017a,b).

The Guidelines on BAT and BEP under Article 5 and Annex C of the Stockholm Convention, Section VI.F, contains relevant provisions for release reduction from the specific chemical production processes listed in Annex C (UNEP 2007).

The Reference Document on Best Available Techniques for the Manufacture of Organic Fine Chemicals (European Commission 2006) covers overall BAT provisions for organic fine chemicals generally applicable to the production of chlorophenols. The Best Available Techniques (BAT) Reference Document for Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (European Commission 2016) contains relevant measures for waste water treatment and air emission abatement including specific provisions for the production of chlorophenols.

All general information provided in Chapter 2 of this document is applicable and should be followed.

3.2. BAT and BEP for the use of PCP for wood preservation

3.2.1. Process description

The wood treatment processes typically consists of four stages (Environment Canada 2013).

Wood Conditioning

Before wood can be successfully impregnated with preservatives, the bark has to be removed and the moisture content reduced by a process involving drying or conditioning. This may be achieved by air seasoning, kiln drying or by a process carried out in the treatment cylinder, for example, a steam/vacuum process or boiling-under-vacuum (Boultonizing) in the presence of the treating solution.

The method chosen depends on the wood product, specifications, the available equipment, desired moisture levels and the preservative used. For poles to be treated with PCP/oil, a steam/vacuum process is preferred; Boultonizing is common with ties and marine pilings to be treated with creosote or creosote/oil solutions.

Wood treatment

The PCP treating solution is a mixture of PCP and diluent oil.

PCP is generally purchased as solid blocks, usually weighing 907 kg. The PCP blocks are dissolved by placing them in the treatment cylinder or into a mix tank and recirculating heated oil between the cylinder or mix tank and the bulk storage tanks to produce a concentrated solution. The concentrate is then diluted to working concentration (5–9%) (Environment Canada 2013).

The application of the preservative can consist of two processes (Environment Canada 2013):

1. The Pressure Treatment (Empty-cell) Processes

This category includes two processes, the Rueping and the Lowry, both of which are typically used with creosote (an alternative to PCP) and PCP for treatment of utility poles, railway ties, posts and construction lumber, and timber. The processes are designed to give deep penetration, while maximizing preservative retention.

- The Rueping process applies an initial air pressure (200–500 kPa for 15 minutes) to the wood charge in the cylinder prior to admitting the preservative. The pressure compresses the air inside the wood. Hot preservative is then admitted to the wood without releasing the air pressure. The pressure is increased to a typical maximum of 1040 kPa and held until predetermined solution absorption has been achieved. When the pressure is released at the completion of the impregnation cycle, the compressed air in the wood expands and expels excess preservative. This effect, which is called the "kickback," is usually enhanced by a quick final vacuum. Excess preservative is returned to storage for use in subsequent treatments.
- The Lowry process is similar to the Rueping process, except that no initial air is applied and the preservative is admitted at atmospheric pressure. The remainder of the process continues in the same manner as the Rueping process. There is usually a smaller amount of preservative recovered by the kickback in a Lowry process.

2. The Thermal Treatment Process

This process is applied with PCP/oil solutions for the pole butt treatment of dry utility poles.

A pressure vessel is not required to carry out the process. The lower ends of poles (butts) are impregnated with preservative in upright, open-top tanks. During the cycle, dry wood is first immersed in hot preservative (88 to 113°C) for a minimum of six hours (hot bath). Thereafter, the hot preservative is quickly replaced by cooler preservative for at least two hours (cold bath). Excess preservative is returned to the storage tank.

After-impregnation Processes

Treatment cycles are followed by a final vacuum, which equilibrates internal pressure, removes air and preservative from the surface fibres of wood and, in the case of oil-borne treatments that use elevated temperatures, cools the wood. A final vacuum may not be adequate to create clean surfaces. In these cases, the impregnation cycle may be followed by an expansion bath or a final steam cycle, both of which add a final vacuum step. These processes can be quite effective, but the final steam cycle creates large volumes of contaminated water that must be treated to meet all discharge criteria.

Storage After Treatment

Treated wood is stored on a drip pad until preservative drippage has stopped. The duration of this storage may vary from hours to days. Important elements for storage after treatment in order to minimize sources of releases are either storage under roof or on paved ground with collection of run-off water. When fixation has been verified, the treated wood may be transferred to a designated yard area for storage until shipment or it may be directly loaded for immediate shipment.

Releases during wood treatment

At the wood treatment facility releases to the environment (air, water and soil) may occur:

- during the dipping process (volatilisation to air);
- during transport from dipping to drying (runoff from wood surface to soil);
- during the drying/fixation process (volatilisation to air and leachates to soil or water);
- as solid waste, sludge from the bottom of dipping/treatment tank.

Figures 1 and 2, reproduced from Environment Canada (2013), illustrate the potential sources and releases from the pressure treatment process and from the thermal treatment process, respectively.

Figure 1: Potential chemical releases from PCP pressure treatment plants (Source: Environment Canada 2013)

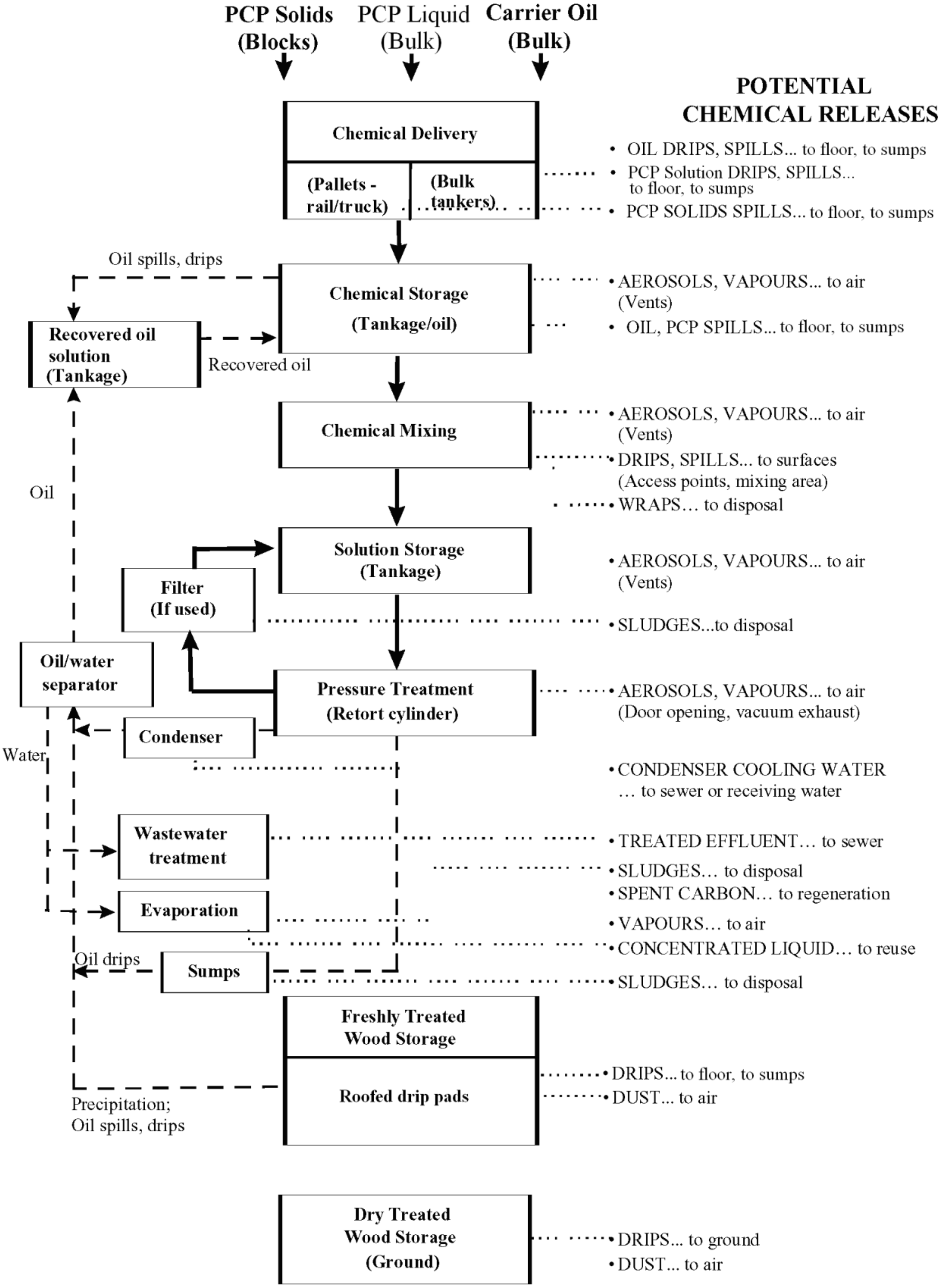
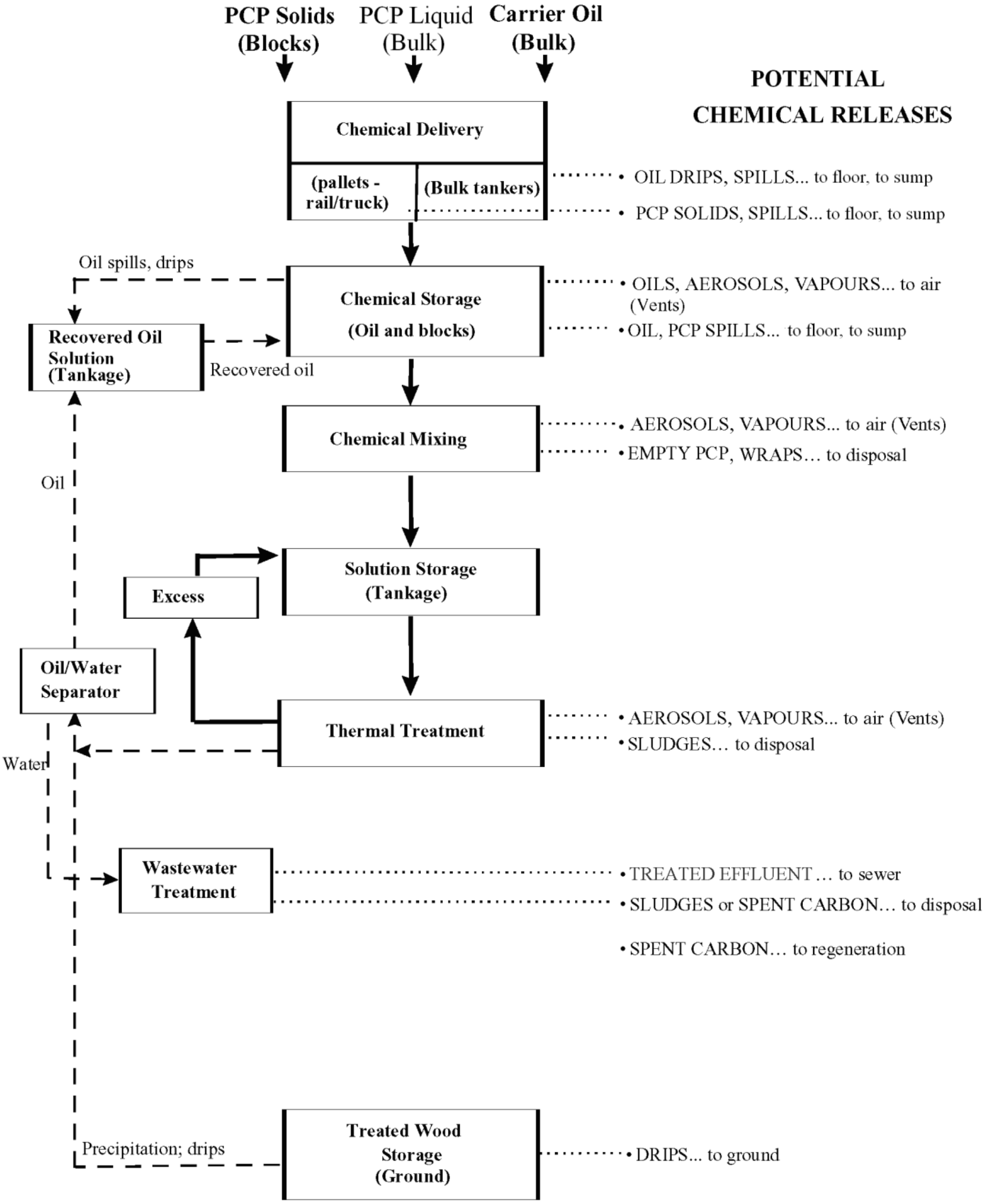


Figure 2: Potential chemical releases from PCP thermal treating plants (Source: Environment Canada 2013)



The process of wood preservation requires that consideration is given to the whole operation, including safe storage, handling, use transport and disposal of all materials used, as well as the end product. Effective health and safety policies, arrangements and procedures must be prepared and properly implemented. These should cover the provision, use and maintenance of safe plant equipment, systems of work and health, and welfare facilities.

The following Section 3.2.2. provides specific guidance for the various stages of the wood treatment process (Ireland EPA 2011, IEO-WEI 2011, Environment Canada 2013, Norden 2014, European

Commission 2017). Section 3.2.3 provides information on alternatives to PCP for wood preservation under the exempted application (USEPA 2008, KEMI 2016, UNEP 2014, 2017c).

The general guidance provided in the Chapter 2 should be considered together with the information contained below.

3.2.2. BAT and BEP measures for wood preservation

3.2.2.1. Site operation (receiving, storing and handling of pesticides)

Preservative should be delivered to the site either by bulk tanker or in sealed, labelled containers (appropriate drums or intermediate bulk containers). A trained representative of the receiving company should authorise and attend the delivery of the product, whether it is to be delivered in bulk quantities or smaller packages and containers.

Deliveries should be made according to a written supervision procedure that includes a checklist covering all the safety-critical steps in the delivery process. During delivery, use drainage shut-off valves, where needed, to isolate from the drainage system. All areas where preservatives are delivered, stored, transferred and used should be secure: the site itself should be secure with local measures to ensure security, such as lockable connections to storage tanks or a lockable container storage area.

Roofing

All areas where preservatives are delivered, stored, transferred and used should be roofed. This includes bulk preservative storage tanks, preservative container storage areas, mixing tanks, the wood treatment vessel, and the holding or dripping area for wet, freshly-treated timber (i.e., the dripping area) and the storage area for treated timber until fixation of the preservatives is ensured or until dry to touch (according to the wood preservative specifications).

Containment

Bunding (containment) should be in place for all preservative storage tanks, delivery connections to bulk storage tanks, mixing tanks, the wood treatment vessel, fixation/drying areas of freshly treated woods, and the storage area for preservative containers. The containment area or bund can - depending on site layout - incorporate the whole plant or consists of separate dedicated containments for parts of the WPC plant, e.g. containment of wood preservative delivery, storage and mixing area, of treatment vessel(s) and associated loading/unloading areas, the treatment area.

The bund for plants with a single storage tank should be constructed with a capacity of at least 110 % of the preservative (chemical) storage capacity. For multiple tanks in the same containment or bund it should be 110 % of capacity of the largest tank or 25 % of the total volume that could be stored in all tanks in the containment/bund - whichever is greater. In other scenarios (e.g. storage of preservative in drums) it should be at least 25 % of the total volume that could be stored at any time.

The containment/bund should fulfil the following design features:

- capacity to retain all preservative fluid (chemicals) in case of leakage or accident;
- impervious and resistant to the chemicals (preservative used);
- able to withstand static pressure of liquids (volume) to be captured.

The site operator should train one or more employees who are able to inspect the bund and report on its condition and to observe any leaks or areas requiring remedial action. The bunds should be periodically inspected and a record kept of each inspection. Ideally the plant bund should contain no liquid or debris so the bund walls and floor can easily be inspected.

Operational practices to eliminate the spread of preservative contamination on vehicle wheels and footwear should be implemented. This can include the following measures in the preservation process area, as appropriate: plant design and layout, raised walkways, dedicated forklift trucks in preservative containing areas, restricted vehicle access, restricted personnel access, good housekeeping and wheel washes.

Suitable spill handling and containment equipment should be readily available in all preservative handling areas.

All process pipelines should be over ground.

Other storage requirements

All mixing, storage vessels and containers should be enclosed or fitted with adequately fitting lids. Containers should be sealed when not in use.

All fixed storage and mixing tanks should be fitted with high-level alarms and level indicators and/or automatic shut-off valves in liquid supply to prevent overflow.

All preservative tanks and containers should be labelled indicating the contents.

Organic solvent containing waste (e.g., absorbents, wipes, protective clothing, etc.) should be stored in sealed containers.

Water supply should be monitored and controlled.

Security

The plant and equipment should be regularly inspected and serviced to ensure proper functioning; this includes especially the check of the integrity and/or leak-free status of valves, pumps, pipes, tanks, pressure vessels, drip trays, containment facilities and bunds and the functionality of alarms/warning systems.

3.2.2.2. Wood conditioning

Any impregnation process requires a certain level of wood moisture, in order to achieve the optimum result of the impregnation. Measuring the wood moisture before impregnation and - if needed - adjustment of wood moisture ensure the required quality of the impregnated wood. Wood with suboptimal moisture content is brought to the optimal wood humidity level before the treatment (e.g. by extending seasoning (air drying) or by active drying (kiln drying)). European Commission (2017) details two methods for determining the moisture content, namely electric resistance measurements and weighing procedures.

As the packs of timber are invariably transported protected in plastic-based sheeting to protect the timber and prevent it taking up moisture, such plastic wrappings should be removed from wood packs to avoid wood preservatives being trapped in the plastic and being emitted after treatment (e.g. as drippings) or generating hazardous waste (i.e. contaminated plastic waste).

3.2.2.3. Wood treatment

Pressure treatment and thermal treatment processes are described to be in use to treat wooden poles and cross-arms with preservatives (Environment Canada 2013, BMU 2013, UBA 2015, Environment Canada 2017, European Commission 2017).

Different preservative application systems vary in their application efficiency (i.e. the amount of preservative used to achieve certain retention in the wood; how much of the preservative solution actually affects the wood during the treatment procedure). Application system where the wood is immersed in the preservative solution have a higher efficiency than, for example, spraying. The application efficiency for dipping and brushing is close to 90%, and using the vacuum process with full containment is close to 100 %. Spraying has a much lower efficiency, i.e. from 10 % to 50 % (European Commission 2017).

Consumption of treatment chemicals is controlled by: a) weighing of the wood/wood product before and after impregnation or b) calculation and verification of the impregnation rate during and after impregnation (requiring measurement of liquid levels in vessels and tanks). The amount of treatment chemical introduced in the wood should be within the range required by product quality standards (e.g. use class, penetration class) and the retention amount for treatment chemicals as proposed by supplier.

It is recommended to:

- Use a trolley design, which minimises the amount of preservative retained on wood when it is removed from the treatment vessel.
- Fill the plant to capacity with timber and avoid part loads.
- Loading of timber for the treatment process vessel should be done in a manner to avoid retention of excess preservative, including where possible:
    - Sloping the timber;
    - Stacking the timber so that the greatest surface area is available for the treatment solution;
    - Using spacers to avoid capillary retention between surfaces;
    - Positioning shaped profiles to limit the amount of liquid preservative trapped in any such profiles.

The wood charge should be optimized to allow free movement of the preservative solution and optimum draining of the solution after treatment, thus reducing consumption and drag-out of preservatives, and the risk of emission to the environment.

The use of a tilting treatment vessel, which aids the drainage of preservative during the final treatment stage, is recommended.

Impregnation installations

The following recommendations should be considered for impregnation installations:

- Waterproof and preservative-resistant catch basin when using single-walled impregnation cylinders or open steeping tanks. The volume of the basin has to match (at least) the quantity of the preservative used in the process. Automatic leak indicating device when using a catch basin where one cannot look inside.
- Double-walled impregnation vessel for non-pressure treatments with leak indicating device.
- Protection against leaks and overflows of the impregnation installation.
- During pressure impregnation, one must make sure that it is possible to look at the vessels and ducts to check them. During pressure impregnation, one must make sure that the cylinders cannot be opened (especially when under pressure) during the impregnation process.
- A special drip collector or a catch basin needs to be placed at the opening of the cylinder in order to prevent emissions of wood preservatives when the cylinder is opened.
- Aerosols may form inside the cylinder after the pressures are equalised. A release of these aerosols can be prevented by waiting for an hour until the liquid droplets which are present in the cylinder have precipitated.
- The ducts attached to the metering, mixing and storage vessel are to be installed in such a way as to avoid the formation of droplets arising from the recycling of the preservative solution – e.g. installing the recycling duct from the pressure pump not lower than just above the level of the liquid or cover up the area.
- At the exhaust side of the vacuum pump there must be devices to prevent emissions of wood preservative solutions in the form of aerosols (e.g. liquid separators).
- When preparing or mixing wood preservative solutions, the use of compressed air must be avoided to prevent the formation of aerosols.

Additional measures for treatments with creosote

Additional BAT and BEP measures for treatments with creosote include:

- Reduce VOC emissions by using creosote of the type WEI C instead of type WEI B (see UBA 2015, Chapter 4.3).

- Use gas displacement devices, below-surface filling or suction with exhaust gas cleaning devices when transferring tar oils.
- Use exhaust air suction for treatment processes with tar oil together with exhaust gas cleaning (thermal afterburning, using the supply air for the cylinder for energy supply, or activated coke filter). Achievable VOC emission levels with activated coke filter < 10 mg VOC/Nm^3 (measured O_2 content)
- When using tar oils for pressure process, it is advisable to leave the soaked material in the impregnating cylinder until it has fully cooled down in order to prevent or minimise the release of organic compounds.
- Woods impregnated with creosote may lose part of the wood preservative through “sweating” after treatment. Treatment-specific measures (sufficiently high final vacuum, avoidance of too much tar oil absorption) can help to reduce these losses.
- Sludges which form in impregnation installations as a result of wood contamination or abrasion have to be disposed of regularly as there is a risk that they may be deposited on the surface of the soaked material and blown away during the drying process in the form of contaminated dust containing wood preservatives.

Recovering the wood and wood products from the cylinders/tanks of impregnation installations

It is recommended to:

- Recycle residual liquids and dripping solution
- Provide for a solid base, impermeable to wood preserving solutions, within the area of the impregnation installation, in the pull-out section and in the drip dry zone. Provide for a feed channel around the solid base.
- Allow sufficient time for the wood preserving solution to drip from the wood when removing it from the pressure cylinder or tank.

Treatment vessel working pressure

Precautionary design features for pressure treatment vessels (autoclaves) comprise the following techniques:

- Safety locks for vessel door: the treatment vessel is locked shut and sealed once the wood pack/vessel loading system is loaded and before treatment takes place. Process controls are in place that prevent the operation of the treatment vessel unless the vessel is locked and sealed;
- Process controls displaying whether liquid is present in the treatment vessel;
- Process controls prevent the treatment vessel from opening before all preservative solution is removed from the treatment vessel: process controls prevent the opening of the treatment vessel while it is still pressurised and/or filled;
- Catch-lock for the treatment vessel door: the door of the treatment vessel is equipped with a catch-lock to prevent the release of fluid in case the treatment vessel door needs to be opened in an emergency situation;
- Safety pressure-relief valves: treatment vessels are fitted with safety relief valves to allow emptying of vessel in a controlled manner. The valves should be designed to ensure that any discharge is directed to a tank of sufficient capacity. Pressure/vacuum-relief valves should be examined at regular intervals for signs of corrosion, contamination, incorrect fitting and to be cleaned and/or corrected as required.

Pressure vessels must have a safety relief valve fitted to enable them to be operated safely:

- All vessels should be fitted with a safety relief valve set at a maximum of 10% above the maximum design pressure to act as the over-pressure relief valve unless the vessel design code permits a higher value;
- All vessels should be fitted with a second relief valve or alternative system to control the working-process pressure of the plant and this pressure should not be set above the maximum design pressure of the autoclave;
- In the case of high pressure treatment plants either relief valves or pressure switches may be fitted to control the working pressure of the plant;
- All treatment vessels should be fitted with either a pressure or a vacuum gauge certified and checked on a regular basis; that give an accurate indication of the conditions inside the vessel and should be located next to the plant door and any gauges should be easily seen from the vessel door area.

3.2.2.4. After impregnation processes

A final vacuum step is applied in the treatment vessel before opening it to remove excess treatment chemicals from the gas phase surface of treated wood and to avoid dripping.

Application of a final vacuum may not be necessary if the removal of excess treatment chemicals from the surface of treated wood is ensured by the application of an appropriate initial vacuum (e.g. less than 50 mbar).

Prior to discharge from the vessel, as much holding time within the vessel as allowable together with mechanical shaking of the load, where possible, should be carried out to minimise preservative liquid being removed from the vessel. Establish and implement appropriate dripping times within the vessel before removal of the timber load.

The use of a tilting treatment vessel, which aids the drainage of preservative during the final treatment stage, is recommended.

3.2.2.5. Storage after treatment

Removal of treated wood from working area should only be conducted after fixation stage (minimum holding time according to wood preservative specifications). Bulk quantities of dry treated timber should be stored under cover or on an impermeable surface to prevent possible contamination of surface and / or groundwater. Post-treatment area should be located in proximity to the treatment area.

Treated wood that has completely dried should be stored, where feasible, under cover to prevent groundwater and surface water contamination through leaching during periods of wet weather. If this is not feasible, it should be stored on an impermeable surface with the treated wood placed on supports to avoid contact with runoff water and the surface water from this area collected separately, with the facility to monitor/sample, prior to any dilution with any other surface waters.

Treated timber should be stored according to the instructions given in the wood preservative manufacturer’s technical literature.

Freshly preserved wood must be stored in a place where it is protected from the weather (e. g. canopies, roofs), in particular during the prescribed fixation period. Any contact with the ground of freshly impregnated wood must be avoided and sufficient ventilation of the impregnated material must be ensured. Adequate store rooms (with suitable containment systems) or storage areas (on a solid base) must be provided.

Dripping

To collect and recover wood preservatives (chemicals) from process steps where dripping may occur (e.g. when opening the autoclaves, unloading the treatment vessel (pressure and non-pressure), or from freshly treated wood after transfer from the treatment vessel loading system), drip trays (also referred to as drip pans, drip pads or collecting trays) should be installed. The collected preservative solution should be recirculated into the treatment chemicals system.

The floor in the areas where drippage, spills or accidental releases of preservatives/treatment chemicals or solvents may occur should be sealed, and spills and/or surface run-off water should be collected and used/reused in the preservative system.

After the treatment with preservatives, the treated wood should be held for a sufficient time over the treatment vessel to allow surplus treatment solution to drip into the treatment vessel or the wood is held over a dripping pad which inclines towards the treatment vessels and allows the drippings to flow to the dipping vessels, thus avoiding the release of preservatives from the tanks or vessels.

Stacking of timber after the treatment process vessel should be done in a manner to promote dripping of excess preservative in the dripping area, measures include:

- Sloping the timber;
- Using spacers to avoid capillary retention between surfaces;
- Positioning shaped profiles to promote the preservative to run out of any such profiles.

Holding or Dripping Area

The holding or dripping area for wet, freshly-treated timber must be under roof, contained and impermeable, must be located adjacent to the processing plant, must be adequately sized, and must facilitate the collection of drips for reuse or safe disposal (e.g., sloped and sumps to enable collection and storage). Treated wood should be removed from the holding or dripping area and sent for storage only after dripping has completely stopped. As an example, before leaving the post-treatment drying area, treated wood/wood packs are lifted by mechanical means and suspended for a minimum of 5 minutes. If no dripping of treatment solution occurs, the wood is deemed to be dry.

Process modification, timber packing in the vessel and good carriage design which prevents accumulation of preservative will all help to eliminate or minimise post-treatment dripping. Post-treatment should follow the label instructions of the wood preservatives.

A covered and/or contained and impermeable dripping area for freshly treated timber should be provided and be situated adjacent to the plant and the storage tank bund.

Minimum holding times and other requirements may be required to be met before the treated timber can be moved from the treatment area.

3.2.2.6. Techniques for managing releases

At the wood treatment facility, releases to the environment (air, water and soil) may occur (see also Figures 1 and 2):

- during the dipping process (volatilisation to air);
- during transport from dipping to drying (runoff from wood surface to soil);
- during the drying/fixation process (volatilisation to air and leachates to soil or water);
- as solid waste, sludge from the bottom of dipping/treatment tank.

Air emissions

The main emission source is from the solvent content of the applied substances. Fugitive and contained emissions can be reduced with the help of abatement equipment. Solvents which remain in the wood after complete drying evaporate over longer periods of time. Fugitive emissions occur during handling, application and drying stages. However, the majority of the emissions occur during the drying process. Processes using traditional solvent-based preservatives need treatment with end-of-pipe techniques and occupational health care. Two secondary measures are possible: thermal oxidation and carbon adsorption.

Emissions can be reduced by applying a solvent management plan, enclosing the process wherever possible so that air can be extracted through abatement equipment and using alternative low solvent coatings.

The extracted waste gases can be treated. In large wood preservation plants, treatment of emissions is carried out. In smaller plants, abatement equipment may not be economically viable, but occupational health care must be deployed. Solvent absorption with either off-site recovery or disposal of absorption cartridges may be the most viable option.

Mist eliminators should be used where appropriate, to remove liquid droplets of preservative entrained in the air stream.

Waste Water

Wood treatment processes generally do not generate any direct process effluent.

In order to prevent or contamination of rain and surface run-off water, rain and surface run-off water are kept separated from areas where treatment chemicals are stored or handled, from areas where freshly treated wood is stored and from contaminated water. This is achieved by using at least the following techniques:

- drainage channels and/or an outer kerb bund around the plant;
- roofing with roof guttering of areas where treatment chemicals are stored or handled (i.e. treatment chemicals storage area, treatment post-treatment conditioning and interim storage areas, pipes and ductwork for treatment chemicals, creosote (re)conditioning facilities);
- permanent weather protection (e.g. roofing, tarpaulins) for the storage of treated wood where there is a risk of leaching of treatment chemicals.

However, surface water run-off may potentially be contaminated with preservative. Surface run-off water from areas that are potentially contaminated with treatment chemicals is collected separately. Appropriate buffer storage capacity is provided using a risk-based approach (e.g. taking into account the nature of the pollutants and the expected quantity). The discharge of waste water from this buffer storage is only possible after appropriate measures are taken (e.g. monitor, treat, use). After its collection, potentially contaminated surface runoff water is collected and reused completely for the preparation of water-based wood preservative solutions. This is only applicable to plants using water-based treatment chemicals. Applicability may be also restricted by the quality requirements for its intended use.

The separate collection and monitoring where required, of surface water from areas that can be potentially contaminated with preservatives should be carried out.

Because PCP wood preservation facility sites are generally large, considerable volumes of storm runoff waters may originate from these sites. Liquid discharges from the pressure treatment process, include:

- Condensates removed from the wood during conditioning and during the initial application of the vacuum process;
- Water released by the wood during the treating cycle and subsequently separated from the unabsorbed treatment oil prior to recycling;
- Wash waters (water used to wash equipment and containers is recovered and reused in the preparation of water-based wood preservative solution).

Although no liquid process wastes are produced during thermal treatment, the following situations could create liquid releases:

- Spills or overflows of liquid from open treatment tanks;
- Infiltration of groundwater into tank containment systems;
- Leaks from treatment tanks that have no containment provisions;

- Surface runoff from the treated wood storage areas.

These liquids can contain PCP and must be treated before discharge as a waste stream. For liquid wastes, leaks and drips of oil solutions are contained and reused in the treatment process. Liquids such as condensates, wash waters and infiltrating waters, which cannot be reused, require treatment to remove oil and PCP prior to discharge.

The use of sumps/interceptors for such separate drainage areas can assist in catching leakage or spillage losses.

Contaminated water solutions require waste water treatment in order to remove oil and PCP prior to discharge. The techniques may include one or a combination of the following:

- Gravity separation;
- Oil/water API separation, plate separation;
- Activated sludge treatment;
- Activated carbon treatment;
- Physical-chemical treatment (i.e. flocculation);
- Evaporation/condensation.

It is also recommended that surface runoff from storage areas should be monitored for chlorophenols and oil. In certain situations treatment facilities may be necessary for surface water from areas that can potentially be contaminated with preservatives used at the installation. Treatment options can include grit chamber, sedimentation tank or pond, retention pond, sand filter.

The need for treatment must be evaluated on a site specific basis.

Solid Waste

In order to reduce solid waste sent to disposal, debris (e.g. sawdust, woodchips) is removed from the surface of the wood/wood products before treatment.

Solid wastes from treatment facilities that use oil-borne PCP may include the following:

- Sludges from treatment and storage tanks, sumps and pressure cylinders;
- Sludges from wastewater treatment processes (e.g. flocculated material);
- Containers or wrappings and pallets from bulk PCP;
- Contaminated soils;
- Pallets and wrappings from bulk PCP.

All waste generated from treatment facilities should be managed in an environmentally sound manner in accordance with the Stockholm Convention provisions and taking into account the Basel Convention technical guidelines namely:

> “The General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants“ (UNEP 2017a); and
>
> “Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with pentachlorophenol and its salts and esters“ (UNEP 2017b).

The guidelines on BAT BEP section VI.E: Combustion of contaminated wood, such as urban wood waste and demolition wood, should be strictly limited to installations with efficient emission control – it is preferable that this material is not used in boilers and it should not be used in domestic ovens.

3.2.3. Alternatives to the use of PCP for wood preservation

Several approved and specified chemical alternatives to PCP for wood preservation and non-chemical (functional) alternatives to wood for utility poles and cross arms are reported (USEPA 2008, UNEP 2014, KEMI 2016, UNEP 2017c, and company-specific websites: e.g. www.cwc.ca, www.woodpoles.org). A number of chemical alternatives (such as chromated copper arsenate, creosote, copper naphthenate, and ammoniacal copper zinc arsenate) exist and are broadly comparable in price and application process to PCP. Other registered alternatives include copper azole and ACQ. Salt-based products that include at least one of the following copper compounds as an active substance; Cu-HDO, Cu-hydroxide, Cu-hydroxide-carbonate (1:1) and Cu-oxide in combination with other compounds such as quaternary ammonium compounds, boric acid, propiconazole and tebuconazole are used as wood preservatives including for utility poles in Europe (KEMI, 2016). It should be noted, however, that alternative products might not be directly interchangeable and will have specific strengths and weaknesses for any given application. Some of the commonly used commercial chemical alternatives to PCP, namely chromium or arsenic containing substances, and polyaromatic hydrocarbons containing substances (e.g. creosote), exhibit hazardous properties.

Non-chemical alternatives to PCP-treated wood for wood poles (such as steel, concrete, fibreglass composite, undergrounding) offer possible options, with potentially longer life spans, in certain circumstances, reduced maintenance costs, and pest/fire resistance. However, initial costs for manufacture and installation are significantly higher than treated wood and different life cycle analyses exist, demonstrating that life-time costs and environmental profile can be either better or worse than treated wood with no clear resolution.

Sections 3.2.3.1 and 3.2.3.2 provide detailed information on the principle chemical and non-chemical alternatives that are available and applicable for the specific use of PCP for wood poles and cross-arms.

3.2.3.1. Chemical Alternatives

Wood treatment using chemical alternatives to PCP should equally consider BAT and BEP measures to minimize releases of harmful chemicals into the environment. European Commission (2017) provides specific BAT requirements for wood preservatives. Other specific guidance is available in the frame of other regulations worldwide (e.g. Environment Canada 2004, 2013). The standards for preservative treating of wood utility poles for the USA are set by the American Wood Protection Association (AWPA; http://www.awpa.com/) and detailed in the AWPA Book of Standards; for Canada by the Canadian Standards Association (CSA; www.csagroup.org) and detailed in CAN/CSA O80 Series-15 – Wood Preservation.

Chromated Copper Arsenate (CCA)

CCA is a product blend (in a ratio of 5:3:2) of chromic acid (CAS No. 1333-82-0), arsenic acid (CAS No. 7778-39-4) and cupric oxide (CAS No. 1317-38-0) (UNEP 2014). The product is widely used in North America and is recognised as the main preservative wood treatment product in the USA for industrial use, with 44% market share (USEPA 2008). It is also widely used in Canada and New Zealand (Canada 2014, New Zealand 2014). CCA is typically used for Southern Pine and Western Red Cedar poles. CCA is an effective preservative because it chemically "fixes" or bonds to the wood, reducing potential migration of the preservative into the soil or groundwater. To improve climbability, an oil-based emulsion treatment can be added and the poles are marketed as CCA-ET treated poles. The emulsion additive allows for better climbing gaff penetration (AWPA; http://www.awpa.com/).

CCA is typically used in a pressure treatment process for wood following a similar process to PCP and creosote, although CCA is used at lower application temperatures: 65°C compared to 100°C for PCP and creosote (USEPA 2008). On completion of pressure treating (for all preservative types) it is necessary to include a drying cycle. For CCA an accelerated fixation process ensures that the preservative chemicals are highly leach resistant. Such a process entails a heating cycle, usually in the presence of high humidity. Fixation chambers are employed or the process may be carried out in drying kilns (Environment Canada 2013). The pressure treatment process, when correctly applied, provides high fixation rates for CCA with the metal components tightly bound to wood (Environment Canada 2004).

CCA is recognized as producing a clean, dry, odour free finish which is easy to paint. However, CCA treatments can have an effect on moisture content of wood leaving them particularly dry. This has previously caused additional problems for climbing utility poles, now overcome with the use of softeners

(Canada 2014). For hot dry climates the use of CCA can also be an issue for shrinking, cracking or warping of wood. This is particularly an issue for load-bearing structures such as cross-arms for utility poles (GEI 2005). The use of oil-based preservatives such as PCP and creosote provide an additional 'suppleness' to wood which can protect against warping and cracking in hot dry climates. CCA is also recognized as being corrosive to some metal types meaning that galvanized metal fastenings should be used in combination with CCA applications (UNECE 2010). This approach is taken as the industry standard in the USA (USEPA 2008).

CCA contains two carcinogens, hexavalent chromium (CrVI) and arsenic, along with copper which is highly toxic to aquatic organisms (USEPA 2008, CDC 2013, USEPA 2013). A summary of potential health effects of (short-term and long-term) exposure to CCA solutions has been published by Environment Canada (Environment Canada 2013: https://www.canada.ca/en/environment-climate-change/services/management-toxic-substances/publications/environmental-recommendations-wood-preservation-facilities/chromated-copper-arsenate/table-4.html; accessed on 10 January 2019). The GESTIS database (http://gestis.itrust.de/nxt/gateway.dll/gestis_en/000000.xml?f=templates&fn=default.htm&vid=gestisen g:sdbeng; accessed on 10 January 2019) lists the following Hazard Statements (H-Phrases) for the constituents of the product:

- Chromic acid: H271: May cause fire or explosion; strong oxidiser, H301+H311: Toxic if swallowed or in contact with skin, H330: Fatal if inhaled, H314: Causes severe skin burns and eye damage, H317: May cause an allergic skin reaction, H334: May cause allergy or asthma symptoms or breathing difficulties if inhaled, H335: May cause respiratory irritation, H340: May cause genetic defects, H350: May cause cancer, H361f: Suspected of damaging fertility, H372: Causes damage to organs through prolonged or repeated exposure, H410: Very toxic to aquatic life with long lasting effects;
- Arsenic acid: H301: Toxic if swallowed, H331: Toxic if inhaled, H350: May cause cancer, H410: Very toxic to aquatic life with long lasting effects;
- Cupric oxide: H302: Harmful if swallowed, H410: Very toxic to aquatic life with long lasting effects.

Further, ICC (2014a) and ACAT/IPEN (2014) have raised concerns regarding CCA's environmental and human health impacts, noting that CCA contains highly toxic and carcinogenic substances with concerns for these substances reaching the natural environment. Environmental and health concerns with the use of CCA, including possible arsenic exposure to humans have resulted in its use being significantly restricted or limited. It was voluntarily removed from use on wood intended for the domestic/residential (e.g. homeowner) use market in 2003 in both the USA and Canada. It is now limited to use on wood intended for industrial applications and handled by professional users (USEPA 2008, Environment Canada 2013). Similar restrictions have been imposed in other regions, such as the EU where CCA approval ceased in September 2006.

Laboratory studies by Kamchanawong (2010) and Mercer (2012) assessed the leaching potential of CCA within hypothetical environments that simulate unlined landfill conditions. The results of these studies highlighted potential for leaching which in real world environments may cause a concern for groundwater.

Creosote based products

Creosote (CAS No. 8001-58-9) is produced from the distillation of coal tars and contains between 200-250 chemical species, 85% of which are polycyclic aromatic hydrocarbons (PAHs) (Environment Canada 2013).

Creosote is widely used in the USA (with 16% of the utility pole market according to USEPA, 2008), as well as in Canada (Canada 2014) and Sri Lanka. Information from Sri Lanka suggests service life is 30 to 50 years under harsh tropical climates (Sri Lanka 2014).

In the EU, only Grade B or Grade C creosote as specified in European Standard EN 13991:2003 is used (Sweden 2010, 2014). The use is limited to pressure impregnation: preventive treatment of railway sleepers and of wood poles for overhead electricity and telecommunication according and to EN Standard 335 (Sweden 2010, 2014). According to the European Electricity Industry Association (Eurelectric 2010), about

1 million m^3 of wood were treated with creosote each year in the EU and one of the most common applications is to use creosote wooden poles in overhead power lines. However, some EU countries have already replaced creosote for preventive treatment of wood poles for overhead electricity and telecommunication (e.g. Germany and Switzerland). In France a voluntary commitment charter that restricts the application of creosote to the treatment of railway sleepers has been released in December 2018 (https://www.ecologique-solidaire.gouv.fr/substances-toxiques-charte-dengagement-volontaire-sur-bois-traites-creosote-signee-sous-presidence; accessed on 10 January 2019).

Creosote, like PCP, is an-oil based product used within industrial pressure, immersion or vacuum treatment of wood. In Canada, it is also used as a brush-on treatment for newly cut surfaces of pressure-treated creosote timbers and lumber for industrial applications and handled by professional users (PMRA 2011). The use of oil-based preservatives provides a waterproof layer to wood surfaces and to an extent also the metal fittings during service life. The use of oil-based preparations such as creosote provides ‘suppleness’ to treated wood which can help prevent shrinking, warping and twisting, particularly in harsh climatic conditions (UNECE 2010). This is of particular importance for load bearing structures such as railway cross-ties and cross-arms of utility poles (USEPA 2008).

Creosote contains a number of toxic substances contained in creosote including PAHs, phenol, and cresols. Concerns have been raised regarding potential health and environmental effects of creosote. A summary of potential health effects of (short-term and long-term) exposure to creosote has been published by Environment Canada (Environment Canada 2013: https://ec.gc.ca/pollution/default.asp?lang=En&n=59303C3F-1&offset=4; accessed on 10 January 2019). KMG highlights that the main constituents of creosote are PAHs which are already recognized as a Persistent Organic Pollutant (POP) under the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP) (PCPTF-KMG 2014). The Netherlands Trade Union Confederation (FNV 2010) highlights that the use of creosote has been in discussion for several decades because of the harmful impact on the environment and health of workers carrying out preservation. Carpenters and construction workers are also likely to be exposed during use of treated wood. Both IARC and US EPA have determined that coal tar creosote is a probable human carcinogen (ATSDR 2002) and a harmonised classification exists in Europe for carcinogenicity 1 B according to Annex VI to Regulation (EC) 1272/2008. The GESTIS database lists the following H-Phrase: H350: May cause cancer.

In the USA, Canada, and in the EU, creosote is limited to industrial applications only (USEPA 2008, Sweden 2010, 2014). Moreover, creosote meets the PBT criteria (Sweden, 2010) and authorised products are eligible for comparative assessment according to the Biocidal Products Regulation (EU) No 528/2012 (KEMI 2016). Health Canada’s Pest Management Regulatory Agency (PMRA), who carried out the risk assessment for heavy duty wood preservatives, notes that the assessment for creosote is expected to have overestimated risk, since Canadian wood treatment facilities are now required to follow industry guidelines which greatly reduce the risk of exposure and environmental loss (PMRA 2011, Environment Canada 2013).

Copper Naphthenate

Copper naphthenate (CAS No. 1338-02-9) is an oil-borne wood preservative, which is produced as a mixture of copper salts and naphthenic acid - a by-product of petroleum refinery processes (Feldman 1997). Copper naphthenate has been approved as a wood preservative with many applications in the USA (USEPA 2007). Copper naphthenate is approved for above ground, ground and freshwater use but not suitable for coastal/marine applications. It can be used in the pressure treatment processes similarly as PCP, CCA and creosote.

Information from the Toxnet database (Toxnet 2011) illustrates that despite its wide use the environmental profile and toxicity of copper naphthenate is poorly characterised. The assessment by USEPA (2007) noted no information on carcinogenicity; it also indicates potential health effects for occupational exposure when manually applying copper naphthenate to wood in domestic and residential settings. The GESTIS database lists the following H-Phrases for this compound: H226: Flammable liquid and vapour, H302: Harmful if swallowed, H410: Very toxic to aquatic life with long lasting effects.

Copper naphthenate is not an alternative of PCP in Canada, since it is not registered for industrial pressure treatment of wood. It is, however, registered as a remedial wood preservative for both commercial and residential applications.

Ammoniacal Copper Zinc Arsenate (ACZA)

ACZA is an aqueous product based on active ingredients in the ratio of 5:3:2: for cupric oxide (CAS No. 1317-38-0), zinc oxide (CAS No. 1314-13-2) and arsenic acid (CAS No. 7778-39-4), respectively. The ACZA product comes pre-mixed with active concentrations accounting for 10% of the formulation and ammonia as a transfer agent. ACZA can be used in pressure treatment where evaporation of the ammonia fixes the metals compounds to the surface of the wood and additionally ammonia also provides corrosion protection of working metal parts in the tank itself during transfer of ACZA (UNEP 2014, 2017c).

ACZA has a high fixation rate. It may also provide better performance than CCA in protection against insect and fungal attack, due to the presence of zinc, which improves fixation of arsenic (USEPA 2008). ACZA is also approved for use in coastal/marine applications with only a limited number of other approved preservatives (notably creosote). However, while CCA provides a clean, dry, odour-free finish to treated wood, ACZA treated wood tends to retain an ammonia odour which may be less suited to public locations such as pavements or pedestrian areas.

ACZA contains arsenic, which is carcinogenic, and copper oxide, which is highly toxic to aquatic organisms. ACZA has the potential to leach from wood, including treated utility poles (Lebow 1996 and USEPA 2008), it also has the potential to be toxic and an irritant on direct exposure for workers (Environment Canada 2013). Within the USA it is listed as a 'restricted use pesticide' reserved for industrial purposes (USEPA 2008). Health Canada's Pest Management Regulatory Agency (PMRA), who carried out the risk assessment for heavy duty wood preservatives, notes that the original assessment for ACZA, developed prior to the Technical Recommendations Document (TRD) (labelling, storage, risk management plans) guidelines, is expected to have overestimated risk, since Canadian wood treatment facilities are now required to follow the guidelines which greatly reduce the risk of exposure and environmental loss, and because ACZA is used only within closed systems (PMRA 2011, Environment Canada 2013).The GESTIS database lists the following H-Phrases for the constituents of the product:

- Cupric oxide: H302: Harmful if swallowed, H410: Very toxic to aquatic life with long lasting effects,
- Zinc oxide: H410: Very toxic to aquatic life with long lasting effects,
- Arsenic acid: H301: Toxic if swallowed, H331: Toxic if inhaled, H350: May cause cancer, H410: Very toxic to aquatic life with long lasting effects.

Ammonium/Alkaline Copper quaternary (ACQ)

ACQ compounds are waterborne wood preservative used similarly as CCA (Environment Canada 2013). ACQ comes as four different products labelled types A-D that contain both copper (i.e. copper oxide, CAS No. 1317-38-0) and quaternary ammonium compounds ("quat") as actives. Many variations of ACQ have been standardized.

Since the removal of CCA from the domestic wood market in Canada and the USA in 2003, the use of ACQ has grown significantly. In 2007 ACQ (and micronized CQ) was the most used (by weight) waterborne wood preservative, accounting for 45% of all waterborne wood preservatives used in the USA, with CCA placed second (Vlosky 2009). ACQ is currently registered in the USA for utility poles (residential use) (see https://www.epa.gov/ingredients-used-pesticide-products/overview-wood-preservative-chemicals). Salt based formulations including ACQ are used in Europe for use as class 4 (permanent ground contact) according to KEMI (2016). In Canada, while ACQ is widely used (mainly in the domestic wood market), it is not used within infrastructure applications and is not registered for use on utility poles (Environment Canada 2013). ACQ's widespread use has been focused within the domestic wood market and soft woods, due in part to the low occupational risk for workers and minimal risk of environmental loss (Environment Canada 2013). The GESTIS database lists the following H-Phrases for the constituents of the product:

- Cupric oxide: H302: Harmful if swallowed, H410: Very toxic to aquatic life with long lasting effects;

- Quaternary ammonia compounds: H302: Harmful if swallowed, H314: Causes severe skin burns and eye damage, H400/H410: Very toxic to aquatic life with long lasting effects.

ACQ is recognized as being useful for treating Douglas Fir which is typically hard to treat, but is also more corrosive to metals than CCA and ACZA. The use of ACQ would require the use of stainless steel fittings in treatment facilities which can be expensive (USEPA 2008). More recently, the advent of micronized ACQ provides a product with lower corrosivity and greater penetration, using finely ground copper oxide within the product to improve application (Vlosky 2009).

Copper azoles including Tebuconazole or Propiconazole

Copper azole is a waterborne product made up of copper-amine complex and co-biocides (USEPA 2008), e.g. tebuconazole (CAS No. 107534-96-3) or propiconazole (CAS No. 60207-90-1). Two formulations exist based on the ratio of copper to other compounds. The product is supplied as a concentrate and then diluted at point of use (Environment Canada 2013).

In the USA it is approved for above ground, ground and freshwater use (but is not appropriate for use in tropical conditions or coastal/marine applications (UNECE 2010). It is currently registered in the USA for utility poles (residential use) (see https://www.epa.gov/ingredients-used-pesticide-products/overview-wood-preservative-chemicals).

Copper azole products are authorised in Europe for utility poles (e.g. Tanalith E 3462 in Austria, http://www.biozide.at/ms/biozide/de/biozidprodukte/bpv).

In Canada, copper azole has recently been registered for use on wood poles, but has yet to be utilized for that purpose by industry.

Copper azole is corrosive to metal fastenings and so stainless steel would be required, which can be expensive for treatment facility upgrades (USEPA 2008). However, a micronized copper azole product does exist with lower levels of corrosivity and potential for deeper penetration of wood (Vlosky 2009).

Tebuconazole (the non-metal biocide ingredient in copper azole) has a half-life of 100 days in soil and is moderately toxic to aquatic life and reprotoxic (Environment Canada 2013, EU GHS harmonised classification https://echa.europa.eu/de/information-on-chemicals/cl-inventory-database/-/discli/details/995; accessed on 10 January 2019). Under the EU regulation for placing biocidal products on the market (EC 528/2012), Tebuconazole has been identified as a candidate that meets the Persistent and Toxic (PT) criteria and is considered a candidate for substitution. The GESTIS database lists the following H-Phrases for:

- Tebuconazole: H302: Harmful if swallowed, H361d: Suspected of damaging the unborn child, H410: Very toxic to aquatic life with long lasting effects;
- Propiconazole: H302: Harmful if swallowed, H317: May cause an allergic skin reaction, H410: Very toxic to aquatic life with long lasting effects.

Copper based preservatives using polymeric betaine and/or boric acid as a co-biocides

Härtner et al. (2009) describe copper-based waterborne heavy duty preservatives using polymeric betaine as a co-biocide. These systems were developed in Europe in the 1980's as chromium-free preservatives. Impralit™ KDS and KDS-B contain 12.5% CuO and 10% polymeric betaine Technical Grade Active Ingredient. KDS has 8% boric acid (BAE, CAS No. 10043-35-3) while KDS-B does not contain additional boric acid as a biocide. The function of boric acid in poles is based on its diffusion over time throughout the entire cross-section, thus it can protect heartwood and areas of the pole not penetrated by the main preservative.

Polymeric betaine is synthesized from didecyl amine and ethylene oxide in the presence of boric acid and glycols. In its simple form, polymeric betaine is didecyl bis(hydroxyethyl) ammonium borate also known as didecyl polyoxyethyl ammonium borate, or DPAB (CAS No. 214710-34-6). It belongs to the family of quaternary ammonium compounds (quats). To overcome the disadvantages of conventional quats used for wood preservation, such as distribution problems and corrosion problems, polymeric betaine was developed.

Polymeric betaine and/or boric acids as co-biocides in copper based preservatives have applications in the wood pressure treatment. Typical applications of KDS and KDS-B include wood poles (see ICC-ES 2011 and information on the manufacturer's website: https://impra.co.uk/impralit/vacuum-pressure-impregnation/impralit_kds, https://impra.co.uk/impralit/vacuum-pressure-impregnation/impralit_kds_b). Due the fact that polymer betaine fixes excellent to wood and can be degraded in soil and boron is a low toxic substance in the environment the leaching behaviour of Impralit KDS is defined by leaching of copper. In a comparative leaching test with wood preservatives on the market it was demonstrated that the copper in Impralit KDS is fixed at the same stage as copper of CCA (Härtner et al. 2009). The GESTIS database lists the following H-Phrases for the constituents of the product:

- Cupric oxide: H302: Harmful if swallowed, H410: Very toxic to aquatic life with long lasting effects,
- Quaternary ammonia compounds (DPAB): H302: Harmful if swallowed, H314: Causes severe skin burns and eye damage, H400/H410: Very toxic to aquatic life with long lasting effects,
- Boric acid: H360FD: May damage fertility or the unborn child.

3.2.3.2. Non-Chemical (Functional) Alternatives

Non-chemical (functional)alternatives are materials that offer the similar functionality as wood utility poles and cross arms treated with PCP. It is possible for these specific applications, if they meet the required specifications, to adopt alternative materials such as:

- Concrete;
- Steel;
- Fibreglass reinforced composite (FRC);
- Underground utility lines.

The application of concrete, steel and FRC provide both generic and specific technical improvements and weaknesses compared to treated wood (UNEP 2014). BAT/BEP considerations for production, installation and use of alternative technologies is important but is outside the scope for this document. In addition, these alternatives might not be suited to replace single poles and/or cross-arms but are intended as replacements for entire distribution lines.

Concrete

Concrete utility poles provide a standardized product with high tensile strength and durability (USEPA 2008). KEMI (2016) documents two types of concrete utility poles: cast concrete poles and spun concrete poles:

- Cast concrete are manufactured by pouring concrete into a tapered form with a square, polygon or H-Section. Pre-stressed steel stands are also typically included to increase the strength and resistance to bending. This type of pole can be considered maintenance free but there remain some concerns surrounding long-term corrosion of the reinforcing bars;
- Spun concrete poles are similar in characteristics to cast concrete poles but are circular in cross section and have a hollow interior. For a given strength spun concrete weighs less than cast concrete. Spun concrete poles have the additional advantages that they are round in profile and thereby less affected by wind. The spun concrete poles are more expensive than cast concrete poles. Spun concrete poles have been available on the market for 40 years, they are however not universally used.

There are wide variations in the use of concrete utility poles between individual companies and countries. The reasons for this are primarily the increased financial cost and physical weight of concrete poles compared to wood poles. In addition, like cast concrete poles, spun concrete poles cause a reduced electrical transient performance on the overhead line due to the need for them to be earthed (KEMI 2016).

A manufacturer's claim states that the service life of concrete poles can potentially reach 75 years (Stresscrete 2014), while Canada (Canada 2014) provided information estimating average treated wood life span of 20-100 years (Mankowski et al. 2002). Detailed information has not been provided on how geographic climatic considerations affect the relative longevity of concrete and wood poles. The strong durability of concrete poles and standardised formulation can be a key factor in maintaining a long service life and preventing premature failure. This also allows the use of fewer poles per mile. The most significant disadvantage for concrete compared to treated wood is weight, where concrete poles are approximately three times the weight of wood (Bollin and Smith 2011). The overall weight of concrete utility poles adds to freight and installation costs (USEPA 2008).

Concrete poles have the advantage of not requiring pesticide treatment. Forest ecosystem protection and conservation of trees are additional benefits of the use of concrete rather than wood poles if trees are not from commercially managed forests. On the other hand, cement and concrete come from finite resources that must be excavated and there can be other environmental impacts in production of cement, such as high energy consumption, the use of fly ash or other harmful substances, as well as emissions of air and water pollutants (ACAT/IPEN 2014); while wood poles from commercially managed forests represent a renewable resource. Life cycle analysis studies by the wood preservative industry (Bollin and Smith 2011, Aqua-e-Ter 2012, Bollin and Smith 2013) conclude that in comparison to wood based products, manufacture of concrete posts have a greater demand for natural resources such as water, and importantly are linked to much higher carbon dioxide and air quality pollutant emissions (the study assumed that treated wood and concrete poles have similar service lifespan).

Concrete poles are also hygroscopic meaning that they are more susceptible to freeze/thaw damage in harsh climates. USEPA (2008) also quotes data from EPRI (EPRI 1997) which suggests that concrete posts cannot be used in coastal/marine applications as sea-salt attacks the concrete. However, a major manufacturer of concrete poles, StressCrete indicates effective use of concrete in both fresh water and saltwater environments when specifically formulated for this environment. Because of their corrosion resistance, durability, and lack of chemical treatment, they are used in proximity to sensitive water bodies and can be used in freshwater and saltwater environments. One additional drawback for concrete structures relates to end of life: while treated wood poles can be re-installed at different locations during a working life, concrete posts can only be installed once, although the material can be recycled with certain limitations, or repurposed (e.g. as fill and does not have to be consigned to a hazardous waste landfill).

Steel

Steel utility poles are manufactured as hollow structures, which allow them to be lighter than treated wood poles (by 30-50%) with similar or greater load bearing strength (USEPA 2008, UNECE 2010, ACAT/IPEN 2014). This reduced weight improves freight and installation costs. The USEPA and UNECE reviews (USEPA 2008, UNECE 2010) note that steel poles can be open to surface corrosion, which can be difficult to assess by maintenance crews. They are also susceptible to below ground corrosion. However, both of these issues can be overcome by using galvanized steel structures (ACAT/IPEN 2014). Zamanzadeh (2006) states that the use of galvanized steels for below-ground structures alone may not be sufficient. Care is required when assessing the placement of poles as galvanized steel below ground can be subject to attack (particularly in acid soils) leading to corrosion which can significantly reduce service life. Assessment should be made during installation and where necessary additional measures, such as corrosion resistant backfill used. Unlike concrete structures, steel poles can be recycled or used again as needed similar to current treated wood alternatives (Bollin and Smith 2011).

KEMI (2016) notes that although steel poles have been widely available on the market for 40 years, their use is not uniformly distributed within the EU. In some EU Member States they are used extensively but in others the use is limited to a few specialist applications; representing less than 1% of total pole usage. The reasons for their piecemeal use are primarily the increased financial cost and physical weight of steel poles compared to wood poles equivalents. Steel poles are, however, more commonly used at transmission voltages where much higher structures are required than can be catered for by wood poles.

According to KEMI (2016), stainless steel poles have some use in specialist applications particularly on telecommunication networks in locations where there is a requirement for un-stayed angle support in village networks. This however, is restricted to only the lightest duty applications and would not be viable for power distribution networks where much higher mechanical loads are developed. In addition, due to their high cost, these poles could not be more widely used in telecommunication networks.

The main drawback for steel structures is that they need to be handled with care during transport and installation as they can be easily damaged (USEPA 2008, PCPTF-KMG 2014). The USA EPA also notes that in overloaded weight burdens steel poles will buckle rather than split or break, which means that the transmission of electricity will be halted while repairs are carried out. However, electricity may continue to flow until an outage for pole replacement can be managed (USEPA 2008). Additionally, as with any metal structure there is also an increased risk of electrocution not only to animals but also work crews (WPC 2014), although the poles can be insulated to prevent this problem. Steel utility poles, therefore, also have an increased susceptibility to lightning strikes, as compared to wood. This can increase the likelihood of such an event causing disruption to the transmission network.

The use of steel as an alternative material for utility poles has been investigated by some of the utilities in Europe (see KEMI 2016) and in the USA (such as Nevada, Arizona, and Austin Texas) (ACAT/IPEN 2014) with integration in the power generation network done on a strategic targeted basis driven in part by geographic and climatic conditions. Life cycle analysis by the wood preservative industry (Bollin and Smith 2011) concluded that in comparison to wood-based products, the manufacture of steel poles requires greater consumption of energy and natural resources such as water, and most importantly is linked to higher emissions of carbon dioxide and air pollutants. KEMI (2016), in its comparative life cycle analysis, concludes that the most significant environmental aspect is emissions of metals from steel poles during the life cycle. The steel pole was also the pole which had the largest contribution to other environmental impact categories, higher than wooden poles treated with creosote, concrete poles, and composite poles.

Studies by Bollin and Smith (2011) and SGS Global (2013) suggest the service life of steel poles is between 60 – 80 years, while estimates of wood pole longevity are 20 – 100 years (Mankowski et al. 2002). Detailed information has not been provided on how geographic climatic considerations affect the relative longevity of steel and wood poles. The SCS Global study devised a matrix of 21 environmental parameters which demonstrated the longer service life of steel poles combined with reduced maintenance needs meant that steel poles had an overall better environmental profile than treated wood poles.

Fibreglass Reinforced Composite (FRC)

FRC-based alternatives are relatively new to market and so have a limited history of use (WPC 2014). However, like steel and concrete, FRC provides a standardized material with known specifications (USEPA 2008). FRC poles, like steel, are lighter than treated wood meaning a reduction in freight and installation costs. However, FRC-based products can distort when screwing down hardware (WPC 2014) and therefore the mounting hardware may loosen over time making FRC generally not appropriate for components such as cross-arms. FRC poles are engineered for a specific configuration of cross-arms and other attachments. Post installation modification of this is not possible in most situations. FRC poles may also be more susceptible to UV radiation, which in hot dry climates can lead to delamination of FRC layers and weakening of the overall structure (USEPA 2008). From published data and response from end users with service experience, the service life of FRC poles is between 20 and 60 years (KEMI 2016). They remain expensive when compared to wood poles and as such are used in specialist site-specific applications. In Europe, the use of fibreglass poles is a relatively unproven technology in comparison to equivalent steel and concrete poles. Evidence gathered from end users has established that research work is ongoing to address these concerns but is not yet at a level where the widespread application of fibreglass poles in preference to creosote treated wood poles can be considered viable.

Wood Preservative Industry reports (Aqua-e-Ter 2012) provide lifecycle analysis which suggest the energy demand requirements to produce FRC poles are greater than treated wood alternatives and that FRC poles will have a greater carbon footprint than treated wood. However, this is likely to be offset by lower toxicity, and lower disposal costs (ACAT/IPEN 2014). According to the lifecycle analysis conducted by KEMI (2016), FRC poles have generally similar environmental performance to concrete poles but concrete poles have greater impact on eutrophication while composite poles have greater impact on climate change.

KEMI (2016) also distinguishes between FRC poles and poles made of Polymer Composite Fibre Reinforced Steel (PCFRS) and composite poles, which are at the early experimental stage. In essence this type of pole considers the possibility of mitigation of corrosion problems related to the steel reinforcement in concrete poles by replacing this element with glass fibre-reinforced polymer composite material. This type of structure has not yet been taken to a commercial level.

Underground utility lines

Burying utility lines is considered an option where aesthetic or weather conditions preclude above-ground power distribution systems (ACAT/IPEN 2014). However, no information could be obtained if a protective treatment of the lines is required to prevent decay and pest problems. There is also no information on whether there are additional costs and maintenance issues with burying the lines. According to a 2011 paper "Underground Electric Transmission Lines" published by the Public Service Commission of Wisconsin, the estimated cost for constructing underground transmission lines ranges from 4 to 14 times more expensive than overhead lines of the same voltage and same distance. For example, a typical new 69 kV overhead single-circuit transmission line costs approximately $285,000 per mile as opposed to $1.5 million per mile for a new 69 kV underground line (without the terminals). A new 138 kV overhead line costs approximately $390,000 per mile as opposed to $2 million per mile for underground (without the terminals). These costs show a potential initial construction cost differential of more than five times for underground lines as opposed to overhead lines. Costs vary in other regions, but the relative difference between overhead and underground installation costs is similar from state to state. Maintenance costs associated with underground lines are considered difficult to assess due to a number of variables involved and assumptions required.

An analysis conducted by Larsen (2016) noted that while generally it is assumed that the costs of undergrounding transmission and distribution lines far exceed the benefits from avoided outages, undergrounding power system infrastructure can improve reliability and that comprehensive benefits of this strategy can, in some cases, exceed the all-in costs. Cost-effectiveness depends on (1) the age/lifespan of existing overhead infrastructure; (2) whether economies of scale can be achieved; (3) the vulnerability of locations to increasingly severe and frequent storms; (4) the number of customers per line mile; and (5) the geographic terrain and distances over which lines must span.

3.2.3.3. Costs of alternatives

The tables below provide estimates of costs of alternatives on a ‘per utility pole’ basis (USEPA 2008, UNEP 2014, 2017c).

Table 5: Summary of costs for chemical alternatives (cost of preservative on a ‘per utility pole’ basis) (USEPA 2008, UNEP 2014, 2017c)

PCP	CCA*	Creosote	Copper Naphthenate	ACZA	ACQ**	Copper Azoles
$199	$197	$198	$200	$220	$240 $287	-

* Cost includes $20 for softening agents

** Cost includes the requirement for stainless steel fittings at $37 - $75 per pole.

Table 6: Summary of costs for non-chemical alternatives (cost based on ‘per utility pole’ basis for production, installation and maintenance costs) (USEPA 2008, UNEP 2014, 2017c)

Treated Wood	Spun Concrete	Steel*	Fiberglass-Reinforced Composite	Undergrounding**
$800	$1750	$1370	$1650	-

* The Alaska Community Action on Toxics note a separate study suggesting that steel poles are of comparative price to treated wood when assessed for full life span and reduced maintenance costs.

** Estimates of costs are available on a per mile basis (see information provided in Section 3.2.3.2.)

4. Considerations for identification, screening and labelling of PCP containing products and articles and subsequent waste streams

Identification and screening

A list of major uses of PCP and related articles and products is provided in UNEP (2017c,d).

UNEP (2017d) includes guidance for PCP monitoring in products and articles. The screening of PCP in end of life products should be done according to the requirements of the Basel Convention and the Basel Convention technical guidelines should be referred to.

Various methods are used for determination of the total content of chlorine. Most frequently used method is digestion by oxygen combustion and subsequent determination of chlorine by ion chromatography. In case of parameter total chlorine content, it is not possible to distinguish between organically bound chlorines and inorganic chlorine (e.g. NaCl).

As the water soluble chlorine content can be easily determined by a simple and quick ultrasonic leaching procedure with water (liquid to solid ratio=10:1; 20 min), subsequent filtration and IC quantification an estimate for inorganic chlorine contend can be made (see http://www.umweltbundesamt.at/aktuell/umweltanalytik_aktuell/analytiknews_180809/).

X-ray fluorescence (XRF) screening of chlorine can be used for a pre-screening of samples for further analysis. XRF and µ-XRF is used for screening of PCP and other POPs pesticides in wood in particular for wooden art objects (Bartoll et al. 2013). In some countries the screening of chlorine in wood with XRF is relative specific for certain POPs pesticides when mainly these pesticides have been applied for wood applications. XRF spectroscopy has also been used for screening of POPs in textiles. Approximations for organically based chlorine contents can be derived from total chlorine content and subtraction of the water soluble chlorine fraction (see http://www.umweltbundesamt.at/aktuell/umweltanalytik_aktuell/analytiknews_180809/).

Analytical detection of PCP, its salts or esters is typically performed by capillary gas chromatography. As detectors standard methods use normally either GC-ECD or GC/MS. PCP can also be detected by UV spectroscopy or thin layer chromatography.

UNEP (2017a,d) provide details on a number of methods and international standards for determination of PCP in articles and products.

Case study: Management of waste wood in Austria

The general basis for a regulatory framework to manage waste streams is defined by binding national obligations established by law. For EU Member States, the national transposition of the European Waste Framework Directive stipulates minimum requirements for general aspects such as permitting, registration, treatment activities as well as the establishment of a National Waste Management Plan.

Beside material recovery, Member State´s regulatory framework for waste wood also covers thermal recovery options. E.g. the Austrian Waste Incineration Directive defines inter alia minimum quality requirements for waste wood in order to cease to be waste ending up as solid recovered fuel (SRF) products (end-of-waste criteria). In this context, specific limit values for parameters such as PAH and total chlorine content, but not PCP, needs to be ensured in order to fulfil end-of-waste status for waste wood.

In the 1960s and 1970s, wood was widely used indoors and outdoors treated with glazes containing active ingredients in a combination of PCP and lindane. The quantities used were particularly intensive in houses with a high proportion of wood, such as barracks, halls, silos, etc. The topmost layers of wood can have PCP contents of several 1,000 mg/kg (ESWI 2011).

In Austria waste wood (about 750,000 tons per year) is used in the chipboard industry for the production of wood-based panels. The most important type of waste in terms of quantity is construction and demolition wood, followed by wood shacks and wood waste and sawdust made from natural, clean, uncoated wood (BAWP 2017, amended Recycling Wood Ordinance BGBl. II No. 178/2018). The Recycling Wood Ordinance sets limit values for pollutants as well as an obligation to carry out investigations. These limits are variable and depend on the recycled wood content, the proportion of recycled wood in the total wood input required for the production of wood-based materials. The Recycling Wood Ordinance requirements for source separation of waste wood as well as the regulation for sampling, investigations and specific limit values for parameters such as heavy metals, total chlorine, fluorine and PAH for recycling of wood in wood processing industry are the key factors to achieve the quality for recycling. The cleaner the recycled waste wood, the more recycled wood can be used to make wood-based panels. This creates an incentive to carry out a separation into polluted and less contaminated waste wood fractions or a further processing of waste wood already at the point of origin. If the waste wood has a quality comparable to natural wood and fulfils the criteria set in the Austrian Recycling Wood Ordinance, the end-of-waste status for the intended use can be declared (BAWP 2017, amended Recycling Wood Ordinance BGBl. II No. 178/2018).

The mostly visually imperceptible pollution, in particular by wood preservation treatments, is a limiting factor. Possibilities for a further substantial increase in material use are seen above all in the preventive avoidance and use of pollutant-free substances in wood treatment and an improved separate collection of low-pollutant waste wood through increased segregation at the place of origin (BAWP 2017, amended Recycling Wood Ordinance BGBl. II No. 178/2018).

In general, PCP-containing waste wood, wood impregnated with tar oil (e.g. railway sleepers, power poles), impregnated wood (eg salt-impregnated wood) must be collected, stored and transported separately from other waste directly at the place of origin. These waste wood fractions, according to the Recycling Wood Ordinance in Austria, are not suitable for recycling and normally supplied to a thermal disposal. Austrian investigations of PCP in recycling wood fractions in 2008 could demonstrate the impact of the measures undertaken. In 2018 in Austria a guideline for sorting of waste wood was developed by all stakeholders and published in order to assist the amended Recycling Wood Ordinance (see https://www.oewav.at/Publikationen?current=323523&mode=form).

Labelling

According to part VIII of Annex A to the Stockholm Convention, Parties having registered for the exemption for the production and use of PCP, its salts and esters for utility poles and cross arms shall take necessary measures to ensure that those articles containing PCP can be easily identified by labelling or other means throughout its life cycle. The identification is intended to support waste management for the exempted use. The guidance on labelling of products or articles that contain POPs (UNEP 2012) provides Parties with some considerations on this matter.

In cases where PCP wastes are considered hazardous wastes, every container should be clearly labelled according to applicable regulations for example with a hazard warning label and a label providing details of the container and a unique serial number. Such details should include container contents (e.g., exact counts of equipment, volume, weight, type of waste carried), the name of the site from which the waste originated so as to allow its traceability, the date of any repackaging and the name and telephone number of the person responsible for the repackaging operation (UNEP 2017a).

5. Considerations for the environmentally sound management of PCP contaminated sites

Listed below are the types of sites with a potential for PCP contamination (UNEP 2017c):

- PCP production facilities – these are factories/facilities/chemical plants which have been used, either historically, or currently, to produce PCP. This should also include sites which have been shut down/decommissioned as contamination may still be present;

- PCP storage facilities – these are storage facilities/warehouses etc. which have, either historically, or currently, been used to store PCP based chemicals. This should also include sites which have been shut down/decommissioned as contamination may still be present;
- Industrial wood treatment facilities – these are facilities which have, either historically, or currently, been used to treat wood products. This should also include sites which have been shut down/decommissioned as contamination may still be present;
- Treated timber and wood product storage facilities - these are facilities which have, either historically, or currently, been used to store treated timber and wood products. This should also include sites which have been shut down/decommissioned as contamination may still be present;
- Leather tanning and other leather treatment;
- Textile industries where PCP has been formerly used;
- Agricultural areas where PCP has been applied in the past.

It is important to note that polluted sites, in particular at larger chemical production sites, are often impacted by a range of pollutants; contamination with PCDD/PCDF and other unintentional POPs may be coupled with pollution by other organohalogen compounds or heavy metals, which would also be included in the assessment of the site. High concentrations of PCDD/PCDF can be expected at sites where chlorinated phenols were produced (UNEP 2013b).

Application sites of chemicals containing PCDD/PCDF, such as saw mills and timber manufacturing sites associated with the use of PCP, are also potential PCDD/PCDF hot spots. As an example, the application of PCP in Sweden, for example, has released between 5 and 50 kg TEQ on these sites, and a further 200 kg TEQ in the product (Swedish EPA 2005). Inventories can be established using former application quantities and contamination levels. In addition to an inventory of PCP application sites, a rough inventory of former PCP use and related PCDD/PCDF in treated wood might be established.

Since the wood-treating processes and the types of chemicals used as wood preservatives are very similar at all wood-treating sites, the contamination problems and the technologies and strategies that appear to work at these sites are also similar (USEPA 1993, 1995).

Old/abandoned wood-treating sites typically used creosote or PCP in a heated oil-based solution. After treatment, the wood was removed from the pressure chamber and allowed to drip dry outside, resulting in large volumes of contaminated soil. Other treatment wastes include wastewater and sludges. Wastewater was generated as a condensate in the treatment process and also by rinsing tanks and equipment. After separation of recoverable chemicals, wastewater was often spread onsite or stored in evaporation ponds. An oily sludge gradually accumulates in wastewater evaporation areas and also in treatment cylinders and storage tanks. This sludge was historically dumped into unlined pits onsite. Sludge pits found at wood treating sites can contain very high concentrations of the preservative chemicals. The preservatives PCP and creosote are found as contaminants, alone or in combination, at nearly all abandoned wood-treating sites (US Congress 1995).

The identification and inventory of polluted sites is merely a first step to manage related risks and for final clean-up and rehabilitation. The USEPA has determined that it is useful to group wood treating sites together based upon their common characteristics, such as the contaminants present, the environmental media affected by those contaminants, and the clean-up technologies selected. USEPA’s presumptive remedies for treating soil, sludge, and sediments at wood-treating sites with organic contamination from creosote and PCP are bioremediation, thermal desorption, and incineration (USEPA 1993, 1995, US Congress 1995).

Further general guidance on assessing POPs contaminated sites is available in the following documents and is not further described:

- UNIDO “POPs contaminated site investigation and management toolkit”, which aims to assist developing countries in the identification, classification and prioritization of POPs-contaminated sites. The document is available at http://chm.pops.int/Implementation/BATandBEP/AdditionalResources/tabid/1493/Default.aspx;

- World Bank “The Persistent Organic Pollutants (POPs) Toolkit”, which provides training modules and interactive tools for risk-based approaches to prioritize and manage POPs-contaminated sites and other hazardous substances. Available at http://www-esd.worldbank.org/popstoolkit/POPsToolkit/POPSTOOLKIT_COM/DEFAULT.HTM;
- UNEP “Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs under Article 5 of the Stockholm Convention”, Chapter 10 Hot Spots, provides guidance on PCDD/PCDF inventory for contaminated sites. Available at toolkit.pops.int.

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