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Pollutants**

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**Matters related to the implementation of the Convention:
implementation plans**

**Draft guidance on preparing inventories of pentachlorophenol
and its salts and esters and on identifying alternatives for the
phase-out of those chemicals**

Note by the Secretariat

As referred to in the note by the Secretariat on implementation plans (UNEP/POPS/COP.8/11), the draft guidance on preparing inventories of pentachlorophenol and its salts and esters and on identifying alternatives for the phase-out of those chemicals is set out in the annex to the present note. The present note, including its annex, has not been formally edited.

* UNEP/POPS/COP.8/1.

Annex

**Draft guidance on preparing
inventories of pentachlorophenol and
its salts and esters and on identifying
alternatives for the phase-out of
those chemicals**

Draft

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Disclaimer

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Table of Contents

Abbreviations and acronyms.....	6
1. Introduction.....	7
1.1 Pentachlorophenol (PCP) under the Stockholm Convention (the Convention)	7
1.2 Purpose of the guidance.....	8
Overview	8
Objective of the inventory.....	8
1.3 Structure of the guidance.....	9
2. Background information on PCP.....	10
2.1 Introduction	10
2.2 Description of the characteristics of PCP	10
2.3 PCP as a source of dioxins and furans.....	11
2.4 Intentional production and trade of PCP.....	12
2.5 Sources of environmental releases for PCP.....	13
Sources of environmental releases for PCP	13
Sources of environmental releases for PCA	14
2.6 Intentional uses of PCP.....	14
2.7 PCP in stockpiles, products and waste.....	16
2.8 Sites potentially contaminated by PCP.....	17
2.9 Summary of potential emission sources.....	18
3. How to conduct a PCP inventory.....	20
3.1 Step by step approach for planning and conducting a PCP inventory	20
3.2 Step 1: Planning the inventory.....	21
Establish a national inventory team.....	21
Identify key stakeholders.....	21
Define the scope of the inventory.....	23
3.3 Step 2: Choosing data collection methodologies	24
Tiered approach.....	24
Indicative, qualitative and quantitative methodologies	25
3.4 Step 3: Collecting and compiling data from key sectors.....	26
3.5 Step 4: Managing and evaluating the data	27
Overview	27
Data management.....	27
Mechanism for evaluation of the inventory	27
3.6 Step 5: Preparing the inventory report	28
4. Inventory of PCP based on production, use, and waste cycle aspects.....	29
4.1 Introduction	29
4.2 Phase 1 – The intentional production and use of PCP	29
Manufacture of PCP	29
Use of PCP in timber treatment.....	31
Non-timber treatment uses of PCP.....	36
4.3 Phase 2 – In use emissions from products treated with PCP.....	37
Releases from treated timber and equalisation.....	37
Replacement rates for timber.....	39
Identification of treated timber.....	39
4.4 Phase 3 – Management of end of life products treated with PCP	40
Identification of treated timber within the waste stream	40
Apportionment of waste streams.....	42

4.5	Identification of sites contaminated with PCP	45
	Activities to aid in the identification of contaminated sites.....	45
	Contaminated Sites Examples.....	49
5.	Guidance on the alternatives to PCP used for utility poles and cross-arms.....	53
5.1	Introduction	53
5.2	Policy planning for emission control and phase-out of PCP used for utility poles and cross-arms.....	53
	Planned approach for management of PCP	53
	Step 1: Identification of issues at national level	53
	Step 2: Engagement with Industry / Regulatory Agencies / NGOs.....	54
	Step 3: Review and Development of Control Options	55
	Step 4: Development of Control Plans.....	56
	Step 5: Awareness campaigns	56
	Step 6: Monitoring / Compliance / Feedback.....	57
	Step 7: International Activities.....	57
5.3	Chemical Alternatives to PCP	58
	Introduction.....	58
	Chromated Copper Arsenate (CCA)	58
	Creosote	59
	Copper Naphthenate	60
	Ammonical Copper Zinc Arsenate (ACZA).....	60
	Other Alternative preservatives for wood treatment.....	61
5.4	Non-Chemical Alternatives to PCP	64
	Introduction.....	64
	Steel	65
	Concrete	66
	Fibreglass reinforced composite	66
	Heat treated wood	67
	Hardwood alternatives	67
5.5	Summary	67
6.	Summary	72
7.	References	73
	Annex 1: Tables of default data to help inventory development.	81
	Annex 2: Suggested outline for a questionnaire to gather information.....	83
	Annex 3: Named active substances for wood treatment within the EU	87

Abbreviations and acronyms

ACQ – Ammonium Copper Quaternary
ACZA – Ammonium Copper Zinc Arsenate
ANSI – American National Standards Institute
ARRA – American Recovery and Reinvestment Act
AWPA – American Wood Protection Association
CBA – Copper Boron Azole
CCA – Chromated Copper Arsenate
CCB – Copper Chromated Borate
ESD – Environmentally Sound Destruction
EU – European Union
FRC – Fibreglass Reinforced Composite
HCB - Hexachlorobenzene
HCH – Hexachlorocyclohexane (assumed to include both the alpha and beta isomers)
IPPC – Integrated Pollution Prevention and Control (2010/75/EU)
KPa – Kilo Pascals
LCA – Life Cycle Analysis
MSW – Municipal Solid Waste
NaPCP – Sodium Pentachlorophenol
NGO – Non Governmental Organization
NIP – National Implementation Plan
PAHs – Polyaromatic Hydrocarbons
PCA - Pentachloroanisole
PCDD – Polychlorinated dibenzo dioxins
PCDF – Polychlorinated dibenzo furans
PCNB - Quintozene
PCP – Pentachlorophenol
PCPL – Pentachlorophenol Laurate
PIC – Prior Informed Consent
POPs – Persistent Organic Pollutants
POPRC – Persistent Organic Pollutants Review Committee
ROS – Residential Open Space
SBX – Sodium Borates
SLVs – Soil Leaching Values
SRVs – Soil Reference Values
UK – United Kingdom
UNEP – United Nations Environment Programme
USA – United States of America
US DOE – United States Department of Energy
US EPA – United States Environmental Protection Agency
VOCs – Volatile Organic Compounds
VSP – Visual Sampling Plan

1. Introduction

1.1 Pentachlorophenol (PCP) under the Stockholm Convention

On 17 May 2011, the European Union and its member States submitted a proposal to list pentachlorophenol (PCP) and its salts and esters (sodium pentachlorophenate, NaPCP and pentachlorophenyl laurate, PCPL) in Annex A, B and/or C to the Stockholm Convention (UNEP/POPS/POPRC.7/4). The proposal was considered by the Persistent Organic Pollutants Review Committee (POPRC) at its seventh meeting in Geneva in October 2011 (UNEP/POPS/POPRC.7/19), where the Committee deferred its consideration pending the receipt of additional information on the transformation of PCP to pentachloroanisole (PCA).

The Committee, at its eighth meeting, held in Geneva in October 2012 (UNEP/POPS/POPRC.8/16), decided, in accordance with paragraph 4 (a) of Article 8 of the Convention, and on the basis of additional information on the transformation of PCP to PCA presented at the meeting (UNEP/POPS/POPRC.8/INF/7) that, while the PCP molecule itself does not meet all the screening criteria specified in Annex D, PCP and its salts and esters meet the Annex D screening criteria, when its transformation into PCA is taken into account (decision POPRC-8/4). The Committee also decided, in accordance with paragraph 6 of Article 8 of the Convention and paragraph 29 of decision SC-1/7 of the Conference of the Parties to the Convention, to establish an ad hoc working group to review the proposal further and to prepare a draft risk profile in accordance with Annex E to the Convention, as well as, in accordance with paragraph 4 (a) of Article 8 of the Convention, inviting Parties and observers to submit to the Secretariat the information specified in Annex E.

At the ninth meeting of the POPRC, held in Rome in October 2013 (UNEP/POPS/POPRC.9/13), the Committee adopted the risk profile for PCP and its salts and esters (UNEP/POPS/POPRC.9/6), including consideration of the transformation product PCA. The Committee decided that PCP and its salts and esters 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 (decision POPRC-9/3). The Committee decided to establish an ad hoc working group to prepare a risk management evaluation that includes an analysis of possible control measures for PCP and its salts and esters in accordance with Annex F to the Convention and, in accordance with paragraph 7 (a) of Article 8 of the Convention, invited Parties and observers to submit to the Secretariat the information specified in Annex F.

At its tenth meeting, held in Rome in October 2014 (UNEP/POPS/POPRC.10/10), the Committee considered the draft risk management evaluation for PCP and its salts and esters (UNEP/POPS/POPRC.10/2) as well as comments and responses relating to it (UNEP/POPS/POPRC.10/INF/4). The Committee adopted decision POPRC-10/1, by which it adopted the risk management evaluation (UNEP/POPS/POPRC.10/10/Add.1) and decided, in accordance with paragraph 9 of Article 8 of the Convention, to recommend to the Conference of the Parties that it consider listing PCP and its salts and esters in Annex A to the Convention with specific exemptions for the production and use of pentachlorophenol for utility poles and cross-arms.

Taking note of the POPRC recommendation, the Conference of the Parties decided (decision SC-7/13) to amend Part I of Annex A to the Convention to list pentachlorophenol and its salts and esters with specific exemptions for the production and use of pentachlorophenol for utility poles and cross-arms and to insert note (vi) to reflect that pentachlorophenol (CAS No: 87-86-5), sodium pentachlorophenate (CAS No: 131-52-2 and 27735-64-4 (as monohydrate)), pentachlorophenyl laurate (CAS No: 3772-94-9) and pentachloroanisole (CAS No: 1825-21-4) are identified as persistent organic pollutants. Furthermore, each Party that has registered for the exemption for the production and use of PCP for utility poles and cross-arms is required to take necessary measures to ensure that utility poles and cross-arms containing PCP can be easily identified by labelling or other means throughout their life cycle. It is also required that articles treated with PCP should not be reused for purposes other than those covered by the exemption.

1.2 Purpose of the guidance

Overview

Under Article 7, paragraph 1 (a) of the Stockholm Convention, it is a mandatory requirement that all Parties develop and endeavour to implement a plan for the implementation of its obligations under the Convention. Furthermore, Article 15, paragraph 1 of the Convention requires each Party to report to the Conference of the Parties on the measures it has taken to implement the provisions of the Convention and on the effectiveness of such measures in meeting the objectives of the Convention.

To develop effective strategies for the elimination of PCP and its salts and esters (hereinafter collectively referred to as PCP) and the environmentally sound management of stockpiles and wastes containing those chemicals, Parties need to acquire a sound understanding of their national situation concerning its production, uses and releases. Such information can be obtained through an inventory of generated PCP, materials and waste containing PCP and sites contaminated with PCP. The critical issues in developing an emission inventory are two-fold, firstly the availability of accurate and detailed information needed in development of inventories; and secondly the approach adopted to ensure the inventory is i) robust and defensible and ii) comparable to work of other nations also developing inventories. Therefore, the development of guidance documentation in this regard is of high value to support this work.

The purpose of this document is, therefore, to provide the necessary information and guidance to policy makers to enable them to fulfil their nation's obligations under the Stockholm Convention. Specifically, this guidance provides details in relation to three areas:

- How Parties to the Stockholm Convention can develop inventories of PCP for their nation;
- The chemical/non-chemical alternatives to PCP based on current uses; and
- Effective policy measures that could be used to aid the phase-out of PCP and safe management of stockpiles of PCP and PCP treated goods.

Objective of the inventory

The main objective of the inventory is to obtain information needed for the implementation of Parties obligations of the Stockholm Convention. More specifically, the objectives are to:

Establish a country baseline with respect to PCP production, use, stockpile, disposal and contaminated sites;

Provide the basis for development of a strategy in the National Implementation Plan (NIP) (i.e. identify the economic sectors that should be prioritized and the type of actions required for those sectors);

Report to the Conference of the Parties to the Stockholm Convention on progress made to eliminate PCP through national reporting; and

Identify areas where financial or technical support are needed (when resources are limited, to fulfil the obligations of the Convention).

The information obtained about PCP through the inventory includes the following:

- Past and current production of PCP at the national level;
- Intentional uses of PCP;
- Import/export of PCP for use; or where relevant PCP treated timber;
- Recycling practices of PCP containing products;
- Alternatives to PCP available/used in the country;
- PCP stockpiles and wastes, in particular relating to end of life treated timber;
- Import/export of PCP containing waste for environmental sound destruction;
- Sites identified as being potentially contaminated by PCP.

Information collected on the above will provide a broad understanding of the sources of PCP, the scope of their impacts and the risks that they pose to human health and the environment in a country. The information is important for Parties to evaluate whether they comply with obligations under the Convention regarding PCP and identify areas where they need to develop effective strategies and action plans for managing PCP in order to meet the obligations. This will be particularly relevant for management of goods treated with PCP, including end of life management issues.

Information collected as part of the inventory will also provide a valuable basis for Parties to report to the Conference of Parties on measures taken to implement the provisions of the Convention and the effectiveness of such measures (reporting under Article 15).

The inventory process is usually iterative. In establishing the inventory of PCP for the first time, Parties will also identify resources and technical capacity needed to further improve the accuracy of the inventory.

1.3 Structure of the guidance

The guidance has seven chapters and 3 annexes as follows:

- **Chapter 1:** Outlines the purpose of the guidance and the context and background of pentachlorophenol (PCP) and its salts and esters under the Stockholm Convention;
- **Chapter 2:** Provides necessary background information on PCP and its salts and esters for undertaking the inventory;
- **Chapter 3:** Outlines the five main steps involved in conducting an inventory of PCP and its salts and esters. It also provides an overview of considerations that are important for planning the inventory and defining its scope;
- **Chapter 4:** Provides an inventory of PCP based on production, use, and waste cycle aspects, identifies emission 'hotspots' and includes an evaluation of the inventory and methods for improvement;
- **Chapter 5:** Provides guidance on possible chemical and non-chemical alternatives to PCP;
- **Chapter 6:** Provides overall summary of the guidance;
- **Chapter 7:** Provides a list of reference documents;
- **Annex 1:** Table of default emission factors;
- **Annex 2:** Example questionnaire for use in data gathering; and
- **Annex 3:** List of potential alternatives to PCP.

The key design and content features of this guidance are:

- **Step by step approach:** The guidance is designed to provide a clear step-by-step approach that can be followed and implemented by a wide variety of users. A five-step approach is provided for the overall inventory from the planning stage to preparation of the inventory report (see chapter 3). The tiered approach provides the opportunity to countries with different capacities to develop an inventory. More detailed and specific guidance on stakeholders, data collection and others for key sectors can be found in chapters 4 and 5; and
- **Questionnaires:** A template questionnaire is provided to support the gathering of information regarding current and former production and use of pentachlorophenol (Annex 2).

No specific reporting format is suggested in this inventory guidance to provide flexibility to Parties in the reporting formats that they may choose to adopt.

2. Background information on PCP

2.1 Introduction

Chapter 2 is intended to provide an overview of the main intentional and unintentional environmental release points for PCP. This also includes a discussion regarding stockpiles and waste and 'hot spots' for former sites of manufacture and timber treatment. The chapter concludes with a summary table of information to help the reader understand what the main issues are for PCP and which of those issues may be relevant to their own national position. This chapter is intended to be used with chapter 3 (How to conduct a PCP inventory) and chapter 4 (Inventory of PCP based on production, use, and waste cycle aspects).

2.2 Description of the characteristics of PCP

The following information taken from the PCP risk profile (UNEP/POPS/POPRC.9/13/Add.3) provides a brief overview of the physical data held for PCP its salts and esters under the Stockholm Convention.

Table 2.1 Chemical Structures

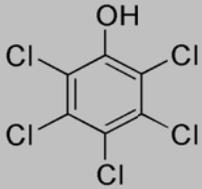
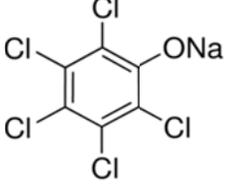
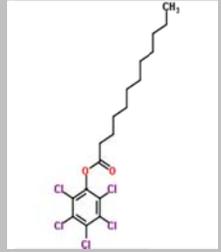
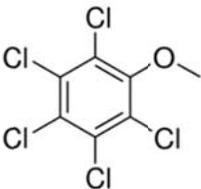
	Pentachlorophenol	Sodium Pentachlorophenate	Pentachlorophenyl laurate	Pentachloroanisole
Molecular formula	C_6HCl_5O and C_6Cl_5OH	C_6Cl_5ONa and $C_6Cl_5ONa \times H_2O$ (as monohydrate)	$C_{18}H_{23}Cl_5O_2$	$C_7H_3Cl_5O$
Molecular Mass	266.34 g/mol	288.32 g/mol	448.64 g/mol	280.362 g/mol
Structural formulas of the isomers and the main transformation product				

Table 2.2 Physical and chemical properties of pentachlorophenol and pentachloroanisole

Properties	Pentachlorophenol	Pentachloroanisole	Reference
	Value ¹	Value	
Water solubility 25°C	0.13% (% weight) 5 mg/L at 0°C ^{1,2} 14 mg/L at 20 °C ^{1,2} 35 mg/L at 50 °C ^{1,2} 14 mg/L at 25 °C ^{1,2}	<1 mg/L 0.24 mg/L 0.19 mg/L	http://cameochemicals.noaa.gov/chemical/20850 EVA method logK _{OW} method
Vapour pressure (25°C)	2 mPa (20 °C) 0.0070-0.213 Pa (25 °C) 1.1 x 10 ⁻⁴ mm Hg (25 °C) ² Intermediate volatility	0.0458 Pa (25 °C) 0.0933 mm Hg Intermediate to high volatility	Modified Grain Method Dobbs and Grant (1980) Kennedy and Talbert, 1977 classification scheme

Henry's law constant atm/m³/mol	2.45x10 ⁻⁶ atm.m ³ /mol ² 0.0248 to 0.284 Pa m ³ /mol	1.94x 10 ⁻³ atm-m ³ /mole (25 °C) (Group method) (1/H = 12.7, K _{AW} = 0.003) 7.12 x 10 ⁻⁵ atm-m ³ /mole (25 °C) (Bond method)	HENRYWIN v3.2 in U.S. EPA 2011
	Potential to volatilise from water or moist soil	Potential to volatilise from water or moist soil	Mackay and Wolkoff, 1973 classification scheme
Dissociation constant (pK_a)	pKa 4.60-5.30 pKa 4.7 ² At neutral pH of most natural waters, PCP is more than 99% ionised.	Not expected to dissociate under environmentally relevant pH.	-
Log Octanol/water partition coefficient (LogKow)	The measured values are between 1.3 and 5.86 and the value appears to be pH dependent. Generally accepted values are 5.12 and 5.18 Potential to bioaccumulate in biota	5.30 (modelled) 5.45 (laboratory) Potential to bioaccumulate in biota	KOWWIN v1.68 in U.S. EPA 2011 Opperhuizen and Voors (1987)
K_{oc}	293 to 900 L/Kg(at 0.0125 mg/L) 1000 L/Kg (calculated) 3000 to 4000 L/Kg (measured) 293-4000 L/Kg ² 706-3420 L/Kg (measured) ² Slight mobility to moderate mobility in soil	2474 L/kg 13800 L/kg Immobile	MCI method, KOCWIN 2.0 K _{OW} method, KOCWIN 2.0 in U.S. EPA (2011) McCall et al., 1981 classification scheme

2.3 PCP as a source of dioxins and furans

Polychlorinated dibenzo dioxins and furans (PCDD / PCDF) are a family of chemicals, which, because of their physical properties and toxicity, represent a risk to human health and the environment. Such are the concerns for these substances that they were two of the twelve POPs targeted by the Stockholm Convention since its entry into force in 2004, with a listing in Annex C. While dioxins and furans have no known commercial use, they are created unintentionally by a number of activities, with combustion in particular an important pathway for the generation and release to environment of dioxins and furans.

Dioxins and furans are by-products in the manufacturing process used to produce PCP, which means that PCP products contain a number of unintended contaminants, including dioxins and furans. This means that when PCP is produced, used, and when PCP-articles are used or disposed of as waste, PCP and its contaminants (including dioxins and furans) are released into the environment (UNECE, 2010). Additionally the UNECE (2010) and Environment Canada (2004) both highlight the risk of combustion for treated PCP timber as an emission source for dioxins and furans, with further data on emission estimates. This will be of particular concern for low temperature, incomplete combustion processes such as bonfires or open burning of waste wood treated with PCP products.

As dioxins and furans are listed in Annex C to the Stockholm Convention, there are obligations placed upon Parties to develop and report source inventories and release estimates for these substances, and to take action to minimise and ultimately eliminate their release. This guidance document is intended to aid the reader with work in the development of inventories for PCP its salts and esters. However additional

guidance on the development of estimates for dioxins and furans within PCP and PCP products is available within the UNEP Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2013e). This includes default emission factors to quantify dioxins and furans within PCP and PCP based products.

2.4 Intentional production and trade of PCP

PCP has been produced commercially and used as a wood preservative since the 1930s. PCP can be manufactured either by the chlorination of phenol at high temperatures in the presence of various catalysts, or by an alkaline hydrolysis of hexachlorobenzene (HCB) (Choudry *et al.*, 1986; IEP, 2008).

At the height of its production, global output of PCP was around 90,000 tonnes per year (IEP, 2008). The Economist Intelligence Unit (1981) estimated world production to be of the order of 50 000-60 000 tonnes per year, based on the North American and European Community output (UNEP, 2011c). However, by the 1990s, widespread use of PCP was discontinued in most countries (UNEP, 2013d). Currently, PCP has either no uses or is banned in all EU Member States, Australia, China, India, Indonesia, New Zealand, Russia and Switzerland, and is used only in the USA and Canada (Amec Foster Wheeler, 2006).

Global production of PCP during the 1990s was estimated to be 8,500-50,000 tonnes/year (UNECE, 2010 [as cited by Hofercamp, 2010]).

PCP and its salt and esters are currently produced only in Mexico and in India, with formulation also taking place in the USA. US chemical company KMG Chemicals Inc. is reported to be the only producer of wood treating PCP in the world (under the commercial name 'Penta'), with a production facility in Matamoros, Mexico and a formulation facility in Tuscaloosa, Alabama, USA (UNEP, 2014c).

It is reported that the KMG plant in the USA formulated 7,257 tonnes of PCP (liquid concentrate) in 2009, marketed for wood preservation purposes in the USA, Canada, and Mexico (UNECE, 2010). No data are provided by the company on the quantities of solid PCP produced in Mexico and shipped to the USA for formulation. However, the Mexican Government reported a similar level of production for 2009 (6,610 tonnes). Mexico reported that 3,670-7,343 tonnes of PCP were exported yearly between 2007 and 2011 to the USA, Colombia and Peru. Mexico also reported imports of PCP from the USA, China and Germany between 1997 and 2011 (UNEP, 2013d). Canada reported that 372-537 tonnes of PCP were imported yearly from Mexico between 2008 and 2012 (Canada, 2014). The USA reported that in 2002, 4,083 tonnes were imported and 1,361-1,815 tonnes were produced domestically (USA, 2014).

The industry association Indian Chemical Council (ICC) reports that Na-PCP is also used in India mainly as a wood preservative but also for the preservation of water-based 'distemper paints' while in storage, with 1,800 tonnes per year of Na-PCP being produced in the state of Maharashtra and West Bengal, India (ICC 2014).

Production of PCP and NaPCP ceased in the EU in 1992. However, beyond this date these chemicals continued to be imported to the European market from the USA. In 1996 a total of 378 tonnes of NaPCP and 30 tonnes of PCP were imported into the EU (OSPAR, 2004). Of the 378 tonnes of NaPCP imported to the EU, the three principal importers were France (126 tonnes), Portugal (108 tonnes) and Spain (144 tonnes). 30 tonnes of PCP were imported to the EU in 1996, 28 tonnes of which were synthesised to 46 tonnes PCPL in the UK. Of the 46 tonnes of PCPL produced, 5-10 tonnes were exported to France and a similar quantity was used in the UK. The rest was exported to countries outside the EU (OSPAR, 2004).

PCP and its salts and esters are subject to a number of agreements, regulations and action plans that restrict its production, trade and use in many countries. PCP is listed in Annex III of the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, and is, therefore, subject to a legally-binding prior informed consent (PIC) procedure, with more than 130 Parties to the Rotterdam Convention. In 2014, PCP (as well as NaPCP and PCPL) were included in Annex A to the Stockholm Convention on Persistent Organic Pollutants (see Chapter 1).

The Oslo Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") is currently signed by 15 European Atlantic countries and the EU controlling the dumping of hazardous materials. OSPAR gave priority to PCP in its 1992 Action Plan and it was included in the 1998 OSPAR list of Chemicals for Priority Action (OSPAR, 2004).

Harmonised EU legislation restricts the use of PCP as a substance or in mixtures (see Chapter 2.3), but some European countries – including Norway, Denmark, Germany, Netherlands and Austria – have implemented additional restrictions to the import and marketing of consumer products containing PCP. As

such, consumer goods treated with PCP may not be placed on the market in these countries if they contain more than 5 mg/kg of PCP and its salts and esters (OSPAR 2004).

2.5 Sources of environmental releases for PCP

Sources of environmental releases for PCP

PCP can be released to the environment during the course of its production, use and/or disposal via a number of release sources. These include (Amec Foster Wheeler, 2016):

- PCP treatment facilities;
- Evaporation during in service life of PCP-treated products and stockpiles;
- Waste handling processes where PCP treated products are sent to landfill or incinerated;
- Contaminated sites resulting from historical use/production of PCP;
- Improper practices (e.g. spills from industrial holding ponds from wood treatment facilities);
- Re-volatilisation from adsorbed residues; and
- Domestic or forest fires.

PCP can be formed unintentionally as a transformation product (metabolite) of other organochlorines such as hexachlorobenzene (HCB), quintozene (PCNB) and lindane (UNEP, 2013d). Therefore, PCP could potentially be produced in soils where these other organochlorine pesticides have been applied. This pathway to PCP is shown in Figure 2.1. Additionally, where PCP contains dioxins and furans as a micro contaminant, it means that the condensation of PCP in the atmosphere has been a major source of dioxin and furan releases into the environment until at least 2000 (Baker and Hites 2000).

It is indicated that PCP can be released to the environment from a number of different combustion processes including the incineration of municipal, chemical and clinical wastes, and the combustion of coal, oil, petrol and gas, however very few data are available on the levels of PCP from these sources (Wild et al., 1992). PCP levels have been measured in MSW fly ash in the UK (Harrad et al., 1991), Finland (Paasivirta et al., 1985), Canada and USA (Goldfarb, 1991[as cited in Wild et al., 1992]). It is expected that combustion processes contribute only a very minor proportion of the PCP released to the environment (Wild et al., 1992). However, combustion of waste containing PCP could be a significant source of PCDD/PCDF (WHO, 1987; OSPAR, 2004).

It is also indicated that PCP can be released to the environment through naturally occurring combustion processes such as forest fires or domestic burning of wood for heating and cooking (OSPAR, 2004). Ahling and Lindskog (1980) analysed flue gases from domestic fires and concluded that the levels of PCP found (19-180 $\mu\text{g}/\text{m}^3$) were too high to have been produced by contamination of the air stream prior to the fire (OSPAR, 2004). However, it is unclear whether natural sources or burning processes form a significant part of PCP releases.

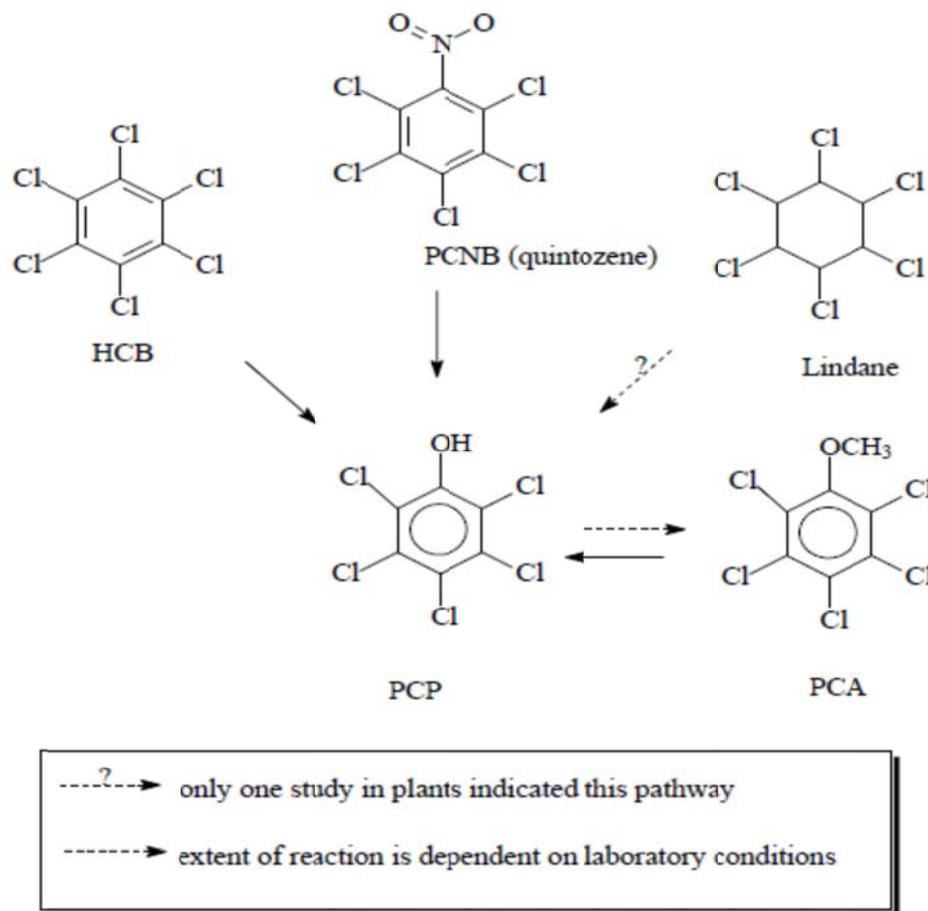
While it is expected that the vast majority of PCP currently found in the environment is as a result of human activity, it is suggested that there exists a 'natural background' of PCP, which anthropogenic emissions supplement. For example, studies have been conducted to differentiated 'historic' deposition rates of PCP from 'current' deposition rate. Salkinoja-Salonen et al. (1984) measured concentrations of PCP in sediments deposited more than 50 years prior in a small lake in Finland, calculating PCP was rained out from the air at an annual rate of 2-4 $\mu\text{g}/\text{m}^2$, compared with the current (1980s) rate of 10-17 $\mu\text{g}/\text{m}^2$. Similarly Paasivirta et al., (1990) analysed sediments as much as 300 years old in another Finnish lake. Annual deposition rates ranged from 0.1-0.8 $\mu\text{g}/\text{m}^2$ while, in sediments deposited since 1961, deposition was calculated to be 2.1 $\mu\text{g}/\text{m}^2$. However, there are only limited data on the potential 'natural' flux of PCP to the environment, so the potential contribution of this source relative to anthropogenic sources is unclear.

It has also been suggested that PCP could also be formed during waste water treatment, as water passes through a chlorination process which is intended to disinfect the water, meaning PCP can be formed due to a reaction between the added chlorine and phenols present as contaminants in the water (Wild et al., 1992). However, very few data are available on this issue. Paasivirta et al. (1985) found higher PCP concentrations in treated water than in raw untreated water. The total production of PCP via this method is unquantifiable and likely to be very minor. Most of the PCP produced by water chlorination is probably

degraded during wastewater treatment or is transferred into sewage sludges (Wild et al., 1992). PCP may also be produced at other chlorination plants, for example, during paper chlorination.

PCP could also be released to soil during the agricultural application of sewage sludge to the land. Wild et al. (1992) calculated, based on sewage sludge estimated increase in soil concentrations of 24 g PCP/kg per annum in the UK, about ten times higher than the UK background PCP concentration.

Figure 2.1. Transformation of HCB, lindane and PCNB to PCP (UNEP, 2013b)



Sources of environmental releases for PCA

Pentachloroanisole (PCA) is not produced commercially and, as such, it is not intentionally released in the environment. PCA is a metabolite that may be formed through the methylation of pentachlorophenol (PCP) by soil or sediment micro-organisms (see Figure 2.1). This occurs primarily in the aerobic environment. As with PCP, PCA may also result from the degradation of structurally related chlorinated hydrocarbons, such as, HCB, lindane and quintozene.

The Risk Management Evaluation prepared for PCP (UNEP, 2014b) stated that “considering the complex degradation and metabolic pathways of PCP and PCA both in the environment and in the biota, they should be considered together in the risk profile”. However, the extent of these potential microbial sources of PCP/PCA in the environment cannot be quantified (UNEP, 2013d).

2.6 Intentional uses of PCP

PCP is a general biocide and has been used extensively as a fungicide, bactericide, herbicide, molluscicide, algaecide, insecticide, disinfectant, defoliant, anti-sapstain agent and anti-microbial agent in various industries including agriculture, textiles, paints, oil drilling and forestry (UNEP, 2013d).

The major worldwide use of PCP, since it was first produced in 1936, has been as a heavy-duty wood preservative, used for utility poles and pilings, railway ties, outdoor construction materials and as a remedial treatment of timber and as a surface biocide for masonry (UNEP, 2013d). This is carried out to protect freshly-felled wood from attack from organisms that could undermine its structure, or stain or discolour the wood, thus reducing its commercial value (OSPAR, 2004). Treatment is used for example when timber in industrial or domestic premises repeatedly becomes wet or stays wet and, therefore, is susceptible to decay by wood-rotting fungi (OSPAR, 2004).

Historically, PCP has also been used in rice and sugar cane production, in water treatment, as a pre-harvest defoliant in cotton, and as a general pre-emergence herbicide (USEPA, 2008a). PCP has also been utilized in a number of products including leather and paper (USEPA, 2008a) and as slimicide in pulp and paper production. Furthermore, PCP has also been used for the production of pentachlorophenyl laurate (PCPL).

PCPL is used in the preservation of textiles and fabrics, particularly those used in heavy-duty military applications, which are subject to attack by fungi and bacteria during storage and use. These include wool, cotton, flax and jute fabrics and yarns used in covers, tarpaulins, awnings, tents, webbing, netting, sails and ropes (OSPAR, 2004).

Sodium pentachlorophenate (NaPCP), was also used as a pesticide, namely as a molluscicide.

PCP (NaPCP and PCPL) has previously been used in the past also for instance as preservative in oil-based paints, as preservative in glues (leather, toilet paper etc.) and in adhesives, as an intermediate product for the synthesis of pharmaceuticals, as an intermediate product in obtaining colouring substances (anthraquinon colorants and intermediates), for wooden trays used in mushroom farms, in slime control in pulp and paper production and as an agricultural chemical in weed control (OSPAR, 2004).

PCP is currently allowed worldwide only for wood preservation uses. Regarding its salts and esters, in addition to Na-PCP use in India for preservation of wood and paint products during storage (ICC 2014), Mexico also reported in their response to Annex E questionnaire registered uses in wood preservation, adhesives, tanneries, paper manufacture and textile manufacture for Na-PCP. However Mexico has now clarified that wood preservation is the only use authorised and that it is not aware of any other active uses (Mexico 2014).

The Canadian response to the Annex F questionnaire reported that PCP is registered for the treatment of wood for utility poles, cross-arms, outdoor construction materials, pilings and railway ties, although it indicated that PCP-treated railway ties have not been installed since 1993 (Canada 2014). Canada has reported an increase of the amount of PCP used, from 372 tonnes in 2008 to 537 tonnes in 2012 (Canada 2014).

The USEPA reported that in 2002, approximately 4,990-5,444 tonnes of PCP were used for utility poles, lumber and timbers in the USA. According to a USA EPA report (USEPA 2008b), there is an estimated 130–135 million preservative-treated wood utility poles in service in the USA, representing over 90% of the pole market and presenting a replacement rate of 2 to 3% (approximately 3-5 million poles) per year (USWAG [as cited in IEP, 2008]). Uses in other countries are not known (UNEP, 2013d).

Na-PCP is currently only used in India, mainly for wood preservation purposes-impregnated wood/ particle boards. In the USA and Canada PCP is only allowed as a heavy duty wood preservative for industrial use, primarily for the treatment of utility poles and cross-arms, which account for more than 90% of PCP-consumption in those countries with the remainder being wood treated for other uses (laminated beams for bridge construction, sound barriers, fence posts and railway sleepers) (UNECE 2010).

The main use of PCP today in the OSPAR region is the production of PCPL. This has been carried out by one plant in the UK (OSPAR, 2004). No country has reported use of PCP-L (within the Annex F survey).

The use of PCP (and NaPCP and PCPL) is restricted by a number of national and international legislative measures (Cooper and Radivojevic, 2012).

For all EU Member States, the use of PCP was restricted in 1991 by Council Directive 91/173/EEC, which prohibited the marketing and use of PCP at a concentration greater than 0.1 %. Restrictions on the use of PCP and its salts and esters were tightened by Commission Directive 1999/51/EC, meaning all uses of PCP including wood preservation were officially terminated at the end of 2008.

According to Annex XVII to the European Regulation (EC) No. 1907/2006 of the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), PCP and its salts and esters shall not be placed on the market, or used as a substance; as a constituent in other substances, or in mixtures, in a concentration equal to or greater than 0.1 % by weight.

Additionally, PCP is not included in the list of authorised substances permitted for use in plant protection products and biocide products under Regulations EC 1107/2009 and EU 528/2012 respectively, meaning such products containing PCP thus must be withdrawn PCP is also prohibited for use in cosmetic products under Regulation EC 1223/2009.

The European Union's Integrated Pollution Prevention and Control Directive (IPPC Directive) 96/61/EC and the new Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control) cover emissions and discharge of installations dealing with treatment of PCP containing material (UNEP, 2014b).

A number of countries also prohibit or limit the production, trade and use of PCP (NaPCP and PCPL) through national legislation or other measures. This includes a number of OSPAR countries including Austria, Denmark, Finland, Germany, the Netherlands, Norway, Sweden and Switzerland (OSPAR, 200b) as well as Japan, Australia, India, Indonesia, New Zealand, Russia, Thailand, Belize, Nigeria (UNEP, 2013b).

Countries such as the United States and Canada have implemented regulatory measures to minimise worker exposure to PCP and minimize environmental releases at treatment facilities and disposal. In both countries, various authorities are involved in the regulation of air emissions, storm water, waste water and control of soil wastes (collection, transportation, handling, storage, treatment, use, diversion, recycling, re-use, recovery, reduction or disposal). Burning of treated wood is not permitted in either country (UNEP, 2014b).

In the United States, PCP is restricted to the treatment of utility poles, lumber and timbers (construction). The industry is heavily regulated and US states have a well-developed approach to managing treated wood and other wastes. They identify different well-defined landfill types with prescriptions of whether treated wood waste can be disposed there and generally provision for incineration for energy subject to meeting air emission requirements (UNEP, 2014b).

In Canada as of 1990, PCP is only used as a heavy duty wood preservative to treat primarily electrical utility poles and cross-arms. It is also used on posts and industrial construction timbers. PCP can only be used in specialised facilities compliant with appropriate technical guidance for the design and operation of wood preservation facilities (UNEP, 2014b).

2.7 PCP in stockpiles, products and waste

The generation of wastes and stockpiles containing PCP will depend on the management of the (former) uses of PCP (chapter 2.3) and on the management of the PCP unintentionally generated (chapter 2.2). Production and use of PCP in industrialised countries was at its peak between the 1970s and 1990s, before increasingly stringent legislation resulted in the use of PCP being reduced significantly in more recent years (chapter 2.1 and 2.3). Use of PCP is still ongoing in a number of countries.

However based on review of the major uses of PCP based products the likely major stockpiles will be dominated by:

- Treated wood and what type of wood (timber in constructions, utility poles, railway sleepers, etc.);
- Treated leather;
- Treated textiles (but shorter lifetime).

Alongside the issue of stockpiles, many sites exist that will be contaminated from the historical use of PCP and from improper practices (e.g. at former production plants and wood treatment facilities prior to the implementation of strict regulations). These sites will continue to be sources of PCP in the environment (Wild et al., 1992). Releases to the environment may also occur through revolatilization from adsorbed residues of PCP/PCA, either from surfaces to which PCP has been applied (e.g. treated wood) or soils/sediments where waste wood has been disposed.

PCP-treated wood contains substantial quantities of the compound. The World Health Organisation (WHO) (1987) detail a number of studies that report highly elevated PCP levels in wood products (e.g. wood

shavings used for livestock litter, PCP-treated wood used in furniture, wood panelling etc.) compared with untreated wood. For example, Gebefuegi et al. (1979) measured PCP concentrations for furniture treated with PCP and compared with untreated wood samples. The top (0 - 1.5 mm) layer of treated wood contained 1,570-2,754 mg/kg PCP, compared with 15.5 to 26 mg/kg in the untreated wood.

The concentrations of PCP in waste wood are difficult to determine and will be highly variable because they depend on the original application rate, the age of the wood and the kind of use of the wood (Pohlandt et al., 1995). Pohlandt et al. (1995) investigated 214 samples of waste wood, including wood packings, pallets, interior decoration, beams, windows, fences, stakes and cable-drums. Countries of origin of the wood packings were among others Argentina, Germany, India, Italy and Spain. In most samples of raw wood, PCP concentrations were below the determination limit of 0.05 mg/kg. The highest PCP content amounted to 0.25 mg/kg. Furthermore, wood packings, pallets, beams, fences, stakes and cable-drums show low PCP concentrations. PCP was only detected at measurable levels in four of the thirty nine wood packings and pallet samples. However, with regard to recycling chips, where it is likely that treated waste wood was used, the highest analysed PCP concentration was 4.43 mg/kg. Relatively high levels of PCP were also found in the wood of interior decoration and windows. In only four of sixty-eight window samples PCP was not detectable.

As discussed in Chapter 2.3, PCP has been used in, or in the production of a number of products for domestic, consumer or household application, including paints, glues, paper and textiles. On the basis of the diverse applications of PCP, it would be expected that a large number of products contain this compound. However, there are few data on PCP levels in these products (WHO, 1987).

Given the relatively short lifespan of these consumer and household products, it could be expected that a large proportion of the PCP that has been used or contained in these products will have now passed to a waste stream. As discussed in Chapter 2.3, many countries now impose restrictions or have banned the use of PCP in most applications other than in wood treatment, so it could also be expected that the levels of PCP contained within products will continue to decline.

2.8 Sites potentially contaminated by PCP

Soil contamination can be an issue at wood preservation facilities if no effective measures are in place (Environment Canada, 2013). Contaminated soil can be spread by vehicles and wind, but it will mostly migrate into runoff water and can potentially contaminate drinking water. Adsorption of PCP to soil is influenced by soil pH and organic carbon content with adsorption generally increasing as soil pH decreases (Environment Canada, 2013). Leaching of PCP tends to increase with high PCP input, high soil moisture, alkaline soil conditions and low organic matter content in the soil (Kaufman 1976 [Cited in Environment Canada 2013]). Over a range of temperatures and pH, the solubility of PCP in the ambient environment was found to vary from 5 to 8000 mg/L.

Contaminated sites such as former PCP production plants, and wood preservation plants may continue to be major sources of PCP to the environment (OSPAR, 2004). Additionally where PCP contains micro contaminants including dioxins and furans, former sites of PCP production will act as a source for these substances too (see section 2.3 on dioxins and furans) In the future it is likely that gross contamination at sites currently producing or using PCP such as wood treatment sites will decline due to reductions in use. However, PCP levels in the non-exposed environment may rise in the short term due to recirculation from contaminated sites, meaning these contaminated sites will act as a source of PCP to the surrounding environment. PCP concentrations in the general environment could therefore lag behind reductions in PCP use (Wild et al., 1992).

Soil contamination is generally confined to areas in which wood treatment with PCP is carried out now or has been in the past. In these areas concentrations may stay high for a long time because of slow degradation in the soil. Degradation in the soil depends on the concentration of the substance, presence of acclimatised bacteria, aerobic/anaerobic conditions, organic matter, pH, nutrients, humidity and temperature. Depending on the soil type, PCP can be very mobile, leading to groundwater contamination.

Data on 154 soil contamination cases were gathered in a Finnish register by environmental authorities in 1992 (Ministry of the Environment 1994 [as cited in OSPAR, 2004]). Two third of the cases were sawmills. In almost all cases the soil had been polluted, but 32 of the cases also illustrated high groundwater concentrations in the immediate vicinity of where the original facility had been based. High concentrations of contaminants were also observed from surface water and air. The volume of heavily contaminated soils (for example more than 4 mg/kg PCP) which needed immediate treatment was 720 m³. Volume of less contaminated soil, where no immediate actions were required (0.4 mg/kg to 4 mg/kg PCP) was 15 000 m³.

Since this inventory was completed these figures have increased. High PCP levels in sawmill areas and wastes have been measured. McNeill (1990) reported the effects of 2 major spillages of wood preservative at a Scottish sawmill/timber treatment plant. Two incidents occurred in 1983, which resulted in the saturation of an area of 50 m² of soil. There was also runoff, contamination of groundwater and the receiving burn and river. In addition to the spillages, poor treatment practices i.e. runoff from stacked timber, contributed to the overall contamination of the soil (ACP 1994).

Similar cases are likely to exist in other countries. In addition to contaminated soil and possible leaching to groundwater, discharges to rivers and sea are also possible. During cleaning of contaminated soil there are also likely to be emissions to air.

2.9 Summary of potential emission sources

Table 2.3 below provides an overview of the potential key sources for PCP to environment. Care should be made when reviewing this table as potential key sources on a nation-by-nation basis will vary and some sources may not be relevant for a given nation.

Table 2.3 summary of key emission sources for PCP¹

Intentional production, trade and use	
Potential Source	Current or no longer used
Production of PCP / PCP treatments	Ongoing
Production of NaPCP / NaPCP treatments	Ongoing
Production of PCP-L / PCP-L treatments	No longer used
Timber treating (utility poles and cross-arms)	Ongoing
Timber treating (particle board – NaPCP)	Ongoing
Use in distemper paints	Ongoing
Use in heavy textiles and fabrics (PCP-L)	No longer used
Use in Oil drilling practices	No longer used
Use in surface biocides for masonry	No longer used
Use in water treatment for sugar and rice crops	No longer used
Use as a defoliant for protection of cotton crops	No longer used
Use in treatment of leather goods	No longer used
Use in treatment of paper goods	No longer used
Use as a preservative in some types of glue	No longer used
Use as a preservative in some oil based	No longer used

¹ Under the Stockholm Convention PCP and its salts and esters were added to Annex A (elimination) with specific exemptions for utility poles and cross-arms. However, for those Parties that have made a declaration in accordance with paragraph 4 of Article 25 and have not yet ratified, accepted, approved or accessed the amendment, the obligations of Annex A with respect to PCP and its salts and esters do not apply. This means that it is also possible for other uses to be ongoing (at least in the short to medium term).

Intentional production, trade and use

paints

Use as intermediate in production of pharmaceuticals	No longer used
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Use as an intermediate in some dyes and colourants	No longer used
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Other sources of environmental release

Potential Source	Major or minor*
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Releases from production of PCP / PCP treatments without proper abatement control	Major
--	-------

Released from production of NaPCP / NaPCP treatments without proper abatement control	Major
--	-------

Releases from timber treating (utility poles and cross-arms) without proper abatement control	Major
--	-------

Releases from timber treating (particle board – NaPCP) without proper abatement control	Major
--	-------

Releases from In-use timber	Major
------------------------------------	-------

Releases from end of life timber consigned to landfill	Minor
---	-------

Releases from combustion of treated timber	Minor
---	-------

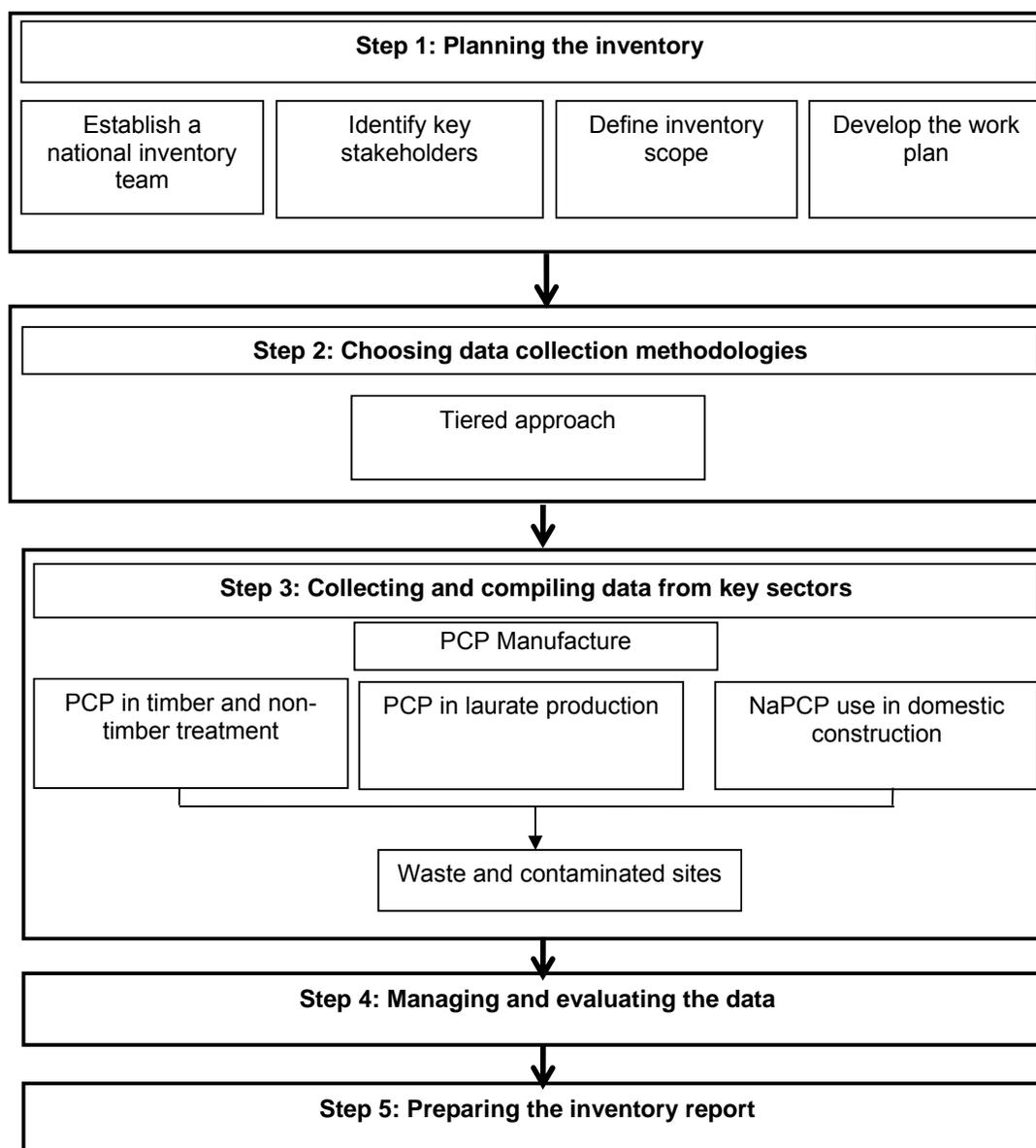
Releases from natural fires	Minor
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3. How to conduct a PCP inventory

3.1 Step by step approach for planning and conducting a PCP inventory

This chapter outlines five steps for planning and carrying out a national PCP inventory. While PCP and its salts and esters were not added to Annex C, so there is no formal requirement for Parties to develop and report emission inventories. The development of inventories is still of high value to help establish an evidence base against which the planning for emission control and minimisation can take place. The national focal point of the Stockholm Convention or national project coordinator could be responsible for initiating the inventory process. The existing Steering Committee on POPs that was formed for the original NIP development could be re-established for updating the NIP and involved in the planning of the inventory.

Figure 3.1 Overview of the national PCP inventory development process



The inventory process might not be conducted in an entirely linear fashion. The inventory team may need to repeat activities in earlier steps depending on how the inventory proceeds and which sectors are involved. For example, although the identification of stakeholders is shown in step 1 (Figure 3.1), there may also be a need to identify further stakeholders at different points during data collection in step 3. The arrow

going from step 4 (Managing and evaluating the data) back to step 2 (Choosing data collection methodologies) in Figure 3.1 indicates that steps 2 to 4 can be repeated until the data quality and coverage of the inventory reach a satisfactory level.

The inventory team will decide on the complexity of the methodology appropriate for their particular situations, taking into account their financial and technical capacities. For many countries, it could be evident at the beginning of the process that a complex monitoring (Tier III) would be out of reach (see section 3.3). Others could decide after evaluating the results of the initial inventory to undertake more in-depth data collection (move to a higher Tier) in the future, and include such activities as an activity within the action plan in their NIPs.

3.2 Step 1: Planning the inventory

The first step in developing a national inventory is to define the scope of the inventory and target the national relevant sectors for PCP. It is important to clearly define the responsibilities for the national inventory team in developing the inventory so as to streamline the work. Parties are advised to establish a multi-stakeholder national inventory team for the task. The development of a national inventory of PCP requires cooperation with the relevant stakeholders involved during the PCP life-cycle Table 3.1.

In order to act in a coordinated and integrated manner, when planning, the inventory team should correlate with other inventory teams set up nationally under the Stockholm Convention. For example, PCP has been used in similar ways as technical HCH including the insecticide lindane (timber treatment), which are also listed in the Convention. Therefore, when conducting the HCH/Lindane inventory, information on PCP should be gathered too.

Establish a national inventory team

The national focal point of the Stockholm Convention could establish and/or lead a multi-stakeholder national inventory team to acquire the necessary competences and access to relevant inventory information. The team would comprise government ministries with a mandate for chemicals and waste management, industry, forestry, the national customs service, the private sector, non-governmental organizations (NGOs), and researchers from universities or research institutes working on old and new POPs, waste management and possibly material flows, among others (see Table 3.1). National POP or waste management consultants and material flow experts, knowledgeable in these issues, could also be hired to facilitate the work of the team.

The national focal point and/or consultants would brief and educate the team on the Stockholm Convention's mandates, obligations and the new listed POP.

Identify key stakeholders

The first meeting of the national inventory team provides the opportunity to determine the available information in various stakeholder organizations and to brainstorm how best to proceed with the inventory exercise.

The inventory development requires cooperation between relevant government authorities and official agencies, producers, importers and distributors, manufacturers, fabricators, community-based organizations and NGOs, organized labour and trade unions, industrial enterprises, other private-sector organizations, the waste management and the recycling sector, and users and owners of articles possibly containing PCP. Representatives from the key sectors could be included in the inventory team, while others could simply be asked to provide data/information.

Making preliminary contact

Making contact with stakeholders at the beginning of the inventory exercise can give them a better understanding of the background, scope and objectives of the inventory and provide them with an opportunity to communicate their views and questions. This initial feedback can help make the inventory more effective by targeting the relevant areas of national use.

General tools that can be used to identify and contact stakeholders include:

- Telephone interviews using phone books/registers;
- Postal communication using national registers;

- Email/Web-based information sourcing; and
- Face-to-face interviews.

Consulting with a small number of relevant stakeholders

During the inventory planning stage, it may be more efficient to contact and consult only a small number of relevant stakeholders such as large-scale manufacturers, national industrial associations and the customs service. For PCP in particular, the end-of-life uses and possible recycling of treated timbers from national infrastructure into other uses (such as parks and gardens) could be important, highlighting the need for contact with national infrastructure organisations such as power distribution companies and railway operators. Gap analyses conducted in the evaluation of the initial assessment or the preliminary inventory could result in the need to contact some of these stakeholders again to get more information or identify other stakeholders to be contacted to help fill in the information and data gaps.

Holding stakeholder group meetings

There may be a range of stakeholder groups involved depending on the areas of use of PCP for manufacturing different products/articles, e.g. treatment of timber and non-timber products, production of laurate or NaPCP use in domestic properties (see Table 3.1, Section 4 and Section 5).

Table 3.1 Sectors and stakeholders involved in the production, use or impact of PCP

Production	Stakeholders
General stakeholders	Ministry of environment and ministry of industry; Ministry responsible for waste management; NIP coordinator and steering committee; Basel Convention ² focal point (and stakeholders in Basel); Rotterdam Convention ³ focal point (and stakeholders in Rotterdam); Custom authorities; NGOs.
PCP production	Authorities granting production permits; Industry producing PCP; Waste management facility owners; Custom authorities.
Treatment of timber and non-timber products with PCP	Timber industry Authorities granting treatment permits; National infrastructure organizations such as utility companies; Waste management facility owners; Custom authorities.
Manufacturing of products/articles where PCP has been used	Textile industry; Laurate production industry; NaPCP industry; Domestic property industry; Authorities granting treatment permits;

² The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, hereby referred to as “The Basel Convention”, is an international treaty signed in 1998 that was designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries. As part of the wider work on ‘POPs’, the Basel, Rotterdam and Stockholm Convention share the same executive body.

³ The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, hereby referred to as ‘The Rotterdam Convention’, is an international treaty signed in 1998 that was designed to promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm and to contribute to their environmentally sound use, by facilitating information exchange about their characteristics, by providing for a national decision-making process on their import and export and by disseminating these decisions to Parties.

Production	Stakeholders
	Waste management facility owners; Custom authorities.
Use of PCP containing materials	Users/owners of treated timber or other products; Users of textiles contain laurate; Domestic users of NaPCP; Ministry of Agriculture or Forestry and institutes and industries working with wood and treatment of wood; Ministry of defence; Ministry of business.
End-of-life treatment	Recycling companies (for textiles and treated wood waste); Housing demolition companies; Landfill owners.

Define the scope of the inventory

Defining the scope of the inventory involves identifying the relevant national sectors to be investigated further. This can be achieved by consulting key stakeholders (see Table 3.1) and focusing on the use categories and life cycle stages discussed in Section 2 and detailed in Sections 4 and 5. Since the major use of PCP is timber treatment, this is likely to be the focus of the inventory.⁴

Main information includes:

- Past and current production, import and export of PCP at the national level;
- Past and current use of PCP in manufacturing (e.g. laurate);
- Past and current use of PCP containing products (e.g. timber and other products);
- Presence of products and articles containing PCP on the consumer market (e.g. textiles);
- Alternatives to PCP in manufacture of products and treatments;
- Recycling practices of PCP containing products;
- Disposal practices for production residues and products and articles containing PCP when they become wastes;
- Any stockpiles of PCP or PCP containing articles and products;
- Import/export of PCP containing wastes; and
- Potentially contaminated sites.

The following criteria are important in defining the scope of the inventory:

- Obligations for PCP under the Stockholm Convention;
- Objectives of a PCP inventory;
- Existing resources and capacity; and
- National priorities.

⁴ Past uses of PCP have been dominated by timber treatment, however other uses have included as an intermediate in the manufacture of laurate (used primarily in heavy textiles such as tents). There has also been identification of the use of NaPCP as a pesticide for the treatment of domestic wood products and outdoor murals within at least one nation. However the decision to add PCP to the Stockholm Convention (decision SC-7/13) granted exemptions for the use of PCP on timber only for a set of given applications (utility poles and cross-arms). Therefore any continued use of PCP would be limited primarily to these applications. Therefore timber will form a key focus of the inventory.

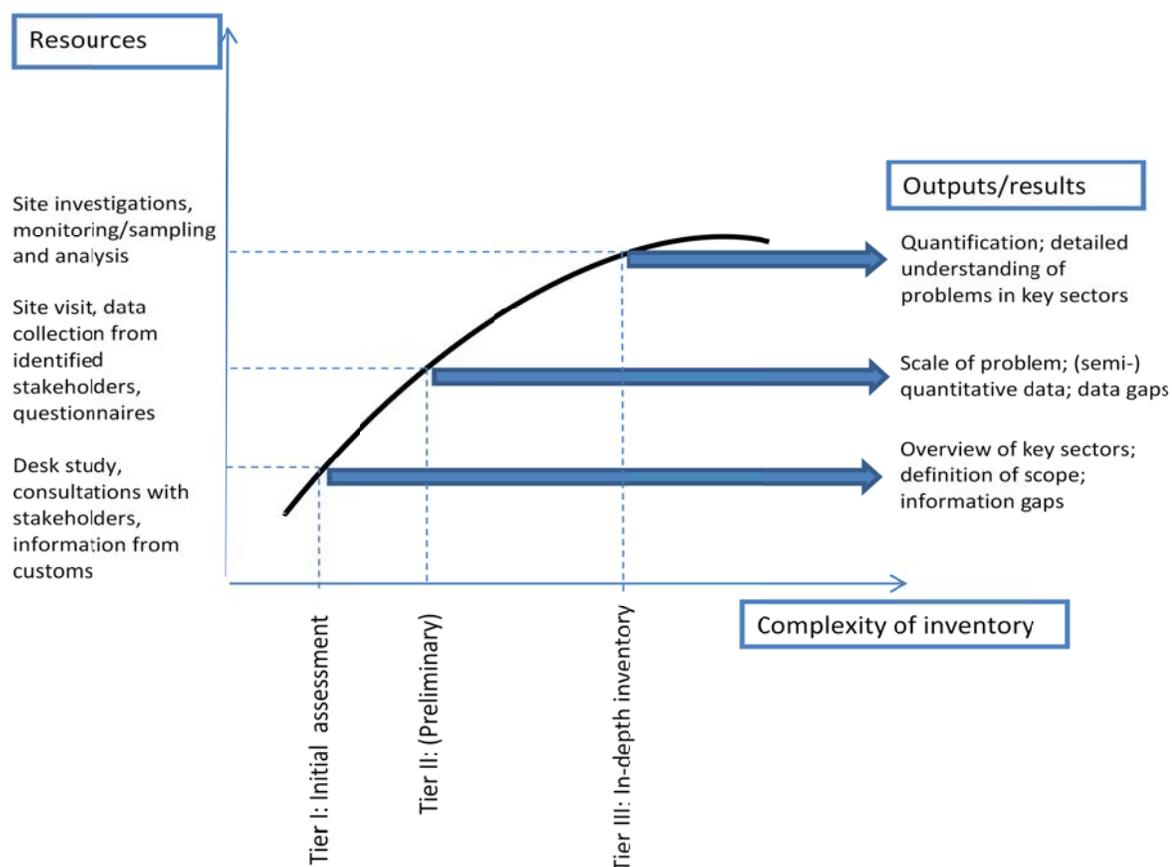
The degree and depth of the inventory can be defined by consulting the tiered approaches mentioned in Sections 3.3 and 3.4, considering the resources needed.

3.3 Step 2: Choosing data collection methodologies

Tiered approach

The tiered approach to collecting data in a PCP inventory is illustrated in Figure 3.2. The suggested methodologies for data collection in the three tiers are described in this section and mentioned in the sections on the individual inventory sectors where appropriate. This approach provides flexibility to a wide range of Parties with varying priorities and capacities. Each tier represents a level of methodological complexity. Moving from lower to higher tiers implies a Party is opting for approaches that are progressively more demanding in terms of complexity and data requirements, and therefore more resources may be needed. However, the higher the tier, the more representative of the national situation the inventory is likely to be.

Figure 3.2 The tiered approach to the inventory of PCP



Tier I: Initial assessment

Tier I methods usually rely on readily available information and statistics. Higher tiers methods involve more resource-intensive data collection activities and possibly country-specific measurements but should also yield more accurate results.

Parties should endeavour to use methods that provide a robust level of certainty, especially when, for example, the preliminary inventory concludes that PCP could pose high human health and environmental risks in the country and more accurate data is needed to prioritize risk reduction measures and estimate their costs, while making efficient use of available resources and taking into account available technical capacity.

The initial assessment (Tier I) provides the inventory team with a general idea of where the problems may lie and, more importantly, which sectors require further investigation and information gaps. Tier I outputs

are rather qualitative and require (subsequent) verification. The (preliminary) inventory (Tier II) focuses on the major sectors and generates (semi)quantitative data. The in-depth inventory (Tier III) uses in depth assessment and possibly, includes analytical measurement methods to obtain precise data on the relevant sectors.

Tier II: (Preliminary) inventory

The preliminary inventory generally focuses on specific sectors, as shown in Figure 3.2. It involves surveys and site visits to better estimate national data that were identified as missing in the initial assessment/Tier I.

Possible applications and uses and target locations can be identified, followed by site visits including:

- Current and former production sites of PCP;
- Current and former manufacture sites of PCP containing products;
- Companies which use/have used PCP containing products (wood/timber, leather, textile, pulp and paper factories etc.);
- Agricultural areas where PCP has been used;
- Waste collection centres and recyclers;
- Storage and disposal locations of materials containing PCP; and
- Waste management facilities.

Tier III: In-depth inventory

The in-depth inventory may be undertaken if the preliminary inventory concludes that PCP could pose high human health and environmental risks in the country and more accurate data are needed to prioritize risk reduction measures and estimate their costs. Data collection in this tier relies on the use of analytical methods that may include monitoring measurements with instrumental analysis. It may also involve detailed inspections of sites mentioned in Tier II and in the inventory chapters below.

Indicative, qualitative and quantitative methodologies

A number of different methodologies can be used for gathering information about PCP. The methodologies can be divided into three groups:

- **Indicative method:** provides initial information for further planning of the inventory depending on the availability of resources. This method is quick and does not require significant human and financial resources. Activities include desk study of existing information, workshops, and interviews. It is normally used in the initial assessment;
- **Qualitative method:** uses questionnaires to obtain more specific data. Data management is based on estimations from known levels of quantities of PCP use and production. Workshops and interviews with stronger obligations (legal tools) may also be helpful in obtaining data from the industry. This method is normally used in the initial assessment and preliminary inventory;
- **Quantitative method:** provides accurate and specific numerical information, but needs to be carried out by experts or involve experts in the relevant fields of PCP and the sectors of investigation. This is an advanced stage of the inventory that includes detailed interviews with industry and possibly site inspection. The quantitative methods might also use sampling and analysis for some areas where the extent of PCP usage is not known. Such investigations might be extensive and labour intensive and, if instrumental analysis is involved in such an assessment, would become costly. This method is normally used in the in-depth inventory.

Four approaches that can be used for data collection are discussed briefly in the next chapters.

Desk study of existing information

The desk study involves gathering information about existing, past and current national data on production and use of PCP. This information might be obtained from this inventory guidance, related Basel Convention technical guidelines (UNEP, 2016), the customs service, national bureau of statistics, published literature in scientific journals, technical reports or notes from industry and industry associations, commissioned research reports, and Internet searches. The information should be collated, evaluated and verified if

possible, and a gap analysis of the data could be undertaken as well. This approach is typically used in the Tier I assessment.

National sensitizing/inventory workshop on Stockholm Convention and new listed POPs including PCP

A national workshop involves major stakeholders in the production and use of PCP. The national importance of the inventory exercise would be emphasized to participants while demanding their cooperation and unhindered release of available data in their custody in the national interest. If confidential business information is involved, agreements should be reached with respective industries. Breakout sessions and group meetings can be organized during the workshop to ensure that all sectors involved in the use or production of PCP are adequately covered as well as to get consensus on how best to collect and compile data.

Questionnaires

Questionnaires might be valuable instruments for primary data collection in inventory programs. Based on preliminary contact and consultation meetings with stakeholders, a questionnaire with explanatory notes can be developed and sent to the relevant stakeholders. Simple questionnaires could be developed covering questions to gather the information needed to compile data for a Tier II or Tier III assessment.

Questionnaires (see Annex 2) can be administered through various outreach mechanisms, including electronic distribution, postal distribution; supply chain distribution; distribution via trade unions, NGOs, local governments and community leaders. Questionnaires might also be used for one-on-one interviews or in the frame of a stakeholder workshop.

Site inspection, sampling and analysis

Samples can be gathered during in site inspections of relevant (former) production sites, and waste disposal/storage facilities (landfills and dump sites). The screening and analysis of articles and products containing PCP is described in the *Draft Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles* (Secretariat of the Stockholm Convention, 2013).

3.4 Step 3: Collecting and compiling data from key sectors

The inventory team should investigate whether the following data exist in the country:

- Former and current production of PCP;
- Industries using or formerly using PCP;
- Products and articles containing PCP in use/used;
- Imports and exports of products and articles containing PCP;
- Disposal practices for products and articles containing PCP when they become wastes;
- Articles containing PCP that were recycled, the possible extent of recycling, and the types of articles produced from recycling, including the life cycle of PCP and its potential for emissions;
- Stockpiles and wastes from current and former production and use in industries (countries that produced/produce PCP or used/use PCP in industries); and
- Sites with activities that could have potentially contaminated the sites or environment with PCP.

It is desirable to collect and compile the following numerical data in the inventory:

- Quantities of PCP formerly and currently produced, traded nationally and exported;
- Quantities of products containing PCP (e.g. leather, textiles, treated timber, treated railway sleepers, treated products), recycled and quantities of products made from recycling;
- Quantities of waste generated containing PCP; and
- Quantities of PCP historically used in agriculture.

Data collection approaches will vary from country to country based on the data gathered in steps 1 and 2; they may be by estimations, using statistical data, industry provided data or possibly measurements.

The focal sectors to be investigated in the national inventory fall under following key areas:

- PCP production;
- PCP use for the treatment of timber, leather and other products;
- PCP use in laurate manufacture;
- NaPCP use in the domestic construction sector;
- PCP use in agriculture; and
- Identification of contaminated sites and hot spots.

In addition, data collected for the first four areas will form the basis for the preliminary inventory of contaminated sites and hot spots.

3.5 Step 4: Managing and evaluating the data

Overview

The development of emission inventories provide a valuable tool to assess what are the key emission sources and trends for a given pollutant. However, in developing an emission inventory it is also important to recognise that the data developed will be based on emission estimates, which naturally carry a level of uncertainty as all estimates will. Therefore, it is also of high importance to properly evaluate the emission inventory in order to:

- Ensure that the data gathered is properly managed, referenced and well understood;
- That uncertainty within the data is understood and properly reported; and
- That evaluation of the emission inventory is used to better understand gaps and weaknesses which need to be targeted in future updates of the emission inventory.

This will minimise uncertainty and ensure as robust as possible evidence base upon which to make policy planning decisions.

Data management

Since Parties have different designs and levels of legal framework, political organization and economic support for environmental management, different methodologies may be applied in the data gathering process as described in Section 3.3. The management of collected data should be done as consistently and as transparently as possible. During the data processing, all the assumptions and conversion coefficients adopted as a result of expert judgement, where needed, should be recorded and mentioned when the results are presented.

Before the inventory development starts, all the data formats including questionnaire survey formats should be determined to anchor the consistency of the data collection as much as possible. If some data conversions and estimations are done by stakeholders, the inventory team should provide training on how to estimate the amount of PCP and how to fill out the questionnaire. This will reduce the possibility of errors during the data management activities.

Mechanism for evaluation of the inventory

An evaluation of the process, strategy used and information collected can take place along with a decision on what further actions are needed to make the inventory more complete.

The evaluation includes identification of the following:

- Gaps and limitations;
- Need for validation of the information compiled in the inventory;
- Further actions needed to make the inventory more complete;
- Actions needed to meet the requirements of the Stockholm Convention.

Important elements in this evaluation step are to identify any gaps and limitations, and the measures needed to make the inventory more complete. Other ways to involve the stakeholders and other data collection strategies (see steps 2-4) could then be considered. A gap analysis in the evaluation of the initial assessment or preliminary inventory could result in the need to contact some of the stakeholders again to get more information or identify other stakeholders to be contacted to help fill the gaps.

For inventory sectors with limited information, stakeholder meetings may be a necessary measure. In some cases, government regulations may be required to ensure that stakeholders report their holdings, cooperate with the national authorities and engage in the national inventory. To draft a regulation and bring it into force may require a long time (a year at a minimum in some places).

Gaps, limitations and necessary actions to complete the inventory will also be valuable information for the NIP, especially for developing countries with a need of financial support. It is important for developing countries to identify whether and what technical and financial support is necessary to complete the inventory. Even if the inventory is very incomplete, the NIP is expected to provide information on gaps and the limitations of a Party's resources and capacities — information that is useful to identify technical and financial needs.

It is also important to identify whether the current situation meets the requirements of the Convention, including the actions needed to fulfil the obligations of the Convention.

The inventory might also require revision at a later stage when the action plan is updated. This can also be conducted using the strategies described in this guidance.

3.6 Step 5: Preparing the inventory report

The final step for the inventory team is to prepare the PCP inventory report. This report will include the inventories of all sectors investigated by the Party (see sections 4 and 5), as well as information on potential contaminated sites and hot spots.

Although its aim is to support the development of the NIP, the report can also be used for other purposes such as feeding into Article 15 reporting, developing post NIP projects, and developing effective strategies and action plans for managing PCP to meet the obligations of the Convention.

The essential elements of the report are:

- Objectives and scope;
- Description of data methodologies used and how data were gathered, including all the assumptions and conversion coefficients adopted as a result of expert judgement;
- Final results of the inventory for each sector considered a priority for the Party (using a format to be provided in this guidance, as such or adapted from that format);
- Results of the gap analysis and limitations identified for completion of the inventory; and
- Further actions (e.g. stakeholder involvement, data collection strategies) to be taken to complete the inventory and recommendations.

4. Inventory of PCP based on production, use, and waste cycle aspects

4.1 Introduction

This chapter provides a detailed overview for all potential emission sources using a life cycle approach. This covers the manufacture of PCP, treatment of wood with PCP based products, in-use emissions, and end of life management and potential emissions. It also includes comment on potential hot spots and need to identify and inventory these sites also. Some useful case studies regarding hotspots have also been provided as examples of the kind of issues that can be encountered. The information provided within this chapter is intended to give useful default values that can be used. However, best practice will be to make use of country centric data wherever possible. It is also important to recognise that practices may vary regionally as will climatic conditions and this may affect the rate of emission as well as the importance of specific emission vectors (e.g. air, land, water). A table of default emission factors based on the details in this chapter is provided within Annex 1.

It should also be noted that in the frame of the Stockholm Convention BAT/BEP expert process there is work to develop guidance on emission abatement and emission reduction. This guidance document is intended to aid the reader in the development of emission inventories to act as the evidence base for policy planning in targeting emission control and minimization. Please also refer to the guidance to be developed by the BAT/BEP experts for further details on emission abatement approaches.

4.2 Phase 1 – The intentional production and use of PCP

Manufacture of PCP

PCP can be produced by several methods, including the following (IEP, 2008; UNEP, 2013e):

- Direct chlorination of phenols and hydrolysis of hexachlorobenzene. 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.

It is difficult to determine exact volumes of releases to the environment from sources of PCP, NaPCP and PCPL production. Emission factors for PCP and NaPCP 'product' were reported by UNEP (2013e) as 634 µg TEQ/kg product and 12.5 µg TEQ/kg product respectively. Emission factors for air, water, land and residues were not reported in this study.

Only few data are available on the release of phenolic and nonphenolic compounds into the environment during the normal production of PCP or NaPCP. In a study by UBA (1985) [as cited in IEP, 2008] an emission concentration for PCP of 0.7 mg/m³ and mass flow of 9 g/h were derived for PCP production processes.

Air emissions rates (maximum values) of phenolic and non-phenolic compounds during PCP production were also reported by BUA (1986) [as cited in IEP, 2008]. The annual air emission value for PCP resulting from the production of approximately 2000 tonnes of PCP or NaPCP were estimated to be 18 kg/year and 65 kg/year respectively.

While no waste water is expected to occur during the production of PCP, the annual loss of various compounds resulting from NaPCP production into the waste water was estimated at 60 kg/year (BUA, 1986 [as cited in IEP, 2008]). The volume of contaminated wastewater generated during the production of Na-PCP is small, because manufacturers and regulatory agencies have emphasized efficient process design (IEP, 2008).

The production of approximately 2000 tonnes of PCP/year typically generates an estimated 8 tonnes of washing methanol, 4 tonnes of activated charcoal, and 2 tonnes of other wastes. These wastes, as well as the filtration sludge resulting from NaPCP production, contain considerable amounts of hazardous

chemicals (IEP, 2008). This includes the production of PCP at rates of 1350 kg/year and 900 kg/year (see Table 4.1).

Table 4.1. Phenolic and non-phenolic compounds in the combined wastes (PCP production) and filtration sludge (NaPCP production). Source: IEP (2008)

Compound	Combined wastes (kg/year)	Filtration sludge (kg/year)
PCP	1350	900
Other chlorophenols	0.7	Ns
Hexachlorobenzene	ns	6000
Decachlorobiphenyl	ns	3400
Decachlorophenoxybenzene	ns	44
OCDD (OCDF)	0.98	0.67 (0.67)
H7CDDs (H7CDFs)	0.13	0.17 (0.045)
H6CDDs (H6CDFs)	0.013	0.092 (0.015)
P5CDDs (P5CDFs)	0.003 x 10 ⁻³	0.016 (0.005)
T4CDDs (T4CDFs)	0.002 x 10 ⁻³	0.007 (0.001)
2,3,7,8-T4CDD	ns	0.001

Products, which are used in wood treatment or in textile impregnation, may be ready-for-use products or may need some dilution, dissolution or addition of other (active) substances. Formulation of the treatment fluid may take place by the importer or the producer or the end user of the substance. In the absence of detailed information on products and preparations on the market at present, no quantitative emission estimation from formulation is possible to be carried out. However, it could be assumed that the emissions will be probably lower during formulation compared to emissions during use of substances (IEP, 2008).

Total annual PCP releases to municipal waste water treatment facilities were estimated to be 5,300 kg (USEPA, 1980 [as cited in IEP, 2008]). Most of the pentachlorophenol removed from effluent streams by waste water treatment processes is adsorbed to sludge solids. Sludges from wood preservation industries historically have been estimated to contain up to 14 000 kg of PCP per year.

As mentioned in Chapter 2.1., no precise estimates can be made of the total world production of PCP and NaPCP. It is now thought that only one production plant of PCP still exists, located in Mexico, with a formulation plant of PCP located in the USA. It is reported that the KMG plant in the USA formulated 7 257 tonnes of PCP (liquid concentrate) in 2009, marketed for wood preservation purposes in the USA, Canada, and Mexico (UNECE, 2010). Mexico reported production of 6 610 tonnes of PCP in 2009.

Pentachlorophenyl laurate (PCPL) is being manufactured by one company in Europe. In the synthesis of laurate, imported PCP is used as starting material. According to the manufacturer, discharges of PCP to water from production do not exceed 10 g/l in their trade effluent. The manufacturer also states that this level of discharge applies also to the companies processing the textile fabrics. The trade effluent from the production plant is discharged to sewer from where it goes to a sewage treatment plant, which treats both industrial and domestic sewage from a wide area (OSPAR, 2004).

Use of PCP in timber treatment

A comprehensive description of the wood treatment process has been provided by USEPA (2008c) [following the recommendations of the American Wood Preservers' Association (AWPA)] and by Environment Canada (2013). A flow diagram, summarising the wood treatment process, and the points at which emissions occur in this process, is presented in Figure 4.1.

The wood treatment processes typically consists of four stages:

Preparation

Before wood preservative chemicals can be applied, the wood must be appropriately prepared for treatment. The first stage is typically the 'peeling' of wood, which is necessary on round or slabbed wood products to enable them to dry quickly enough to prevent rotting or insect damage. This also removes bark to increase penetration of the preservatives, as bark may prevent penetration of preservative and any bark that survives the overall treatment process may later fall off and expose the untreated interior to decay) (Becker et al, 2008).

These "Peeler poles" are then measured to determine the class and length best suited for each pole and then cut to the appropriate size. Poles also are "framed" by drilling holes and cutting flat "gains" for mounting hardware to meet customer requirements. Other framing may include incising or through-boring to improve preservative penetration Bollin and Smith (2011).

Drying and conditioning

Wood needs to dry prior to application of the PCP/carrier oil mixture. The moisture content of the wood can be reduced by one of several conditioning methods. These include by air drying, kiln drying or by artificial processes carried out in the treatment cylinder—for example, the application of steam and subsequent vacuum, or boiling under a vacuum, typically in the range of 82°C to 104°C for one to 24 hours in the presence of the treating solution (so-called Boultonising) (USEPA, 2008c; Environment Canada, 2013; Bollin and Smith, 2011).

The choice of conditioning method will be dependent on the wood species and the intended end use. For example, kiln drying is most common for lumber destined for the residential market; air seasoning is most economical for large commodities, such as ties, timbers and poles; a steam/vacuum process is preferred for poles to be treated with PCP/oil; and Boultonising is common with ties and marine pilings to be treated with creosote or creosote/oil solutions (Environment Canada, 2013).

In Canada, air seasoning is the most common means of conditioning poles.

Wood treatment

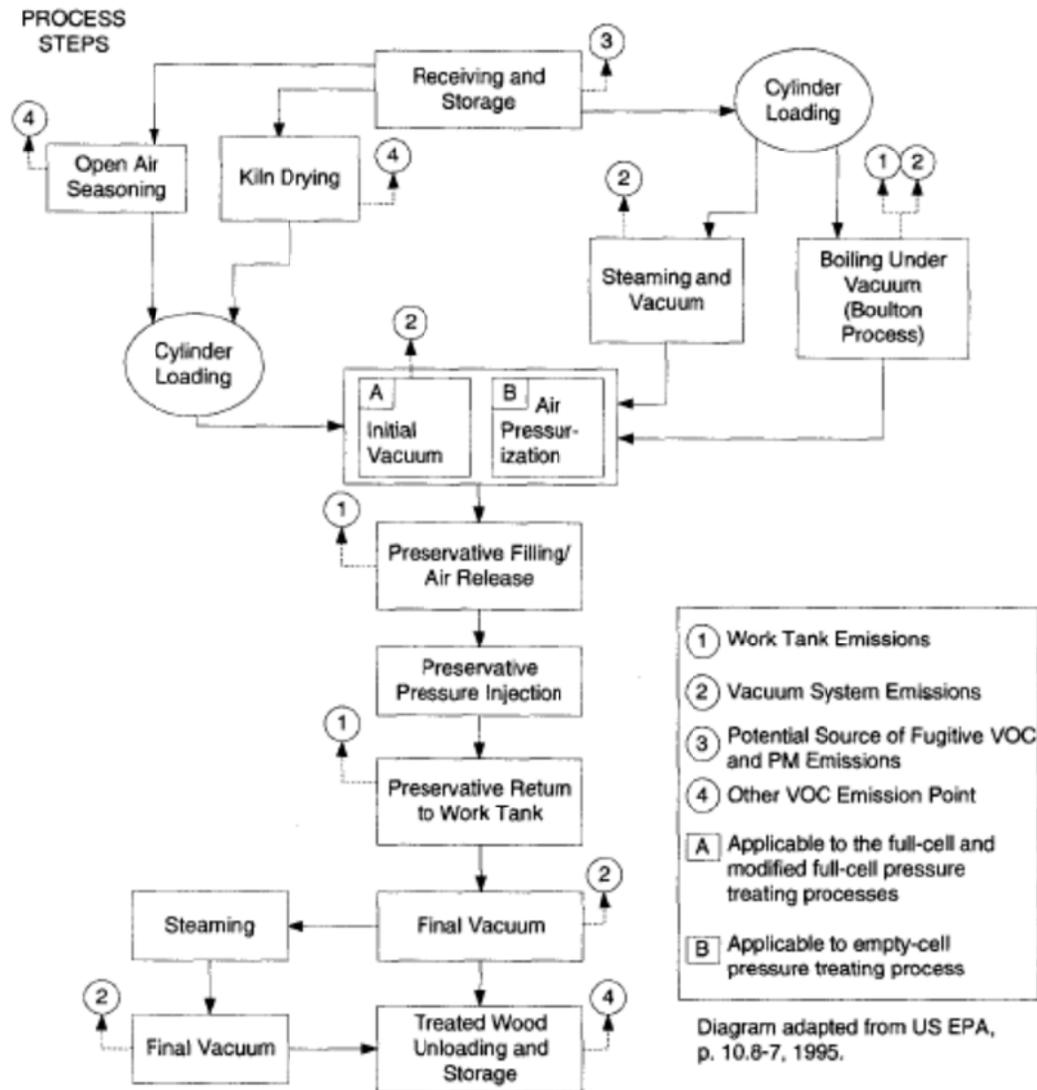
The PCP treating solution is a mixture of PCP and diluent oil.

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).

Based on the reported use of PCP and survey results for the use of diluent, approximately 2 kg of diluent oil per cubic foot of treated pole was used on average (Bollin and Smith, 2011). An average retention of 5.7 kg/m³ was calculated (Bollin and Smith, 2011).

The PCP preservative mixture is applied in a pressure cylinder, which is typically up to 45 m long x 2 m in diameter. Specific treatment parameters (e.g. temperature, pressure and duration) will vary depending on the specific purpose of application and will be dictated by the species of wood, the wood product and the initial moisture content of the wood (USEPA, 2008c).

Figure 4.1 Flow diagram of the typical wood pressure treatment process (USEAP, 2008).



As detailed by Environment Canada (2013), the wood-preserving treatment process can consist of two processes, either:

- A pressure treatment process – typically the ‘empty cell’ process, which can consist of either:
 - 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 – 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;

- According to the AWPA, temperatures during the entire pressure period for treatment using oil-borne preservatives shall not exceed 100°C (USEPA, 2008c).
- A thermal treatment process:
 - 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). A pressure vessel is not required to carry out the process;
 - 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. The impregnation cycle may be followed by an expansion bath or a final steam cycle, both of which add a final vacuum step. The poles are left in the treatment tanks to cool and to allow any excess preservative to drip off;
 - Typical preservative PCP retention in treated wood 3.4–16 kg/m³ of treated wood preservative (Environment Canada, 2013).

Storage

The treated wood is withdrawn from the treating cylinder and stored on a drip pad until dripping has stopped. From there the treated wood is removed from the drip pad and stored in a designated area until it is transported to the customer.

The PCP oil-borne treatment processes (both pressure and thermal) generate liquid and solid wastes and emissions to air. The points in the treatment cycle where emissions occur are shown in Figure 4.1. Here, these emission sources (for both pressure and thermal processes) are summarised briefly. It should be noted that measured emission data or data to estimate emissions are not available for many of these processes (IEP, 2008).

The TRI estimated the amounts of PCP discharged to the environment from manufacturing and processing facilities in the United States in 1999 (TRI99, 2001 [as cited in IEP, 2008]). These are shown in Table 4.2. It should be noted, the TRI data should be used with caution because only certain types of facilities are required to report (IEP, 2008).

According to a Finnish study at the beginning of the 1980s PCP-containing solid waste of about 0.3 litres per m³ treated wood was collected (Viitasaari, 1988 [as cited in IEP, 2008]).

Table 4.2. Estimated levels of PCP discharged to the environment from manufacturing and processing facilities in the USA in 1999. Source: TRI99, 2001 [as cited in IEP, 2008]

Number of facilities	Reported amounts released in (kg/year)					
	Air	Water	Land	Total onsite release	Total offsite release	Total on and off-site release
47	592	579	44832	46006	7941	53947

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.

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.

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.

Because PCP wood preservation facility sites are generally large, considerable volumes of storm runoff waters originate from these sites. Precautions are, therefore, required to avoid contamination of storm runoff water. The PCP content in runoff waters depends on many factors, including drip and vacuum time in the last step of the pressure process; viscosity of the wood preservative; wood species; moisture content of the wood prior to application of preservative (i.e. adequacy of conditioning step); specific treatment process (i.e. Rueping or Lowry); effectiveness of the post pressure-cycle processes applied (expansion bath, final steaming, final vacuum); and exposure to the weather.

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; and
- Pallets and wrappings from bulk PCP.

Air emissions from pressure treatment facilities that use oil-borne PCP are generally localized and may include the following:

- Dust and vapours from manual unwrapping of PCP blocks;
- Vapours from block storage;
- Emissions during wood conditioning and the final vacuum step;
- Vapours from tank vents;
- Vapours from venting cylinders;
- Vapours from the opening of cylinder doors;
- Vapours from freshly treated charges; and
- Vapours from vacuum system outlets.

In Canada PCP can only be used in specialised facilities compliant with appropriate technical guidance for the design and operation of wood preservation facilities (Environment Canada, 2004). This technical guidance aims to minimise potential adverse effects to the environment and/or human health, establishing Best Management Practices for PCP treated products (Environment Canada, 2004). This applies to both the design of facilities and the operating procedures for both pressure and thermal treatment processes.

Environment Canada (2013) provides a detailed description of best practice measures treatment plants should implement in order to prevent and/or reduce releases of PCP to the environment. These measures are summarised in Table 4.3.

Contaminated water solutions may be generated during this process, requiring oil and PCP to be removed from wastewaters 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); and
- Evaporation/condensation.

It is also recommended that surface runoff from storage areas should be monitored for chlorophenols and oil.

The most feasible disposal option for chlorophenol wastes appears to be high-temperature thermal destruction by an approved facility.

While awaiting disposal, the contaminated solids should be held in leak proof containers in a specially designed area that is curbed with a paved or concrete sealed surface. The area should be roofed to protect the wastes from precipitation. Any seepage or leachate generated at the site should be contained.

Table 4.3 Examples of disposal practices for PCP-contaminated wastes

Waste category	Examples	Recommendations
Liquid PCP/oil solutions	<ul style="list-style-type: none"> • Spilled PCP/oil concentrates • PCP work solutions • Drips from freshly treated timber • Material skimmed from the oil separators 	<ul style="list-style-type: none"> • Collect and reuse
Liquid PCP/water solutions	<ul style="list-style-type: none"> • Condensates • Wash waters • Infiltrating waters 	<ul style="list-style-type: none"> • Treatment to remove oil and PCP to regulatory limits • Dispose of treated waters as per regulatory requirements
Contaminated solid wastes	<ul style="list-style-type: none"> • Debris and bottom sludge from storage tanks, sumps and pressure cylinders • Soils contaminated by spills • Clean-up absorbents • Filter and cleaning vacuum processes • Solid fine residues from PCP or PCP/oil storage areas • Wrapping used for PCP blocks • Scraps, cuttings and shavings from PCP-treated timber 	<ul style="list-style-type: none"> • Drain and/or drum, store and dispose of in accordance with provincial regulatory requirements (high-temperature thermal destruction at authorised facilities appears to be the most feasible disposal option)
Miscellaneous solid wastes	<ul style="list-style-type: none"> • Empty containers and wrapping rinsed with alkaline water 	<ul style="list-style-type: none"> • Dispose of in authorised sanitary landfills (subject to approval by the provincial regulatory agency) • Recuperated by authorized facilities
Contaminated storm runoff	<ul style="list-style-type: none"> • Storm runoff or contaminated liquid discharges containing PCP require consultation with regulatory agency 	<ul style="list-style-type: none"> • Prevent or minimize contamination of storm runoff to greatest possible extent • Monitor surface water discharges (in consultation with

Waste category	Examples	Recommendations
		<p>the provincial regulatory agency) to assess contamination concentrations and determine need for control</p> <ul style="list-style-type: none"> • Provide means for collection of contaminated storm runoff
Firefighting water runoff	<ul style="list-style-type: none"> • As above for contaminated storm runoff 	<ul style="list-style-type: none"> • Consider containment for where PCP or PCP/oil solutions are present • Consult with provincial regulatory agency to determine acceptable disposal practices

Non-timber treatment uses of PCP

As discussed in Chapter 2.3, PCP has historically been used in a wide variety of non-timber applications.

Leather treatment

PCP was commonly used as a preservative in leather from the 1970s to protect leather goods from fungal damage during the wet processing of these materials. However its use for this purpose declined rapidly in many countries as its use became increasingly restricted due to human health and environmental concerns (Fontoura and Gutterres, 2015). PCPL and NaPCP have also been used in the treatment of leather (UNEP/POPS/POPRC.9/INF/7).

Historically, PCP has been used for leather preservation in, the USA, Mexico, India, Europe and Russia (UNEP/POPS/POPRC.9/INF/7). Data on the volumes of PCP used for this process are not available. PCP (and PCPL and NaPCP) has not been used for leather preservation in the USA since the 1990s (OSPAR, 2004). In the EU the implementation of Directive 91/173 (pertaining to dangerous substances) in 1993, strictly restricted the use PCP in Europe by prohibiting the sale or use of substances containing PCP esters and salts at concentrations above 0.1%. In 1989, Germany enacted its own national legislation mandating a more stringent ban on products containing more than 5 mg/kg PCP. The placing on the market or use of PCP is now prohibited in the EU under Regulation (EC) No 1907/2006 (REACH).

As reported in OSPAR (2004), several studies have been conducted (between 1990 and 1993) on the PCP content of leather goods in Germany, since the restrictions on PCP came into force in 1989. 660 samples of leather products (shoes, gloves, insoles, etc.) were analysed in 11 German Federal States. The PCP content in 24% of leather goods exceeded the limit value of 5 mg/kg. In another investigation in 1992, 86 samples of leather products were analysed and in 29% the 5 mg/kg limit value of was exceeded. A Swiss campaign in 1996 studied 47 samples of leather and the highest PCP levels detected were in the range of 1,000-3,000 ppm (mg/kg), with 4.3% of cases exceeding the 5 mg/kg limit (OFEFP 1998 [as cited in OSPAR, 2004]).

It is expected that PCP will have been released to the environment in waste water effluent from leather production facilities and from imported leather products (e.g. clothing, home furnishing and industrial applications) during their useful life or upon disposal. Moreover, imported goods can also be treated with PCP may not comply with national or international standards and therefore may not be accepted for this specific use in particular countries. Since it is not possible to estimate the volume or number of treated products produced in or imported into specific countries or regions, release estimates from these sources cannot be made (OSPAR, 2004).

Textile treatment

PCP, NaPCP and PCPL have been used to treat textiles which are subject to attack by fungi and bacteria during storage and use.

In the UK, PCP and NaPCP has been used as an anti-mildew agent in the wool textile industry, as well an antifungal agent in textiles other than wool (cotton, Flax and jute fabric, ropes, cordage and tentage) (IEP, 2008). The USA has also reported the use of PCP as a microbiocide for burlap, canvas, cotton, rope, and twine (IEP, 2008). PCPL was developed especially for application on fabrics (IEP, 2008) and is used in the

treatment of fabrics and webbing, and also of yarns and ropes, particularly those used in heavy-duty military applications. Industries such as leather tanning and textile factories may have released up to 2,000 kg and 5,500 kg of PCP, respectively, in their waste water discharges to surface waters on an annual basis in the 1970s (EPA, 1980 [as cited in IEP, 2008]).

Pentachlorophenyl laurate (PCPL) is insoluble in water and so is applied either in solvent solution or, more commonly, as a concentrated aqueous solution/emulsion (IEP, 2008). Releases to waste water may occur where equipment is washed out between batching processes. During dyeing treatment 80% of the PCPL in the emulsion is adsorbed to the fibre or yarn. When textile-finishing operations include a highly alkaline wash the pH of the wastewater is high and when wastewater- containing PCPL is mixed with this water, PCPL is likely to undergo chemical hydrolysis, producing PCP in its ionic form (IEP, 2008). Broad estimates of PCPL releases to water are around 900 kg and PCP releases around 600 kg per year from the production of PCPL (IEP, 2008).

Agriculture

PCP and NaPCP have been used in a number of agricultural applications. This has included the large scale use of PCP in a number of geographic regions e.g. Australia (Camenzuli et al. 2015) China (Zheng et al. 2012), Japan (Masunaga et al. 2001, Yao et al. 2002), Suriname (National Implementation Plan Suriname, 2011). Examples of usage for these products include:

- To prevent wood decay, in farm buildings, fences, and storage facilities;
- As a herbicide and desiccant for forage seed crops, a herbicide for non-food vegetation control, a biocide in the post-harvest washing of fruit, and for general weed control;
- As an insecticide for use in beehives, seed plots, and greenhouses;
- As a herbicide in paddy and upland rice fields, particularly in Japan and also the USA.
- For formulation of fungicidal and insecticidal solutions and for incorporation into other manufactured pesticide products.

NaPCP production

PCP is also used to produce NaPCP. Until 1984, NaPCP was produced using the alkaline hydrolysis of hexachlorobenzene. Now, however, it is produced by dissolving PCP flakes in sodium hydroxide solution (Borysiewicz 2008). The industry association Indian Chemical Council (ICC) reports that NaPCP is also used in India mainly as a wood preservative but also for the preservation of water-based 'distemper paints' while in storage (ICC, 2014). NaPCP has also been used for control of the intermediate snail hosts of schistosomiasis (WHO, 1987).

Other application and uses

PCP and NaPCP had been approved for a number of applications in the food industry, such as biocides in packaging materials and glues (IEP, 2008). PCP has also been used as preservative in oil-based paints and adhesives and as an intermediate product in the synthesis of pharmaceuticals as well as colouring substances. PCP has been used in slime control in pulp and paper production as well as waste water treatment. It is estimated that approximately 2000 kg of PCP, used as a biocide in cooling tower waters were discharged to surface waters in the USA in 1978 (USEPA, 1979 [as cited in IEP, 2008]). Other reported applications of PCP included health-care products and disinfectants for use in the home, farms, and hospitals. PCP might also be contained in dental-care products, bactericidal soaps, laundry products, and medical products for the skin (IEP, 2008).

There are very few data on the emission rates of PCP to the environment from the above applications and sources. PCP is no longer permitted for use in these applications in most countries, therefore, it is expected that release to the environment from these sources will no longer be significant. However, it is relevant to get estimates how much of PCP has been used in this area. In particular treated products (e.g. textiles, leather) have a long lifetime or if the application will lead to long lifetime for PCP in the environment.

4.3 Phase 2 – In use emissions from products treated with PCP

Releases from treated timber and equalisation

PCP is considered to be a relatively volatile compound. Based on its Henry's Law constant [1.94×10^{-3} atm-m³ / mole (25°C) (HENRYWIN v3.2 in U.S. EPA 2011 [as cited in UNEP, 2011a]), it has the potential to

readily volatilize from surfaces (e.g. treated wood products, soils and water) (UNEP, 2013a). Volatilisation of PCP from treated wooden utility poles and other structures is, therefore, expected to be a significant route of loss for PCP during their service life. However, the extent and rate of PCP loss will vary depending on the age and type of the treated wooden products and different studies vary in their estimate of volatilisation rates for PCP.

For example, a typical loss rate of PCP from treated wood is estimated in the UK to be ~5% of the total amount of the preservative applied) per year (Wild et al., 1992). However, during the first 12 months evaporation rates are shown to be much higher, with around 30% of PCP loss reported in some cases (UNECE, 2010) as freshly treated timber will contain PCP more readily available for volatilisation.

In the US, PCP has historically been estimated to volatilise from the surface of treated wood products at an estimated rate of 340,000 kg annually, or roughly 2% of the total amount of preservative applied (IEP, 2008). These estimates are representative of usage of the compound in those applications in the 1970s (USEPA, 1980 [as cited in IEP, 2008]).

A2 (Bollin and Smith 2011) report the results of a model, estimating that over its service life, a PCP-treated utility pole would release 60 per cent of its PCP (based on a 60-year service life). It was predicted that 1.8 percent would be released to the air and 57.2 percent released to the ground. This release model assumes $1.28 \times 10^{-4} \text{ kg/m}^3$ of PCP is released over the first 10 years followed by a release rate at 20 percent of the initial rate for the remainder of the pole life.

In the UK, Wild et al. (1992) consider that direct releases by spillages, volatilisation and PCP in wastewaters from the timber, textile and agricultural industries were by far the most important release sources, with volatilisation releasing the highest levels of PCP.

PCP can also be released through surface runoff, either from treated wood in situ during its service life, or during storage prior to use. Estimates of PCA release rates from surface run-off during service life are not available.

Estimates of PCP in the runoff from PCP-treated wood in stacks is estimated based on studies done by Morrell et al. (2009) [as cited in Bollin and Smith, 2011]) at approximately 2 ppm. Assuming the treated poles remain at the treatment yard for 1 month and average U.S. rainfall is approximately 33 inches (0.83m) of rain per year, Morrell et al. (2009) calculate a release factor of approximately 0.32 kg/m^3 of PCP-treated poles produced. Similar releases are assumed for storage of PCP-treated poles in stacks at the utility staging areas, prior to placement in-service (Bollin and Smith, 2011).

As much as 228,000 kg of PCP, used in cooling tower waters as an anti-fouling agent, have been released to the atmosphere through volatilization with heated water and steam in the past [USEPA 1980 (as cited in IEP, 2008)]. However, pentachlorophenol is no longer commonly used for this purpose.

Rain may wash NaPCP from the surface of the treated pallets, leading to high local levels in soils where pallets and pallet boards are stored and used in the open (Hobbs et al., 1993).

A study in the US (EPRI, 1995) reports on the analysis of soil samples from 31 wood pole sites, to investigate release and distribution of PCP from treated utility poles. The study noted similarity in PCP behaviour between sites; with a sharp decrease in concentration away from the pole (average of 1 order of magnitude difference between 3 and 8 inches from the pole). This would indicate that PCP concentrations are highest in close proximity to the poles, suggesting volatilisation and/or wash off of PCP from treated utility poles could be a source of soil contamination close to their point of use.

NaPCP may also reach the environment by volatilisation in spite of its low volatility. In a doctoral thesis by Marchal (1996) [as cited in IEP, 2008] PCP emission rates from NaPCP treated wood were measured. In this study, small pine wood blocks were treated by immersion in NaPCP for 18 hours and then dried for 3 weeks. PCP emissions were measured in a flux chamber. An average steady-state flux rate of $10.8 \text{ } \mu\text{g/m}^2/\text{hour}$ was observed after 96 hours, based on a loading rate of $5.4 \text{ m}^2/\text{m}^3$ (wood surface/chamber volume). Marchal observed that PCP emissions were strongly affected by both temperature and the loading rate. Wood treated with NaPCP showed lowest emissions to air ranging from 33 to $46 \text{ } \mu\text{g/m}^3$.

An estimate of PCP emissions to air from NaPCP treated wood can be derived from a doctoral thesis by Marchal (1996). Based on the flux rate from the Marchal thesis, emissions to air in Portugal are: 516 kg/year, in France 344 kg/year, in the UK 229 kg/year and in Spain 115 kg/year. Depending on the solvent, temperature, pH, and type of wood 30 – 80 % of PCP may evaporate within 12 months from dip- or brush treated wood (WHO 1987).

Replacement rates for timber

In the USA the Utility Solid Waste Activities Group (USWAG) members represent more than 85 percent of the total electric generating capacity of the United States, and service more than 95 percent of the nation's consumers of electricity (IEP, 2008). A 2002 USWAG Survey revealed that approximately 44 million treated wood poles currently are in service by those USWAG members. When extrapolated out to reflect the entire electric power and telecommunication industries, USWAG estimates that there are approximately 130 to 135 million treated wood poles currently in service in the USA (IEP, 2008).

Respondents to the USWAG Survey reported that they purchased approximately 719,000 new treated wood poles annually, either to provide electrical service to new service areas or to replace damaged poles in existing service areas. When extrapolated out, one can estimate that at least several million treated wood poles are purchased annually in the U.S. by electric utilities alone (IEP, 2008).

Vlosky (2009) reported, based on a survey of wood preserving operations provided by the Southern Forest Products Association (SFPA) in the USA, that an estimated 651,000 m³ of utility-distribution poles, 337,000 m³ of utility-transmission poles, and 65,000 m³ of fence posts (round) were treated with oil-borne preservatives in 2007. In addition, an estimated 23,000 m³ of dimension lumber is estimated to have been treated in 2007. Totalled together, these applications therefore used approximately 991,000 m³ of utility poles in 2007. In 2004, PCP represented 93% of total volume of oil borne preservatives used (Vlosky, 2009) Respondents in this study reported using 9.7 million kg of PCP active ingredients in 2007.

For 2007, Douglas-fir accounted for 60% of lumber treated with oil borne preservatives followed by Southern pine (26%). Southern pine accounts for 70% of treated Roundwood followed by Douglas-fir (29%).

The length of time that a treated wood pole remains in a utility line is dependent upon a number of factors. Often, poles are removed from service before the end of their useful service life, such as for road widening (Bollin and Smith, 2011). It is expected pole service lives will be between 30 and 59 years, but replacement rates indicate longer average lives of between 60 and 80 years (based on survey of one US utility company).

Christodoulou et al. (2009) provided a statistical analysis, for the evaluation of the life expectancy and the production of a survival curve of a typical Hellenic distribution wooden poles in-service. Modelling these results derived a life expectancy of 45-47 years.

Pope (2004 [as cited in (Bollin and Smith, 2011)]) uses pole inspection data of over 750,000 poles showing that poles with no maintenance had an average service life (50 percent rejected as needing replacement) of 40–50 years, but with normal inspection and maintenance (the current practice), the average service life would extend to 60 or more years. Thus, assuming current inspection practices will continue, the average service life of 60 years is typically quoted (Bollin and Smith, 2011).

Replacement of wooden utility poles can result due to a number of factors, including failure caused by weather (e.g. strong wind/lightning); corrosion and/or decay; defective materials; road re-routing or widening etc.

SCS (2013) conducted a survey of 260 utilities in the USA (sample representing ~25% of all poles in service) and estimated the average service lifetime for each material type; this average lifetime was used to calculate annual average failure rates, determining the number of poles requiring replacement. It was estimated that an average wood pole service life of 30-40 years, corresponding to an annual failure and replacement rate of around 2.5%.

Identification of treated timber

Most utility poles, during the manufacturing process, are typically marked in accordance with the requirements found in ANSI O5.1 or CSA O15-15. The typical information contained on the marking includes a supplier trademark or code, the year of treatment, a code for the plant location, the species of wood, the preservative type and the class and length of the pole. Additional information may be included based on a utility's specifications.

The information is either burn-branded on the pole or embossed on a recessed metal tag affixed to the pole. The tag is normally located at 10 feet from the butt on poles shorter than 55 feet, and at 14 feet from the butt on poles 55 feet and longer. Given the typical setting depths of poles, this normally places the information in the zone from 2 to 6 feet from the ground on an installed pole.

4.4 Phase 3 – Management of end of life products treated with PCP

PCP, its salts and esters are listed in Annex A to the Stockholm Convention, meaning Parties to the Convention must prohibit and/or take the legal and administrative measures necessary to eliminate production and use. Parties to the convention listed in the register of specific exemptions are permitted to produce and use PCP for utility poles and cross-arms, in accordance with the specific provisions. However, treated wood has a finite life-span and, at the end of its useful life, must be disposed of.

Additionally there may be a number of historic uses, particularly leather and suede, where there are significant existing stockpiles that need to be managed suitably. Details on the scale of these stockpiles are unclear and therefore it is difficult to provide further information. Section 4.2 of this guidance document provides further details on non-timber uses of PCP, its salts and esters. It should be assumed that where such stockpiles exist, intervention is needed to manage the suitable end of life disposal and potential release to environment.

Where the dominant use of PCP, its salts and esters has however been for timber treatment, and it can be expected that this will form the largest legacy issue for safe management at end of life, the remainder of this section focus on timber within the waste stream.

Identification of treated timber within the waste stream

In general, wood used in a commercial/industrial setting will be treated by some means to prevent degradation and to increase its service life. Typically wood will be treated with one of three product types; PCP, Creosote or chromated copper arsenate (CCA).

As stated in Section 4.2, such wood should be appropriately labelled to allow quick identification of the treatment product. However, if not appropriately labelled the treatment product can be established through suitable sampling and analysis.

Additionally, where appropriate labelling is absent, and in absence of, or prior to undertaking sampling and analysis, the treatment product used can sometimes be inferred through visual inspection (noting that this is an indicative method and should not be used to replace labelling and/or sampling and analysis):

- CCA – the surface of the wood will often appear to have a slight blue/green tint to it due to oxidation of the copper in the CCA;
- Creosote – This is a tar like substance which often gives the surface of the wood a black/dark brown tar like (often sticky) finish; and
- PCP – PCP itself is not noticeable leaving the surface of the wood apparently unchanged to its natural appearance. Thus if the wood does not appear to show signs of CCA or creosote, it is likely to have been treated with PCP.

Examples of CCA, creosote and PCP treated timbers are shown in Figure 4.1, Figure 4.2 and Figure 4.3 respectively.

Figure 4.1 Timber treated with CCA



(Reference NPIC, 2015)

Figure 4.2 Timber treated with creosote



(Reference Bayou Forest Products, 2017)

Figure 4.3 Timber treated with PCP



(Reference Environment Canada, 2017)

Apportionment of waste streams

The Basel Convention has developed a number of technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with POP wastes. “The general technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs)” (Basel Convention, 2014), provides guidance on the options for Environmentally Sound Disposal (ESD) of POPs and its addendum “Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with pentachlorophenol and its salts and esters” (Basel Convention, 2016) advises ESD options specifically for PCP.

These two documents have identified a number of ESD options for PCP contaminated wastes which can be divided into three groups.

Destruction and irreversible transformation methods

The methods described in this subsection are the only ESD options for wastes containing a high PCP content (typically assumed to be >100 mg/kg), although they are also suitable for options with PCP levels below this (Basel Convention, 2016):

- **Hazardous Waste Incineration** – Waste is subjected to a controlled flame combustion process, usually in a rotary kiln. For effective treatment of PCP (Basel Convention, 2014):
 - Temperatures must be in excess of 1,100°C;
 - Conditions must ensure appropriate mixing;
 - There must be a sufficient oxygen supply (> 6 per cent oxygen); and
 - The residence time must be >2 seconds.

The high temperature and abundant oxygen supply ensures complete combustion of the PCP with studies typically observing a 99.99% destruction rate (Basel Convention, 2014). Studies have observed that the exhaust gas from processes incinerating PCP treated wood do have slightly elevated chlorinated volatile organic carbon (VOC) contents but conclude that incineration is an effective method of destroying PCP (USEPA, 1998).

Pre-treatment for such process usually includes; blending, dewatering and/or size reduction of the waste (Basel Convention, 2014).

- **Advanced Solid Waste Incineration** – this term is typically used to describe two advanced thermal treatment technologies (Defra, 2013):
 - **Pyrolysis** – In contrast to combustion, pyrolysis is the thermal degradation of a substance in the absence of oxygen. This process requires an external heat source to maintain the temperature required. Raw waste is usually not appropriate for pyrolysis and typically requires some mechanical preparation and separation of glass, metals and inert materials (such as rubble) prior to processing. The products produced from pyrolysing materials are a solid residue and a synthesis gas (syngas). The solid residue (sometimes described as a char) is a combination of non-combustible materials and carbon. The syngas is a mixture of gases (combustible constituents include carbon monoxide, hydrogen, methane and a broad range of other VOCs). This syngas can then either be condensed into liquid hydrocarbons, such as biodiesel or fed into a secondary combustion chamber where this is burned to recover energy via a steam circuit.
 - **Gasification** - Gasification can be considered a process between pyrolysis and combustion in that it involves the partial oxidation of a substance. The temperatures employed are typically above 650°C and, as with pyrolysis, raw waste is usually not appropriate for pyrolysis and typically requires some mechanical preparation and separation of glass, metals and inert materials (such as rubble) prior to processing. The main product of gasification is a syngas which contains carbon monoxide, hydrogen and methane. Typically this is fed into a secondary combustion chamber where this is burned to recover energy via a steam circuit.

Whilst destruction rates and emission data for pyrolysis and gasification of PCP were not available, it can be assumed, due to the similarities of the processes (particularly the high temperatures and combustion in the secondary combustion chambers), that both destruction rates and emission constituents will likely be similar to those from hazardous waste incineration.

It is important to note for all thermal treatment options identified above that it is important to cool the exhaust gasses rapidly following combustion. This is because of a process called De-Novo synthesis which can occur in the exhaust gases. De-Novo synthesis is the broad name of a number of processes where complex organic molecules are formed from simple short-chain molecules. Pertinent to the thermal treatment of POPs is the De-Novo synthesis of dioxins and furans, both environmental pollutants, from chemicals present in the exhaust gas from the treatment processes. The temperature window for the De-Novo synthesis of dioxins and furans is from 200-450°C (USEPA, 1998). Thus, if the hot exhaust gas is not cooled quickly it can spend sufficient time in this temperature range for dioxins and furans to form which is undesirable.

Disposal of PCP contaminated wood via incineration at a suitably permitted facility is also recommended by the United States (US) Treated Wood Life Cycle Management Coalition and the Washington State Department of Ecology (Washington State, 2003).

Other disposal methods when neither destruction nor irreversible transformation is the environmentally preferable option

Where the POP content (in this case PCP content) is low, where neither destruction nor irreversible transformation is the environmentally preferable option, countries may allow such wastes to be disposed of by other methods than the methods referred to above (Basel Convention 2014, and 2016). These include:

- **Disposal in Specially Engineered Landfill** – this is a landfill which is specially engineered to remove any threat to the environment in the short- as well as in the long-term. Typically, during the operational phase a geological barrier and a bottom liner system is employed and a top liner is added during the closure and post-closure phases to prevent pollution of soil, groundwater and surface water. Additionally, landfill leachate treatment technologies should be in place to reduce and prevent toxic leachate entering the environment and measures should be taken to control and reduce the production of methane gas.

Moreover, monitoring procedures during the operation and post-closure phases of such a landfill should be established in order to identify any adverse environmental effects of the landfill.

Disposal of PCP contaminated wood via suitably permitted landfills is also recommended by the United States US Treated Wood Life Cycle Management Coalition and the Washington State Department of Ecology (TWLMC, undated).

- **Permanent Storage in Underground Mines and Formations** - Permanent storage in facilities located underground in geohydrologically isolated salt mines and hard rock formations are an option to separate hazardous wastes from the biosphere for geological periods of time.

In such a facility wastes should be disposed of in a manner that excludes any undesirable reaction between different wastes or between wastes and the storage lining. This typically involves placing the wastes into chemically and mechanically secure containers. Liquid and gaseous wastes or wastes that emit toxic gases or are explosive, flammable or infectious should not be stored underground in mines.

It is, however, noted that this option is likely to be considerably more expensive than engineered landfills.

Where the POP content (in this case PCP content) is low, where none of the above disposal methods are suitable they should be disposed of in accordance with pertinent national legislation and international rules, standards and guidelines, including the specific technical guidelines developed under the Basel Convention (Basel Convention, 2014).

Additionally, whilst not strictly a disposal method, it is worth noting that in the US re-use of PCP treated timber is an acceptable management option provided that it is re-used in a manner consistent with its original application (Defra, 2013). However, this is not recommended for two reasons:

- Firstly, all wood which is re-used will still ultimately require disposal via one of the above methods when it reaches the end of its useful life. Re-using the wood simply postpones ultimate disposal, it does not eliminate its requirement; and
- Secondly, an issue with this in the US is that such re-use sees PCP contaminated wood being used as fence posts in domestic settings. This is undesirable as when this re-used wood reaches the end of its useful life in a domestic setting it is often not disposed of safely due to a lack of regulatory enforcement.

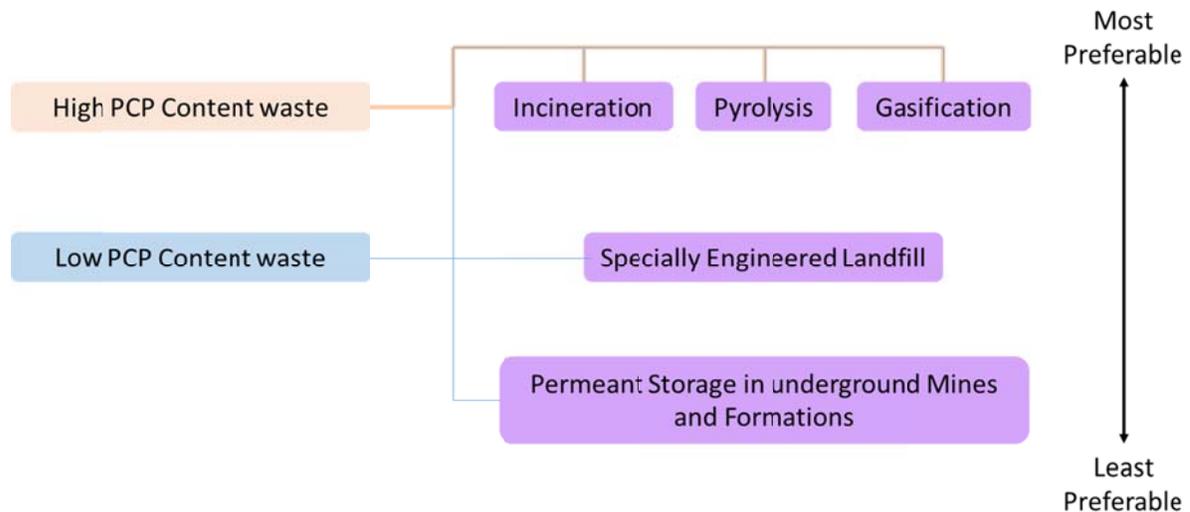
Summary

In summary, disposal via thermal treatment technologies (incineration, pyrolysis and gasification) are the preferred methods of disposing of PCP contaminated wood and the only methods suitable of disposing of wood with a high PCP content.

For PCP contaminated wood with lower PCP contents, disposal via specially engineered (permitted) landfills and via permanent storage in underground mines and formations are also suitable methods, although the latter is likely to be very costly.

An overview of the disposal options for PCP contaminated wastes is outlined in Figure 4.4.

Figure 4.4 Disposal Options for PCP Contaminated Wastes



4.5 Identification of sites contaminated with PCP

Activities to aid in the identification of contaminated sites

A general structured approach to identifying PCP hotspots within a country has been developed using United Nations Environment Programme (UNEP) guidance (UNEP, 2013e) and adopting it specifically to identifying PCP hotspots, and industry experience in characterising contamination. This structured approach comprises three sections:

- Identifying Potentially Contaminated Sites;
- Compiling a Facility History File and Ranking the Identified Potentially Contaminated Sites; and
- Detailed Assessment.

Stage 1 - Identifying Potentially Contaminated Sites

The first stage in this approach involves identifying potentially contaminated sites. To do this, it is first important to understand what type of sites may have produced, used, stored or emitted PCP, and, therefore, might be contaminated with PCP. These types of sites can then be identified within a country and, in this approach, should be preliminarily designated as “Potentially contaminated sites”.

Listed below are the types of sites which should be identified within a country when identifying PCP contaminated sites:

- **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.**

An assessor should then look to identify all of the above types of sites within a country and preliminarily designate them “potentially contaminated sites” noting that further investigation is needed to confirm the presence of contamination and to quantify if there is contamination present.

Stage 2 – Compiling a Facility History File and Ranking the Identified Potentially Contaminated Sites

In this second stage, these “potentially contaminated sites” are subject to further assessment to establish, in more detail:

- Details of historic production of PCP are considered. Specifically:
 - The chemical process employed;
 - The quantities of PCP produced;
 - The process management employed;
 - The waste management and disposal routes employed on-site;
 - Situation of associated landfills;
 - Details of any known accidents/environmental incidents to have occurred.
- Details of historic storage of PCP are identified. Specifically:
 - How it was stored;
 - The quantities of PCP stored;
 - The storage management employed;
 - The waste management and disposal routes employed on-site;
 - Details of any known accidents/environmental incidents to have occurred.
- Details of historic treatment of wood are collected and assessed. Specifically:
 - The treatment process employed;
 - The quantities of PCP used and associated amount of PCDD/F;
 - Quantities of other wood treatment chemicals used at the related sites (HCH, DDT, CCA);
 - The process management employed;
 - The waste management and disposal routes employed on-site;
 - The storage of treated wood on-site;
 - Situation of the soil;
 - Details of any known accidents/environmental incidents to have occurred.
- Details of historic storage of treated timber and wood products are collected and analysed. Specifically:
 - The amount stored;
 - Details of the storage arrangements (was it outside/inside/partially covered?);
 - The waste management and disposal routes employed on-site;
 - Details of any known accidents/environmental incidents to have occurred.
- Details of historic treatment of leather:

- The amount of PCP used in the respective leather tanning factories;
- Release vectors from the respective factory (water and related sediments);
- Management of related residues from leather tanning;
- Situation of landfills and dumping areas where residues were disposed.
- Details of historic use of PCP as slimicide in pulp and paper production:
 - Pulp and paper factories having used PCP as slimicide;
 - The amount of PCP used in the respective factory in history;
 - Release vectors from the respective factory (water and related sediments);
 - Management of related pulp and paper sludge (in particular application to agricultural land);
 - Situation of landfills and dumping areas where residues were disposed.
- Details of historic use of PCP in agriculture:
 - Areas where PCP has been applied to agricultural area;
 - Amount of PCP used in history on these areas;
 - Current use of these areas in particular if these areas are used for cattle grazing.

Release vectors from the respective factory (water and related sediments)

Detailed records of the location of the sites should be compiled e.g. places where the potentially contaminating operations took place and where associated wastes have been disposed of, ideally using geospatial data. The current use of the site and any associated human exposure risks should also be assessed and recorded.

Such data might be documented in archives of the respective companies or competent authorities responsible for facility inspection/audits. In addition, data from facilities with similar production or technologies employed may be used to infer semi-quantitative estimates.

The information gathered can then be used to compile facility history files for the identified facilities and facilities can be designated either; “likely not contaminated site”, “likely contaminated site” or “contaminated site” (although noting that this will not be definitively confirmed until appropriate sampling and monitoring has been conducted).

This designation allows all sites identified to be ranked in terms of priority for further sampling and monitoring activities. Additionally, a preliminary risk assessment should be undertaken for each site to aid ranking. For example, for two sites designated “potentially contaminated”, if one is in a remote area and, for examples sake, the other is near an aquifer used for drinking water, the latter would be ranked as a higher priority.

Stage 3 - Detailed Assessment

In this third stage, informed by the facility history files compiled in Stage 2, a detailed assessment of the site should be conducted and should include:

- Production of a sampling plan. Dedicated software such as the US Department of Energy’s (DoE’s) Visual Sampling Plan (VSP) software is recommended for compiling such a plan. Such plans should include a mix of:
 - Targeted samples – these are sample locations identified based on information in the building history file and from site walk overs. For example, if from the building history file it is identified that PCP treated wood was stored in a yard, and if in that yard an area of dark staining is observed during a site walk over, it would be sensible to place a targeted sample here;
 - Randomised samples – These are randomly placed samples and software such as VSP can generate randomly placed samples;

Additionally, samples should also contain a mix of (where appropriate):

- Soils;
 - Sediments;
 - Asphalt and concrete areas;
 - Surface water; and
 - Groundwater.
- Chemical analysis of samples should be undertaken to establish:
 - Whether PCP and PCDD/PCDF is present;
 - Quantification of the PCP and PCDD/PCDF levels if it is found to be present.

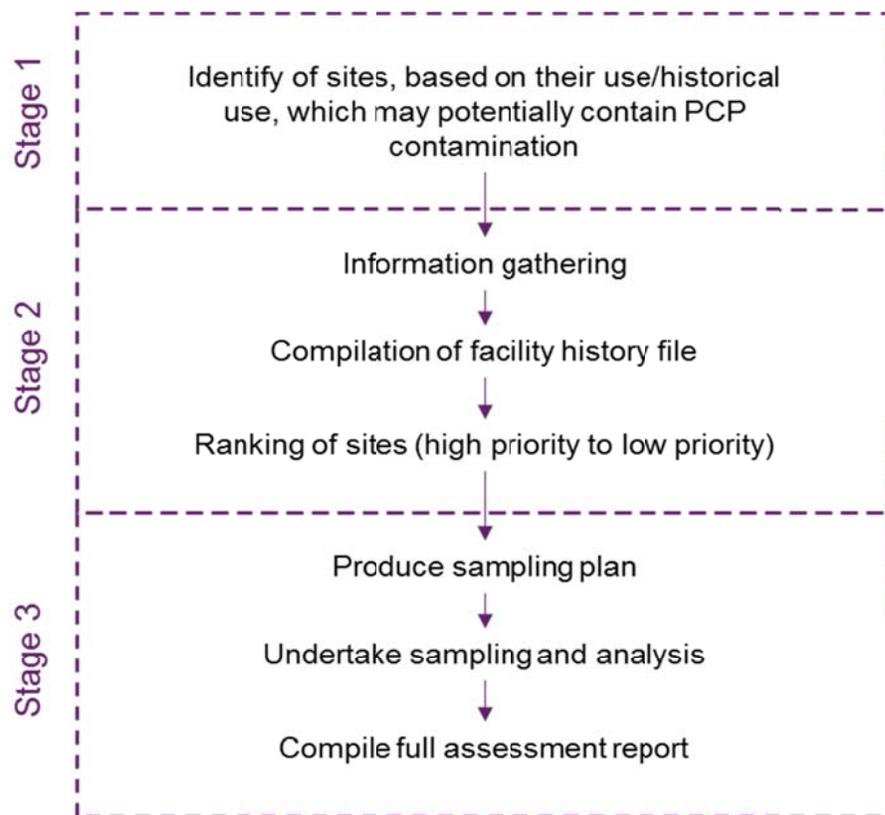
Note: whilst this guidance is aimed specifically at identifying PCP contamination, at this stage it would also be advisable to sample for any other contaminants which may be present based on assessment of the historic/current use of the facility.

- Evaluation of potential releases and human exposure via all relevant pathways;
- A detailed risk assessment and a conceptual site model should be developed.

Summary

A summary of the approach is detailed in Figure 4.5.

Figure 4.5 Summary of the approach



Contaminated Sites Examples

Detailed below are selections of PCP contamination case studies.

Pentachlorophenol Contamination of Private Drinking Water from Treated Utility Poles, Vermont, US (Karlson et al, 2013)

In 2009, the Vermont Department of Health and state partners responded to 2 cases of private drinking water contamination with pentachlorophenol (PCP). Both were attributed to ingress of PCP to the water table from newly installed utility poles in the vicinity of the local water source.

- In the first case, the water was from a shallow dug well and had a PCP concentration of 2.06 milligrams per litre, and a subsequent sample had a concentration of 1.15 milligrams per litre, respectively about 2,000 and 1,000 times the EPA maximum contaminant level (0.001 mg/L);

In response, the Vermont Department of Environmental Conservation and the utility company were contacted to coordinate a clean-up. The utility company replaced the poles with non-treated cedar poles and paid for a new 705-foot drilled well to be installed;

- In the second case, the water was from a private spring. When a sample was taken; it had a PCP concentration of 0.007 milligrams per litre, and a subsequent sample had a concentration of 0.002 milligrams per litre, both of which were above the EPA maximum contaminant level.

Again, the utility company replaced the poles with non-treated cedar poles and paid for a point-of-entry charcoal filtration system to be installed allowing the water to be used. Within three months of the replacement of the poles, PCP was not detected in samples collected directly from the spring.

National Wood Preservers Site, Delaware County, Pennsylvania, US (USEPA, 2017)

From 1947 to 1991, National Wood Preservers ran a wood treatment operation at a site in Delaware County, Pennsylvania. The site has been characterised and it was found that groundwater and several soil areas were contaminated with PCP, arsenic, dioxins, volatile organic compounds (VOCs), and petroleum hydrocarbons. Contamination of the local groundwater is thought to be partly due to the operations undertaken, but also due to the operator disposing of liquid wastes, thought to contain PCP, in a well leading to groundwater under the plant.

Detailed site characteristics are not available but the clean-up operation is ongoing and has been extensive. A summary of the clean-up operation is provided below:

- In 1976, the EPA performed various remedial actions to contain the contamination and the site was listed on the National Priorities List for federal clean-up;
- In 1987, the EPA put up a fence around the property to restrict access to the site and sponge-like barriers and a catch basin were installed in Naylor's Run (a small local stream) to contain chemicals;
- In 1992, the EPA removed tanks and drums from the facility in which about 97,000 tons of liquids, 55 gallons of solids, and 60 tons of sludges – all containing hazardous wastes – were disposed of off-site;
- In 1996, a three-acre synthetic cap was installed over the areas of contaminated soil in the vicinity of the source area, eliminating the threat of potential exposure;
- Since August 2001, a groundwater treatment plant has been successfully operating full time and removing contamination from the shallow groundwater;
- In May 2003, the EPA discovered an abandoned sewer line transferring contaminated groundwater to a Residential Open Space (ROS) Area. The sewer line was properly cleaned and sealed;
- In the summer of 2005, EPA surveyed the area to determine property lines along Naylor's Run, sampled soil and groundwater, and assessed the extent of the contamination caused by the leaking abandoned sewer line;

- In August 2005 the EPA completed its third five-year review of the site. The EPA found that there has been no new or recent exposure to site soils or groundwater;
- In April 2006, two additional extraction wells were added to the treatment facility;
- In April 2006, the EPA finished construction of two more extraction wells which extract the contaminated groundwater from the deeper aquifer and transports it to the treatment system;
- In March 2007 the Remedial Investigation of the deep groundwater soils and sediments of Naylor's Run as well as the ROS area were finalized, and in August 2007 the Feasibility Study was finalized;
- In August 2007 the EPA issued the Proposed Plan for the Site and conducted a public comment period;
- The Record of Decision for the deep groundwater, soils and sediments of Naylor's Run and the ROS area was signed on April 16, 2008;
- In 2009, the EPA used \$3.2 million in American Recovery and Reinvestment Act (ARRA) funds to remove contaminated soil from residential properties and from an ROS area, to improve the performance of the groundwater treatment system, and to install additional groundwater extraction wells;
- The Site reached construction completion on September 16, 2010. The groundwater continues to be extracted and treated on a continuous basis;
- In September 2009 the EPA completed its fourth five-year review of the site and found that the site is protective in the short-term because the groundwater extraction and treatment facility is operating as intended, the multi-layer geotextile cap prevents contact with contaminated soil in the Source area and the excavation and off-site disposal of the soils from the Recreation and Open Space area prevent exposure to contaminated soil in that portion of the site;
- The EPA is currently conducting the fifth five-year review for the site.

Cedar Service site, Northeast Minneapolis, Minnesota, US (ATSDR, 2006)

The Cedar Service site in Northeast Minneapolis, Minnesota was contaminated with wood treatment products from a former wood treatment operation, primarily pentachlorophenol (PCP), polynuclear aromatic hydrocarbons (PAHs), and dioxins/furans. Residual contaminated soil remains at the site at depth, and is also present at the surface in some areas, although exposure is likely minimal. Groundwater is heavily contaminated with PCP on- and off-site.

The site was operated from 1926 to 1972 and was used for wood treating operations using creosote (until the mid-1960s) and later pentachlorophenol (PCP) mixed with fuel oil. The company used a variety of steel-lined concrete tanks and vats for their operations in a main process area on the western part of the site. Treated wood was typically shipped out to customers by rail, and not stored on site.

Around 1961, it was reported that approximately 30,000 gallons of PCP wood treatment fluid were spilled when a truck accident caused a pipe rupture at the PCP pump house located at the southern end of the wood treatment area. The spilled PCP reportedly flowed south toward a low area. Details regarding the spill and the response to it are not available. Cedar Service, Inc. ceased operation at the site in 1972, and the structures associated with the operation were demolished in 1973. Cedar Service, Inc. reportedly buried between 8,000 and 10,000 gallons of wood treatment sludge on the property. The former main process area remains vacant.

Soil Investigations and Remediation

The first large-scale investigation at the site was conducted in 1995 and found soil contamination in two distinct areas: the former process area and a small fill area located just north of the former process area.

- Shallow soils (less than 10 feet deep) were found to be contaminated with PCP at concentrations as high as 1,300 mg/kg and total PAH concentrations were as high as 1,000 mg/kg;

- Soil samples from the deeper soil borings (10 to 34 feet below ground) showed lower concentrations of PCP and total PAHs, with maximum values of 22 mg/kg and 75 mg/kg respectively;
- Soil samples collected from below the water table (at depths greater than 34 feet) also showed contamination, with PCP levels as high as 250 mg/kg and total PAH concentrations as high as 630 mg/kg. Concentrations of petroleum-related VOCs were lower.

The above values generally exceed soil evaluation criteria developed by the Minnesota Pollution Control Agency (MPCA) known as Soil Reference Values (SRV) and Soil Leaching Values (SLVs).

- The SRVs represent the concentration of a contaminant in soil at or below which normal dermal contact, inhalation, and/or ingestion are unlikely to result in an adverse human health effect;
- The SLVs represent the concentration of a contaminant in soil above which leaching could contaminate the groundwater to levels above established standards.

In 1997, approximately 12,200 tons of contaminated soil were excavated and removed from the site for transport (by rail) to an out-of-state land disposal facility. Confirmatory testing did show some areas of PCP contaminated soil (up to 400 mg/kg) remained at depths of 12 feet but the majority of the contaminated soil identified in previous investigations was removed from the site.

The excavations were subsequently backfilled with 2,800 tons of amended soil that was then covered with 9,400 tons of clean fill. It was thought that the removal of the PCP contaminated soil and the use of soil amendments would also act to reduce PCP concentrations in groundwater over time.

The 2005 soil investigation showed that several areas of PCP contaminated soil remain at the site, both at the surface and at depth. PCP was detected in 30 of the 42 soil borings done at the site. The highest levels of PCP were found near the former process area, and PCP in four surface soil samples exceeded the MPCA commercial/industrial SRV.

The results of the investigation showed that a significant area of soil contamination, extending to below the water table was present at the site in at least two locations, and that groundwater at the site had been severely impacted by site contaminants.

Groundwater Investigations and Remediation

- Since site investigation activities began, numerous monitoring wells have been installed on and off the site to evaluate groundwater conditions.
 - In 1995, PCP was detected at a concentration of 8,400 micrograms per litre ($\mu\text{g/L}$) at one well location with other locations showing very low levels;
 - In 1997, PCP was detected at a concentration of 3,900 $\mu\text{g/L}$ from one of the sites monitoring wells just south of the former process area;
 - The most recent groundwater monitoring event, conducted in 2005, detected PCP at a number of locations, the highest of which being 20,000 $\mu\text{g/L}$, was found at the same monitoring well just south of the former process area. PCP breakdown products were also detected in some wells, although at much lower concentrations;
 - High levels of PCP contamination have also been identified in the local St. Peter aquifer, with the extent of contamination being extensive with the highest level of PCP found to be 11,000 $\mu\text{g/L}$. High concentrations of PCP (in excess of 1,000 $\mu\text{g/L}$) have also been found in monitoring wells located over 1,000 feet south of the site at depths of approximately 160 feet below grade. The full extent of the groundwater contamination in the lower St. Peter has not been defined, but extends at least 3,000 feet south of the site;
 - Lower levels of PCP have been detected in the underlying Prairie du Chien formation. The maximum level of PCP detected in the Prairie du Chien was 1,100 $\mu\text{g/L}$. The extent of PCP contamination in the Prairie du Chien is still being defined;
 - In 2004, PCP, along with other POPs, was detected at a concentration of 35 $\mu\text{g/L}$ in a monitoring well not normally considered part of the Cedar Service Site monitoring

network. However, it is not known whether this contamination originated from activities from this site or from other, unrelated activities.

As of March 2006, groundwater investigations were ongoing with remediation activities on the remaining contaminated soil at the site, and groundwater contamination both on and off-site being undertaken.

Additional case studies relating to PCP and dioxins and furan contamination

As indicated in section 2.3, the production of PCP means that PCP based products will contain a number of micro contaminants including the POPs dioxins and furans, which are of high concern. This document is chiefly intended to provide guidance on PCP, its salts and esters only. However further useful case studies which highlight the issues surrounding contamination of land and farm animals by dioxins and furans as a result of PCP include:

Karouna-Reniera et al. (2007) Serum profiles of PCDDs and PCDFs, in individuals near the Escambia Wood Treating Company Superfund site in Pensacola, FL Chemosphere 69, 1312–1319 <http://www.sciencedirect.com/science/article/pii/S004565350700639X>

Dahlgren J1, Takhar H, Schechter A, Schmidt R, Horsak R, Paepke O, Warshaw R, Lee A, Anderson-Mahoney P. (2007) Residential and biological exposure assessment of chemicals from a wood treatment plant. Chemosphere. 2007 Apr;67(9):S279-85. Epub 2007 Jan 17.

Kopper Wood treatment Site <https://www3.epa.gov/region5/cleanup/rcra/koppers/>

Baker et al. 2007 Completion of in-situ thermal remediation of PAHs, PCP and dioxins at a former wood treatment facility. IT3'07 Conference, May 14-18, 2007, Phoenix, AZ

Fries GF, Feil VJ, Zaylskie RG, Bialek KM, Rice CP Treated wood in livestock facilities: relationships among residues of pentachlorophenol, dioxins, and furans in wood and beef. Environ Pollut. 2002;116(2):301-7.

Huwe JK1, Davison K, Feil VJ, Larsen G, Lorentzsen M, Zaylskie R, Tiernan TO Levels of polychlorinated dibenzo-p-dioxins and dibenzofurans in cattle raised at agricultural research facilities across the USA and the influence of pentachlorophenol-treated wood. Food Addit Contam. 2004 Feb;21(2):182-94..

Piskorska-Pliszczynska J, Strucinski P2, Mikolajczyk S3, Maszewski S3, Rachubik J3, Pajurek M3, Pentachlorophenol from an old henhouse as a dioxin source in eggs and related human exposure. Environ Pollut. 2016 Jan;208(Pt B):404-12. doi: 10.1016/j.envpol.2015.10.007. Epub 2015 Nov 11.

5. Guidance on the alternatives to PCP used for utility poles and cross-arms

5.1 Introduction

This chapter provides further guidance on the logical steps and planning that can be undertaken by policy makers and/or regulatory agencies to control and minimise the environmental emissions of PCP. It will also consider the planning and policy options to aid the phase-out of PCP and transition to alternative approaches, including both chemical and non-chemical alternatives. Section 5.2, of this chapter provides a step-by-step logical progression of the planning and thinking that can be undertaken to achieve emission control and ultimate phase-out of PCP. Section 5.3 of the chapter then provides detailed information on the available chemical and non-chemical alternatives. This section is provided as an update of the sections covering chemical and non-chemical alternatives within the PCP risk management evaluation (POPS/POPRC.10/10/add1).

5.2 Policy planning for emission control and phase-out of PCP used for utility poles and cross-arms

Planned approach for management of PCP

PCP its salts and esters are listed under Annex A (banned) of the Stockholm Convention, with exemptions for the continued use of PCP for utility poles and cross-arms. Manufacturing of PCP is limited to only a small number of countries, with the use of PCP for treatment of timber also limited to a smaller number of nations. However there are also a number of former uses for PCP, and continued legacy issues from timber treated with PCP. In order to manage PCP at national level it is necessary to understand what are the issues relevant to a given country at national level, what control measures are needed, what form of stakeholder engagement is needed, and what activities should be undertaken to help minimize releases to environment and, therefore, human exposure.

Figure 5.1 provides an illustrative set of steps which could be used to help understand the main issues, establish contact with the relevant Parties and undertake work to further control and minimize emissions, as well as facilitating the phase-out of PCP and transition to safer alternatives (both chemical and non-chemical). The remainder of this chapter looks at each of these steps in turn.

Figure 5.1 Planning process for management of PCP and transition to alternatives



Step 1: Identification of issues at national level

The first step within the planning for management of PCP is to better understand the key important issues at national level. For example, where only a limited number of nations manufacture PCP or make use of PCP based products for timber treatment, the emissions associated with these activities may not be directly

relevant for a given nation. However, import of previously treated timber may be an issue, as may handling of waste legacy aspects of treated timbers, former sites of manufacture, or even former uses. Therefore, the first step is to understand which issues are of key importance.

The Development of emission inventories (as detailed in chapters 2, 3, and 4 in this guidance document) provides a valuable tool to help provide an evidence base for what the key issues are likely to be. Additionally, it will be necessary as part of this inventory development work to gather data from a variety of sources and engage with relevant industry groups, regulatory agencies and NGO stakeholders (see chapter 3). The completion of this first stage should help the policy maker fully understand what the main issues are and where further control and work is needed. They should also inform the policy maker on how and where PCP is being used within their nation and by which industry sectors including the full life cycle (i.e. waste handling aspects should also be included).

Step 2: Engagement with Industry / Regulatory Agencies / NGOs

The second step involves the early preparatory work for development of control options for PCP, and the work needed to support the phase-out of PCP in favour of safer options. The completion of the first step will have identified a set of key issues which need to be addressed. As part of the emission inventory work specific stakeholders may have already been contacted to provide data. This second step has a different focus to the stakeholder engagement. The contact in this case could be used to help serve the following purposes:

- Establishment of working groups between regulatory officials and industry representatives, to help understand the key obstacles to phase-out of PCP for safer alternatives. This would provide a mixture of policy and regulatory expertise with technical expertise from industry on how PCP is used and what the possible options for phase-out might be;
- Additionally these kinds of working group can prove useful to help identify and manage key priorities for existing use. For example if the risk of human exposure from manually treating activities is identified as high risk, the working group can be used to communicate to industry the urgency with this issue and need to move to automatic / closed systems of treatment;
- Establish key contacts for government departments and regulatory agencies. One of the key issues for managing PCP will be awareness. Establishing communication routes and training on key information to enforcement agencies will help establish a more effective control, while providing valuable feedback loops on information from those agencies carrying out enforcement;
- Finally contact with a wider audience such as NGOs and the public can be used to help gather feedback on what others perceive as being the priority issues for management. This could be conducted as targeted consultation, public surveys (as part of the work linked to national implementation plans), or as part of the awareness campaigns in step 5.

The completion of this second step is intended to inform the key issues, and technical / socio-economic obstacles that may be presented in managing the control and phase-out of PCP. Further guidance on the potential likely issues that might present obstacles to phase-out and transition are given below:

- The availability and applicability of alternatives varies by region. There may not be economically viable non-chemical alternatives to PCP in some regions, for example where there is limited infrastructure for steel or cement production. Additionally, climatic conditions (i.e. particularly low or high temperatures/humidity) may render some chemical alternatives less effective than PCP;
- The existence of poorly documented and regulated secondary markets. Even if PCP use in industry is restricted or prohibited, materials such as utility poles or railroad ties may be sold for reuse, where they may be installed in residential settings such as for garden borders (USA 2013). Such items can continue to leach PCP into the environment for many years. It is likely to be difficult to identify and control use of PCP-treated wood for such uses;
- Socio-economic impacts. The majority of the socio-economic impacts of a PCP prohibition would fall on those other countries still using PCP in wood preservation. There would be limited or no costs for countries that have already prohibited use. The main cost elements associated with a prohibition on use would include:
 - Differences in costs for purchasing and processing the alternatives in manufacture of utility poles and other products (see the section on 'information on alternatives').

Alternatives with a higher initial purchase price may actually be more cost effective over the life of the product when durability and other factors are taken into account;

- Changes in material and labour costs due to a different frequency of replacement of e.g. utility poles (wooden poles treated with less efficacious preservatives would need more frequent replacement; steel and concrete poles may need less frequent replacement, dependent on application);
- Changes in the associated equipment needed to install, inspect, and maintain utility poles made of alternative materials (e.g., steel). The resulting effects on worker safety have not been quantified for either PCP-treated poles or for alternatives;
- Costs for wood treaters and manufacturers associated with loss of revenues and potentially costs associated with loss of residual value of their capital equipment, offsets by potential gains by other treatment. Arrangements should be made for industry to work with government to identify suitable options to gradually eliminate PCP, without causing excessive economic impacts. A region-specific cost benefit analysis of options should be developed.

Step 3: Review and Development of Control Options

The third step in the planning process is the review and development of control options, following the identification of key issues (step 1) and further engagement with key stakeholders to better understand the socio-economic and technical issues (step 2). This next step is intended to develop possible control options to manage the existing use of PCP and to aid the phase-out of PCP for safer alternatives. At this stage the development of control options should aim to encompass all possible viable options (the selection of control options / filtering of options happens in the next step, Step 4). This process could include policy options such as a restriction on the re-use of treated timber for applications other than the original use, or it could include technical control options, such as labelling for timber treated with PCP to ease identification at end of life.

As part of the development of control options it will be necessary to undertake a feasibility assessment or cost-benefit study to help identify which options are likely to provide the best benefit against cost. This can also be used to filter out those options which are less likely to prove useful. Specific control options will be dependent on the outputs of the first two steps detailed here. However some example control options (both policy based and technical) could include the following.

Possible Policy control options

- Restrictions placed upon industry to prevent the re-use of treated timber for other applications (e.g. domestic) beyond the original use;
- Waste is often dealt with regionally rather than at a country level. National authorities should, therefore, co-ordinate with regional authorities to ensure that appropriate disposal procedures are adhered to, and that PCP-containing wastes are clearly identified. Guidance and awareness documents can also be provided online, such as the materials developed by the USEPA.⁵ These provide information to the public and industry about how to dispose of PCP products correctly, and who to inform in relation to their disposal;
- Policy options aimed to support innovation and development of alternatives to PCP that could be brought to market. These could include:
 - Financial incentives for development of commercially ready alternatives to PCP which are demonstrated to be safer;
 - Establishment of innovation networks to help industry support one another with management and development of PCP alternatives for specific applications. For example, European Enterprise Network for SMEs: <https://een.ec.europa.eu/> or the ITF innovation network: <https://network.itfenergy.com/>;

⁵ <https://www.epa.gov/ingredients-used-pesticide-products/pentachlorophenol>.

- Establishment of communication channels to provide information on innovation and case studies of how technological advances have been made. For example similar to the Subsport innovation portal: <http://www.subsport.eu/>;
- The Stockholm Convention details time-limited exemptions for the continued use of PCP in utility poles and cross-arms. Working with industry groups it could be possible to set phase-out dates after which the use of PCP is prohibited.

Possible Technical control options

- The labelling, or branding (as practised in Canada US) of new PCP-treated wood would help to facilitate proper environmentally sound management of stockpiles and wastes. Branding would be preferred, as it has the potential to last longer. There should also be multiple brands, so that the mark can be identified even if the utility pole is dismantled;
- Pressure-treated wood at the end of its service-life will still contain some PCP, although there are some indications that the amount remaining will be relatively low (USA 2014). Incineration can lead to the unintentional production of dioxins and furans. The BAT/BEP guidelines (UNEP 2007)⁶ and provisions of Annex C to the Stockholm Convention provide information on the appropriate elimination or disposal technologies to be used;
- Identification of key restriction measures to limit the release of PCP from treated timber and potential exposure to both workers and the environment. For example, a restriction meaning that all timber treatment must be completed as an automated process with manual activities for movement of recently treated wood banned would minimise exposure in application of PCP to materials. Restrictions placed on timber treatment facilities to limit the 'dripping / leaching' from recently treated timber may also be relevant. This could take the form of additional drying before the timber is sent for use;
- Additional training for enforcement agencies, particularly within the waste sector to help identify and manage treated wood more easily. This could also include obligations for monitoring of waste timber to clarify PCP content before wood can be reused / recycled.

Step 4: Development of Control Plans

The previous step should provide an exhaustive list of possible viable control options to help manage and minimize the emissions from existing use of PCP; as well as promote the phase-out of PCP for safer alternatives (both chemical and non-chemical). The preceding step is intended to develop a list of all available options for control, minimization and transition to alternatives. As part of the preceding step it is also necessary to assess these options and identify which ones have the best potential benefit to achieve these goals.

The next stage in this process is to develop a plan of integrated options based on this list which should work together to help manage, control and minimize emissions and facilitate the transition of PCP for safer alternatives. These control plans should form part of the national implementation plan for POPs in order to document them publically and also to allow for other ongoing work on other POPs to be taken into consideration.

In developing these control plans it will also be necessary to set achievable targets over an appropriate timescale and to put in place mechanisms to assess how successful each option has been. In practice the development of plans should be seen as an evolution, with the possibility for further tailoring or amendment of options depending on the outcome of other work or changes occurring within given nations.

Step 5: Awareness campaigns

The preceding two steps detail the activities that could be undertaken to identify possible options for the control of PCP to manage emissions and facilitate the transition to safer alternatives. An additional important step to these options will be to ensure that the work undertaken is done so in a transparent fashion and with emphasis made to help raise awareness within all key stakeholder groups. Raising awareness of the key issues surrounding PCP and the need for control will help ensure that the control options utilised are as effective as possible and that all key stakeholders remain engaged with the process.

⁶ <http://chm.pops.int/Implementation/BATandBEP/BATBEPGuidelinesArticle5/tabid/187/Default.aspx>.

In particular ensuring a high level of communication with industry will be of importance to help ensure that they remain compliant and are part of the overall process to aid transition to safer alternatives.

Awareness campaigns can be conducted in a variety of ways and should be tailored to best meet the needs of the target groups receiving the information. For example, public awareness campaigns on the safe management of waste wood should be communicated in non-technical language in an easy accessible fashion (e.g. national leaflet campaign, radio campaign, website etc.). Awareness campaigns targeted at industry for the safe treatment and management of timber would use more technical language, and would likely take the form of guidance on how they need to ensure they remain compliant (e.g. industry helpline; regulatory website, training/communication from agency enforcement officers during site visits).

For example the US EPA website specifically provides information for the general public on PCP, and management of treated timber in a non-technical format: <https://www.epa.gov/ingredients-used-pesticide-products/pentachlorophenol>

Step 6: Monitoring / Compliance / Feedback

The next step is intended to focus on the control options which have been implemented and to monitor their rate of success. As highlighted, the development of options should be seen as an evolution, with the possibility for further tailoring or amendment dependent on how existing control options work and changes at national level affect the use and emission of PCP. In order to capture this information it will be necessary to develop mechanisms to ensure compliance with existing control options (e.g. labelling and waste handling) as well as feedback on how successful these options have been.

The use of stakeholder engagement in step 2 such as industry working groups and communication with enforcement agencies could be used to provide information on compliance and feedback on how successful the options within the control plan have been.

One additional element may be the need for additional monitoring. The guidance in chapter 4 on development of emission inventories includes details on the need to reduce uncertainty in emission estimates and fill data gaps where read across or default data has been used. Additionally chapter 2 and 4 have also highlighted the possibility for 'hot spots' at former sites of manufacture and use.

The use of environmental monitoring programmes to assess ambient concentrations of PCP in the natural environment will also be important to help track progress against the objective of reducing emissions to the natural environment, as well as ensuring the correct issues are being targeted. The development of monitoring programmes is potentially expensive, and should, therefore, be developed in line with the preceding steps to ensure that monitoring is as targeted and risk-based as possible.

The outputs from monitoring, compliance work and feedback from stakeholders, can be used to help further tailor the understanding on key issues, and the work carried out in the preceding steps, in order to further develop planning.

Step 7: International Activities

The final step includes the broader international focus of work on POPs under the Stockholm Convention, and related work under the Basel and Rotterdam Conventions. The preceding steps have detailed the logical process that can be used for planning when assessing the key issues and potential options for control of existing uses of PCP and transition to safer alternatives. However, where PCP poses international issues (in part because of its ability to undergo long range transport), it is also important to give consideration to some international activities which can also be used to help control the movement of PCP and PCP treated timber.

PCP is listed under Annex III of the Rotterdam Convention, meaning that prior informed consent is required before PCP can be transported across politically boundaries as a commercial good. Chlorophenols are also listed under Annex I of the Basel Convention, meaning that waste contaminated with PCP also requires prior informed consent before crossing political borders for final destruction. Notification should also be provided to the Secretariat of the Basel Convention from national level of what wastes have been granted consent.

The Stockholm, Basel and Rotterdam Convention already enforce a number of control measures for the movement of PCP, PCP treated goods and wastes contaminated by PCP. However, additional international activities could include bilateral exchanges to help ensure that national planning is in alignment with neighbouring nations. This is particularly important where integrated markets exist for the supply and use of

PCP and PCP treated timber. It may also be possible to make use of national planning and proposed monitoring programmes to share efforts and resource burdens with neighbouring nations to maximise the benefit of such monitoring programmes.

These aspects promote the need for communication and knowledge exchange between partnering nations to help establish the best possible use of resources. Equally the Stockholm Convention regional centres provide a valuable focal point for awareness raising and information exchange.

5.3 Chemical Alternatives to PCP

Introduction

Chemical alternatives to PCP are substances which offer the same uses as PCP, but have a reduced potential for environmental harm. The key use of PCP is for industrial wood treatment (POP RC, 2014). This section, therefore, explores alternative chemicals that may be used for this purpose. A number of accepted wood preservation chemicals exist with potential to replace PCP dependent on the specific application. The US EPA (2008) and Environment Canada (2004) 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); and
- Additional preservatives including Ammonium Copper Quaternary (ACQ), Copper Naphthenate, copper azoles and azoles/permethrin.

This section provides a breakdown of each alternative with an analysis of its technical feasibility, highlighting its potential strengths, weaknesses and risks to health and the environment.

Chromated Copper Arsenate (CCA)

CCA is a product made up of active ingredients in a ratio of 5:3:2 for chromic acid, arsenic acid and cupric oxide, respectively (POP RC, 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 (US EPA 2008). It is also widely used in Canada and New Zealand (Canada, 2014; POP RC, 2014). While CCA is widely used for wood treatment, 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 due to public health concerns about the leaching of arsenic. It is now limited to use on wood intended for industrial applications and handled by professional users (Environment Canada, 2013; US-EPA, 2008). However, the US EPA have stated that the restrictions were just a precaution, and that CCA-treated domestic/residential structures should remain in place as they pose no significant threat to health if applied properly. Similar restrictions have been imposed in other regions, such as the EU (European Commission, 2003). In this region, Copper Chrome Arsenic (CCA) approval ceased in September 2006. Wood already on the market treated with CCA can still be sold and used for permitted uses (not inside buildings for example).

CCA is typically used in a pressure treating 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 (Becker et al 2008a). On completion of pressure treating (for all preservative types) it is necessary to include a drying cycle. It is, however, not appropriate to use kiln drying for CCA (air drying is preferred) as there is the potential to release chromium to air (Becker et al 2008a). 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 has both strengths and weaknesses in treatment of wood compared to PCP. CCA is recognized as producing a clean, dry, odour free finish which is easy to paint. Conversely, as PCP is an oil-based wood treatment, PCP-treated wood can 'bleed' and typically has a phenolic odour (GEI 2005). This makes CCA-treated wood more applicable to public locations such as pavements or pedestrian areas. The high fixation rates for CCA also mean it is suitable for use in areas with high moisture soil content or high water table. 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 (Becker et al, 2008).

The ICC (2014) and ACAT/IPEN (2014) have both 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. CCA contains two carcinogens, hexavalent chromium (CrVI) and arsenic, along with copper which is highly toxic to aquatic organisms (CDC 2013, USEPA 2013, USEPA 2008d). However, post fixation, in service CCA treated wood does not contain hexavalent chromium, but rather trivalent chromium (USEPA 1998). Trivalent chromium is classified as a group 3 ("Not classifiable as to its carcinogenicity to humans") carcinogen while hexavalent chromium is group 1 ("Carcinogenic to humans") (IARC 2014). Furthermore, KMG (PCPTF-KMG 2014) notes that CCA is no longer authorized for use in the European Union under the Biocidal Products Regulation.

Health Canada's Pest Management Regulatory Agency (PMRA), who carried out a joint risk assessment with the US EPA for heavy duty wood preservatives, notes that the original assessment for CCA is expected to have overestimated risk, and that wood treatment facilities following the TRD (labelling, storage, risk management plans) would greatly reduce the risk of exposure and environmental loss. The same document also states that CCA used in freshwater conditions has a low potential for leaching and that any material lost from utility poles in submerged conditions is retained in the sediment at the foot of the pole with minimal risk for exposure to aquatic species (PMRA 2011 and US EPA 2008c). Laboratory studies by Kamchanawong (2010) and Mercer (2012) assessed the leaching potential of CCA within hypothetical environments that simulate unlined landfill conditions; For the Kamchanawong this was under tropical conditions. The results of these studies highlighted potential for leaching which in real world environments may cause a concern for groundwater. However, the environmental relevance of these studies is unknown. In Canada and the USA, registrants voluntarily withdrew consumer (i.e. non-industrial) uses of wood treated with CCA as of 2004. These uses are, therefore, prohibited in Canada and the USA, as is export of wood for these purposes (US EPA 2014, US EPA 2003, PMRA 2002, and PMRA 2006).

It is difficult to treat certain wood species used for utility poles with CCA due to the inability of the treatment to penetrate blocked wood pores. In addition, CCA-treated utility poles are more difficult to climb. (UNECE 2010).

In Sri Lanka, copper chromated borate (CCB) is used as an alternative to CCA within specific applications but not on utility poles (Sri Lanka 2014).

Creosote

Creosote is produced from the distillation of coal tars and contains between 200-250 chemical species, although 85% of these are polycyclic aromatic hydrocarbons (PAHs) (Environment Canada 2013) with a large number of toxic substances contained in creosote including PAHs, phenol, and cresols. Creosote is a widely-used preservative for wood with proven efficacy, although it has negative environmental and health consequences. Efficacy studies show that creosote is effective against a broad spectrum of harmful organisms, including wood rotting fungi, against wood rot in soil and water contact, against insects, and against marine borers (Sweden 2014). Creosote is widely used in the USA with 16% of the utility pole market (Becker et al, 2008) and 31% of all wood in the USA (Vlosky 2009) as well as Canada (2014) and Sri Lanka, although information from Sri Lanka suggests service life is 30 to 50 years under harsh tropical climates (Sri Lanka 2014). In the EU, creosote is extensively used across the EU Member States, and according to the European Electricity Industry Association, Eurelectric (2010), about 1 million m³ of wood were treated with creosote each year. Creosote is of particular use in railway ties and cross-arms for utility poles (UNECE 2010) and in the EU the majority of creosoted wood is accounted for by these uses (WEI-IEO 2008).

Creosote, like PCP, is an oil based product used within industrial pressure, immersion or vacuum treating 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 and PCP 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 (Becker et al, 2008). Canada (2014) states that the Canadian railway system is around 50,000 km long with approximately 90 million ties in service. Canada also states that creosote is the only significant wood preservative currently used to treat railway ties. Production and availability of creosote is tied to steel production and any market fluctuations in the steel market. PCP has been identified as an important alternative for this use, should creosote become unavailable. This highlights the importance of PCP within the resilience of the rail infrastructure for Canada.

Concerns have been raised regarding health and environmental effects of creosote. KMG (PCPTF-KMG, 2014) highlight 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). 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 in the USA and Canada creosote is limited to industrial applications only (Becker et al, 2008). In Europe it was added to Annex I of the biocidal products directive 98/8/EC, meaning it can no longer be placed on the market without authorisation (Sweden, 2014). It is also mentioned in annex XVII of the European REACH regulation (EC 1907/2006) covering specific restrictions on use. 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, and that wood treatment facilities following the TRD (labelling, storage, risk management plans) would greatly reduce the risk of exposure and environmental loss (PMRA, 2011).

Copper Naphthenate

Copper naphthenate is an oil-borne wood preservative (UNECE, 2010), which is produced as a mixture of copper salts and naphthenic acid, a by-product of petroleum refinery processes (Feldman, 1997). While the composition of copper salts is well understood, the naphthenic acid component can be of variable composition depending on the nature of the source petroleum processed (Feldman, 1997). Copper naphthenate has been approved for both industrial and domestic use in the USA (Becker et al, 2008). Unlike CCA and creosote, Copper naphthenate is not a registered pesticide and can be used in domestic applications in both the USA and EU. However, there are some concerns about its non-toxic status.

Copper naphthenate holds a smaller proportion of the wood treatment market than CCA, PCP and creosote but demand is expected to grow (Becker et al 2008). The US-EPA data for 2004 quotes 900 tonnes used in the USA with further potential for growth. Copper naphthenate is approved for above ground, ground and freshwater use but is considered unsuitable for coastal/marine applications. Equally it can be used in the USA within pressure treating processes as can PCP, CCA and Creosote.

Smith et al (undated) quotes quality issues experienced during the mid-1990s with specific batches of product. In these cases, the product formed an emulsion during pressure treating which led to patchy treatment of utility poles and poor protection in areas where oil coverage was also poor. This notes that copper naphthenate would be concentrated in the oil fractions. Poles treated with these batches of copper naphthenate began to experience problems within four years of installation. Wood damage from fungi and pests particularly at the mid-to-top end height of the poles was experienced in a number of cases. One case study in Wisconsin, USA in 1997 quotes 217 poles where 43% were in poor repair. No recent batching issues are known to exist.

Information from the Toxnet database (Toxnet 2011) illustrates that despite its wide use the environmental profile and toxicity of copper naphthenate is poorly characterised; due in part to the variable nature of the petroleum product. This takes into account that the petroleum product component can have the presence of multiple compounds including notably benzene (Feldman, 1997). Toxnet also highlights that, like CCA, copper naphthenate leaches from wood and that studies on mice suggest that this substance may have potential to be genotoxic. However, the naphthenate acid molecule is not expected to bioconcentrate significantly; modelled bioconcentration factors (BCFs) are 1464-1659 (U.S. EPA, 2011), which are well below the Stockholm Convention criterion of 5000. US EPA (1996) also indicate potential health effects for occupational exposure when manually applying copper naphthenate to wood in domestic and residential settings, including anaemia caused by hydrocarbon contaminants.

Ammonical Copper Zinc Arsenate (ACZA)

ACZA (also traded under the name Chemonite) is an aqueous product based on active ingredients in the ratio of 5:3:2: for cupric oxide, zinc oxide and arsenic acid, 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.

ACZA is a refinement of an earlier formulation, ACA, which is no longer available in the United States. In Canada ACZA superseded ammoniacal copper arsenate (ACA) with full registration in 1999. In the USA, ACZA is more typically used in the Western States due in part to its particular ability to treat Douglas Fir, the prevalent wood type in that area (Becker et al, 2008). ACZA is less widely used in the Eastern and Southern United states. Production facilities are centred in the Western United States.

ACZA, like CCA, has a high fixation rate. It can also provide better performance than CCA in protection against some species of pest (Becker et al 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.

The environmental profile and concerns for ACZA are broadly similar to those for CCA with the presence of both arsenic and copper oxide. ACZA has the potential to leach from wood, including treated utility poles (Lebow 1996 and US EPA 2008c) and 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 (Becker et al, 2008). Health Canada's Pest Management Regulatory Agency (PMRA), who carried out the risk assessment for heavy duty wood preservatives, notes that the assessment for ACZA is expected to have overestimated risk, and that wood treatment facilities following the TRD (labelling, storage, risk management plans) would greatly reduce the risk of exposure and environmental loss and that the use of ACZA is used only within closed systems.

Other Alternative preservatives for wood treatment

Alongside the chemical alternatives described above, additional chemical alternatives exist; within North America, Alkaline copper quaternary (ACQ), copper azoles and sodium borates (SBX) also form part of the mixture of wood treatment products available. These alternatives are also used within New Zealand. Additionally, (Subsport 2012) also identify silicone polymers as a viable alternative. In the European Union under the EU biocidal products regulation (EU 528/2012) there are 32 named active substances approved at EU for use in wood preservative biocidal products, including a number of those already detailed (EU biocides 2012). However, the vast majority of these 32 biocide active substances are not used for industrial wood preservation. Annex 3 provides details of these substances together with applicable legislation on use restrictions for Europe. Further detailed explanation of ACQ, copper azoles and SBX as potential alternatives to PCP is given below, as approved by the American Wood Protection Association (AWPA).

Table 5.1 AWPA approved uses for preservatives in wood treatment (UNECE, 2010)

Product/application	Creosote and oil borne preservatives					Waterborne Preservatives					
	Creosote	Creosote-petroleum	Creosote Solution	PentaChloroPhenol	Copper Naphthenate ^d	Chromated Copper Arsenate ^e	Ammonium Copper Quaternary (ACQ) – type C and type D	Ammonium Copper Quaternary ACQ – type B	Copper Azole type A	Ammonical Copper Zinc Arsenate	
Lumber, timbers and plywood											
C2-lumber, timber, bridge ties and mines ties	+	+ ^a	+	+ ^a	+ ^a	+	+ ^a	NA	+ ^a	+ ^a	+
C9-Plywood	+	+	+	+	NA	+	+	NA	+	+	+
C22-Permanent Wood Foundations	NR	NR	NR	NR	NA	+	+	+	+	+	+
C28-Glued laminate members	+	NA	NA	+	+	+	+	NA	NA	NA	+
Piles											
C3-Piles	+	+	+	+	+ ^b	+	+	NR	NR	NR	+
C18-Marine construction	+	NR	+	NR	NA	+	NR	NR	NR	NR	+
C21-Marine lumbers and timbers	+	NA	NA	+	+	+	+	NA	+	+	+
C24-Sawn timber used to support residential & commercial structures	+	NA	NA	+	NA	+	+	NA	NA	NA	+
Poles											
C4-Poles	+	NR	+	+	NA	+	NR	+	NR	NR	+
C23-Round poles and posts used in building construction	+	NR	+	+	NA	+	NR	NR	NR	NR	+
Posts											
C5-Fence posts	+	+	+	+	+	+	+	+	+	+	+
C14 – Wood for highway	+	+	+	+	+	+	+	+ ^f	+ ^c	+ ^c	+
C15 – Wood for commercial residential construction	+	+	+	+	+	+	+	NA	+	+	+
C16 – Wood used on farms	+	+	+	+	NA	+	+	NA	+	+	+
Cross-ties and Switch ties											
C6-Cross-ties and Switch ties	+	+	+	+	NR	NR	NR	NR	NR	NR	NR

It should be noted that although these uses may be “approved” by AWPA, the actual regulatory approvals must come from PMRA in Canada and USEPA in the USA.

NA: Not available, NR: Not recommended

- a) Not for saltwater use
- b) Land and freshwater use; not for foundations
- c) Posts sawn four sides only
- d) Copper Naphthenate is also approved by AWPA as a waterborne preservative for some uses.
- e) Chromated Copper Arsenate is available for industrial applications only
- f) Round, half-round, and quarter-round only

ACQ is a waterborne wood preservative used in a similar fashion to CCA (Environment Canada, 2013). 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 ACQ) accounted for 45% of all preservative wood treatments in the USA with CCA second placed (Vlosky 2009). However, ACQ is not currently used in the USA for utility poles and cross-arms. In Canada, while ACQ is widely used (mainly in the domestic wood market), it is not used within infrastructure applications including 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). 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, particularly aluminium. The use of ACQ would require the use of stainless steel fittings in treatment facilities which can be expensive (Becker et al, 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). ACQ is applied by industrial vacuum-pressure impregnation at a timber treatment plant.

ACQ comes as four different products labelled types A-D that contain both copper and a quaternary ammonium compounds ("quat") as active ingredients. Of these, ACQ-A and ACQ-B contain the "quat" 'DDAC', ACQ-C contains 'ADBAC' and ACQ-D contains both 'DDAC' and 'DDACB'. All four products types are based around the ratios of copper oxide to "quat" and may contain either ammonia or ethanol amine as the carrier solution (Environment Canada, 2013). DDAC is persistent in both water and soil, while ADBAC has lower persistence issues, with a half-life of ADBAC in soil of 13 days. DDACB the active in ACQ-D is persistent and harmful to soil organisms and has guideline maximum concentrations for water at 0.0015 mg/L (Environment Canada, 2013). ACQ-A, ACQ-C and ACQ-D are all used within Canada (Environment Canada, 2013). The ammoniacal component evaporates quickly within air leaving copper oxide which is highly toxic to fish should it reach the natural environment (Dubey 2010). Copper is released from ACQ-treated wood in landfill leachates raising concerns over further contamination (Dubey 2010).

Copper azole is a waterborne product made up of copper-amine complex and co-biocides (Becker et al, 2008). It is similar to ACQ, the difference being that dissolved copper preservative is augmented by an azole co-biocide rather than the quat biocide used in ACQ. 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) and is not currently used in the USA for utility poles and cross-arms. In Canada it is approved for the domestic wood market only and is not used on infrastructure applications including utility poles (Environment Canada, 2013). Like ACQ, copper azole is corrosive to metal fastenings and so stainless steel would be required, which can be expensive for treatment facility upgrades (Becker et al, 2008). However, a micronized copper azole product does exist with lower levels of corrosivity and potential for deeper penetration of wood (Vlosky 2009). This particular product is still relatively new to market with an unknown long term track record for use in infrastructure applications (Becker et al, 2008). Copper azole is not known to be carcinogenic (Environment Canada, 2013).

Tebuconazole (the non-metal biocide ingredient in copper azole) has a half-life of 100 days in soil and is also moderately toxic to aquatic life (Environment Canada, 2013). However, tebuconazole degrades more quickly in aquatic conditions than in soil and is largely eliminated by fish reducing the potential for bioaccumulation. The product produces irritation on direct contact with skin and long term occupational exposure can lead to lung, liver and kidney damage. Azoles such as Tebuconazole are effective against decay fungi, but not against termites or mould. Thus, they must be used with other chemicals, notably copper (Townsend, 2013). Under the EU regulation for placing biocidal products on the market (EC 528/2012); Tebuconazole has been identified as a candidate who meets Persistent, Bioaccumulative and Toxic (PBT) criteria.

The use of copper-based preservative systems as a replacement for pentachlorophenol for treatment of critical structural components like utility poles and cross-arms may not be suitable because of the presence of copper-tolerant fungi widely distributed in the environment. A variety of fungi are capable of detoxifying copper-containing compounds either by immobilization or uptake (Morrell, 1991 [Cited in the risk management evaluation for endosulfan]).

Sodium borates are a waterborne preservative with varying amounts of borate (Becker et al, 2008). The product comes as a powder which is then mixed to the desired strength prior to use (Environment Canada, 2013). In Sri Lanka (Sri Lanka, 2014) sodium borates are used to treat rubber wood as a diffusion treatment, but their use as a replacement for PCP is limited. Sodium borates leave wood with a clean, dry,

odour-free finish. Borates compounds are toxic for reproduction in accordance with the UN GHS criteria. However, they also readily leach from wet wood affecting performance (Becker et al, 2008). Sodium borates are reserved specifically for use within indoor applications or above ground where wood is continuously protected from water (UNECE, 2010) and, therefore, sodium borates are not an alternative for current PCP uses.

Copper boron azole (CBA) has been proposed as an alternative to CCA but not specifically for use on utility poles and cross-arms (ICC-ES 2013). Monoethanolamine is usually used to complex with the copper, which increases costs (Townsend 2006). Copper is released from CBA-treated wood in landfill leachates raising concerns over further contamination (Dubey 2010). Copper is highly toxic to aquatic organisms (USEPA 2008d).

Silicone polymers also provide a possible option to treating timber products. Instead of killing fungi, this approach creates a physical barrier to fungal attack. Inorganic silicone polymers and organic acid are used in a water-based wood treatment and dried under elevated temperature (Subsport 2012). The mixture encapsulates the wood fibres, creating a physical barrier on the wood surface and making it inaccessible for rot fungus. The product is sold under the trade name OrganoWood along with a surface coating for industrial uses called OW-surface coating, by Organoclick based in Sweden (Organoclick 2014). However, PCPTF-KMG 2014 and Canada (2014) note that silicone polymers appear to be untested for wide scale industrial use, particularly for utility poles and that furthermore, silicone polymers are not registered within Canada for industrial wood use. The recommendations made by Organoclick, 2014 suggest use for above soil application. PCPTF-KMG 2014 raise a concern about the use of silicone with ground contact application as a potential issue and that given the importance of ground contact for utility poles this should be considered. While silicone polymers pose an interesting option for wood treatment their largely untested nature on the wider industrial scale means that in the short term they are not a viable replacement option for PCP without further testing.

5.4 Non-Chemical Alternatives to PCP

Introduction

Non-chemical alternatives are materials that offer the same functionality as products made from PCP, but have a lesser impact on the environment. The primary use of PCP is as a preservative for wood treatment. Wood has applications within domestic and industrial construction for a broad range of uses. PCP-treated wood has particular application to infrastructure usage such as utility poles for electricity supply networks and cross-ties for rail networks. It is possible for these specific applications to adopt alternative materials such as:

- Concrete;
- Steel;
- Fibreglass reinforced composite (FRC);
- Heat treated wood; and
- Hardwood alternatives which are more resistant to attack from fungi and pests in some situations.

This section will explore the technical feasibility, efficacy and costs of these non-chemical alternatives. Because non-chemical alternatives are applied and manufactured in methods that are very different to PCP, it is less straightforward to compare their environmental impacts than chemical alternatives. In order to ensure the full environmental impacts of each non-chemical alternative are captured, life-cycle analysis (LCA) must be used. LCA is a technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. It helps to avoid a narrow outlook on environmental concerns. The full environmental impacts of different options can then be compared. Care should be taken when interpreting life cycle data, to ensure that the context is clear (i.e. geographical), so that comparisons can be made appropriately.

The application of concrete, steel and FRC provide both generic and specific technical improvements and weaknesses compared to treated wood. Table 5.2 below provides a brief overview of the generic strengths and weaknesses summarized within the USA EPA review (Becker et al, 2008). A detailed exploration of each of these alternatives is provided in the following section.

Table 5.2 Generic advantages and disadvantages of non-wood alternative materials

	Concrete	Steel	FRC
Generic technical improvements compared to treated wood			
Standardised size and specification	X	X	X
Less maintenance required	X	X	-
Impervious to attack from fungi and pests	X	X	X
Generic technical weaknesses compared to treated wood			
More expensive than wood poles (based on up-front costs).	X	X	X
Non-wood poles cannot be climbed using existing equipment such as 'Gaffs', but are designed to provide their own systems such as 'fixed steps'	X	X	X
Increased risk of animal electrocution requiring additional insulation	X	X	-
Heavier than wood poles	X	-	-

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 (Becker et al, 2008; ACAT/IPEN, 2014; UNECE, 2010). This reduced weight improves freight and installation costs. The USA EPA and UNECE reviews (Becker et al, 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 (Bolin, 2011).

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 (Becker et al, 2008 and 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 (Becker et al, 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 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 (Bolin, 2011) concluded that in comparison to wood-based products, the manufacture of steel poles requires greater consumption of natural resources such as water, and most importantly is linked to higher emissions of carbon dioxide and air pollutants. Studies by SGS Global (2013) and Bolin (2011) suggest the service life of steel poles is between 60 – 80 years, while estimates of wood pole longevity are 20 – 70 years. 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.

There has been limited adoption of Steel railway cross-ties in the USA (Railway Technology, 2016). As a material for railway cross-ties, steel has several advantages over treated timber. They have a lesser reliance on ballast (approximately 60% less than required for concrete; 45% less than wood), which makes them particularly favourable in areas where timber is scarce (Railway Technology, 2016). Steel is also sturdier than timber and less expensive than pre-stressed concrete, as well as being 100% recyclable. However, there are several issues which are creating barriers to the use of steel in railway

cross-ties. Firstly, they are susceptible to corrosion and rail operators have reported in the past that steel ties have been removed from tracks after rail seats became quickly fatigued, especially on lines with many turns. Secondly, they lack insulation. Neoprene composite insulation is used to keep steel ties separate from electrified rails, but any error can wreak havoc on a rail network. A report in the Austin American-Statesman (2010) noted that as a result of conductivity problems and signal failures, one operator had been forced to replace long sections of steel sleepers with timber at an additional cost of \$90,000.

Concrete

Concrete utility poles and cross-ties provide a standardized product with high tensile strength and durability (Becker et al, 2008). This allows them to carry high weight and high speed loads. For this reason, they are preferred for modern, high speed lines. They also provide greater resistance to damage from lightning strikes, fires, vibration, fungal and insect pests and wind (Bolin, 2011). Concrete poles are less likely than treated wood products to warp or twist compared to treated wood (Becker et al, 2008). New Zealand (New Zealand 2014) states that for railway cross-ties the National Rail Company in New Zealand successfully switched to concrete in 1991 which is now the preferred choice of material. The enhanced durability in ideal locations, less frequent maintenance and potential longer service life than chemically-treated wood demonstrated a high level of efficacy in meeting the structural needs of utility poles (Becker et al, 2008). A manufacturer's claim states that the service life of concrete poles can potentially reach 75 years (Stresscrete 2014), while Canada (Canada 2014) states the average treated wood life span has been estimated at 70 years or higher (Mankowski 2002). Other estimates provided for the potential longevity of concrete poles are between 50 and 80 years, while estimates of wood pole longevity are 20 – 70 years. 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 failure of poles at a premature point. This also allows the use of fewer ties per mile. The most significant issue for concrete compared to treated wood is weight, where concrete poles are quoted to be three times the weight of wood (Bolin 2011). The overall weight of concrete utility poles adds to freight and installation costs (Becker et al, 2008), with wide scale adoption of concrete poles likely to have implications for industry who would need to 're-tool'.

Concrete poles have the advantage of not requiring chemical treatment with persistent and toxic chemicals that are released into the environment, thus conferring benefits to worker and environmental health. 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, but 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 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. Although initial purchase costs for the concrete poles are higher as indicated in some studies (Becker et al 2008), these cost differentials may be offset to some extent by added disposal costs, and there could be longer-term cost savings over the life of the poles. Life cycle analysis studies by the wood preservative industry (Bolin, 2011; Bolin & Smith, 2013; Aqua-e-Ter, 2012) 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. The USA EPA report 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 specially formulated for this particular 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 and does not have to be consigned to a hazardous waste landfill.

Fibreglass reinforced composite

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 (Becker et al, 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 load-bearing components such as poles and cross-arms. FRC poles are engineered for a specific configuration of cross-trees 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). FRC-based poles are also only available in lengths under 55 feet which may prohibit some applications depending on terrain (WPC, 2014). Wood Preservative Industry reports (Aqua-e-Ter, 2012; Bolin & Smith, 2013) also provide lifecycle analysis which suggests 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 (including a reduced potential for eutrophication) and lower disposal costs (ACAT/IPEN 2014).

Recently, composite railroad ties manufactured from recycled plastic resins and rubber have entered the market in some regions (Polywood, 2010). Manufacturers claim a service life longer than wooden ties with an expected lifetime in the range of 30–80 years. The ties are also impervious to rot and insects (Grant, 2005) and they can be modified with a special relief on the bottom to provide additional lateral stability when surrounded by ballast. Their resistance to water means they have been applied in niche applications such as underground railway lines in mines (Cromberge, 2005). They also offer benefits on bridges and viaducts, because they lead to a good distribution of forces and reduction of vibrations into respective bridge girders or the ballast. Composite plastic ties are fully recyclable.

Heat treated wood

This approach uses thermal treatment of wood near or above 200°C in low oxygen conditions to make it resistant to decay while maintaining dimensional stability. Principal uses are restricted to above ground non-structural uses such as siding, decking, flooring, garden furniture, playground furniture, window and door frames, and indoor furniture. Therefore, heat treated wood is not a viable alternative to current uses of PCP (i.e. in ground, ground contact, water contact and structural). The treatment process varies according to the wood species and no chemicals are required. Six major processes are available including Thermo Wood (Finland), Plato Wood (Netherlands), Retification (France), Bois perdure (France) Westwood (USA, Canada, and Russia), and Oil heat treatment (Germany) (ECRD, 2001). A comparison of production costs among the various methods indicates a range from 65 – 160 €/m³ (Wang Undated).

Hardwood alternatives

Alongside the non-wood alternatives to PCP-treated wood it is also possible to make use of alternative wood types with greater resistance to attack by fungi and pests. Hardwood varieties can have a viable service life of up to 25 years in US without the need for chemical treatment (Becker et al, 2008). The main issue for greater use of hardwood varieties will be the availability of viable stock which will vary globally. Decay-resistant woods such as cedar, and hardwoods may be used without chemical treatment (UNECE 2010). These woods have greater mechanical strength than chemically-treated softwoods, although initial purchase cost is more expensive than chemically treated woods. Switching to hardwood varieties that have greater resistance to attack by pests would likely have adverse effects, both economically with additional cost of wood but also on forestry and local ecosystems with the need to meet demand for wood (Becker et al, 2008). The use of hardwood varieties will have varying efficacy based on climatic conditions, application and availability of suitable stock. This is offset by the enhanced benefits of reduced chemical use and emission to environment compared to PCP treated wood.

5.5 Summary

Overall, there are several viable chemical alternatives to PCP for wood preservation and non-chemical alternatives to wood for utility poles and railway ties.

Creosote was the first substance used for wood preservation and has well proven efficacy. Similar to PCP, it is oil-based, which provides suppleness to treated wood. However, it has many negative health and environmental consequences. CCA produces a clean, dry, odour free finish, but can also dry out wood and like creosote and there are environmental concerns surrounding the use of CCA in some applications due to its arsenic content. Both CCA and creosote are registered pesticides in the USA and EU. Unlike, CCA and creosote, copper naphthenate is an oil-based wood preservative that is approved for use in domestic applications. However, there are some environmental concerns around the substance and it is not approved for coastal or marine use. ACZA is an aqueous based preservative that has similar environmental to CCA because it contains arsenic. However, it is approved for use in coastal and marine applications. Other aqueous preservatives include ACQ and copper azoles, which have grown in popularity among

manufacturers due to their lower potential for leaching and associated environmental damage. However, they are corrosive to metals. Waterborne preservatives are used primarily to treat softwoods, because they may not fully protect hardwoods from soft-rot attack. Most hardwood species are difficult to treat with waterborne preservatives. Recently, manufacturers have been applying micronized ACQ and copper azole treatments. These minimise environmental damage further by increasing the penetration of the preservative and reducing the quantity of preservative used. Sodium borates are another aqueous preservative with a low environmental profile. However, they are not suitable for water contact or ground contact applications as SBX readily leaches. Silicone polymers provide a low environmental impact method of chemical preservation, by forming a protective barrier on wood. However, their application in an industrial context remains untested.

Manufacturers are turning to alternative copper wood preservatives that don't contain arsenic, such as Copper naphthenate, ACZA and ACQ

A summary of the potential alternatives to PCP is provided within Table 5.3.

Table 5.3 Summary of potential alternatives to PCP

Chemical alternatives			
Alternative	Description	Pros	Cons
Chromated copper arsenate (CCA)	5:3:2 for chromic acid, arsenic acid and cupric oxide. Similar pressure treating process as PCP and creosote, but lower application temperatures (65°C compared to 100°C).	High fixation rates for CCA with the metal components - suitable for use in areas with high moisture soil content; Clean, dry, odour free finish which is easy to paint; Does not 'bleed' - more applicable to public locations; Can help prevent shrinking, warping and twisting, particularly in harsh climatic conditions.	Concerns regarding environmental and human health impacts – contains highly toxic and carcinogenic substances; Potential for leaching may cause a concern for groundwater; Corrosive to some metal types meaning that galvanized metal fastenings must be used; Difficult to treat certain wood species due to the inability of the treatment to penetrate blocked wood pores.
Creosote-based products	Produced from the distillation of coal tars; An-oil based product used within industrial pressure, immersion or vacuum treating of wood.	Proven efficacy against a broad spectrum of harmful organisms; Can help prevent shrinking, warping and twisting, particularly in harsh climatic conditions.	Environmental and health concerns - large number of toxic substances contained in creosote including PAHs, phenol, cresols and various POPs.
Copper Naphthenate,	Oil-borne wood preservative, produced as a mixture of copper salts and naphthenic acid, a by-product of petroleum refinery processes.	Not a registered pesticide and can be used in domestic applications; Relatively low bioconcentration factor.	Reported cases of the product forming an emulsion, leading to patchy treatment and poor protection of utility poles; Impact on human health and the environment is poorly characterised; Health risks due to occupational exposure.

Chemical alternatives

Alternative	Description	Pros	Cons
Ammoniacal Copper Zinc Arsenate (ACZA)	Aqueous product - ratio of 5:3:2 cupric oxide, zinc oxide and arsenic acid; ACZA can be used in pressure treatment where evaporation of the ammonia fixes the metals compounds to the surface of the wood.	High fixation rate; Provides corrosion protection of working metal parts; Approved for use in coastal/marine applications.	Environmental and health concerns – presence of arsenic and copper oxide; Retain an ammonia odour - may be less suited to public locations; Has the potential to leach from wood, including treated utility poles.
Ammonium Copper Quaternary (ACQ)	Waterborne wood preservative used in a similar fashion to CCA; Widespread use has been focused within the domestic wood market and soft woods	Recognized as being useful for treating Douglas Fir which is typically hard to treat; Advent of micronized ACQ provides a product with lower corrosivity and greater penetration.	Corrosive to metals, particularly aluminium - requires the use of stainless steel fittings which can be expensive; Environmental and human health impacts.
Copper azoles	Waterborne product made up of copper-amine complex and co-biocides, similar to ACQ	Micronized copper azole product does exist with lower levels of corrosivity and potential for deeper penetration of wood.	Corrosive to metal fastenings and so stainless steel would be required; Unknown long term track record for use in infrastructure applications, human health, occupational and environmental risks; May not be suitable because of the presence of copper-tolerant fungi widely distributed in the environment.
Sodium borates / Copper boron azole (CBA)	Waterborne preservative with varying amounts of borate.	Leave wood with a clean, dry, odour-free finish.	Toxic for reproduction; Leach from wet wood affecting performance; Only suitable for indoor applications or above ground where wood is continuously protected from water; Copper released from CBA-treated wood in landfill leachates - concerns over further contamination.

Chemical alternatives

Alternative	Description	Pros	Cons
Silicone polymers	Used in a water-based wood treatment and dried under elevated temperature; The mixture encapsulates the wood fibres, creating a physical barrier on the wood surface and making it inaccessible for rot fungus.		Untested for wide scale industrial use, particularly for utility poles.

Non-chemical alternatives

Alternative	Description	Pros	Cons
Concrete	Use of concrete is widely applied for both utility poles and cross ties. They are particularly preferred for modern, high speed lines	High tensile strength and durability - allows them to carry high weight and high speed loads; Greater resistance to damage from lightning strikes, fires, vibration, fungal and insect pests and wind; Less likely than treated wood products to warp or twist; Less frequent maintenance and potential longer service life than chemically-treated wood; Don't require chemical treatment – avoids health and environmental consequences; Avoids deforestation; Material can be recycled and does not have to be consigned to a hazardous waste landfill.	Higher initial purchase costs The higher overall weight of concrete utility poles adds to freight and installation costs; Wide scale adoption of concrete poles likely to have implications for industry who would need to 're-tool'; Manufacture requires greater consumption of natural resources e.g. water, and higher CO ₂ emissions; Concrete posts can only be installed once,
Steel	Use of steel as an alternative material for utility poles has been investigated by some of the utilities in the USA; limited adoption of Steel railway cross-ties.	Manufactured as hollow structures - lighter than treated wood poles (by 30-50%) with similar or greater load bearing strength - improves freight and installation costs; Longer potential service life; Recyclable; More preferable option in areas where timber is scarce.	Can be open to surface and below-ground corrosion which can be difficult to assess by maintenance crews; Need to be handled with care during transport and installation as they can be easily damaged; Increased risk of electrocution – workers and wildlife, and lightning strikes; Manufacture requires greater consumption of natural resources e.g. water, and higher CO ₂ emissions

Chemical alternatives

Alternative	Description	Pros	Cons
FRC	Relatively new to market and so have a limited history of use; Recently, composite railroad ties manufactured from recycled plastic resins and rubber have entered the market in some regions.	Impervious to rot and insects; Lighter than treated wood meaning a reduction in freight and installation costs; Longer service life than treated wood; Lower toxicity and disposal costs; Composite plastic ties are fully recyclable; Resistance to water means they have been applied in niche applications such as underground railway lines in mines; Provide benefits on bridges and viaducts.	Can distort when screwing down hardware , so mounting hardware may loosen over time - makes FRC unsuitable for load-bearing components such as poles and cross-arms; Post installation modification of this is not possible in most situations; May be more susceptible to UV radiation, which in hot dry climates can lead to delamination of FRC layers and weakening of the overall structure; 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
Heat treated wood	Uses thermal treatment of wood near or above 200°C in low oxygen conditions to make it resistant to decay while maintaining dimensional stability;	No chemicals are required.	Principal uses are restricted to above ground non-structural applications - not a viable alternative to current uses of PCP.
Hardwood alternatives	Alternative wood types with greater resistance to attack by fungi and pests.	Decay-resistant woods such as cedar, and hardwoods may be used without chemical treatment; Harwood has greater mechanical strength than chemically treated wood.	Availability of viable stock will vary geographically; Effectiveness will also vary depending on climate.

6. Summary

The elimination and environmentally sound management of persistent organic pollutants (POPs) requires a full understanding of the production, uses, releases, wastes, stockpiles and contaminated sites related to these chemicals. The development of emission inventories for POPs such as PCP is essential in this respect, to establish an evidence base against which planning effective emission controls and minimisation can take place, thereby enabling policy makers to fulfil their nation's obligations under the Stockholm Convention. This document has provided guidance on how emission inventories can be developed, specifically relating to PCP and its salts and esters, with the aim of aiding countries in the phase-out of PCP and safe management of stockpiles and PCP treated goods.

A step-by-step approach for planning and carrying out a national PCP inventory has been outlined and discussed, including: i) Planning the inventory; ii) Choosing data collection methodologies; iii) Collecting and compiling data from key sectors; iv) managing and evaluating the data; v) Preparing the inventory report. This process might not be conducted in an entirely linear fashion. A suggested 'three-tiered' methodology for data collection for inventory development (Tier I: Initial assessment; Tier II: (Preliminary) inventory; Tier III: In-depth inventory) is described. This approach is recommended as it provides flexibility to different nations with varying priorities and capacities. It is stressed that inventory development requires cooperation between a wide range of different stakeholders, including government authorities and agencies, producers, importers and distributors, manufacturers and NGOs, and that interaction with these stakeholders will be required at various points of the process.

The guidance has also provided a detailed inventory of PCP emissions and includes an evaluation of the inventory and methods for improvement. This includes a detailed overview for all potential emission sources of PCP, including the manufacture of PCP, the use of PCP in both wood and non-wood treatment processes, in-use emissions, and end of life management and potential emissions. It also includes comment on potential 'hot spots' for former sites of manufacture and timber treatment and emphasises the need to identify and inventory these sites. A summary of default emission factors has been provided, that can be used for inventory development. However, it is emphasised that best practice will be to make use of country centric data wherever possible. It is also important to recognise that practices may vary regionally as will climatic conditions and this may affect the rate of emission as well as the importance of specific emission vectors (e.g. air, land, water).

More detailed and specific guidance on the logical steps and planning that can be undertaken by policy makers and/or regulatory agencies to control and minimise the environmental emissions of PCP has also been provided. A number of considerations are important in this process, including identifying issues at national level and engagement with relevant stakeholders. This also provided an exhaustive list of possible viable policy and technical control options to help manage and minimize the emissions from existing use of PCP; as well as promote the phase-out of PCP for safer alternatives. A range of alternatives to PCP are also presented, which offer the same uses as PCP, but have a reduced potential for environmental harm. This includes consideration of both chemical and non-chemical alternatives, with an analysis of technical feasibility, highlighting potential strengths, weaknesses and risks to health and the environment for each option.

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UNEP	2011b	UNEP/POPS/POPRC.7/19 Report of the Persistent Organic Pollutants Review Committee on the work of its seventh meeting
UNEP	2011c	UNEP/POPS/POPRC.7/INF/5 Additional information on pentachlorophenol and its salts and esters,
UNEP	2012a	UNEP/POPS/POPRC.8/16 Report of the Persistent Organic Pollutants Review Committee on the work of its eighth meeting
UNEP	2012b	UNEP/POPS/POPRC.8/INF/7 Information on pentachlorophenol and its salts and esters (reissued for technical reasons)
UNEP	2013a	UNEP/POPS/POPRC.9/13 Report of the Persistent Organic Pollutants Review Committee on the work of its ninth meeting
UNEP	2013b	UNEP/POPS/POPRC.9/6 Draft risk profile: pentachlorophenol and its salts and esters
UNEP	2013c	Decision POPRC-9/3 Pentachlorophenol and its salts and esters
UNEP	2013d	UNEP/POPS/POPRC.9/13/Add.3 Addendum to the Risk profile on pentachlorophenol and its salts and esters
UNEP	2013d	UNEP/POPS/POPRC.9/13/Add.3. Report of the Persistent Organic Pollutants Review Committee on the work of its ninth meeting, Addendum: Risk profile on pentachlorophenol and its salts and esters
UNEP	2013e	Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs under Article 5 of the Stockholm Convention.
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UNEP	2014d	Decision POPRC-10/1 Pentachlorophenol and its salts and esters

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USEPA	2008c	Cost Estimates for Risk Mitigation Technologies at a Typical Wood Treatment Plant
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Annex 1: Tables of default data to help inventory development

Source	Vector/Receptor	Emission factor	Comments/Details	Reference
PCP Production	Air	18 kg/year	Based on production of approximately 2000 tonnes of PCP	IEP(2008)
NaPCP Production	Air	65 kg/year	Based on production of approximately 2000 tonnes of NaPCP	IEP(2008)
PCP Production	Residue (Combined wastes)	1350 kg/year	USA Facilities	IEP(2008)
NaPCP Production	Residue (Filtration sludge)	900 kg/year	USA Facilities	IEP(2008)
Manufacturing and processing facilities	Air	592 kg/year	USA Facilities	IEP(2008)
Manufacturing and processing facilities	Water	579 kg/year	USA Facilities	IEP(2008)
Manufacturing and processing facilities	Land	44832 kg/year	USA Facilities	IEP(2008)
Volatilisation from PCP-treated utility poles	Air	30% loss in first year of use ; 2-5% subsequent loss from pole per year	based on UK and US data from the 1970s -1990s	Wild et al. (1992); IEP, 2008
Volatilisation from PCP-treated utility poles	Air	1.28 x10 ⁻⁴ kg/m ³ of PCP is released over the first 10 years followed by a release rate at 20 percent of the initial rate for the remainder of the pole life	1.8 percent released to the air	Bollin and Smith (2011)
	Land	1.28 x10 ⁻⁴ kg/m ³ of PCP is released over the first 10 years followed by a release rate at 20 percent of the initial rate for the remainder of the pole life	57.2 percent released to the ground	Bollin and Smith (2011)

PCP in the runoff from PCP-treated wood in stacks	Land/water	0.32 kg/m ³ of PCP-treated poles	Assuming the treated poles remain at the treatment yard for 1 month and average U.S. rainfall is approximately 33 inches (0.83m) of rain per year,	Morrell et al. (2009)
NaPCP volatilisation from treated wood	Air	10.8 µg/m ² /hour	After 96 hours, based on a loading rate of 5.4 m ² /m ³ (wood surface/chamber volume)	Marchal (1996).
PCP concentrations within mixed waste wood	Residue (mixed waste wood for processing)	<0.05 mg / kg	Raw wood with no obvious signs of treatment.	Pohlandt et al (1995)
		0.25 mg/kg	Mixed treated waste wood where PCP is suspected to having been used	

Annex 2: Suggested outline for a questionnaire to gather information

A	Information about the organisation and the site	
1	Name:	
2	Address:	
3	Address of site: (if different from A2)	
4	Phone:	
	Fax:	
	E-mail:	
5	Name/position of contact:	
6	Type of organisation (PCP manufacturer company using PCP / regulatory agency / NGO / academic:	
7	Public or private company?	
8	Location: Industrial zone	
	Other urban area	
	Rural area	
9	Number of staff at visited site: >50	
	10-50	
	<10	
10	Do you manufacture or import PCP? If manufacture, what annual tonnages are produced?	
	If imported, what annual tonnages are imported?	
11	If you manufacture PCP do you have details of abatement systems used as part of an environmental permit? (if yes, please append permit to this questionnaire)	

B	Information related to the potential PCP uses and emissions	
Questions for individual operators		
1	Do you make use of PCP for timber treatment activities? If yes please answer Q 2 - 8	
2	How much timber per annum is treated with PCP as tonnes?	
3	What is the working concentration of PCP in the timber produced at your facility (mg/ft ²)	
4	How much PCP contaminated waste is produced per annum at your facility?	
5	How is waste managed? (i.e. what is the means of final disposal)	
6	Does your facility use other pesticides for timber treatment as well as PCP? If so which?	
7	Does your facility carry out any routine monitoring for PCP emissions? If so please answer Q 8.	
8	Emission monitoring data as emission rates / annual totals	Emissions to air (g/m ²)
		Emissions to water (g/l)
		Emissions to waste (kg/tonne)
		Annual emissions to air kg
		Annual emissions to water kg
		Annual quantities of PCP in waste as kg
9	Do you make use of PCP for uses other than timber treatment, please specify which	
Questions for trade associations / regulators		
10	Do you have any data on annual production rates for timber treated with PCP (tonnes of timber)	
11	Do you have any data on annual quantities of imported timber treated with PCP (tonnes of timber)	
12	Do you have any data on the replacement rates for timber used in infrastructure networks	Type of network (e.g. power/telecoms/rail)
		Replacement rates as % of total in use
13	Average of utility poles / cross-arms within the infrastructure network	

C		Information on wastes liable to contain PCP	
Questions for waste facility operators			
1	Please specify the nature of your facility (recycling, incinerator, landfill, waste handling, other)		
2	Does your facility accept waste known to be contaminated by PCP (either production wastes or treated end of life timber) and how is treated?		
3	What quantity of waste is managed by your facility?		
4	Does your facility have any specific environmental permits relating to the management of hazardous waste? (if yes please append permit to this questionnaire)		
5	Does your facility conduct routine monitoring for releases? If yes please answer question 6.		
6	Please provide details of monitoring data as release rates of annual totals	Emissions to air (g/m ²)	
		Emissions to ground water (g/l)	
		Annual emissions to air kg	
		Annual emissions to ground water kg	
		Environmental monitoring for the site as soil concentrations (g/kg)	
Questions for regulators			
7	Please provide details of sites / facilities known to be managing PCP waste (append to this questionnaire as a separate document)		
8	Do you have any details on enforcement actions brought for environmental release – either at sites of use, or from waste handling locations?		
9	Has the regulator carried out any monitoring to corroborate environmental performance? If yes please answer Q10.		
10	Please provide details of monitoring programmes undertaken as part of compliance checking (please append details separately to this questionnaire)		

D Information on potential contaminated sites (Questions for trade associations / regulating agencies)	
1	Do you have any details on former sites of manufacture for PCP?
2	Do you have any details on former sites conducting timber treatment that may have used PCP in the past?
3	Are you aware of any monitoring or initial research conducted to sample and analyse soils from former sites of manufacture and/or use?
4	Do you have any contact details for representatives that may have further information on this topic? <i>(Please note that we will contact representatives detailed here. Please check that those named are happy to be contacted).</i>
E Information on Historic uses (Questions for trade associations / regulating agencies)	
1	Are you aware of any details surrounding the use of PCP for treatment in leather, textiles, paper and pulp or agriculture? <i>(Please list which industry sectors).</i>
2	Can you please provide details of locations for facilities / former facilities that were known to be using PCP? <i>(Please indicate which industry sector each facility relates to).</i>
3	Are any environmental monitoring data available for the sites identified in question 2 above?
4	Are any environmental monitoring programmes planned for the sites identified in question 2 above?
5	Have any monitoring programmes been used for sampling and analysis of leather, suede or textiles being imported into the country for presence of PCP? If yes, please provide details. <i>Question for regulators only.</i>
6	Have any stockpiles of leather, suede or textile goods contaminated with PCP been identified within your nation? If yes, is data available on quantities and mechanism for final disposal? <i>Question for regulators only.</i>

Annex 3: Named active substances for wood treatment within the EU

Named active substance	CAS number	EU use restrictions
4,5-Dichloro- 2-octyl-2H-isothiazol-3- one (DCOIT)	64359-81-5	Directive 2011/66/EU of 1 July 2011
Alkyl (C12-16) dimethylbenzyl ammonium chloride - C12-16 ADBAC	68424-85-1	Directive 2013/7/EU of 21 February 2013
Basic copper carbonate	12069-69-1	Directive 2012/2/EU of 9 February 2012
Boric acid	10043-35-3	Directive 2009/94/EC of 31 July 2009
Boric oxide	1303-86-2	Directive 2009/98/EC of 4 August 2009
Bifenthrin	82657-04-3	Directive 2011/10/EU of 8 February 2011
Chlorfenapyr	122453-73-0	Directive 2013/27/EU of 17 May 2013
Clothianidin	210880-92-5	Directive 2008/15/EC of 15 February 2008
Copper (II) oxide/ Copper hydroxide	1317-38-0/ 20427-59-2	Directive 2012/2/EU of 9 February 2012
Creosote	8001-58-9	Directive 2011/71/EU of 26 July 2011 Authorisation will only be granted if deemed that no viable appropriate alternative is available. Those Authorities allowing such products in their territory shall report no later than 31 July 2016 to the Commission justifying their conclusion that there are no appropriate alternatives and indicating how the development of alternatives is promoted.
Cypermethrin	52315-07-8	Regulation (EU) No 945/2013 of 2 October 2013
Dazomet	533-74-4	Directive 2010/50/EU of 10 August 2010 The EU level risk assessment addresses only professional use outdoors for the remedial treatment of wooden poles, such as transmission poles, by insertion of granules. If applicants at Member State level wish to seek authorisation for uses not covered at the EU level the authority must assess these uses with concern to protect risks to human populations and the environment.
Dichlofluanid	1085-98-9	Directive 2007/20/EC of 3 April 2007
DDACarbonate	894406-76-9	Directive 2012/22/EU of 22 August 2012
Didecyldimethylammonium Chloride (DDAC)	7173-51-5	Directive 2013/4/EU of 14 February 2013
Disodium octaborate tetrahydrate	12280-03-4	Directive 2009/96/EC of 31 July 2009
Disodium tetraborate (all species)	12267-73-1/ 1303-96-4/ 1330-43-4/	Directive 2009/91/EC of 31 July 2009
Etofenprox	80844-07-1	Directive 2008/16/EC of 15 February 2008
Fenoxycarb	72490-01-8	Directive 2011/12/EU of 8 February 2011
Fenpropimorph	67564-91-4	Directive 2009/86/EC of 29 July 2009
Flufenoxuron	101463-69-8	Directive 2012/20/EU of 6 July 2012
Hydrogen cyanide	74-90-8	Directive 2012/42/EU of 26 November 2012

IPBC	55406-53-6	Directive 2008/79/EC of 28 July 2008
K-HDO	66603-10-9	Directive 2008/80/EC of 28 July 2008
Propiconazole	60207-90-1	Directive 2008/78/EC of 25 July 2008
Sulfuryl fluoride	2699-79-8	Directive 2006/140/EC of 20 December 2006
Tebuconazole	107534-96-3	Directive 2008/86/EC of 5 September 2008 Under the EU regulation for placing biocidal products on the market (EC 528/2012); Tebuconazole has been identified as a candidate who meets Persistent, Bioaccumulative and Toxic (PBT) criteria. Considered a candidate for substitution with phase out of active use.
Thiabendazole	148-79-8	Directive 2008/85/EC of 5 September 2008
Thiacloprid	111988-49-9	Directive 2009/88/EC of 30 July 2009
Thiamethoxam	153719-23-4	Directive 2008/77/EC of 25 July 2008
Tolyfluanid	731-27-1	Directive 2009/151/EC of 27 November 2009