TRAINING MANUAL

THE ENVIRONMENTALLY SOUND MANAGEMENT AND DISPOSAL OF PERSISTENT ORGANIC POLLUTANTS (POPs)

Developed under the project 'GEF 5558 - Development and Implementation of a Sustainable Management Mechanism for POPs in the Caribbean'

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TRAINING MANUAL ON THE ENVIRONMENTALLY SOUND MANAGEMENT AND DISPOSAL OF PERSISTENT ORGANIC POLLUTANTS (POPs)

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Abbreviations and Acronyms

Abbreviation	Full name
ABS	Acrylonitrile-butadiene-styrene
ADN	European Agreement Concerning the International Carriage of Dangerous Goods by Inland Waterways
ADR	The European Agreement concerning the International Carriage of Dangerous Goods by Road
AFFF	Aqueous Film Forming Foam
alpha-HCH	Alpha-hexachlorocyclohexane
ASR	Auto Shredder Residue
BAT	Best Available Technologies
BCD	Base Catalyzed Decomposition
BCRC-Caribbean	Basel Caribbean Regional Centre for Training and Technology Transfer for the Caribbean
BEP	Best Environmental Practices
BFRs	Brominated Flame Retardants
BRS	Basel, Rotterdam, Stockholm Conventions
CD	Catalytic Dichlorination
c-decaBDE	Commercial Decabromodiphenyl ether
CHD	Catalytic Hydrodechlorination
c-OctaBDE	Commercial Octabromodiphenyl ether
COP	Conference of the Parties
c-pentaBDE	Commercial Pentabromodiphenyl ether
CRT	Cathode Ray Tubes
DDT	Dichlorodiphenyltrichloroethane
ECD	Electron Capture Detector
EEE	Electronic and Electrical Equipment
ELVs	End of Life Vehicles
EPA	Environmental Protection Agency
EPS	Expanded Polystyrene
ESM	Environmentally Sound Management
E-waste	Electronic Waste
FAO	Food and Agriculture Organization
GEF	Global Environment Facility
GEF 5558	Development and Implementation of a Sustainable Management Mechanism for POPs in the Caribbean
GEF SGP	GEF Small Grants Programme
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
GPCR	Gas Phase Chemical Reduction
HBB	Hexabromobiphenyl
HBCD	Hexabromocyclododecane
heptaBDEs	Heptabromodiphenyl ether

Abbreviation	Full name
hexaBDEs	Hexabromodiphenyl
HIPS	High Impact Polystyrene
HSE	Health, Safety and Environmental
ICAO	International Civil Aviation Organization
IMDG	International Maritime Dangerous Goods Code
LTTD	Low Temperature Thermal Desorption
MPPI	Mobile Phone Partnership Initiative
NIPs	National Implementation Plans
OECS	Organisation of Eastern Caribbean States
PACE	Partnership for Action on Computing Equipment
PBDEs	Tetra- and Penta-bromodiphenyl ether, Hexa-and Hepta-bromodiphenyl ether & Decabromodiphenyl ether - Polybromodiphenyl ethers
PCBs	Polychlorinated biphenyls
PCD	Photochemical Dichlorination
PCDD	Polychlorinated dibenzo-p-dioxins
PCDF	Polychlorinated dibenzo-p-furans
PCNs	Polychlorinated naphthalenes
PCP	Pentachlorophenol
PCTs	Polychlorinated terphenyls
pentaBDEs	Pentabromodiphenyl ether
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
PFOS-F	Perfluorooctane sulfonyl fluoride
pH	Potential of hydrogen
PIC	Prior Informed Consent
PMD	Plasma melting decomposition method
POPs	Persistent Organic Pollutants
PPE	Personal Protective Equipment
ppm	Parts Per Million
PUR	Polyurethane
RID	Regulation Concerning the International Carriage of Dangerous Goods by Rail
SCBA	Self-Contained Breathing Apparatus
SCCPs	Short-chain chlorinated paraffins
SCWO	Supercritical Water Oxidation
SDS	Safety Data Sheets
t-BuOk	Potassium tert-Butoxide
TEQ/kg	Toxic equivalency quotient per Kilogram
tetraBDEs	Tetrabromodiphenyl ether
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization

Abbreviation	Full name
UPOPS	Unintentional Persistent Organic Pollutants
USA	United States of America
UWI	University of the West Indies
UWI-ALJGSB	UWI Arthur Lok Jack Global School of Business
WEEE	Waste Electronic and Electrical Equipment
WHO	World Health Organization
XPS	Extruded Polystyrene

1 Background

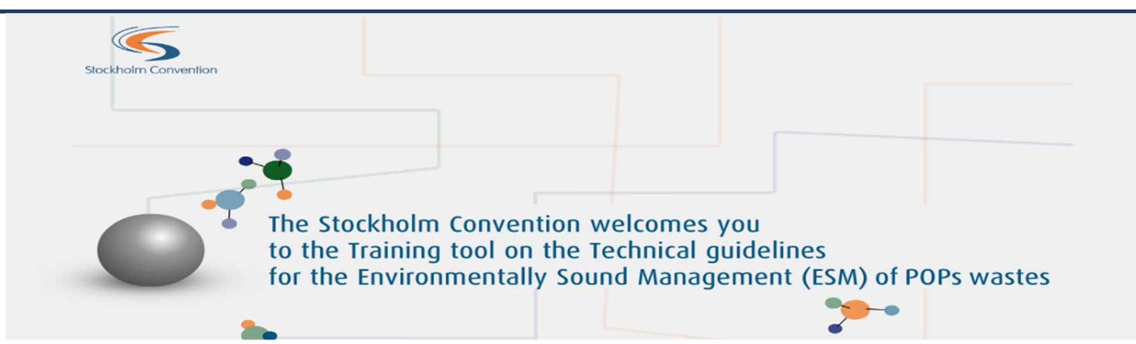
The UWI Arthur Lok Jack Global School of Business (UWI-ALJGSB) was commissioned by the Basel Caribbean Regional Centre for Training and Technology Transfer for the Caribbean (BCRC-Caribbean) to conduct a regional training needs assessment in eight (8) project countries, as part of the GEF 5558 project entitled *The Development and Implementation of a Sustainable Management Mechanism for Persistent Organic Pollutants (POPs) in the Caribbean*. The project countries are Antigua and Barbuda, Barbados, Belize, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname and Trinidad and Tobago. The findings of the training needs assessment informed the development of the requisite training on five (5) prioritised thematic areas. This training manual is specific to the **Environmentally Sound Management (ESM) and Disposal of POPs**, which is aimed at building the capacity within the respective countries to store, handle and dispose of POPs in accordance with the Best Available Technologies (BAT) and Best Environmental Practices (BEP).

The primary objectives of this Training Manual are:

1. To improve the background knowledge of the POPs currently listed under the Stockholm Convention and the main potential sources of POPs in the Caribbean.
2. To outline the legal international framework which may be considered for the cross jurisdictional cooperation in the handling, management and disposal of POPs.
3. To provide a broad knowledge base on the handling, management and disposal of wastes generated from or contaminated with POPs.
4. To enable countries with the capacity to coordinate initiatives to implement the BAT/BEP practices and systems for the environmentally sound management (ESM), including labelling, storage, packaging, handling and transport of POPs.
5. To raise awareness of existing technologies for the destruction of articles containing or contaminated with POPs.

1.1 The Stockholm Convention Training Tool on the Technical Guidelines for the Environmentally Sound Management (ESM) of Persistent Organic Pollutants (POPs) wastes

In addition to this regional manual, a key tool for the ESM and safe disposal of POPs is the "Stockholm Convention (SC) Training Tool on the Technical Guidelines for the Environmentally Sound Management (ESM) of Persistent Organic Pollutants (POPs) wastes".



The SC's Electronic Training Tool and can be accessed at:
http://chm.pops.int/Portals/0/flash/popswastetrainingtool/eng/index.html

2 Introduction to Persistent Organic Pollutants (POPs) and the Legal Framework

2.1 Persistent Organic Pollutants (POPs)

Persistent Organic Pollutants (POPs) are synthetic (man-made), organic, carbon-based chemical substances that possess a combination of physical and chemical properties once released into the environment[1].

POPs can adversely affect the environment and studies have linked POPs exposures to decline in populations, diseases, or abnormalities in a number of wildlife species, including certain species of fish, birds, and mammals (USEPA, 2020). Additionally, exposure to humans can lead to increased cancer risk, reproductive disorders, alteration of the immune system, neuro-behavioural impairment, endocrine disruption, genotoxicity and increased birth defects[2].

In a 2015 study, a total of 438 samples of human blood and urine samples were analysed from 10 Caribbean countries. POPs were detected in almost all samples[3]; however, these were generally low when compared with North American results. This study clearly indicated that there is prenatal exposure to harmful toxins and chemicals in the Caribbean.

The key characteristics of POPs:

Persistent **–** they remain intact for exceptionally long periods of time (many years);

Long-range transport **-** they become widely distributed throughout the environment as a result of natural processes (in soil, water and/or air);

Bioaccumulate **-** accumulate in the fatty tissue of living organisms including humans, and biomagnify are found at higher concentrations at higher levels in the food chain. This is mainly due to their lipophilic properties (tendency to remain in fat-rich tissues); and

Highly Toxic **–** they have acute and high-level toxicity.

2.2 The Stockholm Convention on Persistent Organic Pollutants

The Stockholm Convention targets chemicals listed as POPs under three Annexes[1]:

- **Annex A (Elimination)** - Parties must take measures to eliminate the production and use of the chemicals listed under Annex A. Specific exemptions for use or production are listed in the Annex and apply only to Parties that register for them.
- **Annex B (Restriction)** - Parties must take measures to restrict the production and use of the chemicals listed under Annex B in light of any applicable acceptable purposes and/or specific exemptions listed in the Annex.

[1] The Stockholm Convention on POPs - http://chm.pops.int/TheConvention/ThePOPs/tabid/673/Default.aspx
[2] The World Health Organisation - https://www.who.int/foodsafety/areas_work/chemical-risks/pops/en/
[3] Forde,M.S. and Dewailly, E. 'What Is in the Caribbean Baby? Assessing Prenatal Exposures and Potential Health Outcomes to Environmental Contaminants in 10 Caribbean Countries. West Indian Medical Journal, Vol 64, Issue 1: Jan (2015). DOI: 10.7727/wimj.2015.112

- **Annex C (Unintentional production)** - Parties must take measures to reduce the unintentional releases of chemicals listed under Annex C with the goal of continuing minimization and, where feasible, ultimate elimination.

2.3 POPs Sources and Categories

The three (3) main categories of POPs sources can be grouped as follows:

- **POP-Pesticides** - A pesticide is any substance or mixture of substances intended for preventing, destroying or controlling any pest. POP Pesticides originate almost entirely from anthropogenic sources and are associated largely with the manufacture, use and disposal of certain organic chemicals[4]. POP-Pesticides currently listed by the Stockholm Convention include: Aldrin, Chlordane, Chlordecone, DDT, Toxaphene, Dicofol, Dieldrin, Endrin, Heptachlor, Hexachlorobenzene[5], Mirex, Alpha-hexachlorocyclohexane (alpha-HCH), Beta-hexachlorocyclohexane (beta-HCH), Lindane, Pentachlorobenzene[5], Pentachlorophenol (PCP) and Endosulfan. Some pesticides are also applicable to the industrial chemicals as well as unintentional POPs.

- **Industrial chemicals** - The Industrial Chemicals listed under the Stockholm Convention are: Polychlorinated biphenyls (PCBs)[6]; Polychlorinated naphthalenes (PCNs)[6]; Short-chain chlorinated paraffins (SCCPs); Hexachlorobutadine[6]; Brominated Flame Retardants (Hexabromobiphenyl (HBB), Tetra-and penta-bromodiphenyl ether, Hexa-and hepta-bromodiphenyl ether & Decabromodiphenyl ether (PBDEs), Hexabromocyclododecane (HBCD)); and Fluorinated Surfactants (Perfluorooctane sulfonic acid and its salts (PFOS /Sulfluramide and PFOS-F)[7] and Perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds).

- **UPOPS unintended industrial by-products** - The Unintentional POPs listed under the Stockholm Convention are: Polychlorinated dibenzo-p-dioxins (PCDD) and dibenzo-p-furans (PCDF). Dioxins and Furans, as they are commonly known, are formed during the burning of organic materials such as garbage, or fossil fuels such as coal, oil and natural gas. Processes that can create dioxins and furans include the manufacture of pesticides and wood preservatives, and chlorine bleaching in the wood pulp and paper industry.

A summary of the potential sources and uses of POPs and UPOPs (Unintentional Produced POPs) from each category is provided in Annex A of this manual and additional information on POPs in the Caribbean context can be accessed in the ***Regional manual for POPs inventory development for NIPs update in the Caribbean***[8].

[4] SC's Guidance on Guidance for POP pesticides - http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-NIP-GUID-Pesticides.En.pdf
[5] Also relevant under Industrial chemicals and UPOPs
[6] Also relevant under UPOPs
[7] Also relevant under Pesticides
[8] Regional manual for POPs inventory development for NIPs update in the Caribbean, Basel Convention Regional Centre for Training and Technology Transfer for the Caribbean, 2017.

2.4 Status of POPs in the Caribbean

The summary of the current status of POPs in the Caribbean is based on the 2016 National Inventory Reports for each of the eight (8) project countries[9]. Detailed inventories on Dicofol, Short-chain chlorinated paraffins; Decabromodiphenyl ether and Perfluorooctanoic acid, have not yet been conducted in the region.

2.4.1 POP-Pesticides

Most POP-pesticides have been prohibited for use and sale throughout the eight (8) countries assessed in this study with few exemptions in certain countries. While there may have been historic use of these products, there is no/limited use of these pesticides at present. Control on the use of these pesticides has been ongoing through the existing Pesticides and Chemical Control Boards in the respective jurisdictions. However, there is inadequate data collection or enforcement on the life cycle and residual effects of pesticides.

Based on 2016 inventories, Belize, Saint Kitts and Nevis and Trinidad and Tobago have recorded use of some POP pesticides, specifically DDT and Mirex (Mirex-S/Sulfuramide). In Belize, there is limited use of DDT as a pesticide in the fight against Malaria. In Saint Kitts and Nevis and Trinidad and Tobago, Mirex was previously used in the agriculture sector against leaf-cutting ants and fire ants. Mirex has an import exemption but the chemical is not registered for use and the actual quantities used in the country is unknown.

Figure 1: Existing Hazardous Waste Storage Assessment Photos (*RWA, 2020*)

[9] https://www.bcrc-caribbean.org/information-dissemination/

2.4.2 Industrial Chemicals

2.4.2.1 Polychlorinated biphenyl (PCBs)

The main concern surrounding PCBs in the Caribbean include its use as a dielectric fluid in transformers, capacitors, tanks, breakers, and switches. Inventories of stored PCB contaminated equipment/materials for disposal was conducted in 2016 for six (6) of the eight (8) project countries, Antigua and Barbuda, Barbados, Saint Kitts and Nevis, Saint Lucia, Suriname and Trinidad and Tobago. At the time of the rapid inventory, the other two (2) countries, Belize and Saint Vincent and the Grenadines, indicated that the PCB contaminated equipment/materials were already identified and disposed. The main types of equipment assessed were power generation and heavy-duty equipment such as transformers, capacitors, tanks, beakers, switches, motor starters, cables, ballasts, fluorescent tubes, drums of used oil and electrical insulating fluids. PCB-containing and PCB-contaminated equipment and oil (over a 40mg/kg threshold) was found in Antigua and Barbuda (3 transformers), Suriname (2 power transformers and 1 tank) and Trinidad and Tobago (1 transformer). All equipment assessed in Barbados, Saint Lucia and Saint Vincent and the Grenadines were within allowable limits or PCB free. Equipment identified as PCB contaminated under this exercise was tagged for disposal under a separate regional FAO initiative[10] and detailed studies which will inform management and disposal plans are ongoing under the GEF 5558 project in Antigua and Barbuda, Belize, Saint Lucia and Suriname.

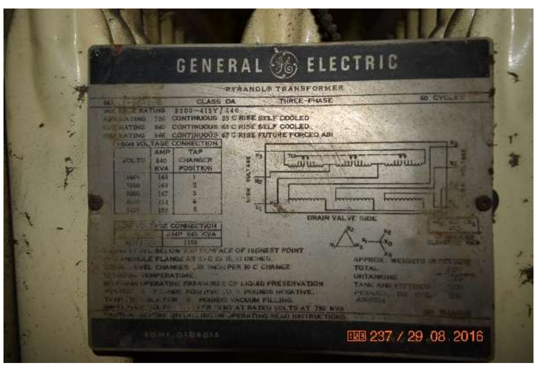


Figure 2: PYRANOL (A50P524) oil power transformer *(BCRC-Caribbean, 2016)*

Figure 3: Sampling of a pole-mounted transformer *(BCRC-Caribbean, 2016)*

Figure 4: Oil-filled cables *(BCRC-Caribbean, 2016)*

Figure 5: Sampling of a PCB oil storage drum *(BCRC-Caribbean, 2019)*

[10] http://www.fao.org/gef/projects/detail/en/c/1056800/

2.4.2.2 Brominated Flame Retardants (Hexabromobiphenyl (HBB), Tetra-and penta-bromodiphenyl ether, Hexa-and hepta-bromodiphenyl ether & Decabromodiphenyl ether (PBDEs), Hexabromocyclododecane (HBCD))

Tetrabromodiphenyl ether, pentabromodiphenyl ether, hexabromodiphenyl ether and heptabromodiphenyl ether (POP-PBDEs) contained in commercial PentaBDE and OctaBDE are listed as the first brominated flame retardants under the SC. The concerns with the brominated flame retardants in the Caribbean were found to mainly involve its presence in Electronic and Electrical Equipment (EEE), Waste EEE (WEEE) and End of Life Vehicles (ELV). The concern with other products (such as carpets, textiles, construction material and food and beverage containers) could not be determined to a great extent due to the limited testing capability and insufficient labelling realised during the 2016 inventories.

With respect to the EEE and WEEE, the concern was mainly with the Cathode Ray Tubes (CRT) monitors in older models of televisions and computers. Estimations of total impacted polymer in the imported, in-use (households, government institutions and businesses) and WEEE could not be established in most countries due to limited data records at the Customs and Excise agencies, limited responses and access to information during the inventory process. However, the overarching issue with this group of chemicals surrounded the improper disposal of contaminated equipment that remain in the general/domestic waste streams and contribute directly or indirectly to environmental contamination and human health implications. Based on the findings of the inventories, import of CRT computer monitors was only prevalent in Saint Lucia and the lack of WEEE management was a recognised issue in Suriname. The c-OctaBDE chemical was most prevalent in CRT TV's in households across the majority of countries but most notably in Trinidad and Tobago, while Saint Vincent and the Grenadines recorded the highest quantity of c-OctaBDE in CRT monitors and TVs in government institutions. Barbados and Saint Kitts and Nevis recorded the highest quantity of c-OctaBDE of CRT monitors and TVs in the waste stream and Belize and Saint Vincent and the Grenadines were the only two countries reporting the presence of c-OctaBDE in CRT monitors and TVs in the private sector.

With respect to ELVs, estimations of the polyurethane (PUR) foams and POP-PBDEs polymers (plastic, foam and synthetics like textiles) in cars (historical imports and vehicles in use) indicated higher levels in Belize followed by notable quantities in Suriname and Saint Vincent and the Grenadines. Estimates could not be derived for Antigua and Barbuda and Trinidad and Tobago due to insufficient data.

Figure 6: WEEE at a regional landfill
(BCRC-Caribbean, 2019)

Figure 7: ELVs at a regional landfill
(BCRC-Caribbean, 2019)

2.4.2.3 Perfluorooctane sulfonic acid and its salts (PFOS /Sulfluramide and PFOS-F)

For the Caribbean region, the former and current relevant use of PFOS and related chemicals is most likely, specific to firefighting foams. Other possible uses in the region are for pesticide use (sulfluramide), for oil drilling and plating industry, as aviation hydraulic fluids on oil drilling operations, stocks in consumer articles. Based on an inventory stockpile assessment of firefighting foams in the eight (8) countries, PFOS was found and/or used mainly in the firefighting industry with a focus on combatting hydrocarbon fires. Stockpiles of PFOS containing firefighting foams currently exist in several countries such as Suriname, Saint Lucia, Saint Vincent and the Grenadines and Antigua and Barbuda. PFOS has been historically used at several firefighting training facilities in the region (Saint Lucia, Saint Kitts and Nevis) and there are existing stocks of firefighting foam where the content of PFOS could not be determined (Belize, Saint Kitts and Nevis, and Trinidad and Tobago) due to lack of proper labelling, records and data sheets. Meanwhile, the majority of foams in Barbados were found to be PFOS-free.

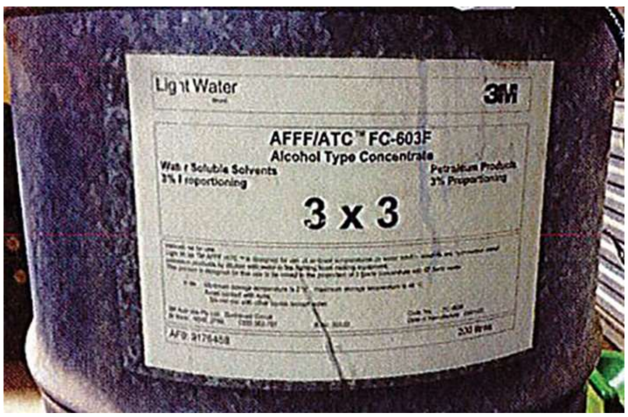


Figure 8: PFOS containing firefighting foams ***(CARPHA, 2018)***

Figure 9: A firefighting training facility ***(CARPHA, 2018)***

2.4.3 UPOPs

The chemicals listed in Annex C of the Stockholm Convention as UPOPs include polychlorinated dibenzo-p-dioxins (PCDD/Dioxins), polychlorinated dibenzofurans (PCDF/Furans), polychlorinated biphenyls (PCB) and hexachlorobenzene (HCB). These chemicals are semi-volatile compounds that undergo a series of evaporations and condensations in the environment, making them mobile. Dioxins and Furans are most relevant to the region and estimations for the project countries showed higher levels of emissions in the larger and more industrialised countries such as Suriname, Belize, Barbados, and Trinidad and Tobago while the levels in the other countries were negligible. The majority of the UPOPs emissions were to the air as opposed to emissions to water, soil or residual generation. The main sources of UPOPs in the 2016 inventories included:

- Open burning of waste (domestic waste, sugarcane fields and spontaneous fires at landfills);
- Waste disposal to landfills/ Waste incineration (municipal and medical);
- Metal smelting/Chlorine production;
- Thermal wire reclamation and e-waste recycling (open burning of cables);
- Chlorinated chemicals/products production;
- Petroleum refining.

	
Figure 10: Landfill fire ***(BCRC-Caribbean, 2019)***	**Figure 11: Backyard Burning** ***(BCRC-Caribbean, 2020)***

2.5 The International Framework for the Environmental Sound Management of POPs

The Basel, Rotterdam, Stockholm (BRS) Conventions are the multilateral environmental agreements that address the protection of human health and the environment from hazardous chemicals and wastes including POPs. The Basel, Rotterdam and Stockholm conventions specify the conditions under which POPs, hazardous wastes, hazardous chemicals and pesticides are to be managed and traded internationally.

Learn more about the BRS Conventions at http://www.brsmeas.org/

2.5.1 The Stockholm Convention

As explained in Section 1.2, the Stockholm Convention prohibits the production and use of the POPs listed in the Convention and restricts their trade across international boundaries.

As outlined in Section 2.2, the main provisions of the convention include[11]:

Learn more about the Stockholm Convention at http://chm.pops.int/

- Prohibit and/or eliminate the production and use, as well as the import and export (Annex A);
- Restrict the production and use, as well as the import and export (Annex B);
- Reduce or eliminate releases from unintentionally produced POPs (Annex C);
- ESM of stockpiles and wastes consisting of, containing or contaminated with POPs;
- Support the transition to safer alternatives and targeting additional POPs for action.

Specific to the ESM and disposal of POPs, **Article 6** of this Convention, requires that stockpiles and wastes consisting of, containing or contaminated with POPs are managed safely and in an environmentally sound manner. The Convention requires that such stockpiles and wastes be identified

[11] The Stockholm Convention website - http://chm.pops.int

and managed to reduce or eliminate POPs releases from these sources. **The Convention also requires that Parties take appropriate measures so that wastes containing POPs are transported across international boundaries considering relevant international rules, standards, and guidelines. These include the relevant provisions in existing international prior informed consent (PIC) instruments (Article 3 paragraph 1 (b)), for instance the PIC procedures provided by the Basel and the Rotterdam Conventions.**

2.5.2 The Basel Convention

The Basel Convention addresses the Control of Transboundary Movements of Hazardous Wastes and their Disposal[12]. **Several types of POPs wastes are listed as wastes in Annexes I and VIII of the Basel Convention text**. As such the Basel Convention addresses the ESM and Disposal of POPs and POPs wastes. The improper treatment or disposal of a waste consisting of, containing or contaminated with POPs can lead to releases of POPs into the environment and some disposal technologies have the potential to lead to the unintentional formation and release of POPs. Additionally, **Article 6, paragraph 2 of the Stockholm Convention mandates its Parties to cooperate closely with the appropriate bodies of the Basel Convention on common issues of relevance.**

The Basel Convention defines "***environmentally sound management***" of wastes subject to its control as taking all practicable steps to ensure that these wastes are managed in a manner which will protect human health and the environment.

The Basel Convention has since developed technical guidelines for the environmentally sound management of the wastes falling under its scope including guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs)[13].

Under the Basel Convention, a Party is not allowed to import hazardous wastes from a non-Party, unless a specific agreement is concluded[14]. In a similar way, imports and exports of POPs are allowed only for the purpose of environmentally sound disposal or for a use which is permitted by the importing State. Other requirements for trade to be considered "legal" may be imposed by other international treaties as well as by the national legal framework of a country. Such requirements must therefore also be contended with in order to determine whether a particular shipment is legal. **Of particular concern to the ESM and Disposal of POPs is the Prior Informed Consent procedures (PIC)** under the Basel Convention which specifies the procedures that need to be followed for each transboundary movement of hazardous or other wastes that takes place. These conditions and procedures aim at ensuring, *inter alia*, that there is adequate information exchange among concerned States and that shipments are willingly received by an importing State with the actual capacity to manage them safely.

Learn more about the Basel Convention at http://www.basel.int/

[12] The Basel Convention - http://www.basel.int
[13] The Basel Convention Technical Guidance - http://www.basel.int/Implementation/POPsWastes/TechnicalGuidelines/tabid/5052/Default.aspx
[14] Basel Rules From Start to Finish- http://www.basel.int/Portals/4/Basel%20Convention/docs/legalmatters/illegtraffic/trman-e.pdf

2.5.3 The Rotterdam Convention

The Rotterdam Convention on the Prior Informed Consent Procedure for certain hazardous Chemicals and Pesticides in International Trade[15] provides Parties with a first line of defence against hazardous chemicals. The Convention covers pesticides and industrial chemicals that have been banned or severely restricted for health or environmental reasons by Parties and which have been notified by Parties for inclusion. It promotes international efforts to protect human health and the environment as well as enabling countries to decide if they want to import hazardous chemicals and pesticides listed in the Convention. The ESM and disposal of most intentionally produced POPs and POPs waste are subject to the provisions of the Rotterdam Convention. As such, once it is established that a POP of concern is listed in Annex III of the Rotterdam Convention, Parties interested in importing or exporting the POPs or POPs waste are required to consult with the existing respective import decisions under the PIC procedure. In addition, an exporting Party, when exporting chemicals that are to be used for occupational purposes must:

a) Ensure that an up-to-date safety data sheet is sent to the importer; and
b) That labelling requirements for exports of chemicals are included in the PIC procedure.

Learn more about the Rotterdam Convention at http://www.pic.int/

[15] The Rotterdam Convention - http://www.pic.int/

3 Environmentally sound management of wastes consisting of, containing or contaminated with the POP-Pesticides

3.1 Waste consisting of, containing or contaminated with the POP-Pesticides

The main potential sources of pesticide wastes addressed in this section are:

- Stockpiles of obsolete pesticides;
- Contaminated equipment such as shelves, spray pumps, hoses, personal protective materials and storage tanks;
- Contaminated packaging materials such as drums, bags and bottles;
- Buried pesticides;
- Contaminated soil/ sewage sludge;
- Contaminated sediment (marine and freshwater);
- Contaminated building materials; and
- Stockpiles of production wastes (such as in the case of lindane where its production created large amounts of waste containing other isomers of HCH including the alpha and beta isomers).

This section is concerned with POP-Pesticides listed under the SC[16] and the associated waste generated and is primarily based on the ***Basel technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with the pesticides aldrin, alpha hexachlorocyclohexane, beta hexachlorocyclohexane, chlordane, chlordecone, dieldrin, endrin, heptachlor, hexachlorobenzene, hexachlorobutadiene, lindane, mirex, pentachlorobenzene, pentachlorophenol and its salts, perfluorooctane sulfonic acid, technical endosulfan and its related isomers or toxaphene or with hexachlorobenzene as an industrial chemical***[17], Revised final version of 5 May 2017.

In accordance with Annexes A and B of the Stockholm Convention, with few specific exemptions for use or production and acceptable purposes, Parties should aim to eliminate and/or restrict the production and use of the listed pesticides. As such, the development of waste management plans for obsolete POP-pesticides and the associated waste should be actioned.

Toolkit for the sound management of DDT for disease vector control[18]

- DDT is currently listed in Annex B of the Stockholm Convention with its production and/or use restricted for disease vector control purposes in accordance with related World Health Organization (WHO) recommendations and guidelines.
- The DDT Toolkit provides the information and resources regarding the life-cycle management of DDT and other vector control insecticides within the context of chemicals and waste Conventions.

[16] http://www.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx
[17] http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.13-6-Add.6-Rev.1.English.pdf
[18] http://www.pops.int/Implementation/PesticidePOPs/DDT/DDTToolkit/tabid/5080/Default.aspx

3.2 Identification of POP-pesticides

In order to properly manage materials, it may be necessary to identify (including sample and analyse for) pesticides and pesticide-related wastes which may include:

- Liquids: Liquid pesticide formulations; Leachates from burials and landfills; and Biological fluids (blood, in the case of worker health monitoring);
- Solids: Solid pesticide formulations and pesticide production wastes; soils, sediments and municipal and industrial sludges; packaging; and building materials.

Additional information on the Inventory of pesticides can be accessed in the ***Regional Manual on POPs Inventory Development for National Implementation Plans (NIPs) Update in the Caribbean***[8] or the ***FAO's Training Manual for inventory taking of Obsolete Pesticides***[19]and additional information on the sampling and analysis of POP-Pesticides can be accessed in the ***Introductory Manual for Caribbean Countries - Sampling and Analytical Methods for the Determination of POPs***[20].

Note: Most pesticides can be analysed using capillary gas chromatography (two columns of different polarity) coupled to an electron capture detector (ECD).

3.3 Handling

POP pesticides, including stocks in use and obsolete stocks, should be handled separately from other chemicals or waste types in order to prevent cross contamination. Recommended practices for handling these include:

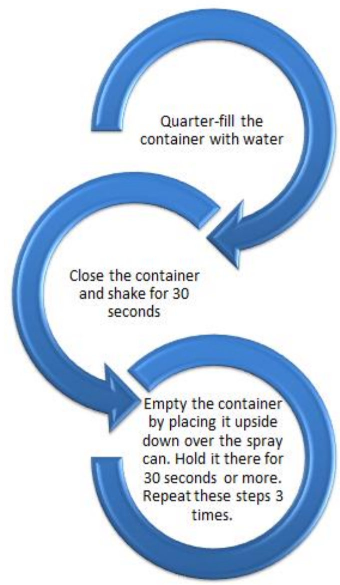
- Ensure proper PPE is used. This includes eye and ear protection, chemical-resistant gloves, and where indicated, respirators, when a potential hazard is present.
- Inspect containers for leaks, holes, rust, high temperature (which may result in chemical reactions), and appropriately repackage if necessary.
- Handle at temperatures below 25ºC, this is due to increased volatility at higher temperatures.
- Install and maintain adequate spill containment measures to mitigate against spillage of liquid waste.
- Place plastic sheeting or absorbent mats under containers before opening them if the surface of the containment area is not coated with a smooth surface material (paint, polymers or polymeric resin).
- Remove liquid wastes either by (i) removing the drain plug or (ii) by pumping using a peristaltic pump (safeguarded against ignition and fire risks). *Note: Use suitable chemical-resistant tubing*.

TIPS TO REDUCE PESTICIDES CONTAMINATION:

- Stabilization of the site: leaking pesticides should be segregated and repacked;
- Reduction of the number of storage sites, repackaging of pesticide POPs and safe storage at a limited number of centralized storage sites.

[19]http://www.pops.int/Portals/0/Repository/TechAss1/FAO%20training%20manual%20for%20inventory%20of%20obsolete%20pesticides.pdf
[20] Introductory Manual for Caribbean Countries - Sampling and Analytical Methods for the Determination of POPs, BCRC-Caribbean, 2019

- Use dedicated pumps, tubing and drums to transfer liquid wastes.
- Clean up spills with cloths, paper towels or specific absorbent materials.
- Triple rinse contaminated packaging materials (such as metal drums) with a solvent to remove all residual POP-pesticides and puncture so that the rinsed containers cannot be recycled.
- Treat all solvents, contaminated absorbent materials from triple rinsing, contaminated disposable protective equipment and plastic sheeting as pesticide wastes.



See more on 'How to Triple Rinse?' at Croplife LatinAmerica https://youtu.be/HAWbSIh0ZFI

Note: Additional Details can be accessed from the ***FAO's Environmental Management Tool Kit for Obsolete Pesticides***[21]

3.4 Collection

Due to the nature of pesticide storage, it is likely that obsolete stocks will be in located at multiple sites in small quantities. As such, consolidation may be necessary for disposal to be economically feasible. Consideration needs to be given to:

- POP pesticides collection depots and collection activities should be managed according to appropriate guidelines and, if necessary, separately from those for all other wastes. Consideration much be given to the use of appropriate PPE. Receptacles should be designated for pesticide container storage only and designed secure containment within the receptacle.
- It is imperative that collection depots do not become long-term storage facilities for pesticide POPs wastes.

Initiatives on the Empty Pesticide Container Management

Croplife International - Roadmap for establishing a container management program for collection and disposal of empty pesticide containers[22] and Croplife International and GEF SGP 'A pilot project to study the feasibility of a national empty pesticide container management programme was initiated by CropLife (Mauritius), as part of its product stewardship framework'[23].

[21] http://www.fao.org/3/a-i0474e.html
[22] https://croplife.org/wp-content/uploads/2015/11/Roadmap-for-establishing-a-container-management-program_final_Sept.pdf
[23] https://sgp.undp.org/all-documents/country-documents/961-empty-pesticide-container-management-pilot-project/file.html

3.5 Packaging and repackaging

Wastes consisting of, containing or contaminated with POP-pesticides should be properly packaged before storage or transport:

- Place liquid wastes in double-bung steel drums or other approved containers.
- Place large amounts of wastes or equipment consisting of, containing or contaminated with POP pesticide inside large containers (overpack drums) or heavy plastic wrap if leakage is a concern.
- Place small pieces of equipment (whether drained or not) should be in drums with an absorbent material. Numerous small pieces of equipment may be placed in the same drum so long as an adequate amount of absorbent material is present in the drum. Loose absorbents may include sawdust, vermiculite or peat moss. The quantity of absorbent material should be determined based on the characteristics and relevant instructions.
- **Repackaging should be carried out in such a way that different types of hazards represented by the chemicals are not mixed.** Repackaged pesticide POPs wastes should be fixed with wooden structures and/or straps in sea containers before shipping.
- Adequate precautions should be taken to ensure that pesticide containers cannot be used for other purposes, particularly the storage of food or water for human or animal consumption (see also triple rinsing where the puncturing of used containers is recommended).

NOTE: *Prior to repackaging, certificates for the UN code for each type of container used should be requested from the contractor responsible for safeguarding. In the event that no UN codes are visible on new packaging materials, the materials should be considered as not having been approved by the United Nations. Some UN codes normally used on packaging materials for pesticide POPs include:*

- *UN1H1/….. for polyethylene drums for liquid wastes (closed top)*
- *UN1H2/….. for polyethylene drums for solid wastes (open top)*
- *UN1A1/….. for steel drums for liquid wastes (closed top)*
- *UN1A2/….. for steel drums for solid wastes (open top)*

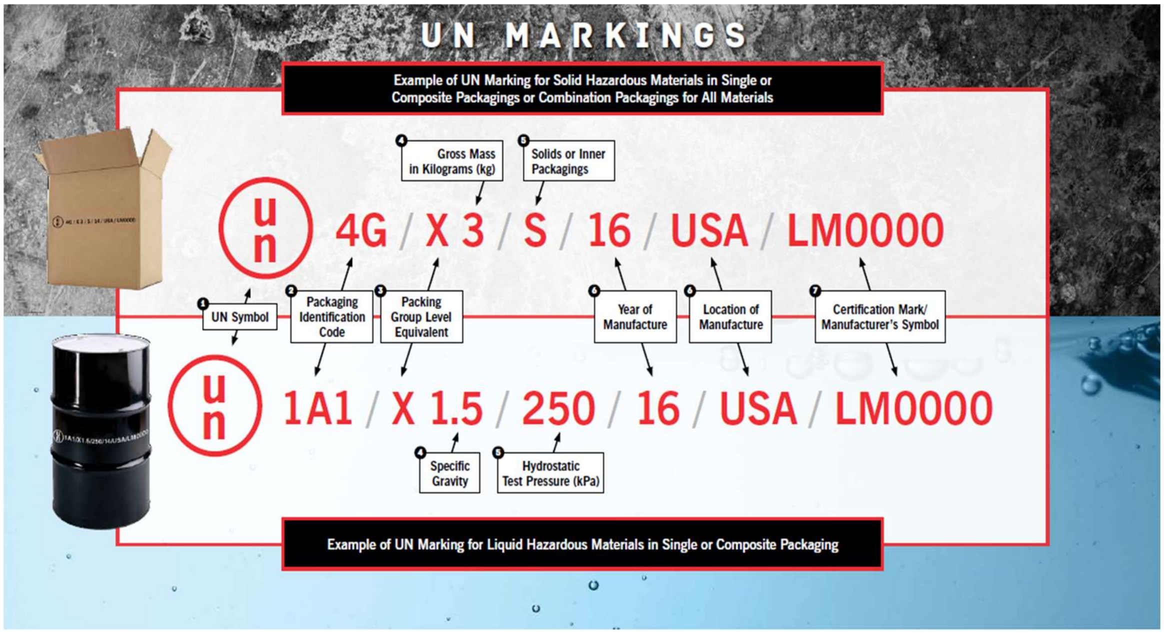


Figure 12: Example of Approved containers: UN Markings Guide ***(Labelmaster, n.d.)***

3.6 Labelling

Clearly label **all** containers/vehicles/vessels containing POP-pesticides with (i) a hazard warning label **and** (ii) a label which gives the details of the container and a serial number. The details should include:

- the exact counts of volume and weight of the contents,
- the type of waste,
- the trade name,
- the name of the active ingredient (including percentage),
- the name of the original manufacturer,
- the name of the site from which it originated to allow traceability,
- the date of repackaging and the name and telephone number of the responsible person during the repackaging operation.

NOTE: It is generally expected that the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) will be adopted for pesticides. More specifically, the UN GHS Document (known as ***UN GHS Purple Book***)[24]:

- Defines physical, health and environmental hazards of chemicals and harmonizes classification criteria;
- Standardizes the content and format of chemical labels and Safety Data Sheets.

Additional guidance on the labelling of Pesticides can be accessed in the '***Guidelines on Good Labelling Practice for Pesticides***'[25].

[24] http://www.unece.org/trans/danger/publi/ghs/ghs_rev07/07files_e0.html

Figure 13: Commonly Used GHS Pictograms on Pesticides Labels
(ChemSafetyPRO, 2019)

The Food and Agriculture Organization (FAO) promotes the implementation of the GHS in the field of pesticides. Several of its guidelines have been revised and include recommendations and guidance for classification and labelling of pesticides in accordance with GHS criteria. These include:

- FAO Guidelines for the Registration of Pesticides (2010),
- FAO Guidelines on Good Labelling Practice for Pesticides (2015),
- FAO Guidelines on Highly Hazardous Pesticides (2016).

3.7 Storage

In general, POP pesticides waste should be stored as hazardous waste. The FAO guidelines for pesticide storage and stock control and for the design and structure of pesticide stores provides more details[26]. These guidelines are summarised below:

- Choice of site –
    - Avoid storage near dwellings or to hospitals, schools, shops, food markets, animal feed depots and general stores;
    - Avoid storage near water courses, wells and other supplies of water for domestic and stock animal use;
    - Avoid storage near high groundwater levels;
    - Ensure that the building is easily accessible for vehicles, including for fire-fighting vehicles and equipment in case of emergency;
    - Avoid storage near environmentally sensitive or protected areas.

- Design and structure of buildings –
    - Ensure that the building is large enough to accommodate up to an additional 15% of the pesticide than currently stored. Consider the need for spill containment and drainage in order to prevent contamination of surrounding areas.
    - Ensure that the building is well ventilated.
    - Ensure that the building floors are smooth and impermeable concrete to avoid absorption of spillages and to allow easy cleaning.
    - The storekeeper's office should be separate from the storage area.
    - Provide washing facilities and stored protective clothing separately from pesticides.
    - Do not comingle herbicides insecticides or other pesticides such as rodenticides and fungicides. Follow a **Chemical Segregation Chart**[27] to prevent mixing incompatible chemicals.

[25] http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Code/Old_guidelines/label.pdf
[26] http://www.fao.org/3/v8966e/v8966e00.htm

- Notices
    - Display a notice of ‘Hazardous chemicals’ on the outside of the store in the local language(s).
    - Place signs in visually obvious places on the inside and outside of pesticide stores. These should read: "No smoking: no naked or half-dressed flame".

3.8 Transport

- Consider local regulatory transport requirements for storage containers (for current or future). In the absence of local regulations consider the international regulations or guidelines provided in **Table 1** below.
- Drums and equipment may be placed on pallets for movement by forklift truck and for storage. Strap drums and equipment to the pallets before they are moved. Waste packages and consignments must be handled in a manner which prevents damage during processing, loading and transportation and must conform to the national and international requirements of the relevant legislation.

Table 1: International Regulations for the Transport of Hazardous Materials[28]

Mode of Transport	Relevant Guideline or Regulation
Air	The Convention on International Civil Aviation, Annex 18 (The Safe Transport of Dangerous Goods by Air) (ICAO)
Road	European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR)
Rail	Regulation Concerning the International Carriage of Dangerous Goods by Rail (RID)
Sea	International Maritime Dangerous Goods Code (IMDG)
Inland sea	European Agreement Concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN)

[27] https://ehs.ucr.edu/sites/g/files/rcwecm1061/files/2020-07/Chemical-Segregation-Guidance-Sheet-Final.pdf
[28] "UN Recommendations on the Transport of Dangerous Goods. Model Regulations Accessed at: http://www.unece.org/?id=3598

3.9 Environmentally Sound Disposal of POP Pesticides

3.9.1 Pre-treatment

When faced with the disposal of POP pesticides, consideration should be given to the need for pre-treatment prior to final disposal. Pre-treatment options relevant to POP pesticides waste include:

- Volume reduction: This is relevant to low density wastes or containers with large void spaces. These can be reduced by crushing contaminated steel drums, emptying, and cutting or shredding plastic containers (where the same type of pesticide can be consolidated).
- Low temperature thermal desorption (LTTD): This is relevant to contaminated soils marked for disposal at treatment/destruction facilities that are far away from the point of origin. The condensed and repackaged volatilised pesticides are better suited for long haul transportation to a destruction facility.
- Solvent washing: This is relevant to the decontamination of empty containers through triple rinsing. The contaminated solvents can be recycled through distillation and further used in the decontamination of other POP pesticides wastes and other pesticide wastes.
- Blending with activated carbon or other adsorbent: This is relevant to the odour control of the waste.

Subsection IV.G.1 of the General technical guidelines[29] provides further information on pre-treatment.

3.9.2 Destruction and irreversible transformation methods

Available technologies for the destruction and irreversible transformation of POP Pesticides wastes outlined in the ***General technical guidelines***[29] include:

- Alkali metal reduction (relevant to Chlordane and HCH only),
- Base catalyzed decomposition (BCD),
- Cement kiln co-incineration,
- Gas phase chemical reduction (GPCR),
- Hazardous waste incineration,
- Plasma arc (relevant to chlordane, chlordecone, DDT, endosulfan and heptaclor), and
- Supercritical water oxidation (SCWO).

Details on these disposal technologies can be obtained in Chapter 8.

[29] General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants: http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.13-6-Add.1-Rev.1.English.pdf

Figure 1: Pesticide store and repacking in Romanian PHARE project (Source: John Vijgen, IHPA [5])

Figure 14: Snapshot from the case study on management and disposal of obsolete pesticide stock in Romania and the Republic of Moldova.

(Păun, et al., 2014)

4 Environmentally Sound Management of Wastes Consisting of PCB Contaminated Liquids and Equipment Containing PCBs

4.1 PCB contaminated liquids, equipment and waste

The main potential sources of PCBs and PCB wastes addressed in this section are:

- Equipment - capacitors, circuit breakers, electrical cables, electric motors, electromagnets, heat transfer equipment, hydraulic equipment, switches, transformers, vacuum pumps, voltage regulators);
- Solvents contaminated with PCBs;
- Oils consisting of, containing or contaminated with PCBs (dielectric fluids, heat transfer fluids, hydraulic fluids, motor oil);
- Electrical cables isolated by polymers containing or contaminated with PCBs;
- Soils and sediments, rock and aggregates (e.g., excavated bedrock, gravel, rubble) contaminated with PCBs;
- Sludge contaminated with PCBs;
- Containers and absorbent materials contaminated through the handling, packaging, transportation or storage of PCB wastes.

This section of this manual is developed mainly based on ***the Basel Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with PCBs, PCTs, PCNs or PBBs, including HBB (adopted by COP.13, May 2017)***[30]**.** Similar management procedures exist for PCTs, PCNs or PBBs, including HBB due to the similar sources and uses with PCBs. However, this manual focusses on PCBs due to its established relevance in the Caribbean. Additionally, the Stockholm Convention calls for each Party to stop using this chemical[31] and **existing equipment that contains or is contaminated with PCBs may continue to be used until 2025.** To ensure that all PCB uses are ceased by 2025, parties, especially those that are developing countries or countries with economies in transition, will need support:

- To complete national inventories of all PCBs and related contaminated equipment;
- To improve the capacity and increase the knowledge of PCB equipment owners on proper maintenance of equipment to avoid further contamination;
- To establish proper storage of discontinued equipment and to ensure disposal of all the PCB oils and contaminated equipment in an environmentally sound manner.

[30] The Basel Technical Guidelines - http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.13-6-Add.4-Rev.1.English.pdf
[31] PCBs and the Stockholm Convention - http://chm.pops.int/Implementation/IndustrialPOPs/PCBs/Overview/tabid/273/Default.aspx

A detailed guide on the identification of PCB Contaminated Liquids and Equipment Containing PCBs is provided in the ***Regional manual for POPs inventory development for NIPs update in the Caribbean***[8] and the ***UNEP Chemical's guide on PCB Transformers and Capacitors: from Management to reclassification and Disposal***[32].

4.2 Labelling

Every container and piece of equipment containing or contaminated with PCBs and building storing PCBs equipment or materials should be clearly labelled with a **hazard-warning label** and **a label giving details of the equipment or container**. Details may include:

- the contents of the container or equipment,
- the name of the site from which the container or equipment originated,
- the date of repackaging and the contact for the person responsible for the repackaging operation.

Consider also your national Hazardous Communication (HAZCOM) Programmes of guidelines.

Due to international guidelines and manufacturing several types of electrical equipment are provided with standard labelling such as 'PCB Free transformer' see Figure 16.

Figure 15: Sample labels for equipment, storage articles and areas containing or contaminated with PCBs ***(Sturmovik, 2012 and SafetySign.com, 2020)***

Figure 16: Label on 'PCB FREE' certified equipment ***(SafetySign.com, 2020)***

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[32] United Nations Environment Programme. May 2002. PCB Transformers and Capacitors: From Management to Reclassification and Disposal - http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-PCB-GUID-TRANSCAP.English.pdf

4.3 Handling of PCB contaminated liquids, equipment and waste

> **NOTE:**
> The symptoms of PCB exposure are chloracne, eye **irritation**, **drowsiness**, **headaches** and a **sore throat**.
>
> Under no circumstances must any operatives or observers smoke in the area where PCB is being handled.

Given the long lifespan of PCB containing equipment routine maintenance is usually required and special attention should be paid to possible leakages due to corrosion and defects. Attention is also required to the potential for damages when moving such equipment. The following general principles apply when handling PCB contaminated liquids, equipment and waste:

- **Use masks and rubber gloves** to avoid inhalation of volatilized PCBs or skin contact when dealing with highly concentrated PCBs;
- **Use appropriate protective equipment (that meet international standards)** such as suitable gloves, disposable coveralls, protective goggles and respiratory protection when working in the proximity of potentially PCB contained equipment or PCB contaminating material;
- **Carefully remove and isolate potentially contaminated material** (such as building joints, window or door sealants or fillers, and paint coatings on steel bridges or structures in renovation or demolition of older buildings) to prevent PCB containing dust from spreading to surrounding areas.

Detailed health and safety considerations are provided in the ***UNEP Chemical's guide on PCB Transformers and Capacitors: from Management to reclassification and disposal***[29].

4.4 Reclassification and retrofilling of PCB containing equipment

Figure 17: Example of alternative to PCB oil
(BCRC-Caribbean, 2018)

Transformers are expensive equipment with a long lifespan. As such, when equipment is not compatible with the operator's mandate on environmental compliance and transformers are found to have a PCB content which is above those levels which are acceptable, the owners of such equipment may opt to only dispose of the PCB oil or PCB contaminated oil and reclassify the equipment for re-use with alternate fluid types (see Figure 17 with alternative to PCB oil used in transformers at an oil refining and distributing facility in Antigua and Barbuda).

The process by which equipment is emptied of its dielectric fluid and replaced with a new non-PCB oil is called ***retrofilling***. A transformer usually contains wooden and possibly paper components which are porous and retain the contaminated oil. There is the potential for contamination of new oil above acceptable levels as there is a gradual leaching out of residual PCBs from the porous components. Therefore, it may be necessary to carry out several retrofilling operations in order for PCB levels of the new oil to be acceptable. As such, the process is usually long and expensive. Details on considerations to be given on the viability of retrofilling and required characteristics of PCB replacement oils can be accessed in the ***UNEP Chemical's guide on PCB Transformers and Capacitors: from Management to reclassification and Disposal*** [29].

4.5 Collection and Packaging of PCB contaminated liquids, equipment and waste

Following the inventory and identification of PCB contaminated liquids, equipment and waste the collection and packaging may be required prior to or during the disposal initiative.

4.5.1 General principles for collecting and packaging PCBs

The following general principles apply when collecting and packaging PCB contaminated liquids, equipment and waste:

- Use **separate collection arrangements and collection depots for PCB** wastes from other waste types.
- Do not allow collection depots to become **long-term storage facilities**.
- Package **drawn out, drained oils and carcasses separately**. Separating insulating oils from transformers during transport to a treatment facility may lower the risk of leakage.
- Perform separation procedures using **professional operators and special tools.**
- Use containers that meet **certain specifications** (e.g., 16-gauge, made of steel, internally coated with epoxy) **for the transport** of these hazardous materials.
- Use heavy duty plastic wraps/polythene **if leakage is a concern**;
- Use **absorbent material** to prevent excessive movement and allow free liquids and spills to be absorbed.
- **Place drums and equipment on pallets** for movement by forklift truck and for storage. Drums and equipment should be strapped to the pallets before they are moved.

4.5.2 Recommendations specific to different PCB waste types

PCB wastes may comprise of the following:

- **Liquid Waste** – including dielectric fluids, heat transfer and hydraulic fluids, PCB-Containing solvents, washings of PCB-contaminated material or fluids leaked/spilled/splashed due to mishandling or accidents and retrofilled fluids exceeding 50 ppm. ***Liquid waste should be stored in sealed, well labelled good condition steel drums and a 100 mm air space should be left between the top of the drum and its contents.***
- **Combustible Solid Waste** – including material used to clean PCB equipment or absorb spills such as rags, absorbents, contaminated clothing or PPE. ***This type of waste should be packed in heavy duty and leak proof polythene sacks and placed in sealed, well labelled good condition steel drums.***
- **Non-combustible Solid Waste** – including obsolete equipment and components, contaminated containers (such as drums or tanks) and scrapped transformers with substitute fluids higher than 50 ppm PCBs. ***Smaller equipment should be stored in heavy duty, leak proof polythene***

sacks within sealed, well labelled good condition steel drums. Capacitors should be left in their cases unopened and stores with the terminals pointing upwards to prevent leakage from bushings. Large equipment should be carefully inspected in for leakage prior to packaging then stored in sealed leak-proof sacks and then into steel containers with absorbent material. Containers should be packed to a maximum of 90% of its total capacity.

4.6 Storage of PCB contaminated liquids, equipment and waste

In the absence of national storage regulations or developed storage guidelines the following additional measures may be implemented:

- Store PCBs in an **enclosed structure** (building, room, or other enclosed containment). Structures should be **curbed, waterproof** (to prevent rain from entering), **well ventilated** and with **spill containments** considerations.
- Place an **oil pan (steel tray) underneath** stored equipment.
- Routinely **maintain and inspect designated storage** sites to verify whether there have been any releases.
- **Install structures** to prevent spillage during natural disasters (e.g. earthquakes and hurricanes).

4.7 Transportation of PCB contaminated liquids, equipment and waste

PCBs are mostly transported mostly in its liquid form. As such, in addition to the measures for collection and packaging provided in Section 4.5 above, consideration should be given to the prevention of leakage during transport. These may include securing equipment in order to **prevent leakage in metallic containers**, to reduce the risk of breakage from impact and the **use of absorbent materials in their packaging**. Consideration should also be given to national protocols for the transportation of hazardous material.

Figure 18: Packaging and Removal of PCB Containing Waste by Air
(Polyeco Group, n.d.)

Figure 19: Land Transportation of PCB Waste (obsolete transformers)
(Boiler and Plant Dismantlers Ltd, n.d.)

4.8 Environmentally Sound Disposal of PCB Waste

4.8.1 Pre-treatment

Specific consideration should be given to the pre-treatment of PCB containing or contaminated equipment and material prior to disposal in dedicated facilities. Persons involved in ESM and disposal operations should ensure that clear pre-treatment requirements are obtained from the respective facility. Pre-treatment requirement may include:

- Cutting, milling or disassembling of external parts (e.g. radiators or bushings of transformers) for the purpose of size reduction;
- Dewatering or oil-water separation in order to avoid violent reaction of water and the excessive consumption of alkali metals during processes such as alkali metal reduction.

Subsection IV.G.1 of the General technical guidelines[33] provides further information on pre-treatment.

4.8.2 Destruction and irreversible transformation methods

Available technologies for the destruction and irreversible transformation of PCB wastes outlined in the ***General technical guidelines***[32] include:

- Alkali metal reduction,
- Base catalyzed decomposition (BCD),
- Catalytic hydrodechlorination (CHD),
- Cement kiln co-incineration,
- Gas phase chemical reduction (GPCR),
- Hazardous waste incineration,
- Plasma arc,
- Plasma melting decomposition method (PMD),
- Supercritical water oxidation (SCWO), and
- Subcritical water oxidation.

Details on these can be obtained in Section 8. It should be noted that unintentional POPs such as PCDDs/PCDFs can be generated from the combustion and incineration of PCBs and related wastes and consideration should be given when choosing the disposal technology.

[33] General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants: http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.13-6-Add.1-Rev.1.English.pdf

5 ESM and Disposal of wastes consisting of, containing or contaminated POPs-Brominated Flame Retardants (BFRs)

5.1 BFR containing articles, material and waste

This section discusses the ESM and disposal of articles containing or contaminated with the following POPs-BFRs:

- **Polybromodiphenyl ethers (PBDEs)** - including commercial octabromodiphenyl ether (c-octaBDE), commercial pentabromodiphenyl ether (c-pentaBDE) and commercial decabromodiphenyl ether (c-decaBDE). The c-octaBDE commercial mixture typically contains mainly Hexabromodiphenyl ether (hexaBDEs) and heptabromodiphenyl ether (heptaBDEs) while the c-pentaBDE typically contains Tetrabromodiphenyl ether (tetraBDEs), pentabromodiphenyl ether (pentaBDEs) and hexaBDEs.
    - **c-octaBDE** was used mostly as an additive flame retardant in the manufacturing of plastic polymers, particularly in acrylonitrile-butadiene-styrene (ABS) polymers. ABS is mainly found in the housings of electrical and electronic equipment (EEE), such as office equipment, automotive parts and appliances, business machines, computers, business cabinets, pipes and fittings. As discussed in Section 2.4.2.2, the regional issues with c-octaBDE surround EEE and WEEE where the main concern involves the import, use and disposal of the Cathode Ray Tubes (CRT) monitors in older models of televisions and computers.
    - **c-pentaBDE** was used almost exclusively as a flame retardant in the manufacture of flexible polyurethane (PUR) foams. Flexible PUR foams were used mainly in automotive and upholstery applications, electrical and electronic appliances, building materials, furniture, textiles and packaging. As discussed in Section 2.4.2.2, the regional issues with c-pentaBDE involve the existence of the PUR foams in automotive and upholstery applications in older vehicles produced before 2004 and ELVs.
    - **DecaBDE** is used as an additive flame retardant and has a variety of applications including in plastics/polymers/composites, textiles, adhesives, sealants, coatings and inks. DecaBDE containing plastics are used in housings of computers and TVs, wires and cables, pipes and carpets. Commercially available decaBDE consumption peaked in the early 2000's, but c-decaBDE is still extensively used worldwide. Regional inventories of DecaBDE have not been completed to date.

NOTE: Before C-pentaBDE was phased out in the United States in 2004, 97 per cent of global production of c-pentaBDE was used in the United States and Canada.

- **Hexabromocyclododecane (HBCD)** – which may include flame retardant textiles (protective clothing, carpets, curtains, upholstered fabrics, tents, the interiors of public transportation conveyances) e.g., automobiles, trains, aircraft, etc.; construction material and demolition waste (expanded polystyrene (EPS) and extruded polystyrene (XPS) used in insulation boards), and to a lesser extent in adhesives and paints and high impact polystyrene (HIPS) for electrical and electronic equipment. As discussed in Section2.4.2.2, HBCD is a minor concern in the Caribbean region due to the limited use of the material of concern.

The production and use of Hexabromobiphenyl (HBB) is also not of major relevance to the Caribbean regions.

This section of the manual will therefore continue to focus on the ESM and disposal of hexaBDE, heptaBDE, tetraBDE and pentaBDE as a group referred to as "POP-PBDEs".

The main potential sources of POP-PBDEs wastes addressed in this section are:

- Solid obsolete stockpiles of POP-PBDEs and their related substances in original packages that are no longer usable;
- Solid wastes from producers and users of POP-PBDEs;
- Wastewater from industrial and municipal processes and residues from wastewater cleaning such as activated carbon treatment;
- Products (e.g., electrical and electronic equipment, building materials, plastics, textiles, vehicles) that have become waste;
- Municipal and industrial sludges; and
- Landfill leachate.

Figure 20: Stockpiles of waste POP-PBDEs related products ***(BCRC-Caribbean, 2019)***

5.1.1 Technical Guidelines on POP-PBDEs

This section of this manual is developed mainly based on the following technical guidelines:

- ***General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants*** (adopted by COP.13, May 2017)[34];
- ***Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with POP-PBDEs*** (adopted by COP.12, May 2015)[35];
- ***Technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment, in particular regarding the distinction between waste and non-waste under the Basel Convention*** (adopted by COP.12, May 2015)[36];

[34] http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.13-6-Add.1-Rev.1.English.pdf
[35] http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.12-5-Add.6-Rev.1.English.pdf
[36] http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.12-5-Add.1-Rev.1.English.pdf

- ***Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane (HBCD)*** (adopted by COP.12, May 2015)[37];
- A series of guidelines developed in the context of two public-private partnership initiatives under the Basel Convention (Mobile Phone Partnership Initiative (MPPI)[38] and Partnership for Action on Computing Equipment (PACE)[39]).

Additionally, a detailed guide on the identification of POPs -BFRs in the Caribbean context is provided in the ***Regional manual for POPs inventory development for NIPs update in the Caribbean***[8].

5.2 Labelling

Clearly label every container storing or carrying POP-PBDEs wastes with a **hazard-warning label**. An **indelible, clear and plainly visible label** should also be included to provide:

- a unique **serial number,**
- **contents of the container** (e.g., exact counts of equipment, weight, type of waste carried),
- the **name of the site** from which the waste originated to allow its traceability,
- if applicable, the **date** of repackaging and the **name and telephone number** of the person responsible for the repackaging operation.

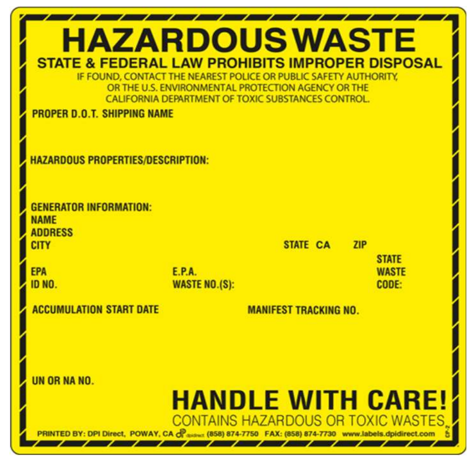

Figure 21: General Hazardous Waste Labelling Example
(dpilabels, n.d.)

5.3 Collection and handling of material or wastes consisting of, containing or contaminated with POP-PBDEs

Generally, POP-PBDEs containing material or waste should be **collected and handled separately** from other types in order to prevent contamination of other waste streams and it is imperative that organisational procedures are established and implemented.

[37] http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.12-5-Add.7-Rev.1.English.pdf
[38] Guidance document on the environmentally sound management of used and end-of-life mobile phones: http://www.basel.int/Implementation/TechnicalAssistance/Partnerships/MPPI/MPPIGuidanceDocument/tabid/3250/Default.aspx
[39] PACE Guidelines, Manual and Reports: http://www.basel.int/Implementation/TechnicalAssistance/Partnerships/PACE/PACEGuidelines,ManualandReports/tabid/3247/Default.aspx

5.4 Storage and Packaging of material or wastes consisting of, containing or contaminated with POP-PBDEs

Generally, consideration should be given to proper packaging to allow for ease of transport and safety to reduce/avoid breakage, leaks and/or spills (e.g. ELV containing liquids). Consideration should be given to the following:

- Store material in designated sites and take appropriate measures to prevent scattering, leakage and underground seepage of POP-PBDEs.
- Consider the installation of partitions to avoid contamination of the POP-PBDEs wastes.
- Designate controlled areas with defined boundaries for the storage of POP-PBDEs.
- Post warning signs around such areas and restrict access to authorized personnel ONLY.
- Ensure there are adequate access roads for vehicles to and from the designated site or facility. Constructed simple roads when necessary.
- Ensure that storage sites have structures to prevent underground leakage of POP-PBDEs.
- Use sealable, easy to store and durable containers.
- Maintain and routinely inspect storage sites to verify whether there have been any releases of POP-PBDEs into the environment.

The following specifics may be also be considered based on the type of material:

- Packaging of solid POP-PBDEs wastes – use corrugated cartons lined with protective anti-seepage plastic bags OR specially designed wooden pallets to raise stored POP-PBDEs wastes above ground level and thereby protect them against moisture;
- Packaging of liquid POP-PBDEs wastes – package in special anti-seepage barrels;
- Packaging of POP-PBDEs contaminated soil - package in triple layered, anti-leak, high-strength laminated bags.

5.5 Transportation of material or wastes consisting of, containing or contaminated with POP-PBDEs

In addition to those recommendations for storage and packaging, the following considerations should be taken when transporting POP-PBDEs:

- Prevent scattering or leakage;
- Avoid mixing with other material;
- Employ trained and qualified drivers, loading and unloading management personnel and escort personnel, all of whom should carry their qualification certificates;
- Ensure that transporters are capable of providing full and accurate information about their cargoes or shipments, safely transfer wastes to their destinations and hand them over to receivers in accordance with national regulations (if applicable).

	
Figure 22: ELV Transportation – LIFE CIRC-ELV Project *(AIMPLAS, 2020)*	**Figure 23: ELV packaging and transport** *(Enclave Resources, n.d.)*

Internationally, regulations and protocols are developed for the collection and handling of specific wastes on a national basis and also by the waste management companies. Examples of these are the US Environmental Protection Agency - Packaging Used Electronics for Transportation[40], MP Packaging - Guidelines for the collecting and transport of e-Waste[41], Japan's Institute for Global Environmental Strategies - Standards for Collection, Storage, Transport, Recovery, Treatment and Disposal to Ensure Environmentally Sound Management of E-waste[42], Veolia Environmental Services - Guidelines for Packaging Electronic Waste[43], Scottish EPA – Waste Regulations and transport and storage of End of Life vehicle[44], UK Environment Agency - Handling end-of-life vehicles (ELVs)[45], U.S. Environmental Protection Agency (EPA)[46].

5.6 Environmentally Sound Disposal of POP-PBDEs Waste

5.6.1 Pre-treatment

Specific consideration should be given to the pre-treatment of POP-PBDEs wastes. These include dismantling, disassembling and mechanical separation, which can be used to reduce the volume of POP-PBDEs wastes.

5.6.2 Destruction and irreversible transformation methods

Available technologies for the destruction and irreversible transformation of POP-PBDEs wastes outlined in the ***General technical guidelines***[30] include: Cement kiln co-incineration; Hazardous waste incineration; and Thermal and metallurgical production of metals. Details on these can be obtained in Chapter 8. It is important to note that unintentional POPs such as PCDDs/PCDFs can be generated from the combustion and incineration of POP-PBDEs related wastes and consideration should be given when choosing the disposal technology.

[40] Packaging Used Electronics for Transportation - https://www.epa.gov/sites/production/files/documents/fecpack.pdf
[41] https://www.europages.com/filestore/gallery/4f/63/10898039_7c928ea1.pdf
[42] https://www.iges.or.jp/en/publication_documents/pub/issue/en/3321/3R_06.pdf
[43] http://www.sydist.com/Portals/0/Literature/VeoliaPackagingGuidelinesMay2013.pdf
[44] http://www.sydist.com/Portals/0/Literature/VeoliaPackagingGuidelinesMay2013.pdf
[45] http://www.bvsf.org.uk/cms/images/PDFs/ELVs-leaflet-2017-FINAL.pdf
[46] Processing End-of-Life Vehicles

5.7 ESM of EEE and WEEE

As indicated in Section 2.4.2.2 above, the concern with WEEE management in this document surrounds the need for proper management at the end of the electronics and electrical equipment's useful life where it is deemed waste. The concern surrounds ensuring that the hazardous component of the waste is managed in a proper manner. Consideration is also given to the recycling industry in this section due to their significant role in the ESM of WEEE.

The document provides a brief overview of the specific ESM considerations, while detailed guidance on the ESM of WEEE can be accessed at:

- ***Technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment, in particular regarding the distinction between waste and non-waste under the Basel Convention (E-waste)***[47] .
- ***The MPPI Guideline on the Collection of Used Mobile Phones (Approved Draft). Mobile Phone Partnership Initiative Project 2.1.*** March 25, 2009[48].
- ***The PACE Guidance Document to provide guidance on the environmentally sound management of used and end-of-life computing equipment***[49].

5.7.1 WEEE Collection

In the case of EEE/WEEE, collection systems should be implemented with three primary goals:

- Divert devices from waste streams destined for disposal in landfills or incinerators;
- Repair, refurbish and preserve used devices in working order, so that they can be used again; and
- Channel unusable (end-of-life) devices into environmentally sound material recovery and recycling.

[47] http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.14-7-Add.6-Rev.1.English.pdf
[48] http://www.basel.int/Portals/4/Download.aspx?d=UNEP-CHW-PART-GUID-MPPI-Project2.1.English.pdf
[49] http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.13-INF-31-Rev.1.English.pdf

5.7.2 Classification and labelling of WEEE

The classification of WEEE in accordance with the Basel Convention can be found in details in Annexes I, III, VIII and IX where the components are distinguished as: H6.1=Poisonous (acute); H11=Toxic (delayed or chronic); H12=Ecotoxic; and H13=Capable. In addition, The United Nations Model Regulations identifies the hazardous classes and divisions for these components[50]. In addition to the health and safety benefits, the proper classification of these waste types will allow for the best determination of the appropriate labelling, handling, storage and disposal methods.

Figure 24: Types of WEEE – E-waste Recycle Hub

(E Waste Recycle Hub, 2017)

5.7.3 Collection, Storage and Packaging of WEEE

Generally, proper storage involves the prevention of accidents, spillage and breakage. When handling material marked for recycling it is important that the value of the material is not depleted through improper storage. Consideration can be given to the following specific recommendations:

- **Store in secured areas**, in order to protect articles against theft and against deposit of other materials.
- **Separate articles with batteries, chargers and accessories**. Attention should be given to the segregation and storage of batteries and other flammable components.
- Use **appropriate storage material and containers** in order to protect articles from undue wear and to preserve their surface appearance, operational capability and market value for possible reuse.
- Store separated components in dedicated, labelled and appropriate containers.
- **Store in sheltered areas with confined drainage systems**. Secondary spillage collection can also be considered.

[50] The Basel Convention's Revised draft fact sheets on specific waste streams http://www.basel.int/Default.aspx?tabid=5843

 **Sims recycling facility in Roseville, California** *(Tesfaye, et al., 2017)*	 **Electronics Recyclers International Facility in Fresno, California** *(The Verge, 2016)*

Figure 25: Examples of WEEE collections, storage, separation and labelling

5.7.4 Packaging and Transport of WEEE

The following considerations should be given when packaging or transporting WEEE for recycling or disposal:

- Use clear labels.
- Take precautions to prevent breakage or release of hazardous components, this can include using lined/wrapped pallets and containers, drums and super sacks.
- Use only licensed permitted and authorised carriers.
- Establish an Emergency Response Plan.
- Ensure that Emergency response information (including SDS (Safety Data Sheets)) and the hazardous waste manifest accompany the WEEE.
- Clearly mark transport vehicles as 'Transporting Hazardous Material'.
- Ensure proper PPE is used by the packaging and transportation team. This includes eye and ear protection, chemical-resistant gloves, and where indicated, respirators, when a potential hazard is present[51, 52].

5.7.5 WEEE Recovery and Treatment

Generally, it is recommended that preliminary evaluation is conducted on WEEE to determine whether the device is potentially reusable. The methods of such evaluation are detailed in the ***PACE guideline on Environmentally Sound Testing, Refurbishment and Repair of Used Computing Equipment***[48]. Equipment that can still be used should be sent for refurbishment or repair and those that cannot be repaired or reused should be sent to either ESM dismantling or recovery.

Key Considerations for Separation and Dismantling:

- Perform manual dismantling, where possible, in order to keep equipment in good working condition. Pay attention to manual removal of hazardous components such as mercury lamps

[51] https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/OHB/HESIS/CDPH%20Document%20Library/eWaste.pdf
[52] https://content.statefundca.com/safety/safetymeeting/SafetyMeetingArticle.aspx?ArticleID=808

and batteries, etc., and their contained substances, some of which are hazardous, so they are not processed together and are not released or mixed with other materials.

- Protection of worker health and safety and the environment is necessary in such conditions, including engineered control systems, personal protective equipment such as gloves and eye protection, and more complex measures such as respiratory masks.
- Ensure proper labelling and segregation of material for refurbishment/repair versus recovery and disposal. Equipment/components can be separated into steel, plastics and circuit boards, among other things. ***Collect material containing POP-PBDEs (such as waste plastics or PUR Foam) separately during dismantling process***.

Key Considerations for WEEE recovery:

- Consolidate material into batches for specialized material recovery.
- Finding the appropriate ESM recovery facilities for separated waste streams is a critical part of ESM, as this final link will largely determine the ultimate material recovery achieved in the chain, as well as the magnitude of environmental impact. Recovery takes the separated batches of materials into more specialized processes, often in a series. Circuit boards, for example, first go through copper recovery, followed by specialized refining of the residues to recover other metals, while engineered thermoplastics are subjected to size reduction and granulation processes.
- Recovery processes often involve high temperatures (e.g. smelting and other pyrometallurgical processes), or very strong chemicals (e.g., hydrometallurgical processing by acids or cyanide), or hazardous emissions and require very high levels of process technology, monitoring and worker and environmental protection. Details on Facility measures to support environmentally sound material recovery and recycling of end-of-life computing equipment is referenced in:
    - ***MPPI Guideline on the Collection of Used Mobile Phones***, and
    - ***PACE Guidance Document on the Environmentally Sound Management of Used and End-of-Life Computing Equipment***.

Detail on E-Waste Recycling Technologies can be accessed at https://www.wipo.int/edocs/pubdocs/en/patents/948/wipo_pub_948_4.pdf

5.8 ESM of ELVs

As indicated in Section 2.4.2.2 above, the concern with ELVs management is this document surrounds the need for proper management at the end of the vehicle's useful life where it's deemed waste. The concern surrounds ensuring that the hazardous components of the waste are managed in a proper manner. The main potential sources of POP-PBDEs in end of life vehicles are found in vehicular-parts manufactured before 2000 in most regions (e.g. Europe, Asia) and 2004 in the United States. A simple check of a vehicle's manufacturing information can help determine the presence of POP-PBDEs materials. These POP-PBDEs may be found in:

- upholstery of seats, headrests and ceilings,
- application in textile back-coating, hard plastic interiors,
- waste oils, waste lead acid batteries, waste tyres,
- electrical and electronic waste.

The reuse of vehicles containing POP-PBDEs is not recommended as it risks human exposure especially in aged vehicles when the interior and parts becomes worn and damaged, releasing fibres and particle into the air.

The document provides a brief overview of the specific ESM and disposal considerations regarding POP-PBDEs in end of life vehicles in accordance with the: ***Guidance on best available techniques and best environmental practices for the recycling and disposal of articles containing polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants***[**]. Additional detailed guidance on the management of ELVs can be accessed at:

- ***Basel Convention - Technical guidelines on the environmentally sound management of used and waste pneumatic tyres***[53],
- ***Technical Guidelines on the Environmentally Sound Management of Waste Lead-acid Batteries***[54],
- ***Basel Convention Technical Guidelines on Waste Oils from Petroleum Origins and Sources*** [55].

5.8.1 Classification of ELVs

The classification of ELVs in accordance with the Basel Convention can be found in details in Annexes I, III, VIII and IX where the components are distinguished as: H6.1=Poisonous (acute); H11=Toxic (delayed or chronic); H12=Ecotoxic; and H13=Capable[49]. In addition, The United Nations Model Regulations identifies the hazardous classes and divisions for these components. In addition to the health and safety benefits, the proper classification of these waste types will allow for the best determination of the appropriate labelling, handling, storage and disposal methods.

5.8.2 Storage of ELVs

The following considerations should be given to the storage of ELVs (even temporarily):

- Store at licensed, permitted and authorised facilities;
- Store in secure areas which have impermeable surfaces, sealed drainage and secondary drainage confinement. Silt traps and oils settlement tanks/oil separators should be included;
- Ensure that sufficient and appropriate (for all hazardous liquids including oils, acids etc.) spills kits are also stored on site;
- Cover engines and greasy car parts with waterproof cover (e.g. tarpaulin) to prevent rain wash off.

5.8.3 Transport of ELVs

The following considerations should be given to the transportation of ELVs:

- Use appropriate and clear labels. Clearly mark transport vehicles as 'Transporting Hazardous Material'.
- Take precautions to prevent breakage or leakage of liquids.
- Use only licensed permitted and authorised carriers. Ensure proper PPE is used by the packaging and transportation team. This includes eye and ear protection and high-visibility gear.
- Establish an Emergency Response Plan.

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53 http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-WAST-GUID-WastePneumaticTyres.English.pdf
54 http://synergies.pops.int/Portals/4/download.aspx?d=UNEP-CHW-WAST-GUID-WasteLeadAcidBatteries.English.pdf
55 http://synergies.pops.int/Portals/4/download.aspx?d=UNEP-CHW-WAST-GUID-WasteOilsPetroleum.English.pdf

5.8.4 Treatment and recycling of end-of-life vehicles

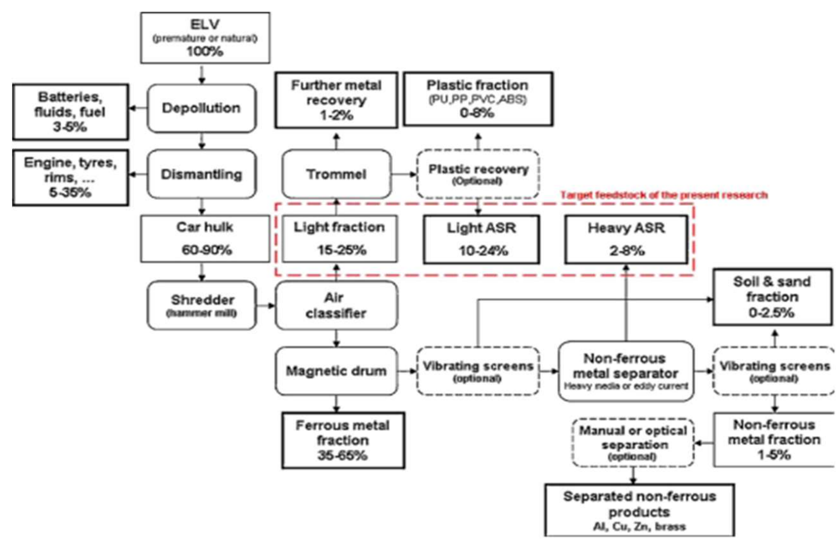

Figure 26: Schematic of the processing of an end-of-life vehicle
(Vermeulen et al., 2011)

The rate of recycling end of life vehicles is at a constant high due to the value of vehicular materials such as the iron, other metals, wires etc. After the recycle materials are taken, the non-recycled fraction of an ELV should not be overlooked, as it is often an environmental concern due to the spent oils and lubricants, heavy metals and POP-PBDEs.

This section is therefore concerned with the different recycling and treatment techniques used when handling end of life vehicles that should be in accordance with Annex C of the Stockholm Convention. The three (3) main treatments and recycling steps are as follows.

- **Dismantling** – involves the removal of the physical components of the vehicle. Before a vehicle is dismantled, obtain the vehicles' model-specific information (such as airbag deployment instructions, identification of mercury- containing components, and information about potentially recyclable parts and components) from vehicle's manufacturer. Proceed to check for leaks and any hazardous or toxic parts to be removed. Remove any reusable and recyclable components with special emphasis on components with a sufficient market value or containing valuable materials.
- **De-pollution** – involves several steps to remove the fluids and hazardous components of the vehicle, the sequence of which can vary based on the type of vehicle. Following de-pollution, it is important to plug all gravity-drained holes and appropriately store the different types of fluids and hazardous material in separate containers/areas. A suggested typical flow for the depollution of a vehicle is presented in Figure 27.

The dismantling and depollution site should be properly suited to carry out processes involving the handling of engines, transmission or hydraulic systems. Ensure that ground surfaces are impermeable and that there is a sealed drainage system as a primary means of containment for runoff management. Additionally, ensure that all tools and equipment used are designed specifically for carrying out the required operations to allow for best practices.

- **Crushing** – Crushing should ideally occur following dismantling and depollution. Vehicle crushers should also be stored on ground surfaces that are impermeable should be within a sealed drainage system as a primary means of containment for runoff management.

- **Shredding** – Industrial shredders may be used to shred materials into smaller pieces or separate for particular processes such as metal recycling at steel mills. Include dust suppression (e.g. Wet shredding) or dust collections mechanisms to prevent the potential emissions including POP-PBDEs releases from treated vehicle parts. Further details on the treatment of auto shredder residue (ASR) can also be sourced in the guidance document.

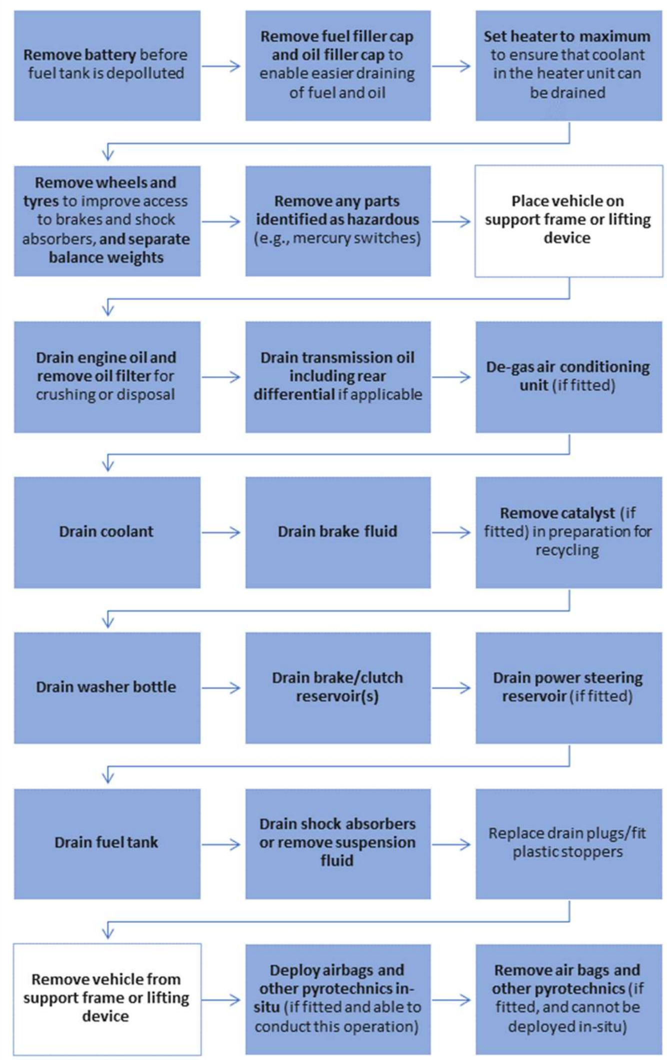

Figure 27: Typical flow for the depollution of a vehicle is presented (adapted from the fact sheet on specific waste streams) ***(Basel Convention, 2017)***

6 Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Perfluorooctane Sulfonic Acid (PFOS), its Salts and Perfluorooctane Sulfonyl

6.1 Waste consisting of, containing or contaminated with PFOS

The main potential sources of wastes related to PFOS addressed in this section are:

- Fluorinated chemicals, aqueous film forming foam (AFFF) fire-fighting foams equipment;
- Aviation hydraulic fluids;
- Obsolete stockpiles of PFOS and its related substances in original packages which are no longer usable because their shelf life has been exceeded or the packaging has deteriorated;
- Wastewater from industrial (metal plating and photography) and municipal (treatment) processes;
- Soil, sediments, sludge, residues from wastewater cleaning such as activated carbon treatment;
- Food packaging materials, paper, textiles (Teflon), leather, rubber, carpets, upholstery (stain and water-repellent fabrics);
- Industrial and household cleaning products;
- Food processed with equipment that uses PFAS or grown in PFAS-contaminated soil or water;
- Landfill leachate.

This section of this manual is developed mainly based on ***Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride***[56].

The human health and environmental concerns surrounding PFOS is still limited, as such specific guidance on the handling, collection, packaging, labelling, transportation and storage of such wastes is not widely documented.

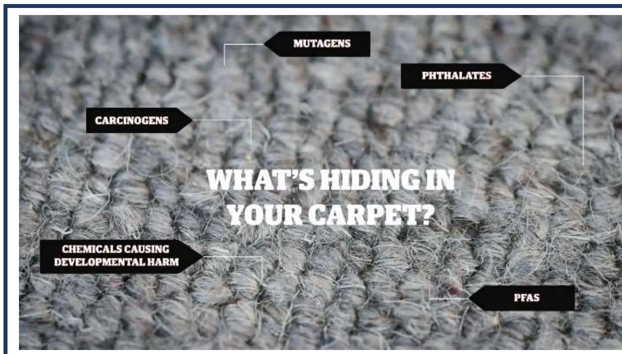

Figure 28: The Chemicals Lurking in Your Carpet
(GAIA, n.d.)

Figure 29: Chemicals hiding in your waterproof, stain-resistant, and wrinkle-free clothes
(Business Insider, 2019)

[56] http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-WAST-GUID-ESM-PFOS-2018.English.pdf

6.2 Packaging, Labelling and Storage of PFOS Waste

Available guidance is based on the state of the material to be managed according to the following categories.

6.2.1 PFOS containing liquids and semi-liquids (i.e., wastewater, landfill leachate, sewage sludge, hydraulic fluids and aqueous film-forming foams):

- Package separately to avoid mixing with and contaminating other materials.
- Store and transfer in areas with secondary containment in order to control accidental releases during storage and transportation. PFOS-containing products should be stored in sealed containers in a cool, dry and ventilated area away from heat, sparks or open flames. The floor should be concrete or have an impermeable coat such as synthetic resin. The design and build of secondary containments should be able to contain releases of liquids at least until the leaked materials are recovered.
- Clearly label containers with details of their contents.
- Storage areas should be approved and designated at enclosed areas that have secondary containment. The sites should be surrounded with a fence. The facilities should be subject to regular inspection and maintenance.
- Avoid long-term storage of liquid and semi-liquid PFOS wastes in large quantities but rather regularly collect and transport to an approved transfer station or to a central processing centre. If the wastes are initially sent to a transfer station, they should be further transported to the most appropriate central processing or disposal facility.
- Take measures to avoid scatter, leakage, underground seepage, or the spread of bad odour from the wastes containing PFOS at the site. The containers should be[57] sealable, easy to store and indestructible.

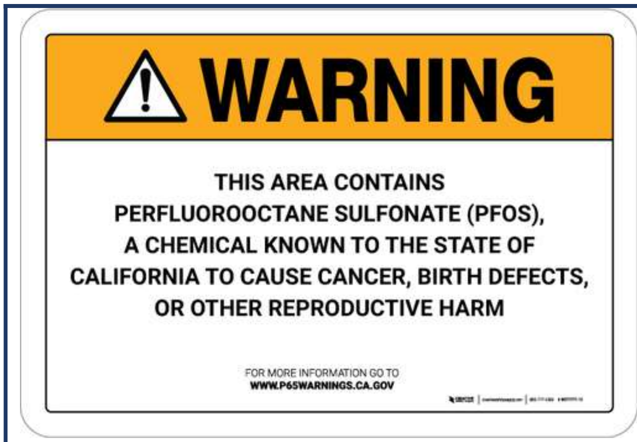

Figure 30: Sample of signage for PFOS containing sites

(Creative Safety Supply, n.d.)

Figure 31: Secondary containment at site where PFOS firefighting foam was used

(BCRC-Caribbean, 2018)

[57] Summary of the Guideline on the Treatment of Wastes Containing Perfluorooctane Sulfonic Acid (PFOS), and Its Salts in Japan - https://www.env.go.jp/en/focus/docs/files/201304-89.pdf

6.2.2 Solid PFOS containing wastes (i.e., household and consumer textiles)

- Handle these wastes separately to avoid mixing with other materials and ensure they are properly labelled with the details of the contents to facilitate their environmentally sound disposal.
- Textile wastes containing PFOS or its related substances should not accumulate in large quantities for extended periods of time and should therefore be regularly collected and transported to an approved transfer station or to a central processing centre.
- PFOS-containing products should be stored in sealed containers in a cool, dry and ventilated area away from heat, sparks or open flames. The floor should be concrete or have an impermeable coat such as synthetic resin.

6.2.3 Transport of PFOS containing wastes

The following considerations should be given to the transportation of PFOS containing wastes:

- Use appropriate and clear labels.
- Take precautions to prevent breakage or leakage of liquids.
- Use only licensed permitted and authorised carriers.
- Establish an Emergency Response Plan.
- Clearly mark transport vehicles as 'Transporting Hazardous Material'.
- Ensure proper PPE is used by the packaging and transportation team. This includes eye and ear protection and high-visibility gear.

6.3 Health, Safety and Emergency Response

SDS should be kept on site and along with stocks being transported. This would allow for proper health, safety and emergency response in accordance with the recommendations of the SDS.

6.4 Special consideration to Fire Services management of PFOS firefighting

- All solid and liquid wastes that contain fluorinated organic compounds (e.g. concentrates, firewater, wash-water, run-off, soils, absorbents, etc.) must be appropriately managed in order to avoid contamination[58].
- Wastewater from firefighting foam containing persistent compounds such as fluorinated organic compounds must be fully contained and not released to waterways or other bodies of water, stormwater, soils, groundwater or to sewer. This may be particularly relevant to the run-off from training facilities where AFFF foams are used during simulations.

[58] Managing Firefighting Foam Policy Explanatory Notes - https://environment.des.qld.gov.au/__data/assets/pdf_file/0022/89140/firefighting-foam-policy-notes.pdf

- PFOS may be orally ingested, absorbed through the skin or inhaled through exposure in the atmosphere. Personnel that come into contact with AFFFs with PFOS should consider the following safety tips[59]:
    - Wear personal protective equipment (PPE) and a self-contained breathing apparatus (SCBA) whenever handling AFFF;
    - Properly remove and bag contaminated PPE prior to transporting;
    - Use cleaning wipes on your face, neck and hands immediately after exposure;
    - Clean contaminated PPE and SCBA before its next use;
    - Shower within one hour of returning to the station or home.
- Guidance on the assessment of alternative foams/less toxic foams that may be used in the firefighting industry can be accessed in the ***Report on the assessment of alternatives to perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride***[60].

6.5 Environmentally Sound Disposal of PFOS Waste

6.5.1 Pre-treatment

Specific consideration should be given to the pre-treatment of PFOS wastes based on the nature and types of PFOS wastes. Available methods include: Adsorption and absorption; Membrane filtration, in particular reverse osmosis and nanofiltration; Mixing; Oil-water separation; and Volume reduction. ***Subsection IV.G.1 of the General technical guidelines***[29] provides further information on pre-treatment.

6.5.2 Destruction and irreversible transformation methods

Hazardous waste incineration is one of the more suitable destruction and irreversible transformation methods applicable for the environmentally sound disposal of wastes with a content of PFOS, its salts or PFOS-F. Details on these can be obtained in Chapter 8.

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[59] U.S. Fire Administration https://www.usfa.fema.gov/training/coffee_break/021120.html

[60] http://www.pops.int/Implementation/IndustrialPOPs/PFOS/Guidance/tabid/5225/ctl/Download/mid/15648/Default.aspx?id=7&ObjID=26475

7 ESM and Disposal of wastes consisting of, containing or contaminated with Unintentional POPs

7.1 Waste consisting of, containing or contaminated with UPOPS

This chapter will focus on the Unintentional Persistent Organic Pollutants (UPOPs): PCDD and PCDF (see Section 2.3). PCDD and PCDF unintentionally form during waste incineration and open burning in the presence of carbon, oxygen, hydrogen and chlorine in elemental, organic or inorganic form. In the Caribbean, the more relevant activities surrounding the management and disposal of UPOPs may be associated with the management of contaminated sites (for which specific guidelines are also available). The main potential sources of wastes addressed in this section are:

- Contaminated soils, sediments, sludge, solid waste, bottom or fly ash,
- Contaminated oils[61],
- Contaminated process water[62],
- Drained equipment[63] and containers[64] with liquid residues,
- Wood contaminated with PCB or impregnated with pesticide,
- Landfill leachates.

This section has been developed based on the following primary sources at which additional details and guidance can be accessed:

- ***Basel Convention - Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with unintentionally produced polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, hexachlorobenzene, polychlorinated biphenyls, pentachlorobenzene or polychlorinated naphthalenes***[65],
- ***General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants***,
- ***Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs***[66].

[61] Internal combustion engines, electrical, hydraulic or heat transfer equipment
[62] Industrial effluent, quench waters, sewage, pollution control scrubbers and curtains
[63] Pesticide application equipment, electrical, hydraulic or heat transfer equipment, internal combustion engines
[64] Waste oil drums, pesticide bottles and storage tanks
[65] http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.13-6-Add.5-Rev.1.English.pdf
[66] http://toolkit.pops.int/Publish/Main/I_01_Intro.html

7.2 Prevention and Minimization of UPOPs and UPOPs waste

Parties to the Stockholm Convention are obligated to seek the prevention and minimization of UPOPs emissions. This involves the identification of processes which may produce UPOPs and implementing Best Available Techniques and Best Environmental Practices such as reducing waste and improving design and management of landfills and separating household waste and composting instead of back-yard burning.

7.3 Collection of UPOPs Waste

- Ensure that collection operations and collection depots for wastes containing or contaminated with PCDD and PCDF handle and store these separately from all other wastes;
- It is imperative that collection depots do not become long-term storage facilities for wastes containing or contaminated with PCDD and PCDF.

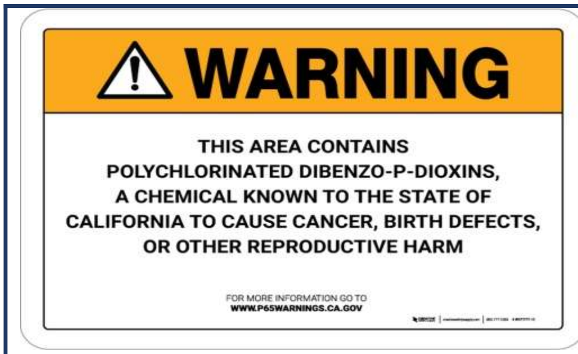

Figure 32: Sample of signage for UPOPs containing sites

(Creative Safety Supply, n.d.)

7.4 Packaging of UPOPs Waste

Proper packaging is important prior to storage or transport. Consideration can be given to the following:

- Place liquid wastes in double-bung steel drums or other approved containers.
- Ensure that containers used for storage meet transportation specifications (e.g., 16-gauge, made of steel, internally coated with epoxy). This proactive approach may prevent the need for additional transfers and further contamination.
- Store large, drained equipment inside large containers (overpack drums) or heavy plastic wraps if leakage is a concern.
- Place small pieces of equipment (whether drained or not) in drums with an absorbent material. This can prevent excessive movement of container contents and enable any free liquids/spills to be absorbed. Numerous small pieces of equipment may be placed in the same drum so long as an adequate amount of absorbent material is present in the drum.
- Place drums and equipment on pallets for movement by forklift truck and for storage. Drums and equipment should be strapped to the pallets before they are moved.

Figure 33: Example of the UN Approved Drums
(Smiths of the Forest of Dean Ltd, n.d.)

Figure 34: Drums storing hazardous waste secure on pallets
(Dangerous Goods Fix Limited, n.d.)

7.5 Labelling of UPOPs Waste

Clearly label every container carrying wastes containing or contaminated with PCDD or PCDF with a hazard-warning label and a label providing details of the container. Such details should include the contents of the container (exact weight or volume of a liquid, type of waste carried), the name of the site from which the wastes originated so as to allow their traceability and, if applicable, the date of waste repackaging and the name and telephone number of the person responsible for the repackaging operation.

Figure 35: Detailed hazardous waste packaging
(Rader Environmental Services, Inc., 2020)

7.6 Transportation and Storage

The general principles for the other POPs contaminated wastes discussed in the sections above apply to the transportation and storage of UPOPs contaminated waste as their properties and toxicity are broadly similar to those of other POPs.

7.7 Environmentally sound disposal

Figure 36: Sludge Suction Transportation Truck

(Hubei Veldlion Machinery Co., Ltd., n.d.)

7.7.1 Pre-treatment

Techniques which separate unintentionally produced POPs from the waste matrix are of particular relevance. Those techniques include solvent washing and thermal desorption as, in most cases, wastes contaminated by unintentionally produced POPs are solid substances such as fly ashes and other residues from off-gas cleaning. Oil-water separation may also be important.

7.7.2 Destruction and irreversible transformation

Available technologies for the destruction and irreversible transformation of UPOPs wastes outlined in the ***General technical guidelines*** [29]***29*** include:

- Base catalyzed decomposition (BCD),
- Cement kiln co-incineration,
- Gas phase chemical reduction (GPCR),
- Hazardous waste incineration,
- Supercritical water oxidation (SCWO), and
- Thermal and metallurgical production of metals.

Details on the pre-treatment methodologies and disposal technologies can be obtained in Chapter 8.

8 Environmentally Sound Disposal of POPs Related Wastes

This section summarises the Best Available Technologies relevant to POPs wastes pre-treatment, destruction and irreversible transformation. The section has been developed based on the following primary source at which additional details and guidance can be accessed: ***Updated general technical guidelines on the environmentally sound management of wastes consisting of, containing, or contaminated with persistent organic pollutants***.

There are no facilities available in Caribbean region which carry out the environmentally sound management (ESM) of POPs and other chemicals. Therefore, the practice of collecting and storing obsolete chemicals pending export to Europe for ESM is common to all countries. The disposal of waste in each of the project countries is generally through landfilling methods, either of the open type, converted landfill or sanitary landfill. In Saint Lucia, four (4) pyrolysis units will be commissioned before the end of 2020; however, waste incineration, waste-to-energy is being considered in other Caribbean countries.

8.1 Pre-treatment Methods

The following operations may be required to properly and safely perform the disposal methods described in subsection 8.2.

8.1.1 Adsorption and Absorption

Both methods, collectively termed sorption, involve the use of solids to remove components of liquids or gases so that they can be concentrated and removed from aqueous wastes or gaseous streams.

- Adsorption treats waste streams or purifies valuable components by removing a concentrate – the adsorbate- (e.g. oils or gases) from one phase and accumulating it on a substrate (the adsorbent) such as activated carbon, zeolite or silica. This method is useful to remove solutes or separate like phases based on different affinities for the substrate.
- Absorption, the phase change involves interpenetration into the second phase such as liquid contaminants onto granular activated carbon (e.g. removal of organic contaminants from waste waters).

8.1.2 Dewatering

This method involves the partial removal of water to prepare wastes for methods that are not suitable for aqueous solutions. Processes involved include filtration and centrifugation wet classification.

8.1.3 Mechanical Separation

This method is suitable to remove large debris or to treat soils and solid wastes. Processes involve the use of force in filtration, sedimentation and centrifugation.

8.1.4 Mixing

This method produces a mixture of waste that is not totally combined or heterogenous, to enable or optimize treatment. However, the mixing of wastes with a POP content[67] above 50 mg/kg with wastes with a POP content below this threshold is not environmentally sound.

8.1.5 Oil-water separation

This method separates the oily and aqueous phases of waste for technologies that only treat one.

8.1.6 pH Adjustment

This method optimizes treatment by using an alkali, acid or carbon dioxide to produce the range over which technologies work most effectively. This method has been demonstrated to work for pre-treatment of PFOS waste (See Chapter 6) using a combined process of aeration and foam collection. In some instances, pH adjustment may be required post treatment.

8.1.7 Size Reduction

This method involves crushing, shearing, grinding, or preparing slurries for technologies that only process wastes of a limited size.

8.1.8 Solvent Washing

This method involves the use of a solvent to dissolve contaminants in liquid, solid or gaseous phase, in order to remove them in solution. It is effective for removing PCBs from capacitors and transformers. It may also be used to remediate soils and extract materials recovered in adsorption or absorption (See Section 8.1.1 – Adsorption and absorption).

8.1.9 Thermal Desorption

This method involves either direct or indirect heat 90-350 ^{0}C or 320-559 ^{0}C which increases the volatility of contaminants to separate them from a solid matrix, such as soil, sludge or a filter cake, depending on their physical properties. The resulting gas stream is collected, condensed or destroyed. UPOPs may result from the treatment of chlorinated compounds so secondary treatment may be required. This method has been encouraged as an off-site remediation technology.

8.2 Destruction and Irreversible Transformation Methods

These methods treat the POP content in wastes using Best Environmental Practices and Best Available Techniques. They may be classified in four categories:

- Physio-chemical treatment- These include Alkali Metal Reduction, Base Catalyzed Decomposition, Catalytic Dehydrochlorination, Gas Phase Chemical Reduction, Plasma Melting Decomposition Method, Supercritical and Subcritical Water Oxidation;

[67] For UPOPs, this threshold is limited to 15 µg TEQ/kg

- Incineration on land - These include Hazardous Waste Incineration;
- Use as a fuel or other means to generate energy - These include Cement kiln Co-incineration and Plasma Arc;
- Recycling or reclamation of metals and metal compounds in primary or secondary metallurgy- These include Thermal and Metallurgical Production of Metals.

Table 2 below presents the technologies relevant to each of the POPs and the following sections give a brief overview of each process.

8.2.1 Alkali Metal Reduction

Alkali metals react with chlorine in halogenated waste to produce salts and non-halogenated waste such as nitrogen, hydrogen, sodium chloride, sodium hydroxide, polyphenyls and water. Reducing agents used for this process include sodium, potassium or potassium-sodium alloy. The process occurs at atmospheric pressure and between 60 ^{0}C and 180 ^{0}C. It may be performed on or off site since mobile facilities are available. Dewatering, through phase separation and evaporation, is essential to a prevent explosions with sodium. Organic dissolution or extraction are further required preparatory steps.

After the reduction, excess sodium must be neutralized or recovered. Volatile organic compounds may be captured with activated carbon. This method is available commercially in the North America, France and Germany.

8.2.2 Base Catalyzed Decomposition

This process treats liquid or solid waste with a reducing oil, an alkali metal hydroxide, carbonate or bicarbonate, and a proprietary catalyst. Hydrogen atoms, produced above 300 ^{0}C, remove contaminants from the waste. Pre-treatment may involve pH adjustment (See Section 8.1.6), size reduction (See Section 8.1.7) and/or thermal desorption (See Section 8.1.9). Base Catalyzed Decomposition facilities use activated carbon to control volatile organic compounds. The inorganic and carbonaceous solids are separated from unreacted oil by gravity or centrifugation. The salts and excess base can be removed from the carbon residue by washing. The unused oil may be reused in a cement kiln as a fuel source (see Section 8.2.4). The remaining sludge may be pre-treated by desorption and used as a neutralizing agent. This process strips chlorine so complete decomposition of PCDDs and PCDFs is essential to prevent the formation of the more toxic low-chlorinated congeners. This technology has been demonstrated in USA, Australia, Spain, Mexico and the Czech Republic[68].

8.2.3 Catalytic Hydrodechlorination

This process uses hydrogen gas and palladium on a carbon catalyst in paraffin oil to dehalogenate waste at atmospheric pressure, between 180 ^{0}C and 260 ^{0}C. It produces hydrogen chloride and non-halogenated waste. Essential pre-treatment includes solvent extraction or vaporization of PCBs and PCDDs/PCDFs, and distillation of water and alcohols. The catalyst and reaction may be reused after the biphenyl is distilled.

[68] https://www.geocycle.com/sites/geocycle/files/atoms/files/co-processing_supporting_document_giz-holcim_guidelines_0.pdf

Table 2: Suitable technologies for POPs covered in this chapter

Technology	PCB	Chlordane	HCH	HBCD	PCP	POP-PBDEs	PCDDs	PCDFs	Chlordecone	DDT	Endosulfan	Heptachlor	HCB	BFRs	PFOS	Aldrin	Endrin
Alkali metal reduction	X	X	X		X												
Base catalysed decomposition	X	X	X		X		X	X		X			X				
Catalytic hydrodechlorination	X						X	X									
Cement kiln co-incineration	X	X	X	X	X	X	X	X	X	X	X	X	X				
Gas phase chemical reduction	X	X	X	X	X	X	X	X	X	X	X	X	X				
Hazardous waste incineration	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Plasma arc	X	X							X	X	X	X	X				
Potassium tert-Butoxide (t-BuOk) method	X																
Plasma melting decomposition method	X																
Supercritical water oxidation and subcritical water oxidation	X	X					X			X				X	X		
Thermal and metallurgical production of metals						X	X	X									
Waste-to-gas conversion	X						X	X									

8.2.4 Cement Kiln Co-incineration

This method produces clinker from heating to at least 1400 ^{0}C and drying of limestone, silica, alumina and iron oxides. Annex 6 of the GIZ-Holcim guidelines[69] present an "Accept-Refuse Chart" to determine if the type of waste is suitable for this process. While it treats both liquid and solid wastes, thermal desorption of solid wastes or homogenization of solid and liquid wastes (by drying, shredding, blending, mixing and grinding) may be required before incineration. Pre-treatment may also include volume reduction and neutralization.

Emission Control is important since emissions can include oxides of nitrogen and sulphur, carbon monoxide, metals and their compounds, hydrogen chloride, hydrogen fluoride, ammonia, PCDDs, PCDFs, benzene, toluene, xylene, polycyclic aromatic hydrocarbons, chlorobenzenes, PCBs and PCN.

This method is cited as a high source of UPOPs in Annex C to the Stockholm Convention. Cement kiln dust, organic compounds, sulphur dioxide and nitrogen oxide must be removed from process gases. Heating minimizes the formations of PCDDs and PCDFs since these form during cooling between 450 and 200 ^{0}C[70]. Recovered dust should be reused.

This method has been trialled in India through 22 demonstrations and endorsed by their Central Pollution Control Board[71]. Additional guidance is provided in ***Technical guidelines on the environmentally sound co processing of hazardous wastes in cement kilns***[72].

Case Study

Japan demonstrated the efficiency of Cement Kiln Co-incineration through a pilot project on 5 batches of wastes with high chlorine content and non-halogenated organophosphorus flame retardants used as alternatives to PBDEs. The facility consisted of a rotary kiln primary combustion chamber, a vertical secondary combustion chamber, a gas cooling zone, a bag filter, an activated carbon adsorption tower and a wet scrubber (Figure 37). Pre-treatment included adsorption onto carbon-rich silica gel, drying and dissolution.

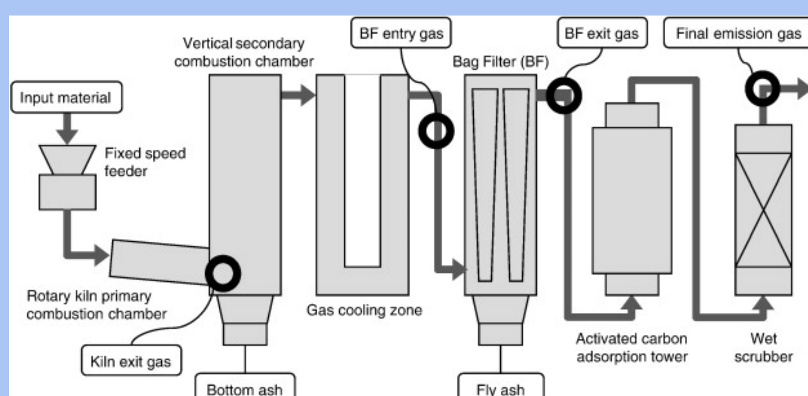

Figure 37: Schematic of Incinerator

(Matsukami et al., 2014)

Source: https://www-sciencedirect-com.ezproxy.lib.uconn.edu/science/article/pii/S0048969714009188

[69] https://www.geocycle.com/sites/geocycle/files/atoms/files/co-processing_supporting_document_giz-holcim_guidelines_0.pdf
[70] PCDD/PCDF can be destroyed during combustion with appropriate temperatures, residence times and mixing. Rapid cooling prevents formation.
[71] https://www.sciencedirect.com/science/article/pii/S1878029616301244
[72] http://www.basel.int/Portals/4/Basel%20Convention/docs/pub/techguid/cement/tg-cement-e.pdf

8.2.5 Gas Phase Chemical Reduction

This process is an alternative to incineration. It treats organic compounds at temperatures above 850 ^{o}C and low pressures using heat and hydrogen. This process is suitable for aqueous and oily liquids, soils, sediments, sludges, transformers and capacitators once contaminants are vapourised. Volatization pre-treatments include thermal reduction batch processors, toroidal bed reactors and liquid waste pre-heater systems. Further required pre-treatment include size reduction below 1 square metre. Effluent gases leave the reactor through a stainless-steel central tube that leads to the scrubber system. Gas scrubbing and disposal of water, heat and acid will be required post-treatment and release control. Hydrogen can be regenerated through steam reforming. The cost efficiency of this process is proportional to the POP concentration. It is commercially available in St. Catherines, Ontario, Canada where PCB concentrate, and PCB contaminated concrete are treated[73].

8.2.6 Hazardous Waste Incineration

This process mixes and heats organic contaminants over 850 ^{o}C, or 1100 ^{o}C if it contains chlorine. It treats 30, 000 to 100, 000 tonnes of waste per year in any phase. Pre-treatment may include blending and size reduction. Post treatment involves solidification and special landfilling. Release controls include cyclones and multi-cyclones, electrostatic and static bed filters, scrubbers, selective catalytic reduction, rapid quenching systems and carbon adsorption.

NOTE:
The process produces carbon monoxide, carbon dioxide, HCB, hydrogen chloride, particulate, PCDDs, PCDFs, PCBs, heavy metals and water vapour.

Case Study

Eleven Caribbean countries remove significant amounts of obsolete pesticides stocks and hazardous wastes

This decision will result in healthier and more sustainable food production

November 15, 2017 (Bridgetown, Barbados). In a commitment to agricultural safety, food security, environmental and human health, eleven Caribbean countries are now free from significant quantities of hazardous pesticide waste, as well as their contaminated containers and stores.

The removal of 319 tonnes of obsolete pesticides stocks and related wastes was confirmed by the Food and Agricultural Organization of the United Nations (FAO) at the 71st Special Meeting of the Council for Trade and Economic Development (COTED) on Agriculture, held at the Secretariat of the Caribbean Community (CARICOM), Georgetown, Guyana last month.

Under the "Disposal of Obsolete Pesticides Including POPs, Promotion of Alternatives and Strengthening Pesticides Management in the Caribbean" project, 11 Caribbean SIDS exported 319 tonnes of wastes for incineration in the United Kingdom (Food and Agriculture Organisation, 2017).

Source: http://www.fao.org/americas/noticias/ver/en/c/1068631/

[73] https://www.nap.edu/read/5274/chapter/8

8.2.7 Plasma Arc

This process involves the pyrolysis - decomposition brought about by high temperatures – (See Section 8.4) of solid waste at high temperatures of 1000 °C to 3000 °C into elemental atoms and ions. It uses air and electricity to treat toxins in municipal garbage and medical waste, recycle metals to produce useable by-products such as synthetic gas (syngas) that can be used for electricity. Solid waste is gasified using a plasma[74] arc. Plasma Arc Gasification is a thermally efficient process that emits little carbon dioxide. Pre-treatment may include thermal desorption (See Section 8.1.9.), solvent washing/extraction (See Section 8.1.8) and crushing (See Section 8.1.7) to increase the surface area for pyrolysis.

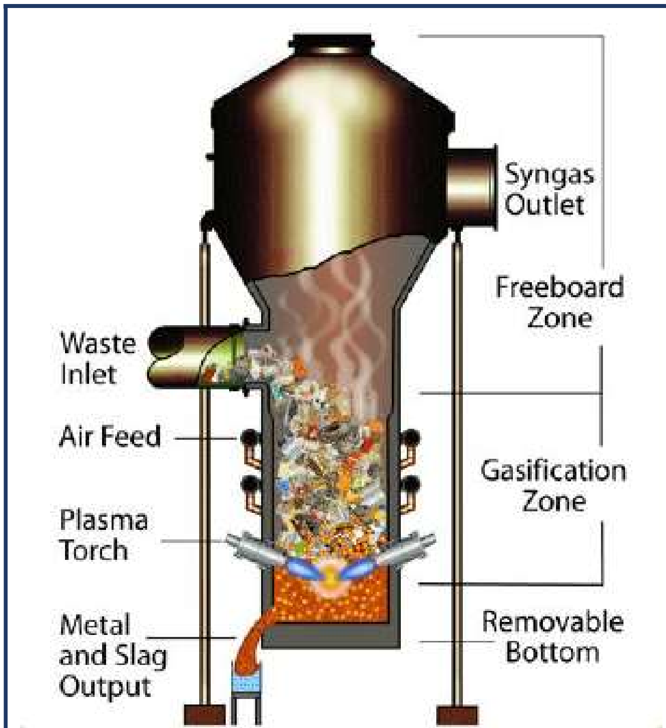

Figure 38: Schematic diagram of a Plasma Gasifier
(Westinghouse Plasma, n.d.)

Advantages of this technology include the reduced production of oxygenated pollutants due to the lower oxygen levels, its compactness and mobility. Four commercial plants are in Australia, four in Japan and one in Mexico.

8.2.8 Potassium tert-Butoxide (t-BuOk) method

This method dechlorinates PCBs to produce salt. Dewatering (See Section 8.1.2) is essential pre-treatment because the reagent will react more readily with water than chlorine. Decontaminated mineral oils may be reused as fuel.

8.2.9 Supercritical Water Oxidation and Subcritical Water Oxidation

These processes increase the solubility of organic materials by using oxidizing agents such as oxygen, hydrogen peroxide, nitrite and nitrate in water. Pre-treatment may involve size reduction (See Section 8.1.7) and dewatering (See Section 8.1.2). They produce carbon dioxide, water and inorganic acids or salts. The conditions for supercritical water oxidation must be above the critical point of water (374 °C and 218 atmospheres) while the conditions for subcritical water oxidation conditions must be below the subcritical conditions (370 °C and 262 atmospheres). These methods treat aqueous wastes, oils, solvents and solids smaller than 200 micrometres, with less than 20% by weight organic content. Supercritical water oxidation involves feed preparation and pressurization, heat exchange, pressure decrease and separation.

[74] Plasma is a superheated column of electrically conductive gas. (Ojha et al., 2012)

8.2.10 Thermal and Metallurgical Production of Metals

These processes reduce waste at 1200°C and quench it to destroy PCDDs and PCDFs and prevent UPOPs, though it may be a source of UPOPs. These can be mitigated with temperature control and rapid quenching. Post-treatment may involve dedusting of sulphur dioxide which can be used to make acid after heat recovery.

8.2.11 Waste-to-gas Conversion

This process doubles as a gasification pre-treatment (See Section 8.4 – Pyrolysis/Gasification) and method that treats organic waste in any phase to produce hydrogen, carbon oxides, and the first four short-chain alkanes (methane, ethane, propane, butane). This gas may be purified into methanol. Required pre-treatment for this method includes size reduction (See Section 8.1.7).

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

These methods are suitable for waste with a POP content above the prescribed low POP content of each contaminant. Sources of wastes permitted for these alternatives include, but are not limited to:

- Combustion facilities[75],
- Ferrous[76] and Non-ferrous[77] thermal metallurgy,
- Construction and Demolition[78],
- Incineration (Ash),
- Vitrification (See Section 8.4).

8.3.1 Specially Engineered Landfill

A Specially Engineered Landfill is one equipped to control deposited waste. Geological and synthetic barriers[79] should be used during operation, closure and post-closure. Figure 39 illustrates a suitable liner system. The production of gases such as methane should be prevented, reduced or controlled and collected where applicable. On-site treatment technologies[80] for leachate should be available to reduce or prevent its entry into the environment. Acceptable waste must be classified. For example,

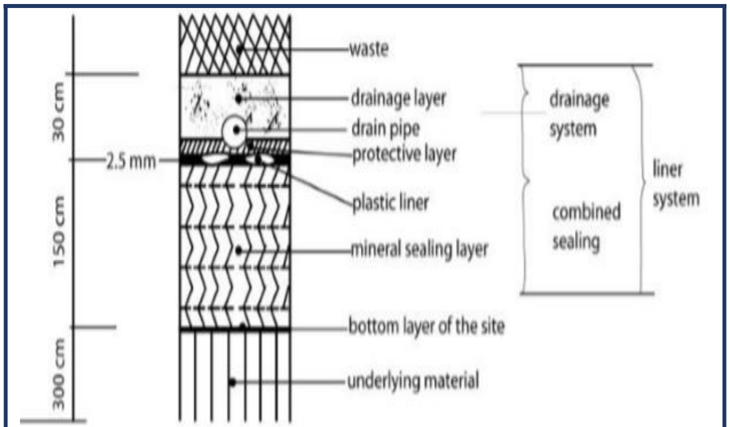

Figure 39: Liner system for a special engineered landfill ***(UNEP, 2002)***

[75] Such as Power Stations
[76] Such as iron and steel
[77] Such as Aluminium, lead, zinc and copper
[78] Excludes PCB-containing equipment. Includes concrete, bricks, tiles, ceramics, soil and stone.
[79] Containment materials may include local soil or waste with high absorptivity and low hydraulic conductivity.
[80] These may be physiochemical (such as active carbon filtration, nanofiltration or reverse osmosis) or biological

they must have a standardized concentration limit value[81]. Wastes that should not be included in a specially engineered landfill include:

- Liquids[82],
- Biodegradable organic wastes,
- Empty Containers (without pre-treatment to reduce volume[83]),
- Chemically unstable wastes[84].

Landfilling is a common practice in the Caribbean region. During an OECS project in the early 2000s, Solid Waste Management Facilities were improved in OECS countries. Although efforts were made to improve landfill facilities in the OECS countries, as of 2016, sanitary landfills were only present in 54% of the Latin American and Caribbean Region[85] with majority of countries relying on open air dumpsites for waste disposal[86]. In the Caribbean region to date, sanitary landfills can be found in OECS countries such as Saint Kitts and Nevis, Saint Lucia and Saint Vincent and the Grenadines, as well as the Bahamas, Barbados, Belize, and Guyana.

The engineered/control landfill is preferred as a temporary measure until destructive technologies are available for developing countries. Waste should be pre-treated to minimize the potential of the POP content entering the environment. Suitable methods include solidification and chemical fixation.

Figure 40: Sanitary Engineered Landfill, Belize
(BCRC-Caribbean, 2019)

Figure 41: Plantation Landfill, Barbuda
(BCRC-Caribbean, 2019)

[81] Considerations should include disallowing the dilution or blending of hazardous waste with non-hazardous material to meet a concentration limit.
[82] This may be free, contained or absorbed. Liquids may be released at high pressure.
[83] By crushing or shredding
[84] These include: shock sensitive explosives, compressed gases, flammable or pyrophoric solids, self-heating spontaneously combustible materials, water-reactive materials, pyrophoric solids, self-reactive wastes, oxidizers, organic pesticides, corrosive wastes, infectious wastes, concentrated acids and alkalis, and substances that react with water, air or dilute acids and alkalis to produces hazardous gases or reactions.
[85] http://documents1.worldbank.org/curated/en/137371475089134876/pdf/000020051-20140612094138.pdf
[86] http://www.caribcement.com/wp-content/uploads/2019/07/Solid-Waste-Management-in-the-Caribbean-Proceedings-from-the-Caribbean-Solid-Waste-Conference.pdf

8.3.2 Permanent Storage in Underground Mines and Formations

Disposal by this method should prevent chemical and physical reactions between wastes and lining through pre-treatment and secure containers. This is not suitable for liquid, gaseous, explosive, flammable, infectious or material that emit toxic gases. Considerations for permanent underground storage include:

- Distance from active and dormant mining sites;
- Depth below zone of available groundwater or isolation from water-bearing zones by impermeable rock or clay layers;
- Geological stability and susceptibility to earthquakes.

8.4 Other disposal methods when the POP content is low

The following methods are also suggested for the environmentally sound disposal of wastes that have a low POP content. These include:

- **Copper Mediated Destruction** - This cost-effective method treats PCBS, PCDD/F and pesticides in all phases. It requires size reduction and homogenization. It has been used for remediation in Poland[87] and DDT and lindane in Czech Republic.
- **GeoMelt™** - This method is a form of vitrification remediation technology. It uses an electric current through graphite electrodes to convert contaminated soil and wastes into a stable glass or crystalline product. This process allows volume reduction. Inorganic hazardous elements are incorporated into the molten zone while organic components are thermally destroyed through pyrolysis. It may be applied on or off site. It is effective on PCBs, PCDD and pesticides. It requires mixing, dewatering, drying. Off-gases must be treated with filtration, dry and wet scrubbing. This method has been used to treat HCB in Australia[88].
- **Mechanochemical Dehalogenation** - This method[89] uses hydrogen, magnesium and sodium in a reduction reaction. It is effective on DDT, Chlordane, PCDD/Fs, PBDEs and PCBs. When used to treat PFOS, sodium hydroxide was found to be a better comilling reagent for PFOS destruction. (Zhang et al., 2013)[90] It was further demonstrated followed by analysis using liquid chromatography, mass spectroscopy, ion chromatography, total organic carbon infrared spectroscopy, x-ray diffraction and x-ray photoelectron spectroscopy. (Yan et al 2015)[91] This method hinders the release of contaminants through a decrease in energy. Required pre-treatment involves drying and size reduction.
- **Mediated Electrochemical Oxidation** - This process uses metal salt in a sulphuric acid electrolyte. It is effective on liquid or slurry PCBs, PCCD and pesticides. It produces hydrogen gas.

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87 http://awhhe.am/wp-content/uploads/2011/02/Destruction_technologies.pdf
88 http://www.orica.com/ArticleDocuments/775/2012_BTP_HCB_Concise-History.pdf.aspx
89 Commercial identity of ball milling technology
90 https://pubs.acs.org/doi/abs/10.1021/es400346n
91 https://pubs.rsc.org/en/content/articlelanding/2015/ra/c5ra15337a#!divAbstract

- **Molten Salt Oxidation** - This method involves a thermal but non-flame process that oxidises organic constituents while retaining hazardous and radioactive constituents. This process is effective on PCBs.
- **Pyrolysis/Gasification** - This method is an offsite process which involves anoxic[92] chemical decomposition in which components are broken down in the absence of oxygen. It is effective on PCBs, pesticides and dioxins such as PCDD in any phase. Drying is required pre-treatment and reduces costs. Required post-treatment includes stabilization of treated media containing heavy metals. It produces char/ash, oil and gas. This method is used to treat Medical Waste in Saint Lucia.
- **Solvated Electron** - This method is effective for PCBs, PCDD and pesticides. It requires dewatering (See Section 8.1.2) and size reduction (See Section 8.1.7).
- **Thermal Retorting** - This process incorporates desorption.
- **Photochemical dechlorination (PCD) and catalytic dichlorination (CD) reaction** - This method dechlorinates PCBs in a mixture of sodium hydroxide and isopropyl alcohol. It produces biphenyl, sodium chloride, acetone and water.
- **Sodium Reduction** - This method treats PCBs in any concentration.

8.5 Overall Considerations

When selecting a POPs disposal method, key points to consider include:

- Stockholm Convention criteria,
- Destruction Efficiency,
- Containment,
- Economic Affordability,
- Environmental Sustainability,
- POP Content,
- Characteristics[93] of organic contaminants determine the appropriate treatment processes.

Details are available in the ***Selection of Persistent Organic Pollutant Disposal Technology for the Global Environment Facility: A STAP advisory document***[90]

8.6 General considerations when dealing with POPs and associated wastes:

- Overall, the SC also strongly encourages the use of alternatives to POPs an s POPs contaminated products and materials. Additional guidance on alternatives can be accessed on the SC's website at: http://chm.pops.int/Implementation/Alternatives/AlternativestoPOPs/tabid/5832/Default.aspx.
- A Hazardous Waste Specialist should be engaged when dealing, handling, movement and disposal of POPs and the associated wastes.

[92] Less than stoichiometric quantity of oxygen.
[93] Molecular size, solubility, ionic form, volatility, oxidizability, hydrolysis, photolysis, and biodegrability.

- A risk assessment should be conducted of the site /material condition that identifies the health safety and environmental (HSE) risks of the waste, containers, location, access, etc. prior to handling, movement, or disposal initiatives. This can inform the management/disposal plan by identifying the risk controls to be installed.

9 Annex A

STOCKHOLM CONVENTION

BCRC CARIBBEAN
Basel Convention Regional Centre for Training and Technology Transfer for the Caribbean

UN environment programme

Fact Sheet

Sources of the Persistent Organic Pollutants (POPs) listed under the Stockholm Convention

Persistent Organic Pollutant	Potential Main Sources
Pesticides	
Aldrin, Chlordane, DDT, Toxaphene, Dieldrin, Endrin, Heptachlor, Hexachlorobenzene (HCB)*, Mirex ▲ Alpha-hexachlorocyclohexane (alpha-HCH)*, Beta-hexachlorocyclohexane (beta-HCH)*, Lindane, Chlordecone, Pentachlorophenol (PCP), Endosulfan, Dicofol	• Insecticides • Herbicides • Rodenticides • Bactericides • Fungicides • Larvicides
Industrial Chemicals	
Polychlorinated biphenyl (PCB)*,▲, Short-chain chlorinated paraffins (SCCPs)	• Heat exchange fluids in electrical equipment e.g. Transformers and Capacitors • Lubricants, Paints, Inks, Adhesives
Brominated Flame Retardants: Hexabromobiphenyl (HBB), Tetra-and penta-bromodiphenyl ether, Hexa-and hepta-bromodiphenyl ether & Decabromodiphenyl ether (PBDEs), Hexabromocyclododecane (HBCD)	• Plastics in electrical and electronic equipment • Polystyrene in transport and construction • Foams for furniture • Textile coating e.g upholstery, furniture, curtains, apparel
Fluorinated Surfactant: Perfluorooctane sulfonic acid and its salts (PFOS■ /Sulfluramide and PFOS-F), Perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds	• Firefighting foams • Oil drilling operations • Chrome plating industry • Aviation hydraulic fluids • Surface treatment of synthetic carpets • Textiles and leather
Unintentionally produced POPs (UPOPs)	
Polychlorinated dibenzo-p-dioxins (PCDD), Polychlorinated dibenzofurans (PCDF), Polychlorinated naphthalenes (PCNs), Hexachlorobutadiene (HCBD)•, Pentachlorobenzene (PeCB) ▲,■	• Waste Incineration • Metal Production • Heat and Power Generation • Production of Mineral Products • Transport

NOTES: Blue Text - Original Dirty Dozen POPs
* Also produced unintentionally
▲ Also used in fire retardants
• Also used as a pesticide

Orange Text - Newly Listed POP
■ Also used as an industrial chemical

BCRC-Caribbean - FACT SHEET on Persistent Organic Pollutants listed under the Stockholm Convention (September 2020)

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10 References

AIMPLAS, 2020. *LIFE CIRC-ELV - About the Project.* [Online]
Available at: https://lifecircelv.eu/project.php
[Accessed November 2020].

Basel Convention Regional Centre for Training and Technology Transfer for the Caribbean, 2017. *Regional manual for POPs inventory development for NIPs update in the Caribbean,* s.l.: s.n.

Basel Convention Regional Centre for Training and Technology Transfer for the Caribbean, 2013. *BCRC-Caribbean Projects (Information Dissemination).* [Online]
Available at: https://www.bcrc-caribbean.org/information-dissemination/
[Accessed 6 October 2020].

Basel Convention Regional Centre for Training and Technology Transfer for the Caribbean, 2019. *Introductory Manual for Caribbean Countries - Sampling and Analytical Methods for the Determination of POPs,* s.l.: s.n.

Basel Convention, 2006. *Basel Convention Training Manual on Illegal Traffic for Customs and Enforcement Agencies,* s.l.: s.n.

Basel Convention, 2009. *Mobile Phone Partnership Initiative Project 2.1,* s.l.: s.n.

Basel Convention, 2011. *Home Page.* [Online]
Available at: http://www.basel.int/
[Accessed 6 October 2020].

Basel Convention, 2011. *Technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns,* Cartagena, Colombia: s.n.

Basel Convention, 2015. *Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane,* Geneva: s.n.

Basel Convention, 2015. *Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromodiphenyl ether and heptabromodiphenyl ether, or tetrabromodiphenyl ether and pentabromodiphenyl ether,* Geneva: s.n.

Basel Convention, 2015. *Technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment, in particular regarding the distinction between waste and non-waste under the Basel Convention,* Geneva: s.n.

Basel Convention, 2017. *Documents developed by the Partnership for Action on Computing Equipment,* Geneva: s.n.

Basel Convention, 2017. *General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants,* s.l.: s.n.

Basel Convention, 2017. *General Technical Guidelines on the Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Persistent Organic Pollutants,* s.l.: s.n.

Basel Convention, 2017. *Technical Guidelines on the Environmentally Sound Management of Waste,* s.l.: s.n.

Basel Convention, 2017. *Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with polychlorinated biphenyls, polychlorinated terphenyls, polychlorinated naphthalenes or polybrominated biphenyls including hexabromobiphen,* s.l.: s.n.

Basel Convention, 2017. *Technical guidelines on the environmentally sound management of wastes containing or contaminated with unintentionally produced polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, hexachlorobenzene, polychlorinated biphenyls, pentachlorobenz,* Geneva: s.n.

Basel Convention, 2019. *Technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment, in particular regarding the distinction between waste and non-waste under the Basel Convention,* Geneva: s.n.

Basel Convention, 2019. *Updating and or Development of Technical Guidelines for the Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Persistent Organic Pollutants.* [Online]
Available at:
http://www.basel.int/Implementation/POPsWastes/TechnicalGuidelines/tabid/5052/Default.aspx
[Accessed 6 October 2020].

Basel Convention, 2017. *Fact sheets on specific waste streams.* [Online]
Available at: http://www.basel.int/Default.aspx?tabid=5843
[Accessed 24 November 2020].

Basel Convention, n.d. *PACE Guidelines, Manual and Reports.* [Online]
Available at:
http://www.basel.int/Implementation/TechnicalAssistance/Partnerships/PACE/PACEGuidelines,ManualandReports/tabid/3247/Default.aspx
[Accessed November 2020].

Boiler and Plant Dismantlers Ltd, n.d. *Industrial Disposal.* [Online]
Available at: https://www.industrialdisposal.net/
[Accessed 26 October 2020].

Business Insider, 2019. *7 toxic chemicals hiding in your waterproof, stain-resistant, and wrinkle-free clothes.* [Online]
Available at: https://www.businessinsider.com/toxic-chemicals-in-clothes-cancer-2019-7
[Accessed November 2020].

California Department of Public Health, 2012. *Electronic Waste Recycling: Working Safely.* [Online]
Available at:
https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/OHB/HESIS/CDPH%20Document%20Library/eWaste.pdf
[Accessed 24 November 2020].

Caribbean Public Health Agency (CARPHA), 2018. *Final Draft National Implementation Plan for POPs in Saint Lucia,* s.l.: s.n.

Chapple, R., 2012. *Hexachlorobenzene (HCB) waste at the Botany Industrial Park, Sydney - A concise history of management and disposal efforts,* Sydney, Australia: s.n.

ChemSafetyPRO, 2019. *GHS and Pesticides 2019.* [Online]
Available at: https://www.chemsafetypro.com/Topics/GHS/GHS_for_pesticides.html
[Accessed 26 October 2020].

Creative Safety Supply, n.d. *Warning: Prop 65 Perfluorooctane Sulfonate (PFOS) - Wall Sign.* [Online]
Available at: https://www.creativesafetysupply.com/warning-prop-65-perfluorooctane-sulfonate-pfos-wall-sign/
[Accessed November 2020].

Creative Safety Supply, n.d. *Warning: Prop 65 Polychlorinated Dibenzo-P-Dioxins - Wall Sign.* [Online]
Available at: https://www.creativesafetysupply.com/warning-prop-65-polychlorinated-dibenzo-p-dioxins-wall-sign/
[Accessed November 2020].

CropLife International, 2015. *Roadmap for Establishing A Container Management Program for Collection and Disposal of Empty Pesticide Containers,* Brussels, Belgium: s.n.

CropLife Latin America CLLA, 2015. *How to perform Triple Rinsing?.* [Online]
Available at:
https://www.youtube.com/watch?v=HAWbSIh0ZFI&feature=youtu.be&ab_channel=CropLifeLatinAmericaCLLA
[Accessed November 2020].

CropLife Mauritius, 2018. *Empty Pesticide Container Management Pilot Project,* s.l.: s.n.

Dangerous Goods Fix Limited, n.d. *Packaging.* [Online]
Available at: https://dgfix.co.uk/packaging/
[Accessed November 2020].

Department of Environment and Heritage Protection, 2016. *Firefighting Foam Management Policy – Explanatory Notes (Revision 2),* s.l.: s.n.

dpilabels, n.d. *CP-2 Custom Hazardous Waste.* [Online]
Available at: https://dpilabels.com/product/cp-2-cust
[Accessed November 2020].

E Waste Recycle Hub, 2017. *Electrical Waste Management & Recycling Solutions.* [Online]
Available at: http://ewasterecyclehub.com/
[Accessed 24 November 2020].

Enclave Resources, n.d. *St kitts - Landfill pictures.* [Online]
Available at: https://www.enclaveresources.net/st-kitts-island
[Accessed November 2020].

Environment Agency, 2017. *Handling end-of-life vehicles (ELVs) what do you need to do?,* s.l.: s.n.

Environmental Health and Safety, 2020. *Chemical Segregation Chart.* [Online]
Available at: https://ehs.ucr.edu/sites/g/files/rcwecm1061/files/2020-07/Chemical-Segregation-Guidance-Sheet-Final.pdf
[Accessed November 2020].

Food and Agriculture Organisation, 2001. *FAO Training Manual for Inventory Taking of Obsolete Pesticides,* Rome, Italy: Food and Agriculture Organisation.

Food and Agriculture Organisation, 2009. *Environmental Management Tool Kit for Obsolete Pesticides.* [Online]
Available at: http://www.fao.org/3/a-i0474e.html
[Accessed 6 October 2020].

Food and Agriculture Organisation, 2015. *Disposal of Obsolete Pesticides including POPs, Promotion of Alternatives and Strengthening Pesticides Management in the Caribbean.* [Online]
Available at: http://www.fao.org/gef/projects/detail/en/c/1056800/
[Accessed 6 October 2020].

Food and Agriculture Organisation, 2017. *Eleven Caribbean countries remove significant amounts of obsolete pesticides stocks and hazardous wastes.* [Online]
Available at: http://www.fao.org/americas/noticias/ver/en/c/1068631/
[Accessed 2020].

Forde, M. & Dewailly, E., 2015. What Is in the Caribbean Baby? Assessing Prenatal Exposures and Potential Health Outcomes to Environmental Contaminants in 10 Caribbean Countries. *West Indian Medical Journal,* 64(1), pp. 23-28.

Freeman, P. N., 2004. *ICR Review for Solid Waste Management Project (Project ID:P006970),* s.l.: OED, World Bank.

GAIA, n.d. *The Chemicals Lurking in Your Carpet.* [Online]
Available at: https://www.no-burn.org/chemicalsincarpet/
[Accessed 24 November 2020].

Herat, S., 2013. *Standards for Collection, Storage, Transport, Recovery, Treatment and Disposal to Ensure Environmentally Sound Management of E-waste,* s.l.: Institute for Global Environmental Strategies.

Holcim Group Support Ltd, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, 2006. *Guidelines on Co-processing Waste Materials in Cement Production,* s.l.: s.n.

Hubei Veldlion Machinery Co., Ltd., n.d. *8m3 Sludge Suction Transportation Truck Garbage Suction Truck.* [Online]
Available at: https://veldlion.en.made-in-china.com/product/NCVJjgKyQihe/China-8m3-Sludge-Suction-Transportation-Truck-Garbage-Suction-Truck.html
[Accessed 25 November 2020].

Jindrich, A. P., 2010. *Technologies for Obsolete Pesticides Destruction and Clean-up Methods,* Yerevan: s.n.

Labelmaster, n.d. *UN Markings Guide: How to Read and Identify UN Packaging Codes.* [Online]
Available at: https://www.labelmaster.com/un-markings
[Accessed 6 October 2020].

Matsukami, H., Kose, T., Watanabe, M. & Takigami, H., 2014. Pilot-scale incineration of wastes with high content of chlorinated and non-halogenated organophosphorus flame retardants used as alternatives for PBDEs. *Science of The Total Environment,* Volume 493, pp. 672-681.

Ministry of the Environment of Japan, 2013. *Summary of the Guideline on the Treatment of Wastes Containing Perfluorooctane Sulfonic Acid (PFOS), and Its Salts in Japan,* s.l.: s.n.

MP Packaging, n.d. *The collecting and transport of e-Waste,* s.l.: s.n.

National Research Council, 1996. Gas-Phase Chemical Reduction Technology. In: *Review and Evaluation of Alternative Chemical Disposal Technologies.* Washington, DC: The National Academies Press.

National Resources Institute, 1996. *Pesticide Storage and Stock Control Manual,* s.l.: Food and Agirculture Organisation.

Ojha, A., Reuben, A. C. & Sharma, D., 2012. Solid Waste Management in Developing Countries through Plasma Arc Gasification- An Alternative Approach. *APCBEE Procedia,* Volume 1, pp. 193-198.

Parlikar, U. et al., 2016. Effect of Variation in the Chemical Constituents of Wastes on the Co-processing Performance of the Cement Kilns. *Procedia Environmental Sciences,* Volume 35, pp. 506-512.

Păun, M. C., Plesca, V., Vijgen, J. & Weber, R., 2014. *Management and disposal of Obsolete Pesticide Stock Case Studies: Romania and the Republic of Moldova,* s.l.: s.n.

Polyeco Group, n.d. *Removal, Packaging, Air Transport & Disposal of PCBs from Kazakhstan.* [Online]
Available at: https://www.polyecogroup.com/case-studies/pcb-management-kazakhstan/
[Accessed 26 October 2020].

Rader Environmental Services, Inc., 2020. *What Is a Lab Pack?.* [Online]
Available at: http://radernow.com/what-is-a-lab-pack/
[Accessed 25 November 2020].

Resources and Waste Advisory (RWA) Group, 2020. *Reduction of UPOPs emissions by improving waste management practices at landfills,* s.l.: s.n.

Riquelme, R., Méndez, P. & Smith, I., 2016. *Solid Waste Management in the Caribbean Proceedings from the Caribbean Solid Waste Conference.* s.l., Water and Sanitation Division Inter-American Development Bank.

Rotterdam Convention, 2010. *Home Page.* [Online]
Available at: http://www.pic.int/
[Accessed 6 October 2020].

SafetySign.com, 2021. *Certified Non PCB Label.* [Online]
Available at: https://www.safetysign.com/products/6750/certified-non-pcb-label
[Accessed 8 January 2021].

Secretariat of the Basel Convention, 2002. *Technical Guidelines on Hazardous Waste: Waste Oils from Petroleum Origins and Sources,* Châtelaine, Switzerland: s.n.

Secretariat of the Basel Convention, 2003. Châtelaine, Switzerland: s.n.

Secretariat of the Basel Convention, 2012. *Guidance document on the environmentally sound management of used and end-of-life mobile phones,* Châtelaine, Switzerland: United Nations.

Secretariat of the Basel Convention, 2013. *Revised technical guidelines for the environmentally sound management of used and waste pneumatic tyres,* Châtelaine, Switzerland: s.n.

Secretariat of the Basel Convention, 2018. *Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride,* Geneva: s.n.

Secretariat of the Basel, Rotterdam and Stockholm Conventions, 2012. *Home Page.* [Online]
Available at: http://www.brsmeas.org/
[Accessed 6 October 2020].

Smiths of the Forest of Dean Ltd, n.d. *Steel drums - recycled, reconditioned, remanufactured and new.* [Online]
Available at: https://www.smithsofthedean.co.uk/drums-and-barrels/steel-drums.html
[Accessed November 2020].

State Compensation Insurance Fund, 2014. *Safely Handling Electronic Waste.* [Online]
Available at:
https://content.statefundca.com/safety/safetymeeting/SafetyMeetingArticle.aspx?ArticleID=808
[Accessed 24 November 2020].

Stockholm Convention, 2013. *Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs,* s.l.: s.n.

Stockholm Convention, 2016. *Toolkit for the Sound Management of DDT for Disease Vector Control.* [Online]
Available at:
http://www.pops.int/Implementation/PesticidePOPs/DDT/DDTToolkit/tabid/5080/Default.aspx
[Accessed 6 October 2020].

Stockholm Convention, 2019. *All POPs listed in the Stockholm Convention.* [Online]
Available at: http://www.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx
[Accessed 6 October 2020].

Stockholm Convention, 2019. *Home Page.* [Online]
Available at: http://chm.pops.int/
[Accessed 6 October 2020].

Stockholm Convention, 2019. *Report on the assessment of alternatives to perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride,* Rome: s.n.

Stockholm Convention, 2019. *What are POPs?.* [Online]
Available at: http://chm.pops.int/TheConvention/ThePOPs/tabid/673/Default.aspx
[Accessed 6 October 2020].

Stockholm Convention, n.d. *PCBs: Overview.* [Online]
Available at:
http://chm.pops.int/Implementation/IndustrialPOPs/PCBs/Overview/tabid/273/Default.aspx
[Accessed 26 October 2020].

Sturmovik, 2012. [Online]
Available at: https://en.wikipedia.org/wiki/File:CP-SLOPE-wb-gantry-power-supply-transformer-PCB-warning.jpg#metadata

Tesfaye, F., Lindberg, D. K. & Humuyuni, J., 2017. *Valuable metals and energy recovery from electronic waste streams.* [Online]
Available at: https://www.researchgate.net/figure/Sorting-and-dismantling-e-waste-at-Sims-recycling-facility-in-Roseville-California-4_fig5_305755282
[Accessed 24 November 2020].

The Verge, 2016. *E-Waste Empire: Tracing New York City's millions of pounds of e-waste from shelf to shredder.* [Online]
Available at: https://www.theverge.com/2016/6/22/11991440/eri-e-waste-electronics-recycling-nyc-gadget-trash
[Accessed 24 November 2020].

U.S. Fire Administration, 2020. *The hidden dangers in firefighting foam.* [Online]
Available at: https://www.usfa.fema.gov/training/coffee_break/021120.html
[Accessed 25 November 2020].

UNEP, 2002. *Basel Convention Technical Guidelines on Specially Engineered Landfill (D5),* Châtelaine, Switzerland: s.n.

United Nations Economic Commission for Europe, n.d. *UN Recommendations on the Transport of Dangerous Goods - Model Regulations.* [Online]
Available at: http://www.unece.org/?id=3598
[Accessed 26 October 2020].

United Nations Environment Programme, 2002. *PCB Transformers and Capacitors From Management to Reclassification and Disposal,* s.l.: United Nations Environment Programme.

United Nations Environment Programme, n.d. *Guidance on POP Pesticides.* [Online]
Available at: http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-NIP-GUID-Pesticides.En.pdf
[Accessed 6 October 2020].

United Nations, 2017. *Globally Harmonized System of Classification and Labelling of Chemicals (GHS).* 7th ed. s.l.:United Nations.

United States Environmental Protection Agency, 2012. *Packaging Used Electronics for Transportation.* [Online]
Available at: https://www.epa.gov/sites/production/files/documents/fecpack.pdf
[Accessed 20 November 2020].

United States Environmental Protection Agency, 2020. *Persistent Organic Pollutants: A Global Issue, A Global Response.* [Online]
Available at: https://www.epa.gov/international-cooperation/persistent-organic-pollutants-global-issue-global-response
[Accessed 23 November 2020].

Veolia ES Technical Solutions, L.L.C., 2010. *Packaging guidelines: Lighting and Electronic Waste,* Port Washington, Wisconsin: Veolia ES Technical Solutions, L.L.C..

Vermeulen, I. et al., 2011. Automotive shredder residue (ASR): Reviewing its production from end-of-life vehicles (ELVs) and its recycling, energy or chemicals' valorisation. *Journal of Hazardous Materials,* 190(1-3), pp. 8-27.

Westinghouse Plasma, n.d. *Plasma Gasification.* [Online]
Available at: https://netl.doe.gov/research/Coal/energy-systems/gasification/gasifipedia/westinghouse
[Accessed November 2020].

White, E. & Singh Gole, R., 2013. *Patent Landscape Report on E-Waste Recycling Technologies,* s.l.: s.n.

World Health Organisation, n.d. *Persistent Organic Pollutants (POPs): About POPs.* [Online]
Available at: https://www.who.int/foodsafety/areas_work/chemical-risks/pops/en/
[Accessed 6 October 2020].

Yan, X. et al., 2015. Mechanochemical destruction of a chlorinated polyfluorinated ether sulfonate (F-53B, a PFOS alternative) assisted by sodium persulfate. *RSC Advances,* 5(104), pp. 2046-2069.

Zhang, K. et al., 2013. Destruction of Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA) by Ball Milling. *Environmental Science & Technology,* 47(12), pp. 6471-6477.

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