Hazardous substances in construction products and materials

Wahlström, Margareta; Teittinen, Tuuli; Kaartinen, Tommi; van Cauwenberghe, Liesbet

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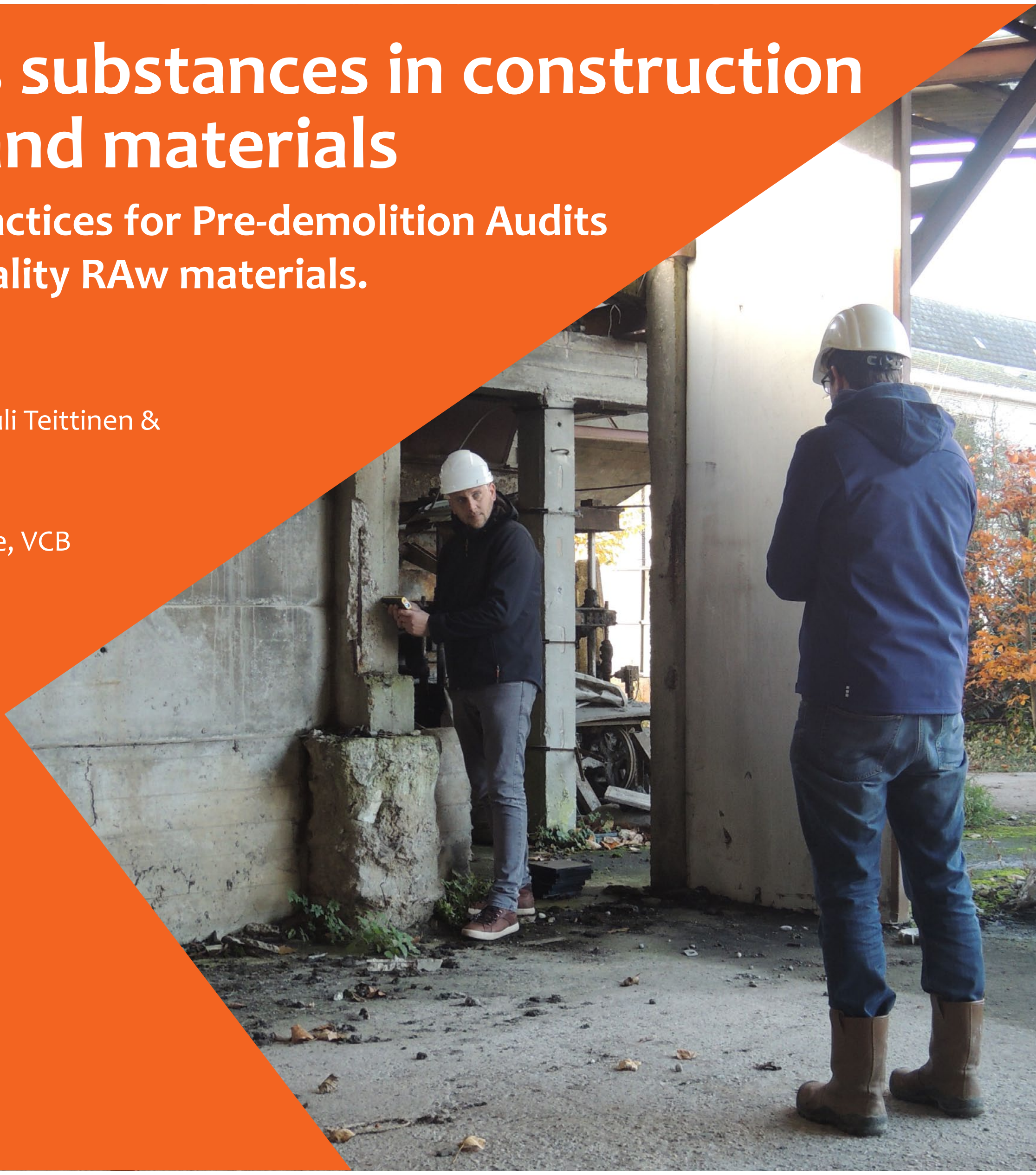
PARADE. Best practices for Pre-demolition Audits ensuring high quality RAw materials.



Margareta Wahlström, Tuuli Teittinen & Tommi Kaartinen, VTT

Annelies vanden Eynde & Liesbet van Cauwenberghe, VCB

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1. Introduction

1.1. Focus of the report

This guidance document aims to give an overview of potential hazardous substances that might occur in construction products and when appearing as waste need attention during renovation and demolition activities. Focus in this guideline is on hazardous substances regulated by EU or international agreements or national legislation.

Although the present legislation restricts the use of many hazardous substances in new building products, there is a considerable concern for compounds present in old construction products, since their presence in construction and demolition waste may limit the recyclability of the material and potentially cause waste management problems. One group of substances that has recently received attention are persistent organic pollutants (POP substances) such as e.g. some brominated flame retardants.

Important characteristic of the construction and building products is the relatively long life span. Because of long lifespan the restricted substances will enter the waste stream many decades after a ban has been placed on their use and they can therefore be found in renovation or demolition waste for a long time. Many of these substances provide important functionality in a wide range of products, e.g. flame retardants.

Besides hazardous substances also degradation in composition and quality aspects (e.g. mould) of construction products needs to be considered.

This document is part of the pre-demolition overall guidance document developed in the PARADE project.

1.2. Why is it important to identify and remove hazardous substances?

EU recycling targets and safe management of C&DW

The EU Waste Framework Directive[1] requires the Member States of the European Union to take the necessary measures to achieve a minimum of 70% (by weight) re-use, recycling and other material recovery (including backfilling) of non-hazardous construction and demolition waste by 2020. Tightening EU regulation puts pressure on more sustainable use of materials in construction and on closing the material loops. The Commission is now considering new reuse and recycling targets for material-specific fractions e.g. wood, plastics, gypsum etc in construction and demolition waste. By just continuing with current practices, future demands and closing the material loops are not achieved. Mandatory waste auditing and requirement on selective demolition and waste sorting are considered as potential tools.

Safe management of demolition waste means that there is knowledge about which waste materials are to be expected (predemolition audit), and specifically the presence of materials containing hazardous substances. And then using this knowledge to make sure they are safely and correctely removed so other recyclable materials are not contaminated.

The EU landfill directive and the Council Decision also give some limits for disposal of waste at landfills for inert waste and landfill for hazardous waste. In the future ever-increasing costs and new restrictions for landfilling (e.g. ban of biodegradable fractions) create needs for sustainable reuse and recycling solutions of different C&D waste fractions. In its current and future strategies and targets EU addresses both the safe material use of building materials and the reduction in C&D waste amounts for landfilling. The high recycling targets and the demand for non-contaminated materials for recycling mean that tools for identification of hazardous substances on-site and also technologies for removal of hazardous substances from the waste needs to be developed.

EU: Non-toxic environment – strategy

There is a concern in EU about the increasing use of chemicals in products. Non-toxicity means that the material cycles as far as possible (or as far as necessary) are free of substances hazardous to health and the environment, as these are defined in the chemicals legislation. Products imported from outside Europe may contain hazardous substances or products produced earlier may contain

[1] Directive 2008/98/EC

hazardous substances which are now regulated. Chemicals which are according to new legislation classified as hazardous might have been added to achieve a certain function or property in the product (e.g. flame retardants).

Especially flooring, carpets, and panel materials may contain substances that are today of concern for human health[2]. Brominated flameretardants and phthalates as plastizers have been used in plastic products[3]. Furthermore, there are also concerns related to the recycling of old construction waste in new products (see Figure 6 about time period for the use of hazardous substances in construction products). Old construction products may contain hazardous substances banned today.

The EU Environnmental Action Programme[4] calls for a non-toxic environment. This can be achieved by minimisation of chemicals in manufactured products and also ensuring that information about chemicals hazardous to health and environment are documented and available. Furthermore, the development of non-toxic material cycles should be supported. This means that there is a need to develop and apply methods for tracing waste and materials in construction.

Green products - market issue

The demands for sustainable development and also the customer´s awareness for environmental values set requirements for green products[5]. Development of green products based on recycled material will bring challenges into ensuring safe raw materials. This sets need for quality and environmental control systems, whose effectiveness can be verified, for example, with certificates and traceability systems. The following trends are drivers for increasing use of recycled materials:

- Increased taxation for use of virgin materials and economic support for use of recycling of waste
- Environmental impacts of products as a competition factor because the customers evaluate and compare products due to environmental awareness

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[2] KEMI 216, Hazardous chemicals in construction products – proposal for a Swedish regulation Report from a government assignment. https://www.kemi.se/global/rapporter/2016/report-4-16-hazardous-chemicals-in-construction-products.pdf

[3] Wassenaar, P.N.H. 2017. Substances of very high concern and the transition to a circular economy An initial inventory. RIVM Letter report 2017-0071, The Netherlands

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013D1386&from=EN

[5] green products are products fulfilling sustainability criteria such as free of Ozone depleting chemicals, hazardous compounds and don't produce hazardous by-product, made of recycled materials, energy efficient, durable and often have low maintenance requirements

The environmental certifications for building (e.g. BREEAM) contain criteria for the contents of hazardous substances in construction products. Lifecycle assessment is often used for market purpose to prove that construction product or material is environmentally sustainable. Credits are given for use of waste related material in construction. Also green public procurement for constructions often contains criteria for recycling of waste related materials.

Figure 1. Example of Eco-lable for green product and services. The EU Ecolabel criteria aim at reducing that impact during the entire life-cycle of the product, from production to disposal.

2. What is a hazardous substance?

2.1. Focus on regulated substances

Within the context of a pre-demolition inventory, hazardous substances are substances that have a negative impact on the environment or the human health (of both employees as residents), and this during the user-phase, the renovation/demolition phase as well as the post-user phase (i.e. landfill or recycling/reuse of materials).

Information about toxicity and hazardous properties of different substances is, however, constantly updated and revised and later introduced in legislation. Therefore the list of hazardous substances will hardly ever be complete requiring constant follow up from construction producers and other shareholders.

Hazardous substances can be divided in to two groups:

- Primary contaminants: substances that occur in (are part of) a construction product (for example tar containing roofing)

- Secondary contaminants: substances introduced in a building material through an external source, for example an incident (a spill, fire, etc.), diffusion, … (for example mineral oil spill from oil tank on concrete floor)

This document focuses on substances that are regulated and might occur in construction products or materials. Part of hazardous substances are regulated by legislation for waste management and part of the hazardous substances by regulation for products. The latter part is of importance if new products are produced from recycled construction products or materials.

In the inventories of hazardous substances, both regulation or restrictions at EU and national level are relevant. The European regulatory framework imposes to all EU members precautionary principles and limit values but each country is free to tighten those principles. The requirements are different for wastes and products. For waste, the main concern relates to safe waste management. For products, the requirement are highly dependent on application and risk related to the use of the product (exposure routes, receptors, environment conditions etc). If waste is used as products, the product regulation needs to be considered. On the another hand, today the end-of-life requirements set demands for product design.

The aim of the chemical regulation REACH[6] is to ensure that all substances are manufactured and used safely. REACH concerns use of substances in products manufactured in EU or imported to EU. In REACH certain substances are listed as Substances of very high concern (SVHC) and published on the webpage of the European Chemical Agency ECHA. SVHC substances may be found in plastics products, e.g. phthalates (DEPH) or flame retardants. The list is constantly updated and new hazardous substances are introduced. The Construction Products Regulation makes references to the Chemical Regulation. It is specifically mentions that, where applicable the declaration of performance should be accompanied by information on the content of hazardous substances in the construction product in order to improve the possibilities for sustainable construction and to facilitate the development of environmentally friendly products.

Figure 2: Grouping of substances in different categories.

[6] The EU regulation REACH (Regulation No 1 907/2006) stands for Registration, Evaluation, Authorisation and Restriction of Chemicals and came into force in 2007.

Box 1. Hazardous substances and regulation

Waste:

- Waste management (hazardous waste classification [7], End-of-waste concept [8], landfilling[9], incineration, permits, shippment etc)
- Bans (asbestos[10] - human safety, POPs[11] – waste to be destroyed)

Products (relevant for recyclables):

- Bans (asbestos[9] - human safety, POPs[10] – use as chemicals in production)
- REACH and ECHA: restriction of substances of very high concern (SVHC) (e.g. additives in plastics)
- Material/Application specific limits (wood, End-of-Waste materials, electronics, construction products - materials in contact with drinking water, indoor air….)
- Additionally for earth construction: leaching criteria

2.2. EU regulation for waste management

The hazardous waste classification is primarily based on the European List of Waste[12] in which the listed waste types are classified as hazardous or non-hazardous. In some cases a particular type of waste on the list can be either hazardous or non-hazardous depending on the specific properties of the waste and in these cases the waste status has to be assessed based on its hazardous properties[13]. The EU guidance for assessment of hazardous waste[14] has in 2018 been published by the Commission and furthermore, national guidance documents have been developed e.g. in

[7] The Waste Framework Directive (2008/98/EC) contains rules on hazardous waste classiciation and gives also the waste hiereachy and targets in waste management.

[8] Waste Framework Directive includes option to set criteria under which specified waste fractions shall cease to be waste and be regarded as product

[9] Directive 1999/31/EC defines landfill categories and and landfill acceptance criteria are established in Council Decision 2003/33/EC

[10] Protection of workers from the risks related to exposure to asbestos Council Directive 2009/148/ECtad

[11] The Stockholm Convention is an international agreement with the aim of reducing and eliminating production, use and release of persistent organic pollutants (POPs). The convention comprises production (both intentional and unintentional), use, waste management and environmental supervision of POPs.

[12] Commission Decision 2014/955/EU

[13] Commission Regulations No 1357/2014 and 2017/0010

[14] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2018.124.01.0001.01.ENG&toc=OJ:C:2018:124:TOC

Austria[15], Belgium , Denmark[16], Finland[17] and UK[18]. However, these guidance documents are giving general information on waste classification and not specifically focusing on the classification of waste from construction and demolitions.

The hazardous waste criteria are the same in all Europe but the implementation may differ. For example in Denmark and Finland, the sum of 7 congeners PCB 28, 52, 101, 118, 153, 138 and 180 is multiplied by a factor 5 to get an estimate of the total content of PCB, but in some countries the arithmetic sum is used. There are also differences in the assessment of metal compounds (choice of substances for the assessement in expert judgement) in waste for the hazardous waste properties. Furtheron, there are several open questions in the assessment of hazardous waste properties in practice , e.g. how to assess a component containing different fractions (e.g. painted products). (see Nordic interpretation in Box 2)

[15] Austrian EPA. 2018. BEWERTUNG DER GEFAHRENRELEVANTEN EIGENSCHAFT HP 14 „ÖKOTOXISCH“ GEMÄSS VERORDNUNG (EU) 2017/997 DES RATES VOM 8. JUNI 2017

[16] Danish EPA. 2018. Vejledning i klassificering af farligt affald. http://mst.dk/media/93596/vejledning-i-klassificering-af-farligt-affald_april-2017.pdf

[17] Häkkinen E. 2019. Classification of waste as hazrdous waste – updated guide. Publications of the Ministry of Environment 2019:2 http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161316/YM_2019_02.pdf?sequence=5&isAllowed=y

[18] Waste classification. Guidance on the classification and assessment of waste (1st Edition v1.1) Technical Guidance WM3. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/719394/Waste-classification-technical-guidance-WM3.pdf

Box 2. Classification of hazardous properties of painted metal beams suitable for reuse

Classification of a steel beam containing brominated flame retardants has been discussed in the Nordic countries due to unclarities in e.g. how to evaluate the brominated flame retardant content in the paint. Depending on the approach in the assessment, the beam can be classified as hazardous waste (if only the paint layer is assessed) or as non-hazardous (if the mass of the whole beam is considered and thus the concentration of brominated flame retardant is essentially smaller).

In the EU PROGRESS project[19], the following recommendations are given for painted beam (considered as waste):

- The beam is non-hazardous waste, if the coating is intact and there is no need to remove the coating- Rationale: beam and paint considered as ”one material”. The rationale for the recommendation is a decision(2017) by ECHA for assessment of paint layer in painted clips.
- If the coating needs to be removed (e.g. sandblasting), the type of paint to be removed is of high concern.

Similar recommendations and discussions have taken place by

- Norwegian Forum for Environmental Inventory and Decontamination “ Norwegian Forum “Forum for miljøkartlegging og -sanering” for classification of painted steel: https://docs.wixstatic.com/ugd/01b968_5619a602ec864db9a716ae731dc4ee9c.pdf,
- Danish Dakofa (DAKOFA is a competence centre on waste and resources and hosts a stake-holder network on C&D waste): Nyhed: Er den malede radiator farligt affald? (News: Is the painted radiator hazardous waste?) https://dakofa.dk/element/er-den-malede-radiator-farligt-affald-1/

[19] EU study PROGRESS - Provisions for greater reuse of steel structures. https://www.vtt.fi/sites/progress/about-the-project

A special attention is needed on the EU POPs regulation (No 850/2004) on persistent organic pollutants requiring that wastes containing substances listed in the annex to the regulation and exceeding certain concentration limits needs to be destroyed and not circulated in new products. Examples of the POP substance are PCB, certain flame retardants (e.g. HBCDD), short chain chlorinated paraffins (SCCP), Bisphenol A and Perfluorooctanesulfonic acid (PFOS) which might occur in some construction products or materials. The list of the POP is continuously updated and new substances are added to the list. One candidate substance under review is pentachlorophenol earlier used as a wood preserving agent.

Potential hazardous substances in historical construction products and materials are compiled in Table 1. The Table also contains the limit values for classification of waste as hazardous. In practice, wastes containing hazardous substance exceeding the values need to be treated as hazardous waste. In addition to the listed substances, also activities causing pollutions need to be considered (e.g. chemical spills, in some cases even radioactivity).

Figure 3. Special requirements for disposal of asbestos waste. Waste must be packed in tight packages labelled with appropriate warnings. Asbestos waste can only be disposed at landfill or in landfill cells approved for asbestos disposal. Photo: VTT

Table 1. Key hazardous substances of concern in old constructions including limit values for hazardous waste classification.. Note for metals: the rules for assessment to be checked, e.g summation rules for some hazardous properties.

Potential hazardous substances in constructions	Hazardous waste limit
Asbestos	total ban
CFC	0.1 %
Organic pollutants (including POPs [a])	
PCB (sum) [b]	50 mg/kg
PAH/creosote	1,000 mg/kg
Hydrocarbon C_{10}-C_{40}	limit depends on composition: 1,000, 10,000 or 25,000 mg/kg[20]
Chlorophenols (candidate POP substance)	2,500 mg/kg (pentachlorophenol)
PCDD/PCDF Dioxine (soil)	15 µg/kg (WHO)
Phthalates	DEHP: 3,000 mg/kg
Chlorinated paraffins (e.g. SCCP)	SCCP: 2,500 mg/kg
Bisfenol A	3,000 mg/kg
Metals	
Arsenic	1,000 mg/kg[c]
Lead	2,500 mg/kg
Cadmium	1,000 mg/kg [c]
ChromVI	1,000 mg/kg
Chrom tot.	2,500 mg/kg[c]
Copper	2,500 mg/kg[c]
Mercury	2,500 mg/kg [c]
Nickel	1,000 mg/kg [c]
Zinc	2,500 mg/kg [c]

a) Note! Not all are persistent organic pollutants
b) PCB is determinated based on the sum of 7 congeners
c) Assessment as compound (worst case)

2.3. National regulation for wastes

All countries have regulation for removal of asbestos prior to demolition or renovation of the construction. The legislative requirement for other substances varies depending on materials used in construction. Legislative requirements for asbestos compiled in the EDA document "Hazardous

[20] see further: Hyks, J. & Hjelmar, O. 2015. Klassificering af shredderaffald ud fra indhold af kulbrinter Miljøprojekt nr. 1662, 2015 https://www2.mst.dk/Udgiv/publikationer/2015/03/978-87-93283-95-4.pdf

waste challenge for demolition contractors - An European overview"[21] giving a good overview on asbestos regulation in selected countries. The Norwegian guideline for hazardous waste classification contains a chapter with a list of hazardous waste in buildings; examples of potential presence of hazardous substances in constructions.

[21] https://view.joomag.com/hazardous-waste-challenges-for-demolition-contractors/M0303187001527600907

Box 3. Examples of hazardous C&DW presented in the Norwegian hazardous waste guildeline[22]

Hazardous substance/ material	Examples of construction products/materials	Hazardous waste limit	List of Waste code
Asbestos	* facade plates (cladding) * roofing plates (inside) * eternit * pipe isolation * pipe bend * tiles and glue * underlays * floor covering	Always hazardous waste	Construction materials: 17 06 05* Insulation material: 17 06 01*
Concrete	* Concrete containing hazardous organic or inorganic substances * Concrete containing PCB	Different limit values for different substances PCB (7 congeners): 50 mg/kg	17 01 06* 17 01 06*
Lead	* Plastic cable channels with lead containing stabilizators		17 09 03
Brominated Flame Retardants	* Flexible elastomeric foam for tube isolation * Expanded polystyrene (EPS) foam * Extruded polystyrene (XPS) closed cell insulation board * Components in electronics	HBCDD: 2,500 mg/kg	17 06 03* 16 02 15*
WEEE	* Fluorescent lamp, energy saving lamps and mercury vapor lamps		20 01 21*
Phtalates	* Vinyl flooring * Vinyl wallpaper * Vinyl baseboard * Cables * Glue *Lacquer * Roof sheet * Insulating window		17 09 03*
CFC	* Isolations in old sectional doors * Isolations in freezers, refrigators	> 0. 1%	17 06 03*
Impregnated wood	* CCA preservatives * Creosote impregnated	Always hazardous waste	17 02 04*
Soil	* Soil that is classified hazardous based on sampling results	Always hazardous waste	17 05 03*
Cooling liquid from liquid-cooling system	* Cooling liquid may contain glycol, GHG, NH_3	Always hazardous waste	16 01 14*
Chlorinated parafins	* Sealant in double glazing window * Paint * Plastics * Rubber baseboards * Sealant * PVC * Vinyl * Roof sheet	SCCP > 2,500 mg/kg	17 09 03*

Example: in Denmark and Norway a special focus is on PCB and in Norway also on CrVI. In many cases, for use of concrete waste from construction .

[22] Farligt avfall, COWI, 2015, Financed by the Norwegian EPA. http://www.norsas.no/Farlig-avfall/Farlig-avfallsveileder

Some European countries (Austria, Belgium/Flanders, the Netherlands, UK) have introduced so called end-of-waste regulation for use of reclaimed concrete as aggregate in earth construction, e.g. roads, field storage. Other countries (e.g. Finland) have notified a simplified regulation of the use of concrete waste in earth construction (evenif the waste status remains). Limit values have been developed for use of waste in earth construction. They are typically given for total content and leaching of harmful substances. That a substance is classified as "hazardous" or "restricted" under the national regulation for earth construction does not necessarily mean that it has properties that are normally associated with "hazardousness" or immediate danger. As an example, chloride which is present in most foods as part of sodium chloride, normal table salt, is registered as a "dangerous" substance. The reason for this is that even though chloride is not classified as hazardous, it can reduce the water quality if released and transported into sensitive surface water or groundwater bodies in sufficiently large amounts.

Examples of limit values for total content and leaching are compiled in Appendix 2.

2.4. Future legislation

In addition, there are a number of substances that – as more scientific evidence on potential impacts on health and the environment emerges – may be regulated in the future, i.e. nanoparticles, fine particles, odorous compounds, soluble compounds, to name a few. Therefore, construction product producers need information about substances that might occur in the waste and are suspected to cause health/ environmental hazards. Concerns have been expressed for example for following materials:

- Respirable cristaline silica (worker safety)
- Nanoparticles especially liberated from products containing nanoparticles (worker safety in handling waste),
- Microagents (antimicrobial compounds, e.g. in kitchen)

3. Focus on selected hazardous substances in historical construction products

3.1. Asbestos

Why dangerous?

Asbestos is the common name for a group of silicate minerals that share the same fibrous nature. Asbestos minerals belong to the serpentine and amphibole families. There are six types of asbestos: chrysotile, amosite, crocidolite, anthophyllite, tremolite and actinolite. Some asbestos minerals are commonly known by their colors, chrysotile as *white asbestos*, crocidolite as *blue asbestos* and amosite as *brown asbestos*. Asbestos fibres tolerate high temperatures, they have insulating properties and are mechanically durable. Because of its unique chemical composition and physical properties, asbestos became a popular building material.

Asbestos-containing building products are classified as friable or bonded. Friable asbestos is easily crumbled by hand, releasing fibers into the air. Bonded asbestos products contain a bonding compound, such as cement, which makes them solid and non-friable. In bonded asbestos products the asbestos fibres are tightly bound in the product and are not normally released into the air.

All types of asbestos are hazardous to health. Inhalation of asbestos fibers can cause serious illnesses such as asbestosis, lung cancer and mesothelioma. Microscopic asbestos fibers cannot be seen, but they are very light and remain airborne for a long time. Asbestos exposure does not cause immediate symptoms, but once asbestos fibres are in the body, they never dissolve and the body cannot remove them. Asbestos-related illnesses often take 10-50 years to develop.

Asbestos use grew rapidly in the 1920s. It was used across the construction industry for various applications such as for thermal and electrical insulation, fireproofing and soundproofing. Asbestos has been used in more than 3000 products including insulation materials (e.g. pipe insulation, acoustinc insulation, spray-on insulation), cement products, roofing, floor and ceiling tiles, heat-resistant fabrics, plaster, paints and coatings.

Asbestos products have been used since the late 1800s. The largest use was from the 1950s to the mid-1970s. The use of asbestos was first banned in Denmark in 1972 and since then asbestos has been banned in more than 60 countries. Many houses built between 1920s and the beginning of 1990s contain asbestos products.

Box 4. Asbestos

Characteristics of asbestos:

- Asbestos is the name for a group of naturally occurring silicate minerals that can be separated into fibres.
- The fibres are strong durable and resistant to heat and fire. They are long, thin and flexible so that they can be woven into cloth.
- Because of these qualities asbestos has been used in thousands of consumer, industrial maritime automotive scientific and building products.

Fibre size: length > 5µm
width < 3 µm
length/ diameter 3/1

Diseases:

- a long delay (15 to 60 years) between the first exposure and subsequent symptoms of the disease

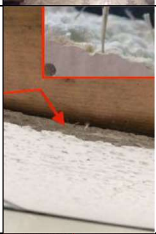
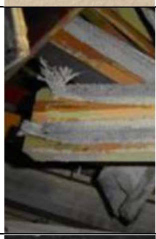
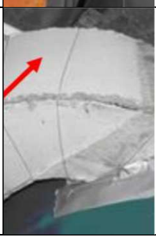
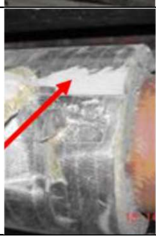
Intake by breathing:

- Asbestosis
    - a scarring of the lung that leads to breathing problems.
    - Workers who have had high long exposures are often affected with asbestosis.
- Mesothelioma
    - is a malignant form of lung cancer that affects the cells that form the lining around the outside of the lungs.

Where can asbestos be found?

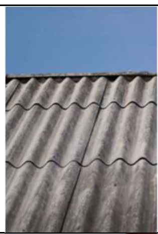
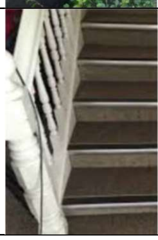
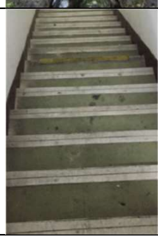
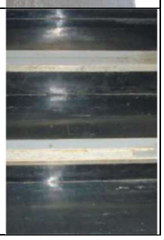
Asbestos have been used in a wide range of products due low price and fire resistance. It can be found for examples in applications listed in Tables 2 and 3.

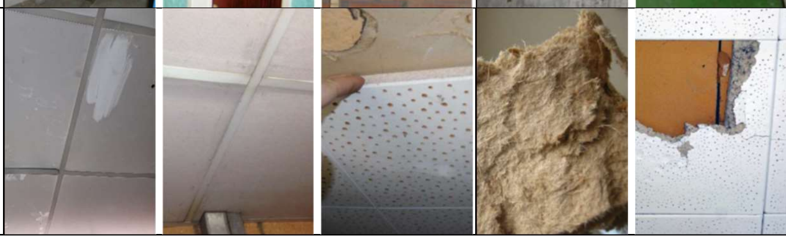
Table 2 Friable asbestos (photos: Tracimat, 2019)

Product group	Good condition			Bad condition (damaged)		
Flange gasket						
Vinyl flooring with asbestos underlayment						
Asbestos plate						
Plaster						
Textile						
Asbestos cardboard						

Sprayed asbestos	
Asbestos rope seal (e.g. in heating)	
Electrical applications	
Insulation	
Glue	

Table 3 Non-friable asbestos (photos: Tracimat, 2019)

Product group	Good condition			Bad condition (damaged)		
Asbestos cement corrugated roofing						
Wall and roof tiles						
Asbestos cement sheet walls, platforms						
Lost formwork						
Cover plates and parapets						
Stairs						

Workshop tables	
Blackboards	
Water pipes	
Chimneys and air ducts	
Ventilation ducts	
False ceiling tiles	

Box 5. Further reading
Document by European Demollition Association: “Hazardous waste challenge for demolition contractors - An European overview”: https://view.joomag.com/hazardous-waste-challenges-for-demolition-contractors/M0303187001527600907   Health and Safety Executive, UK.   Asbestos health and safety: https://www.hse.gov.uk/asbestos/?utm_source=hse.gov.uk&utm_medium=refferal&utm_campaign=asbestos&utm_content=home-page-popular   Asbestos essentials: https://www.hse.gov.uk/asbestos/essentials/index.htm   Australian Health Protection Principal Committee and was prepared by its Environment Health Standing Committee, enHealth. 2013. Asbestos. Guide for householders and the general public: https://www1.health.gov.au/internet/publications/publishing.nsf/Content/asbestos-toc/$FILE/asbestos-feb13.pdf   (in Dutch): Asbest en vervangingsvezels. navb dossier driemaandelijkse uitgave - Bundel N°139, 2013/4. https://www.ovam.be/sites/default/files/atoms/files/navb%20dossier%20139.pdf

3.2. Polychlorinated biphenyls (PCB’s)

Polychlorinated biphenyls are a group of oily organic chlorine compounds (1 to 10 chlorine atoms). PCB’s are characterized by a low solubility in water and a low vapor pressure. However, they are soluble in most organic solvents, oil and grease. Due to their technical properties (high chemical stability, high flash point and high electrical conductivity), PCB’s have been used in a wide range of products such as insulation liquid in transformers and condensors, as hydraulic liquid, coolant , as flameretardant and stabilizer in platics, and in paint, ink, kit, glue and lacquer.

PCB’s are very stable compounds and thus can remain present in the environment for a very long time. A limited number of members of the PCB family have comparable toxic characteristics as dioxine. Furthermore, when PCB’s are incinerated at temperatures below 1000 °C, dioxines can be formed and as such toxicity increases. PCB is an environmental pollutant which accumulates throughout the food chain, thus introducing itself as a potential health hazard for both humans and animals.

Studies also show that PCB compounds in sealant can mitigate and contaminate surrounding construction materials, more in porous light concrete and less in bricks and wood. This means that the presence in surrounding materials also needs to be checked for contamination and needs to be taken into account in assessment of the potential recycling of construction materials. To some extent, there is also a risk for pollution of indoor-air from surface containing PCB (e.g. condensators in lightning). Exposure may cause cancer and neurological diseases (Parkinson, Alzheimer) and increased infertility. Humans can be exposed to PCB by inhalation of dust that contains PCB, through dermal contact or by digestion (children in contact with contaminated soil near buildings containing PCB sealants). The exposure risk set demands for precautions for worker safety during demolition. In replacing or demolishing building components containing PCB as well as waste, storage and removal should be performed such that workers are not exposed to harmful impacts and in a way ensuring that PCB does not spread to the surroundings.

From the 1950's to 1980, PCB's were widely used in Europe in various building related materials and technical installations. Production and use of PCB's have been forbidden in most countries since 1985. A large number of these buildings or installations are now in the state requiring demolition or renovation. In buildings, one might expect PCB to be present in sealants, floorings, paints, mortar, double-glazed windows,and in rubber-like fillers. Rubber fillers are usually applied around windows and doors as well as in joints between various building components, e.g. between concrete elements and in wet rooms. PCB can also be found in capacitors in light fittings, other small capacitors and cable outlets in power supply units.. PCB can also occur in facade paint, floor paint and on galleries and slip-resistant floors.

PCB can be identified by chemical analysis and also by use of kits.

After ban of PCB , short chained chlorinated parafins (SCCP) have been used in sealants. SCCP has also been used in PVC. SCCP is highly toxic to aquatic environment and carcinogenic. It has also a high potential for bioaccumaulation. Production, placing on the market and use of SCCPs has been prohibited by the POP Regulation (Regulation (EC) 850/2004) in the EU since 2012. Both PCB and SCCP are classified as POP substances.

Due to the large focus on PCB in buildings in Denmark and Norway, several publications on PCB have been published over the past years. Further reading:

- The SBI instruction nr. 241 Investigation and assessment of PCBs in buildings [23] describes in detail PCB characteristics in construction . The Instructions also includes information on worker safety, methods for identification and sampling.

[23] SBi-anvisning 241 (2013): Undersøgelse og vurdering af PCB i bygninger (Study and assessment of PCB in buildings – guideline). Statens Byggeforskningsinstitut.

- Management of lamps containing PCB condensors [24]
- Norway: Survey of use of PCB in constructions[25]
- Use of SCCP in products[26]

Figure 4. PCB containing sealants. PCB containing condensors in lamps (marked with red circle) and examples of condensors with manufacturing year visible. Photos: Jarno Komulainen, Vahanen Building Physics Ltd (upper left), VTT OY (upper left) & Danish EPA report Miljostyrelsen nr 10, 201518 (photos below)

3.3. Brominated flame retardants

Flame retardants are added to construction products to lengthen escape time, reduce the heat production, decrease the combustion of a material and reduce the production of toxic gases. Flame retardants are

[24] Danish EPA. 2015. Guidance for handling of PCB containing condensators in lamps. "Vejledning om håndtering af PCB-holdige kondensatorer i lysarmaturer" .Miljostyrelsen nr 10, 2015. https://www2.mst.dk/udgiv/publikationer/2015/01/978-87-93283-47-3.pdf

[25] Identifisering av PCB i norske bygg http://rvofond.no/upload/2012/02/24/pcb-veileder-revidert.pdf

[26] Danish EPA. Survey of shortchain and mediumchain chlorinated paraffins Part of the LOUS-review Environmental project No. 1614, 2014

divided into four different groups: 1) inorganic, 2) halogenated organic 3) organic phosphorus containing and 4) nitrogen containing flame retardants.

Flame retardants containing bromine or chlorine can be found in plastics, furniture and carpeting. The main concern of brominated flame retardants relates to the presence of HBCDD (Hexabromocyclododecane). In this section only HBCDD will be discussed. HBCDD is classified as a POP substance and banned since 2015 in EU.

HBCDD is found world-wide in the environment and wildlife. It bioaccumulates in living organisms and in the food chain. It is persistent in the environment and is transported long distances. HBCDD is highly toxic to aquatic organisms. It also presents human health concerns based on animal test results indicating potential reproductive, developmental and neurological effects.

Flame retardants and softeners are semi-volatile substances that can be released to the air from different types of materials or can end up in dust. Exposure through inhalation of dust is an important exposure route. By recycling some evaporation of HBCDD will likely take place but a significant part will remain in the recycled materials. Also the use of flame retardants in plastics waste maybe cause emissions in waste treatment plants, e.g. during the crushing processes. By energy recovery in incineration plants the substance will be decomposed.

The main part (90 %) of HBCDD is used as flame retardant in polystyrene (PS)[27]:

- Expanded polystyrene (EPS) is extensively used from 1975 to 2015 in building industry because of its durability and insulation properties. EPS insulation is used for example for roofs, facades, ground floor structures, foundations, frost insulation and for civil engineering applications. EPS insulation is manufactured as normal quality and as flame retardant quality (FR quality). Hexabromocyclodecane (HBCDD) is used as a fire retardant in EPS raw material. The EPS of FR quality is only used in the applications were fire protection is needed. These kind of applications are for example wall/facade and roof structures in construction. The content of HBCD is 0.7% in the product. EPS applications are mainly in the building frame, i.e it is not used as a surface or covering material.
- Extruded polystyrene (XPS) is used in roofs, parking levels, ground floor, foundations and frost. HBCD is used as a flame retardant in XPS products. The content of HBCDD is between 0.8% and 2.5% (8,000-25,000 ppm) in products.
- Elastomeric extended foam around tubes. In Norway, HBCDD has been added to materials produced before 2004.[28]

[27] G. Erens M.Sc., J. van Dijk M.Sc. 2016. HBCDD in EPS/XPS waste in the Netherlands Inventory of size and value. Ministry of Infrastructure and the Environment, The Netherlands. December 2016
[28] http://www.miljodirektoratet.no/old/klif/publikasjoner/2613/ta2613.pdf

HBCDD is added as granulates to the construction materials and it is not chemically bound in the material. [29] This means that the flame retardant is not evenly distributed in the material, which is important to note in measuring the content by field XRF-equipment (this sets requirements for several measurement points of the surface).

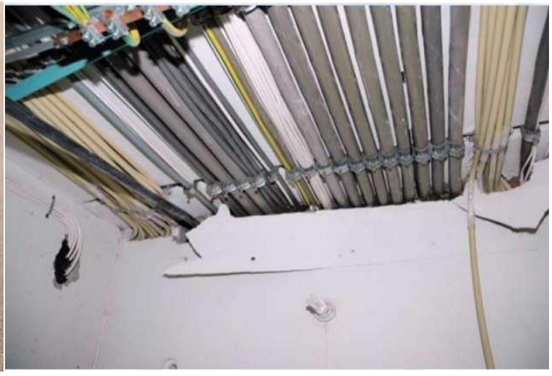



Figure 5. Examples of XPS (left) and extended foam (right picture). (Photo: VTT (left) and Eirik Waerner, Multiconsult, Norway (right))

3.4. PAH / Creosotes

Polycyclic aromatic hydrocarbons (PAHs) are hydrocarbons that are comprised of two or more aromatic rings. There are more than a hundred different types of PAH compounds. However, typically only 16 specified PAH compounds are reported (often as sum). PAHs typically have high melting and boiling points, which means that they are predominantly in solid state. PAHs in general have very low water solubility, but they are higly lipophilic and therefore very soluble in organic solvents. In air PAHs tend to adsorb on organic particulate matter.

Attention to PAH compounds has increased over the years due to their charteristics. Many PAHs are highly toxic, carcinogenic or mutagenic, benzo(a)pyrene as the most toxic one. Besides their carcinogenic properties, PAHs can have also other negative impacts like skin, eye and muscous membrane irritations. PAHs can enter human body by various routes e.g. inhalation, dermal contact (skin, eye, muscous membrane)), and ingestion.

In the past, PAH have been used in building materials, such as tar-containing products as roofing (bitumen), asphalte and cork panels. PAH’s not only occur as primary contaminants, but also as secondary contaminants (for example due to direct contact or absorption).

[29] Hansen, E., Nilsson, N.H., Lithner, D. & Lassen, C. 2013. Hazardous substances in plastic materials.COWI and Danish Technological Institute. Klima – og forurensnings directorate. TA 3017/2013

Creosote is the generic name of a variety of chemicals formed by distillation of tar. Creosotes consist of hundreds of different chemical compounds, such as PAHs, phenols and creosols. Coal-tar creosote is produced as a by-product of high-temperature distillation of coal tar.

Tar products (e.g. tar and bitumen) containing PAHs has ben used for waterproofing purposes on foundations and bathroom walls, for impregnation and surface treatment in roofing felt and tar paper.
Coal tar pitch is used as a binder in asphalt products, in roofing and paving, and as a base for coatings and paint. PAHs also occur in creosote-impregnated wood.

Creosote, an oily, brown, thick liquid, is produced by distillation of wood and coal tar and contains a large number of polycyclic aromatic hydrocarbons, PAHs, some of which are classified as carcinogenic. Substances such as phenols and nitrogen bases are also found in creosote. Creosote occurs primarily in telephone poles and railway sleepers, but can also be found in older building sections

Figure 6. Tar felt containing PAHs. Photo: Jarno Komulainen, Vahanen Building Physics ltd

3.5. Heavy metals

Heavy metals like arsenic (As), cadmium (Cd), chrome (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn) mainly occur as pigments in paint or lacquer applied on plaster, metals or wooden surfaces. Mercury can be found in lamps/light fittings, electronical components and wood preservation substances. Besides these applications, heavy metals can be found in many other construction materials and installations (e.g. pipelines and water drainage systems).

Table 4 Characteristics of metals

Metal	Toxicity and use
Arsenic	Arsenic is used for wood impregnation, primarily in copper chromated arsenate (CCA) that was a popular wood preservative since 1930s. Arsenic compounds may be toxic even in small concentrations and they can also cause cancer. There is a great variety of different arsenic compounds. Inorganic arsenic compounds are classified as toxic by inhalation and swallowing, they can cause cancer and they are very toxic to aquatic organisms. Organic arsenic compounds are less toxic.
Cadmium	Cadmium was used a great deal in the 1960s and 1970s, primarily as a stabiliser or colour pigment in plastic materials. Cadmium was also used for surface treatment of building fittings and sheet metal, and as an alloying element. Cadmium is also used in applications such as nickel-cadmium batteries and in glazes for ceramic materials. Cadmium is toxic and bioaccumulative, which means that it is stored in the human body, primarily in the liver and kidneys.
Chromium	Chromium is used as steel alloy element, metal chromium plating and as additives in paint. Previously, chromium was also used for wood impregnation (CCA-treated wood). Several chromium compounds are allergenic and some are carcinogenic. Chromium is dangerous to the aquatic environment.
Copper	Copper is used for roof tiles and facades, pipes, alloys and electrical cables. Copper has been used also in paint and for wood impregnation. Copper does not break down in the environment and it can accumulate in plants and animals. Copper can inhibit the growth of plants and some copper compounds are poisonous to aquatic organisms.
Lead	Lead can be found in construction materials such as paints, coatings, mortar, concrete and plumbing. Lead can cause serious health problems such as anaemia and kidney damage. Chronic lead poisoning can have neurotoxic and immunological effects. Lead compounds can cause decreased fertility and affect to children's intellectual development.
Mercury	Mercury is found primarily in different electrical equipment and in thermometers and fluorescent light bulbs. If the demolition of such equipment is not performed properly, mercury can be released to the environment. Mercury is highly toxic and it can cause health effects such as damage to the central nervous system and allergic reactions.
Zinc	In construction, zinc is used for coating (galvanizing) iron and steel to inhibit corrosion. Zinc is also used in paints and and for roofing and zinc panels. Although humans can handle proportionally large concentrations of zinc, excess zinc can cause health problems.

3.6. Phtalates

A special concern of phthalates relates to DEHP which used as a softener in plastics. DEHP is on the ECHA list for SVHC.

In EU, DEHP is mainly used in flexible PVC (more than 95 % of use). The content of DEHP in flexible polymer materials varies but is typically around 30% (w/w). Flexible PVC is used in many different articles e.g. toys, building material such as flooring, cables, profiles and roofs. DEHP is also used in other polymer products and in non-polymer formulations and products. DEHP is known to migrate slowly from polymer products during their entire lifetime. [30]

Figure 7. PVC floorings containing DEHP. Photo: VTT

Box 6. Further reading

- the Norwegian inventory [1] of hazardous substances in construction contains illustrative pictures from sampling campaign
- Different materials containing phthalates are reviewed in the Dutch report[1].

[30] https://www.greenfacts.org/en/dehp-dietylhexyl-phthalate/l-3/2-plasticizer-uses.htm

3.7. Radioactive substances

Small amounts of radioactive materials have been used in some smoke detectors. Ionization smoke detectors use a small amount of americium-241 to detect smoke. Americium is racioactive artificial element. In smoke detectors, americium continuously ionizes an amount of air through the alfa radiance it sends out. When smoke particles disrupt the constant flow of ions, the smoke alarm triggers. Some early ionization smoke detectors used naturally-occurring radium (Ra-226).

Ionization smoke detectors with Am-241 or Ra-226 can still be occur in older buildings. New smoke detectors are almost always photoelectric i.e. optical smoke detectors, where smoke is detected through reflection of light. The radioactive material is shielded inside the smoke detector by a metal chamber and does not cause health threat in normal use, but they should not be taken apart. Ionization smoke detectors should be disposed of alongside other small electrical equipment.

Figure 8. Smoke detector Photo: VTT

3.8. Mineral oils

Mineral oils are mainly found as secondary contaminats in places where they were stored (f.e. oil spill due to leaking tank) or used for technical purposes (e.g. in machinery, workspaces, …). Mineral oil substances mainly have a negative impact on the environment. Oil components also migrate in concrete structure and degrade the concrete with time.

Besides analysis of hydrocarbons, also analysis of PCB content is recommended if the building was erected before 1980 and the contaminant can be visually determined to consist of oil from oil tanks, oil boilers, leaking machinery/ installations or similar, analysis. PAH analysis is always recommended. It should be noted that spills of PAHs and/or PCBs are governing factors in waste management.

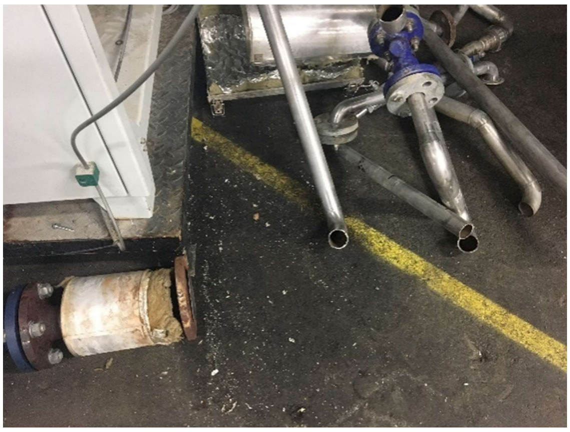


Figure 9. Oil spill (dark spots) on concrete floor in a machine hall. Photo: VTT

3.9. Chlorofluorocarbons (CFCs) - Freons

Chlorofluorocarbons (CFCs) and HCFC (hydrochlorofluorocarbons) often called Freon are a group of odorless manufactured chemicals. CFCs contain chlorine, fluorine, and carbon and HCFCs additionally hydrogen. CFC gases have been used as insulation materials (polyurethane, XPS) especially in refrigators, but also in isolation materials used in construction. To some extent CFCs may have been used in EPS but due to the open structure of EPS, potential CFCs have escaped with time. HCFC have been earlier used in cooling refrigators.

The use of CFCs and HCFCs are banned (CFCs in 1996) due to their damage to the earth's ozone layer. CFC and HCFC containing waste is classified as hazardous waste (see information box in chapter 2) . Handling of CFC and HCFC waste is regulated and requires special collection of the CFC gases during destruction.

For further reading:
Swedish Construction Federation (SCF). 2015. Resource and waste guidelines during construction and demolition.
https://publikationer.sverigesbyggindustrier.se/Userfiles/Info/1094/160313_Guidelines_.pdf

4. Waste audit process for identification of hazardous substances

4.1. Waste audit

The auditing process aims to provide information on potential hazardous substances in the construction and also to give infomation on resources for recycling. This information can be used by the own owner for submission of a building permit application and open a call for deconstruction tenders and potentially also for decontamination. The first step in the waste audit is to make an inventory of the hazardous materials and contaminants present in the building as condition for safe and correct removal and proper C&DW management. Also reusable and recyclable materials are identified prior to demolition and actions can be planned for securing high quality materials during the demolition. A detailed inventory creates the liability for the construction waste to be recycled or reused.

The EU Waste Audit Guideline published by the European Commission[31] forms the framework for the national waste audit guidance document. There is, however, a need for country specific guidance due to the different use of construction products and materials. Also there might be differences in national waste legislation and especially in the waste treatment options.

4.2. Material knowledge - base for waste audit

Knowledge on construction products potentially containing hazardous substances is crucial in identification of materials to be separated prior or during demolition and directed to specific treatment. Also good background information on the use of construction products and material in constructions is important. Several guidance documents with information on period for use of certain materials have been published in Belgium, the Nordic countries and Austria. Figure 10 shows the use of hazardous substances in historical products at different time periods in Finland.

[31] European Commission "Guidelines for the waste audit before demolition and renovation works of buildings", available online from https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en (2018)

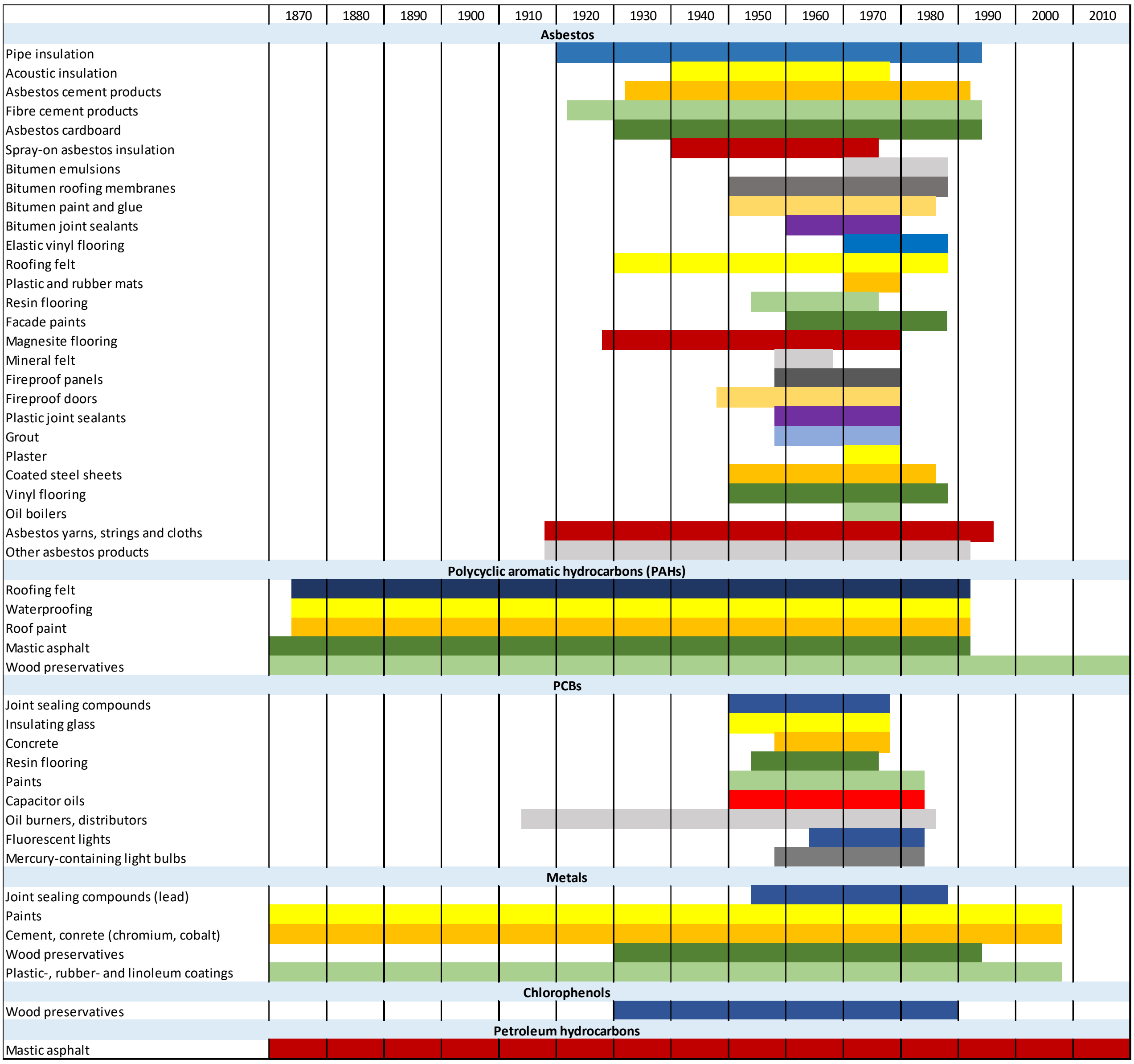


Figure 10. Year for production of construction production containing hazardous substances . Source: RT 18-11245, Rakennustietosäätiö RTS 2016. With permission from Rakennustietosäätiö (2019)

VHGB in Denmark (an independent knowledge centre) has collated fact sheets on typical hazardous substances in C&D waste with guidelines for proper handling (best practice). On their web page, typical hazardous substances found in C&D waste are listed, typical C&D waste fractions and management options are described, central pieces of legislation and a list of relevant reports can be found. The aim is to provide a quick overview for stakeholders (building owners, constructors, consultants and municipalities), on specific relevant subjects.

The Danish Technology Institute (DTI) has compiled the Materialeatlas[32] listing construction products potentially containing hazardous materials. The Danish Materialeatlas is a description of typical construction products used during different building periods and aims to give an overview of which hazardous substances are typically to be expected in the different building parts, and thus gives an overall assessment of whether the building part is potentially suitable for recycling or reuse or not. The target group of the Materialeatlas is architects or other professionals, who are not experts on hazardous substances, but who need an overview of which hazardous substances can be expected. In the database with over 200 construction materials listed, three colours have been used for giving information on suitability for recycling: green for recycling potential and also low content of hazardous substances, yellow for material potentially recyclable and potentially containing hazardous substances and red colour for materials not suitable for recycling and high content of hazardous substance. The Materialeatlas is based on a project carried out for the Danish EPA.

[32] http://vhgb.dk/genanvendelse/materialeatlas/

Figure 11. Danish guidance "Materialeatlas"

4.3. Steps in the waste audit process

An effective process for carrying out a waste audit should follow the steps depicted in Figure 12.The steps in the scheme are following:

1. Desk study or documentation study: collection of all the relevant information from the documentation of the building or other work (age, drawings, materials used, hazardous materials etc)
2. Site visit: visual inspections, comparisons with collected documents, planning of inspections and measurements, preliminary planning of deconstruction techniques and waste handling on site as well as communication between actors engaged by the owner to the process. The audit can be organized by the owner or any actor on his/her behalf.
3. Materials assessment: the results from the potential sampling campaign are evaluated and all findings are documented systematically. Based on the characteristics, the location of materials containing hazardous substances are documented and also a summary of the amount of waste (in mass or volume) in the various European waste classes is reported.
4. Site recommendations: Suggestion for waste management of materials to be removed. The site recommendations can also include recommendations for opportunities to increase recyclability (also reusability) of materials and construction products to minimize the disposal or incineration of the waste.

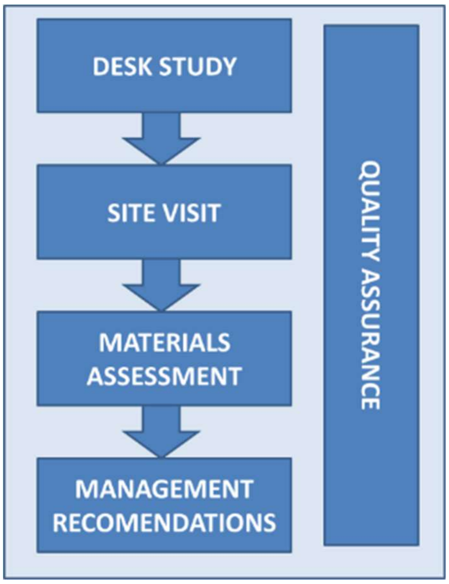


Figure 12. General scheme of waste audit

4.4. Documentation study

The aim of research of available documents is following:

- to provide indication of the age of the building or infrastructure (construction year), most important changes due to renovation, structural type of the building, information about used materials and attachments/joints of materials and structures;
- to provide information on the building history and activities performed in the building (function of certain rooms, use of certain chemicals or other substances, incidents, etc)
- to investigate typical building practices and materials used in its location at the time of its construction, surrounding area and access to the site, location of nearest waste management facilities and salvage yards.

A thorough study of available sources and building documentation shall be conducted before or together with the site visit. The extent of the research shall be decided by the auditor, but the minimum requirement is to study technical drawings and material inventory from the design documentation or any more recent documentation of the building or infrastructure.

Typical sources of documentation are drawings and reports obtained from the building authorities and the owner of the building or infrastructure, memos of housing cooperative board meetings and documentation of the real-estate maintenance company.

Architectural plans and technical drawings, whether or not accompanied by tender specifications or as-built documentation of the construction and/or renovation works contain information that is useful for planning the field survey and drawing up a waste inventory. They serve for preliminary identification of construction date/period, dimensions, construction typology, composition, type of materials, location of machinery and installations, details of hidden or difficult to access spaces, as well as planning of a field survey. Any available documentation of use of the building, infrastructure or their parts shall be studied to identify possible changes of the original building layout, materials or coatings.

Any available design and refurbishment documentation shall be studied:

- to obtain the age of the building or infrastructure and their parts,
- to identify the basic building materials, components and structural systems,
- to prepare the field survey and decide about examination methods during the survey.

The information obtained from open public sources should be verified for instance by the data provided by building authorities or directly on site.

All sources shall be properly listed in the audit report.

4.5. Field study

The aim of the study is to provide the first estimate about the materials, their quantities and possible hazardous nature.

In the field study, it is crucial that the auditor has sufficient knowledge and experience to identify all hazardous materials and to fulfil all the legal requirements for the waste managment. This is based on expert knowledge and experience regarding what type of hazardous substances can be expected in buildings/construction of a certain age, use, with certain types of materials, etc. Examples of hazardous substances to be identified are listed in Table 1.

During the field survey all the rooms of the to-be-demolished building are visually inspected and inventoried. As every building is different, it is not possible to elaborate one specific global method for data collection. It is important to work systematically and methodically. A good and efficient approach consists of 3 parts:

- site visit and general analysis of the building;
- detailed audit and inventory;
- sample taking.

In complex cases, second step might need to be split first to a more general, audit and inventory, and a second detailed one.

The field survey can be done in a destructive or non-destructive manner. A destructive audit can consist in opening of false ceilings and walls, opening of technical shafts, making a hole in wall and floor coverings, (partial) disassembly of technical installations (ventilation ducts, …), and others. Therefore, the field survey takes place preferably when the building is no longer in use. If necessary, samples are taken for analysis.

The field survey has to be performed as complete as possible. However, some rooms/spaces might be difficult or even dangerous to access. Furthermore, the building might not be visited due to a risk of structural collapse or the access to the building might be limited or impossible if during the study it is in use.

Moreover, in some cases certain materials cannot be inventoried (or measured) because they are not visible / (partially) encapsulated / unreachable. Examples: foundations, underground pipelines and cables, underground storage tanks, permanent formwork in asbestos cement… Limitations of the field survey have to be clearly mentioned in the waste audit and waste management plan.

The goal of the detailed audit and inventory is to establish (for every part of the building) which materials occur and for resource inventory also in which quantities.

In the field study attention should be paid to following aspects:

- older buildings can be adjusted in time – renovations or repairs. Some parts of a building can be added later on with visually similar materials whom might differ completely when it comes to composition (for instance asbestos containing tiles versus asbestos-free tiles).
- It is not always possible to easily identify the nature of certain materials visually; especially when they are painted, degraded or not easy to reach. For these reasons it is advised to not only rely on first impressions and extrapolate those impressions to the entire building, but to systematically do some intermediate checks.
- photo's: during the field survey photo's should be taken, especially from smaller elements that are hard to recognize or locate. For every hazardous waste material present in the building and for each location it occurs, a photo is taken and added to the waste audit.
- especifcally for asbestos: during the field survey a risk evaluation has to be performed for every asbestos containing waste material present in the building. This risk evaluation takes into account: the nature of the material, the type of material (bound asbestos or not?), the state the material is in (damages, weathering, …), location of the material, the impact that will be caused when removing the asbestos containing material (what are the chances asbestos fibers will be set free?), etc.

NB! Safety and health measures are important in field study and use if personal protection equipment PPE highly recommended!

Box 7 gives information related to sampling.

Box 7. Recommendation for sampling

Sampling approaches described in some Nordic reports:

- surface sampling for identification of material and identification of hazardous substance in coating (different techniques can be used to remove samples from the surface, e.g. use of adhesive tape for asbestos detection, use of demolition hammer for sampling from coatings on concrete)
- drilling in order to get information of hidden materials under surface (complementary to surface sampling´): Powdered samples (e.g. for PCB determination in concrete)[33] are collected by using a drill machine for concrete: Alternatively sampling by taking drill cores. [34]

NB! it is recommended that photos are taken from the sampling points when possible

Identification of hazardous substances by using non-destructive measurements

The characteristics of the construction products/materials can be analysed by using portable analysators. In these cases only the surface of the material is subject to testing. The testing using portable analysators is typically a rough method to get an indication of the presence of hazardous substances. Typical portable analysators are:

- XRF
- HS LIDAR laser
- Kits for PCB identification

The main challenges:

- hazardous compounds are not homogenously spread in the material (e.g. insulation mateirals and HBCDD)
- selection of surface for testing
- competence of auditor

[33] Danish EPA. 2016. PCB-renovering Forsøg med renovering med ny miljørigtig luftdræningsmetode og PCB-prøvetagning med boremelsmetode. Miljøprojekt nr. 1847, 2016, PCB-renovering Forsøg med renovering med ny miljørigtig luftdræningsmetode og PCB-prøvetagning med boremelsmetode Miljøprojekt nr. 1847, 2016

[34] A Norwegian guideline for sampling and testing for assessment of concrete quality has also been developed and is currently under review

Annex 1 gives information on commercially available analysators and the concentration for measurement of different substances.

Identification of hazardous substances by chemical analysis

Not all materials can be visually identified. Suspicious materials need therefore be sampled and analysed. In most cases the expert will have an idea on what the material might be, but an analysis is needed to confirm it. In other cases the expert will be confronted with materials of which the composition is completely unknown. For those materials a more thorough analysis will be necessary to identify the material.

- be aware: not every laboratory is allowed (or equipped, or does not have the expertise) to perform all kind of analysis. National or regional legislation has to be checked!
- possibly hazardous materials: for the following possibly hazardous materials the expert evaluates if sample taking and analysis are necessary (not limited) ⍰ tar-containing asphalt; polluted wood; floors or walls polluted with polyaromatic hydrocarbons / mineral oil / other due to leakage or spills; cooling liquid used in transformers; asbestos-suspicious materials.

Annex 1 gives information about standardised test methods for testing.

Box 8. Tracimat guidelines sampling asbestos

- Visual identification possible for a lot of applications → know how of the expert
- Mandatory sampling
  - Plastering (differences according to type of building – in most suspect areas: hallways, boiler rooms, …)
  - Hard mastic in / around windows
  - Pipe insulation (in each curve, straight part)
  - if no sampling: considered as containing asbestos

4.6. Material assessment/characterization

The material characterization shall give the following information:

- list of materials containing and not containing hazardous substances (the information level shall be sufficient for decision making on waste management)
- deterioration level of materials and components,
- properties of materials to fulfil the criteria for the recommended waste treatment,
- properties of components to fulfil the criteria for reuse,
- any other properties (such as value or environmental footprint) required by the waste holder.

The observations from the field study complemented with test results from sampling is the base for the characterization of the material. The focus of the assessment is on the content of hazardsous substances, both both materials and products to be recycled/reused and for materials to be removed before demolition or in connection with the demolition process. The desk study and the field study typically also give information on other properties of the material to be collected as waste (material ageing, undesired components, connections - properties not further discussed in this document). Based on the knowledge of the waste characteristics, appropriate waste management can be recommended (see 4.7).

In the assessment, the measured or estimated concentrations of hazardous substances are compared to national action limits for non-polluted materials or limits for hazardous waste classficition (see chapter 2). Especially for recycling of materials or products it is important to prove that hazardous substances are not present. In the Nordic countries, concrete and other crushed mineral wastes are typically used in earth construction, e.g. in road structures. It is interesting to note that there are differences in the approach for to assessing the suitability of non-hazardous concrete for recovery. In Denmark and Norway, the main focus is on verifying the non-contamination of the concrete in the construction prior to demolition, whereas especially in Austria, Belgium/Flanders and Finland the main focus is on the quality control of the crushed concrete for recovery.

Box 9. Swedish recommendation for analysis of oil spills from machinery[35]

“Core drilling is recommended with a core at least 5 cm deep for laboratory analysis. It is then appropriate to divide the core into layers, for example 0-1 cm, 1- 3 cm and "deeper than 3 cm" in order to facilitate delimitation of contamination in terms of depth.

If the coating of the flooring material is suspected to contain PCBs, samples are taken for separate analysis of this surface coating and samples of the underlying material as drill cores. If the contamination can with great probability be assumed to be limited to the concrete surface, a scrape sample can be taken which will then represent the upper 3 mm. After this a core sample is taken where the surface has been scraped away if it is not obvious that the contamination is limited to the surface. In order to obtain knowledge of the horizontal extent of the contamination, more than one sample should be taken for analysis. If the concrete may be contaminated by joint compound containing PCBs, drill cores are taken at different distances from the joint edge, e.g. 1 cm, 2 cm and 5 cm.

Concrete with a PCB (7 congeners) content of 50 mg/kg or more is hazardous waste. In order to be able to reuse concrete as crushed material, approximately 2 cm of the concrete edge should be removed if the joint compound contains or has contained approximately 10% PCBs. Concrete with high levels of contamination often requires special landfilling and can also be an occupational health and safety risk. Where necessary consult an expert regarding decontamination and the local environmental authority regarding decontamination and final disposal.”

Figure. Sampling by drilling (photos: Eirik Waerner, Multiconsult, Norway)

[35] Swedish Construction Federation (SCF). 2015. Resource and waste guidelines during construction and demolition. https://publikationer.sverigesbyggindustrier.se/en/resource-and-waste-guidelines-during-con__1094

In the material assessment, the minimum requirement is that the waste materials are classified materials according to the European List of Wastes. Here both waste classified as hazardous and non-hazardous needs to be included. Furtheron, also the quantities of the waste or material mass needs to be estimated (the levels of details probably varies from case by case, e.g. due to construction site, building type, municipality). The grouping of waste material in further quality categories depends on the demolition work (size of the construction to be demolition, potential materials for recovery, and also to the market situation for the recovery/reusabe materials). It is important that the location of materials to be removed or collected separately for recycling and reuse prior to the location of demolition is clearly escribed. Mixing of different hazardous waste is forbidden according to the Waste Framework Directive or national legislation (check wording).

4.7. Recommendation for management

The waste auditor shall provide the building owner with following information:

- report on hazardousness and contamination of the building materials and components (with details for location of the materials) and recommendations on safe and correct removal of those hazardous materials
- report on reusuability of different components and recyclability of different materials and recommendations for the most feasible management options and potentially a rough estimate on the value or costs for the identified treatement options (here the knowledge of non contaminated materials for recycling/reuse is crucial). Appendix 2 contains examples of maximum content of hazardous substances in concrete waste for recycling in earth construction.
- potentially also a market study on different options for waste management.

In Denmark, a litureratur study[36] on available techniques for removal of materials containing hazardous substances has been published. The report evaluates for applicability of several technologies such as dismantling, cutting, removal of coatings/paint/sealants, sandblasting and chemical treatment. Costs, removal efficiency and environmental emissions are also covered.

[36] Danish EPA. 2015. Metoder til fjernelse af miljøproblematiske stoffer Udredning af teknologier til identifikation og fjernelse af miljøproblematiske stoffer og materialer fra bygninger til nedrivning eller renovering Miljøprojekt nr. 1656, 2015

Reports on common for mangement of hazardous substances have been published in Nordic countries. A summary of recommendation for waste management of contaminated non-recyclable wastes is compiled in Table 5.

Table 5. Recommendation for management of materials containing hazardous substances

	Examples of management
Asbestos	Asbestos waste packed into tightly sealed packaging may be landfilled at separates cells at landfill accepting stable non-hazardous waste with permits for asbestos waste BREF: mentions methods for treatment?
PCB	PCB waste must be destroyed in incineration plants fulfilling the requirements for treatment of POP substances Recommendations for handling of PCB waste is compiled in the Danish guidelines [37] [38] SBi instruction 242 [39] describes how a PCB renovation process generally proceeds and explains possible remediation methods and practical aspects of renovation, including waste management and environmental and health protection measures.
Hydrocarbons	Asphalt waste can typically be recycled. Suitability of landfilling of concrete contaminated by oil decided by a risk assessment.
Creosote	Creosote-impregnated timber is hazardous waste. The incineration of creosote-treated timber can lead to emissions of environmentally hazardous substances. Creosote-treated timber should therefore be incinerated in an incineration facility which has the authorisation to incinerate such material. [40]

[37] Danish EPA. 2014. Guidance for handling of glazed windows containing PCB. "Vejledning om håndtering af PCB-holdige termoruder". Vejledning fra Miljostyrelsen nr 3, 2014.

[38] Dansk Asbetsforening. 2010. Guidance for performing PCB decontamination. Vejledning og beskrivelse for udførelse af PCB sanering. https://www.nedbrydningssektionen.dk/media/27407/pcb-vejledning_red.pdf

[39] SBi-anvisning 242 (2013), Renovering af bygninger med PCB (Renovation of buildings polluted by PCB). Statens Byggeforskningsinstitut.

[40] Swedish Construction Federation (SCF). 2015. Resource and waste guidelines during construction and demolition. https://publikationer.sverigesbyggindustrier.se/en/resource-and-waste-guidelines-during-con__1094

Wood impregnated with CCA	Incineration with energy recovery as hazardous waste in plants with permits for treatement of CCA wood [41]
Soft PVC	Soft PVC waste from construction (e.g. floors) cannot generally be recycled. In Denmark, soft PVC waste is landfilled, while in most countries the soft PVC is incinerated. The reason for the Danish recommendation is that the combustion of PVC wastes (e.g. flooring materials, windows etc.) leads to a huge amount of air pollution control (APC) ash which in turn may be problematic from a waste-handling perspective. In landfill conditions, PVC waste as such does not cause environmental impacts. Therefore, source separation of PVC prior to combustion of C&D waste and landfilling of the separated PVC waste is an environmentally preferrable waste-handling option in Denmark. (Note! this recommendation only concern soft PVC not hard PVC which can be recycled).

5. Quality aspects in hazardous waste inventory

5.1. Harmonized approach

Ideally a harmonized approach to performing pre-demolition audits in EU would support the inventory work and to facilitate that sufficient volumes are created and thus supports the security of supply to the marked. A harmonised protocol with key elements would ensure that level of details are sufficient. A harmonized approach for performing pre-demolition audit could address a list of key hazardous substances to be identified depending on material fractions in questions, potential tools for identification (e.g. photos, methods), good practice and also health safety aspects for the auditors performing auditing (later also demolition workers). Especially development of common templates for reporting would ensure that the waste audit is reported in similar way. Audits should cover all basic building materials and preferably give recommendations for the waste management.

[41] https://www2.mst.dk/Udgiv/publikationer/2017/05/978-87-93529-97-7.pdf

Country-specific hazardous substances or other country-specific features should be listed separately. In addition, documentation is important for the later removal of construction materials containing hazardous substances.

The harmonized protocol could include documents with the following elements:

- key hazardous substances of concern (proposal in Table 1)
- key elements in the desk (documentation) study prior to field visit (chapter 4.4)
- good practice in field visit (chapter 4.5)
- check list of materials potentially containing hazardous substances (including photos and guidance on how to identify the materials) (e.g. Finnish examples in Figure 6, Austrian Tables 4 and 5)
- guidance for sampling and testing (sampling technique, number of samples, analysis methods, etc
- elements to be included in documentation
- templates for reporting of waste
- action limits for materials to be removed when possible
- action limits for recyclables when possible

5.2. Requirement for auditor

The skills for auditor is to be defined nationally.
The DG GROW Waste Audit Framework recommends:

- The auditor shall have sufficient knowledge and experience to identify all hazardous materials and to fulfil all the legal requirements for the waste audit report and waste declaration.
- the auditor is independent in all demolition, deconstruction or renovation projects so the audit results are not biased by the specific interests of the owner or contractor.

The auditor should have adequate educative background and specific training, and knowledge on current and historical construction, constructive systems, standardization, materials and hazardous substances, C&DW management possibilities and reuse and recycling possibilities of different elements and materials.

Ideally auditors educated in one country should be able to prove competence in other countries (many building and demolition companies are working in several countries). The development of an European certification system for auditors is recommended. The creation of a common base of course content is supported based on the education material created in PARADE. Furthermore, some common teaching materials could be developed and shared. In addition, the spreading of good practice is valuable and also benefits the competence in specific topics, e.g. if supported through common teachers.

Figure 13. Courses dedicated to auditors of hazardous substances in construction products are arranged regularly in Belgium and the Nordic countries.

5.3. Tools and best practices for enhancing quality of the waste audit

Tracimat – Traceability as a tool for quality management of waste materials

To qualify for upcycling, recycled construction and demolition materials must be of good quality. Proper management of construction and demolition waste (CDW) – most importantly correct handling of hazardous waste – is thus of great importance and is required to guarantee a good quality of the recycled product. It is equally important that users of the recycled material have confidence in its quality.

In order to do so, the Flemish Construction Confederation (VCB) has founded Tracimat: a non-profit neutral CDW management organisation that will certify the selective demolition process and the produced waste streams, and thereby provide quality assurance for the recycling companies treating the waste originating from selective demolition.

Tracimat will issue a "*certificate of selective demolition*" for demolition waste that has been selectively collected and subsequently has gone through a traceability/quality management system. This system guarantees the selective collection of the demolition waste material, traces it from its point of origin down to the gate of the processing company, and sets as its main goal assuring the processing company of the environmental quality of the input (selectively collected) demolition waste. The Tracimat system is focused on the stony fraction and traces selectively collected stony demolition waste from its point of origin down to the crusher, thereby assuring the crusher of the environmental quality of the input demolition waste. To assure the crusher of the quality of the input demolition waste, Tracimat will check whether both the hazardous waste and the non-hazardous waste that complicates the recycling of the stony fraction of the demolition waste (e.g. plastics, cellular concrete, gypsum, wood), have been selectively collected and properly disposed of.

Traceability of waste materials, and thus quality assurance on their recyclability, starts with knowing which materials will be set free during the demolition/renovation works and thus need to be 'traced'. Therefore, a high quality predemolition inventory is the first and most important step in the procedure. A specific procedure on how to perform and report a waste audit have been written. To make sure this procedure is followed and to guarantee the quality of the predemolition waste audit, Tracimat will check the quality of the waste inventory and issue a declaration on its conformity. The waste inventory and waste management plan and its attestation of conformity are added to the tender specifications for the selective demolition works. In this way the demolition contractor has to take the presence and safe and correct removal of the hazardous substances into account in his price offer.

During the following steps of the traceability system the safe and correct removal of the hazardous materials is checked.

Table 6. TRACIMAT system developed for traceability and monitoring of the quality of stony fractions for recycling.

Scope	The Tracimat focus on the stony fraction from C&DW and covers following steps: 1. Waste inventory and waste management plan; to have a clear idea of the waste materials and how to treat them 2. Dismantling of the building: Removal of hazardous materials, fixed apparatus and machinery, as well as demountable components 3. Structural demolition: demolition of the remaining construction 4. Transport to and acceptance by crusher
Purpose	The purpose of Tracimat is to provide quality assurance by certifying the selective demolition process and the produced waste streams. Non-contaminated waste streams with a low environmental risk clearly have a greater upcycling potential. The certificate will enhance trust in the quality of the material and in the recycled product, resulting in an improved and more widespread marketing of recycled products. The following of the Tracimat traceability system is not mandatory in Flemish regulation, but is driven from an econcomical incentive.
Elements included	- identification of hazardous substances/hazardous waste - monitor the streams - supervise the flows - certification system (demolition certificate shows the processor whether the C&D material can be accepted as "low environmental risk material" which means that the purchaser (recycling plant) can be quite sure that the C&D material meets the quality standards for processing at the recycling plant.
Competence of auditor	The expert has to have the necessary knowledge of current and past building materials and building techniques. Knowledge of the environmental policy and regulation (applicable in the region and/or country), specific regulation on demolition and demolition waste treatment, as well as insight in asbestos and other types of hazardous waste, and the applications these materials have been used in, is equally important. The expert also needs to know how (selective) demolition is performed: what is feasible, which fractions are collected separately given the market, etc
Stakeholders involved	Actors in the tracing procedure for selective demolition are the expert, the CDW management organisation (i.e. Tracimat), the demolition contractor and the processor of the waste (i.e. the crusher).

Tracimat system developers	The development of Tracimat has been carried out by the Flemish Construction Confederation, VITO, the Belgian Building Research Institute (BBRI), the Public Flemish Waste Agency (OVAM), the Belgian Demolition Association (CASO), the Belgian Federation of Producers of Recycled Granulates (FPRG) and the Association representing the Belgian Engineers (ORI).

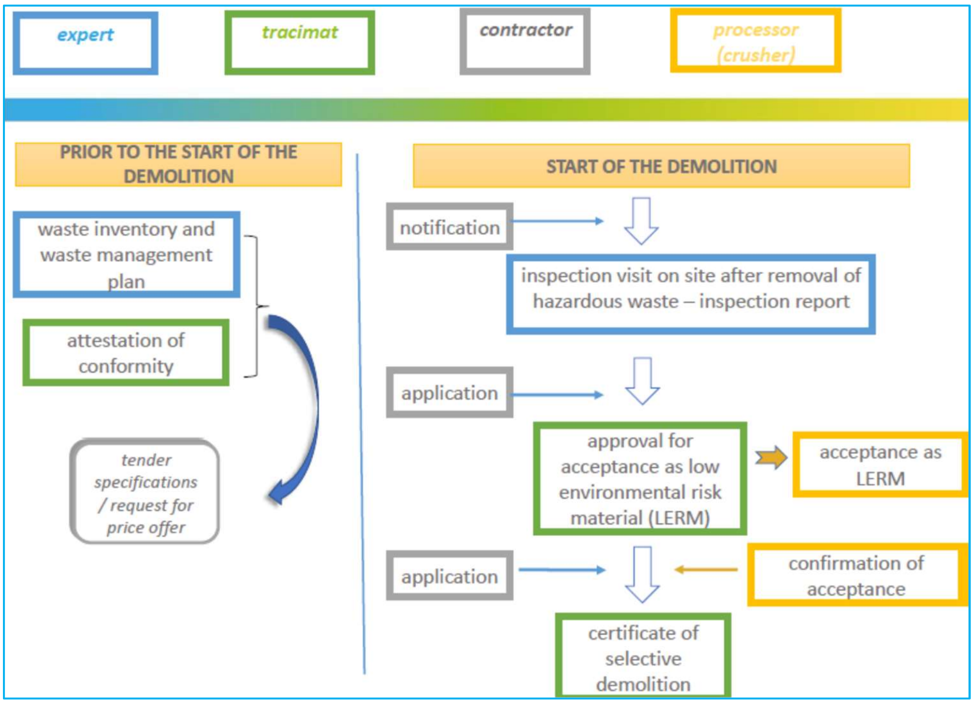


Figure 14. Flowchart of the Tracimat traceability system (LERM = low environmental risk material)

Austrian standard ÖNORM B 3151

The recycling regulation concerning the recycling of waste includes for demolition of buildings also requirements for predemolition audit. The regulation makes references to the Austrian standard ÖNORM B 3151 “Dismantling of buildings as a standard method of demolition”, issued on 1 December 2014, which describes the elements in the predemolition audit and also requirements for controls after demolition.

Based on the result of the pre-demolition audit, a „Concept for deconstruction“ has to be developed. This concept should determine, how all examined materials/construction parts containing dangerous substances or impurities have to be removed and by whom. The plan is described either by an internal or external expert (the limits as for the pre-demolition audit (750 tons, 3500m³) apply here) and has to include:

- Estimated masses out of main components (Asphalt, concrete, excavation material, wood, metals, others)
- Name(s) of the demolition company(-ies) which will execute the removed of relevant materials or construction parts.
- Methods for deconstruction/special provision (e.g. removal of asbestos) – if necessary

The concept for deconstruction is to be documented by a standardized form (ÖNORM B3151), for larger objects a more detailed report is generated generally. After complete removal of all relevant materials or construction parts containing hazardous substances or impurities – according to the concept for deconstruction – the building is ready for mechanical demolition. The confirmation has to be done by an internal or external expert (the limits as for the pre-demoliton audit (750 tons, 3500m³) apply here) based on an on-site inspection. The confirmation has to be documented and represents (together with the documentation for the audit) a „quality certificate“ for the generated demolition waste.

The concept for deconstruction is to be documented by a standardized form (ÖNORM B3151), for larger objects a more detailed report is generated generally.

Box 10. List of C&D materials that need to be removed from the building before demolition – example of Austrian standard ÖNORM B3151 in Annex D

- Loose artificial mineral fiber (if hazardous)
- Components or parts containing mineral oil (e.g. oil tank)
- Smoke detectors with radioactive components
- Industrial smoke stacks (e.g. fireclay boxes, bricks or lining)
- Insulating material of components containing Clorofluorocarbon ((H)CFC) (e.g. sandwich elements)
- Slags (e.g. slags in inserted ceilings)
- Oil contaminated or otherwise contaminated soils
- Fire debris or otherwise contaminated debris
- Isolations containing polychlorinated biphenyl (PCB)
- Electrical properties or equipment with pollutants (e.g. vapor discharge lamps containing mercury, fluorescent tubes, energy-efficient lamps, capacitors containing PCB, other electrical equipment containing PCB, cables containing insulation liquids)

- Cooling liquid and insulations from cooling devices or air-condition-units containing Chlorofluorocarbon ((H)CFC)
- Materials containing polycyclic aromatic hydrocarbon (PAH) (e.g. tar bitumen, tar board, cork block, slags)
- Components containing or impregnated with salt, oil, tar, phenol (e.g. impregnated wood, cardboard, railway sleepers, masts)
- Material containing asbestos (e.g. asbestos cement, sprayed asbestos, night storage heaters, asbestos flooring)
- Other hazardous materials

Box 11. C&D materials representing or containing impurities

- Stationary machinery (e.g. building services, electrical devices)
- Floor constructions and double floor constructions
- Non-mineral flooring and wallcovering (except wallpaper)
- Suspended ceilings
- Non-plastered synthetical installations (e.g. cables, cable channels, sanitations)
- Facade constructions (e.g. curtain-wall facing, glass front, thermal insulation composite systems)
- Sealings (e.g. roofing cardboard, plastic sheeting)
- Buiding materials containing gypsum (e.g. gypsum plaster board, gypsum floorboard, screed containing gypsum) except wall plaster, ceiling plaster, bonded screed
- Partition walls from cork, porous concrete, cement-bounded wood-wool slab, wood, plastics
- Glas, glass walls, glass bricks
- Loose mineral rock wool, glas wool or other insulating material except impact sound insulationDoors and windows (except those for dust protection during demolition)
- Plants and soil (e.g. from vegetated roofs)

Material passport (BAMB)

The building product passport concept developed in the EU BAMB-project “Buildings as material banks”[42] could be a good base for the development.

[42] https://www.bamb2020.eu/

Building information modelling (BIM)

In future, the building information modelling (BIM) can be a tool used for material inventories. BIM carries information of the construction products during the whole life cycle till the deconstruction stage and increase the traceability of the materials. There is a potential to improve the knowledge of the quality of recyclable materials/reusable products and simplify the whole process in the future. This sets the need to also develop the data storage in the BIM system for enabling data digging later in an easy and useful way.

Appendix 1: Tools for identification of hazardous substances

Identification of hazardous substances by using non-destructive measurements

Technique / Analysis	Description	Substances	Limit of detection	Advantages	Limitations	References
Portable XRF devices	X-Ray Fluorescence (XRF) is an instrumental non-destructive analytical technique that measures the elemental composition of a solid substance when exposed to X-ray radiation.	Typically all elements heavier than fluorine	Typically from 10 to 100 mg/kg	Time requirement for a measurement when applying handheld items is only a few seconds. Can be used in the dismantling stage. Has been proven to allow for e.g. fast monitoring of large volumes of waste plastics in screening of brominated flame retardants (Br-detection). Maintenance costs are manageable.	With a cost of approximately US$20,000 to US$50,000, the use in small size enterprises may be limited. Handheld XRF instrument needs a direct contact to the material surface, so it is not applicable for use in automated sorting systems. Coated materials need to be specifically addressed by scratching the coating.	UNEP 2017

Technique / Analysis	Description	Substances	Limit of detection	Advantages	Limitations	References
Hand held Sliding spark spectrometer	Sliding spark spectrometer was developed for identifying halogen-containing plastics and PVC. Halogen detection is performed by the characteristic emission of Chlorine and Bromine in the optical spectra.	Chlorine, Bromine	0,1 % for bromine	Scanning time is quick and takes only a few seconds. With dual-function equipment including NIR, this method can also distinguish different polymer types. The sliding spark technology for the detection of halogens is relatively cheap and costs around US$6,000.	The instrument needs a direct contact to the material surface. Coated materials need to be specifically addressed by scratching the coating.	UNEP 2017
Handheld FT-IR instrument	Fourier-Transform Infrared (FT-IR) spectroscopy identifies chemical bonds in a molecule by producing an infrared absorption spectrum.	Bromine, others?	5 % for Bromine	FT-IR allows quantifying specific compounds using calibration spectra of known concentration. It might be useful for screening POP-PBDE-containing materials. Rapid and non-destructive analysis	Not widely available yet.	UNEP 2017

Technique / Analysis	Description	Substances	Limit of detection	Advantages	Limitations	References
Portable asbestos detector	Asbestos Locating Equipment in Real Time is the a range of portable, real-time warning devices to alert users to the presence of airborne asbestos fibres. They allow for to distinguishing between asbestos and other less dangerous fibers. The Asbestos ALERT works by measuring both the laser light scattering and magnetic properties of individual respirable particles in the air at rates of hundreds of particles per second.	Asbestos		Real time on-site analysis of airborne asbestos fibers	In development stage. A limited number of pre-production sample units are being developed in readiness for robust field trials in a variety of industry sectors.	asbestos alert - website

References

UNEP, 2017. Guidance on best available techniques and best environmental practices for the recycling and disposal of wastes containing polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants.

Asbestos detectors

Real-time asbestos detectors, with the ability to distinguish between asbestos and other less dangerous fibers, are under development yet. Soon in the future there might be commercially available asbestos detectors (see e.g. FP7 Asbestos ALERT website http://www.asbestos-alert.com/).

Hyperspectral Image Analysis

Technology under development for example for detection of flame retardants in plastics.

Further reading:
Caballero, D., Bevilacqua, M., & Amigo, J. M. (2019). Application of hyperspectral imaging and chemometrics for classifying plastics with brominated flame retardants. Journal of Spectral Imaging, 8, [a1]. https://doi.org/10.1255/jsi.2019.a1

Kits for PCB identification

Commercial kits available for on-site checking. Developed especially for detection of contaminated soil.

<u>Identification of hazardous substances by chemical analysis</u>

information about standardised test methods for testing.

Table of standardised methods (CEN/TC 351): standard number, focus, scope (if relevant), measurement range (if relevant)

Substance	Standard number	Name of Standard
Asbestos	ISO 22262-1	Air quality — Bulk materials — Part 1: Sampling and qualitative determination of asbestos in commercial bulk materials
Phthalates	CEN/TS 16183:2012	(WI=00444137) Sludge, treated biowaste and soil - Determination of selected phthalates using capillary gas chromatography with mass spectrometric detection (GC-MS)
Brominated substances	EN 16377: 2013	Characterization of waste - Determination of brominated flame retardants (BFR) in solid waste
Mineral oil	EN 14039:2005	Characterization of waste - Determination of hydrocarbon content in the range of C10 to C40 by gas chromatography
XRF	EN 15309:2007	Characterization of waste and soil - Determination of elemental composition by X-ray fluorescence
PAH	EN 15527:2008	Characterization of waste - Determination of polycyclic aromatic hydrocarbons (PAH) in waste using gas chromatography mass spectrometry (GC/MS)
PCB	EN 15308:2016	Characterization of waste - Determination of selected polychlorinated biphenyls (PCB) in solid waste by gas chromatography with electron capture or mass spectrometric detection
CrVI	EN 15192:2006	Characterisation of waste and soil - Determination of Chromium(VI) in solid material by alkaline digestion

		and ion chromatography with spectrophotometric detection
Metals (aqua regia digestion)	EN 13657:2002	Characterization of waste - Digestion for subsequent determination of aqua regia soluble portion of elements
Metals (microwave digestion)	EN 13656:2002	Characterization of waste - Microwave assisted digestion with hydrofluoric (HF), nitric (HNO3) and hydrochloric (HCl) acid mixture for subsequent determination of elements
Hydrocarbons (aliphatic and aromatic semi-volatile)	EN ISO/TS 16558-2:2015	Soil quality - Risk-based petroleum hydrocarbons - Part 2: Determination of aliphatic and aromatic fractions of semi-volatile petroleum hydrocarbons using gas chromatography with flame ionization detection (GC/FID) (ISO/TS 16558-2:2015)

Table. Addidional information on analysis methods for HBCDD analysis (source:
G. Erens M.Sc., J. van Dijk M.Sc. 2016. HBCDD in EPS/XPS waste in the Netherlands Inventory of size and value. Ministry of Infrastructure and the Environment, The Netherlands. December 2016)

Method	Principle	Detection limit	Price
State of the art laboratory methods	The state-of-the-art laboratory methods use internationally standardized gas chromatography-mass spectrometry (GC-MS) or liquid chromatography –mass spectrometry (LC-MS) techniques. These techniques can be applied to all materials. A small sample of material has to be dissolved in liquid for each measurement.	The techniques detect HBCDD specifically in materials from the low µg/kg range.	The price per sample for this type of methods is high (in the range of € 200-250 per sample).
X-ray fluorescence spectroscopy	X-ray fluorescence spectroscopy (XRF) can be used to detect the element Bromine (Br) in materials. The XRF measurement can be applied on the materials itself. No samples are needed. A problem with XRF is that it detects Bromine and not HBCDD. Since new flame retardants that have replaced HBCDD are also brominated components, these new flame retardants are also measured. XRF cannot distinguish between HBCDD and other brominated flame retardants.	The limit of detection of Bromine for the XRF scanner is approx. 10 mg/kg (10 ppm) which corresponds to approx. 14 mg/kg HBCDD	This measurement technique is relatively cheap. Although the XRF scanner itself is expensive (approx. € 30.000), scanning is cheap because measurement is simple. XRF scanners are available as handhelds.
X-ray fluorescence spectroscopy including extractive method	A new analysing method (2014) was developed by Fraunhofer (HBCD-IG) for the rapid offline identification of HBCDD in EPS/XPS using X-ray fluorescence spectroscopy (XRF) on EPS/XPS samples that are dissolved in acetone (2 g material in 5 g acetone) [7]. This method can distinguish between HBCDD and other polymeric brominated flame	The lower detection limit of this technique is approx. 50 mg HBCDD per kg (= 50 ppm). Problem with this analysing method is that there is little validation or interlaboratory	An exact price per analysis is not available at this stage but can be estimated to be in the range of € 20-100 per sample once an XRF spetroscope is available.

	retardants because HBCDD dissolves in acetone and other flame retardants (polymers) hardly dissolve. The method is attractive because the analysing method is much simpler than GC-MS or LC-MS and the price per sample will therefore be much lower. The method could also be used by recycling companies.	study available and it is not accepted as an international standard yet	

Appendix 2: Limit values for use of reclaimed concrete in earth constructions

Table. Total content: Limit values for assessment of concrete for recycling or for use of reclaimed concrete waste for earth construction (e.g. roads).

	Belgium/Flanders (limit for the use as a construction material)[43] (Note! for metals only binding leaching limits)	Denmark (limit for non-contaminated) -	Finland (content limit for recycling of processed reclaimed concrete waste through a notification system, note leaching additionally to be studied)[44]	Norway (proposed limit values, note! for the paint layer different limit values applies) (recycling of concrete and bricks)[45]	Sweden (content limit for recycling of reclaimed concrete through a notification system, note leaching additionally to be studied[46]
Sampling approach	Sampling of the processed concrete aggregates	Sampling prior to demolition	Sampling from processed reclaimed concrete	Sampling prior to demolition	Sampling from processed reclaimed concrete
PCB	0.5 mg/kg dm	In the statutory order of residues a limit value of 2 mg/kg PCB-total is specified. CDW with a content of PCB below 2 mg/kg can be used as a substitute for raw materials in construction projects under certain conditions	1 mg/kg (note! only arithmetic sum of 7 congeners)	0,01 mg/kg	

[43] VLAREMA, annex 2.3.2: https://navigator.emis.vito.be/mijn-navigator?woId=44707, NB! This annex mentions total concentration values. However, these are not legally binding. They are mostly used as a guide value. In certain cases, you are exempted from doing a column leaching test if the total concentration of your material is below these values.

[44] regulation 843/2017, https://www.finlex.fi/fi/laki/alkup/2017/20170843

[45] Miljødirektoratet, Norway. FAKTAARK M-14|2013. http://www.miljodirektoratet.no/Documents/publikasjoner/M14/M14.pdf

[46] Target for Construction and Demolition Waste. Nordic Working Papers. Published by the Nordic Council of Ministers, NA 2014:916. ISSN 2311 – 0562. http://dx.doi.org/10.6027/NA2014-916

		In order to decide if the CDW is non-contaminated with PCB a guidance value of 0,1 mg/kg PCB-total is used			
Asbestos	100 mg/kg dm For unbound asbestos: 10 mg/kg dm				
CFC					
Arsenic		20 mg/kg[47]		8 mg/kg	10 mg/kg
Lead		40 mg/kg		60 (inorganic lead)	20 mg/kg
Cadmium		0,5 mg/kg		1,5 mg/kg	0,2 mg/kg
ChromVI		20 mg/kg		2 mg/kg	
Chrom tot.				50 mg/kg	40 mg/kg
Chlorinated parafinnes (SCCP)					
Copper		500 mg/kg		100 mg/kg	40 mg/kg
Mercury		1 mg/kg		1 mg/kg	0,1 mg/kg
Nickel		30 mg/kg		60 mg/kg	35 mg/kg
PAH	Limit values for 10 different PAHs, ranging from 8.5 mg/kg dm (benzo[a]pyrene) to 400 mg/kg dm (chrysene)	4 mg/kg	30 mg/kg	2 mg/kg	0,5-2 mg/kg
Naphtalene	20 mg/kg dm		5 mg/kg		
Benzo(a)pyrene	8.5 mg/kg dm			0,1 mg/kg	
Zinc		500 mg/kg		200 mg/kg	120 mg/kg
Benzene	0.5 mg/kg dm		0,02 -0,2 mg/kg (depending on use)		
Toluene-Ethylbenzene-Xylene	Toluene: 15 mg/kg dm Xylene: 15 mg/kg dm Ethylbenzene: 5 mg/kg dm		25 mg/kg		
Hydrocarbon C_{10}-C_{40}	1000 mg/kg dm		500 mg/kg		
Aliphatic C_5-C_6	Hexane: 1 mg/kg dm Heptane: 25 mg/kg dm Octane: 0.5 mg/kg dm			7 mg/kg	
Aliphatic C_6-C_8				7 mg/kg	
Aliphatic C_8-C_{10}				10 mg/kg	
Aliphatic C_{10}-C_{12}				50 mg/kg	
Aliphatic C_{12}-C_{35}				100 mg/kg	

[47] The non-contaminated values for metals are based on soil quality criteria's

Appendix 3: Templates for reporting site visits (source: DG Grow study)

Construction unit:									
Type of material	Material identification	Waste code (EWC and EURAL)	Location	Quantity	Unit	Possible outlets[1]	Recommended outlet[2]	Precautions to take during the deconstruction phase[3]	Pictures and notes

cont.

Building	Level	Material to evacuate	Construction units	Quantity/ weight	Unit	Recommended outlet
Building	Ground floor, Level 1, Level 2					
		TOTAL OF INERT WASTES				
		TOTAL OF NON INERT NON HAZARDOUS WASTE				
		TOTAL OF HAZARDOUS WASTES				

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